Hubert John
Peter Wiklund
Editors

Robotic Urology

Third Edition

EXTRAS ONLINE

Springer

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ISBN 978-3-319-65863-6 ISBN 978-3-319-65864-3 (eBook)
https://doi.org/10.1007/978-3-319-65864-3

Library of Congress Control Number: 2018934726

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

For our loved children Flurina, Wim, and Martin
Your fathers Hubert and Peter

Foreword

Surgery has been the mainstay of medical treatment for a large number of diseases. Approximately 100 years ago, many patients undergoing pelvic or abdominal surgery died from the intervention due to a lack of medical technology. It was only in the last four decades that we have achieved the highest standard of surgical interventions through better delineation of the disease, better selection of patients, and an enormous improvement in medical technology. The current third edition of *Robotic Urology* is a good example of the rapid developments in surgical technology. Robotic urology is also an excellent example: improving surgical results with less invasive and still enabling interventions with the same or even better quality and reduced burden for both the patients and the treating physicians. The origination of urology on the other hand has been the invention of the Nitze cystoscope in 1879. Since then urology has always been at the forefront of minimalization of interventions. It's no wonder therefore that robot-assisted pelvic and retroperitoneal surgery was initially adopted and further developed in urology. We have seen, however, that robotic urology does not mean that the robot takes over the entire work from the surgeon. The current versions are intelligent assistance systems that do whatever the surgeon wants it to do. Despite the best vision, highest precision and smooth movements of the hands, it is still the urologic surgeon who will be responsible and instrumental for the good outcome. A good robotic surgeon must be trained. Part of the training involves traditional skills such as indication and timing of an intervention as well as knowledge of the respective anatomy. A robotic surgeon must also have a deep knowledge of the technology he or she is working with and develop the power of imagination to use all the capabilities of intelligent surgical assistance. The current book is a perfect reference manual for both newcomers and experienced surgeons starting or perfecting robotic urology.

Tübingen, Germany Arnulf Stenzl

Preface

Hubert John and Peter Wiklund on the Rotspitz, 2517 meters above sea level in the Swiss Alps deciding to start the 3th edition of “Robotic Urology”

Urology is a technology-driven speciality and has traditionally integrated new minimally invasive approaches at an early stage. Fifteen years ago in 2002 when both editors began routine robotic urology, it was unexpected that this master-slave telesurgery system would dramatically change operative urology in the following decade. The shift developed in pace with the availability of robotic systems from open to robotic technology on one side and from conventional laparoscopy to robot-assisted laparoscopy on the other side.

In 2004 about 8% of radical prostatectomies were performed robotically in the USA—in 2015 over 85%. At the same time renal and adrenal robotic surgery developed, especially partial kidney resections. Laparoscopic ureteral and reconstructive surgery in the pelvis migrated to robotic procedures and included ureteral reimplantation, vesicovaginal fistula, sacrocolpopexy, and many more. Even robotic radical cystectomies with intracorporeal urinary tract reconstruction are embedded in the routine of distinct centers. Increasingly open procedures were systematically adapted to the robotic approach with the inevitable benefits of decreased blood loss, fewer complications, and faster recovery. While some procedures are completely standardized, others are still under evaluation. In 2016 over 750,000 robotic procedures were performed with the daVinci® system worldwide, indicating that a step back from robotics to open or conventional laparoscopy is presently unthinkable. Challenging laparoscopic interventions have been brought to a broad spectrum of urologists and patients are profiting worldwide. This third edition, following those in 2007 and 2013, is therefore very timely. The authors have again invested great effort and personal experience in order to support other robotic teams around the world. The book highlights the standards of robotic urology today and shows promising new techniques and ideas. We are delighted that this edition has come to a fruitful conclusion within one year of hard work.

Our thanks go to Melissa Morton and André Tournois from Springer London and Kevin Horton in Winterthur for their great editorial assistance. We are especially grateful to our families for their support and tolerance of our high professional workload.

We thank everybody for their motivation as well as for their criticism in the past—all of you have brought forward the vision of less invasive urology with equal or better oncological and functional results.

A dream became reality; pioneer work turned to standards!

Winterthur, Switzerland Hubert John
Stockholm, Sweden Peter Wiklund

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Jens J. Rassweiler, Ali Serdar Goezen, Jan Klein, and Evangelos Liatsikos

Introduction

Robotic surgery has been introduced successfully to facilitate laparoscopic surgery including even radical cystectomy and urinary diversion [1, 2]. However, this was accompanied by monopoly of Intuitive Surgical [3, 4]. The company owns more than 1500 patents regarding robotic surgery of which some of earlier patents will expire in following years (Table 1.1). This promotes new manufacturers to introduce alternate devices (Table 1.2). Recently, we updated significant developments of robotic devices used for urologic surgery and endourology [5, 6]. Based on this, we want to focus on technical modifications of upcoming devices with special emphasis on future clinical applicability.

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History of Robotic Devices for Laparoscopy

It is really fascinating to review the early stages of robotic surgery in urology (Table 1.2).

ARTEMIS

Buess and Schurr pioneered the first tele-surgical laparoscopic porcine cholecystectomy in 1996 using the ARTEMIS-System (Fig. 1.1). They started with a bedside version of a robotic arm [7]. The final device consisted of a user station representing an open console (master) and the instrument station (slave). The surgeon used polarized glasses for 3D–CCD-video-imaging [8]. In 1996, Frederic Moll, co-founder of Intuitive visited the Nuclear Research Centre in Karlsruhe, Germany (A. Melzer, personal communication). Despite various promising experimental trials in abdominal and cardiac surgery, the device never made it beyond the experimental state [9]. Subsequently, all existing patents expired (Table 1.2).

ZEUS

ZEUS (Computer Motion, USA) represented the first clinically used robot based on patents registered in 1999 (Table 1.1). The surgeon sat at an open console on a high-backed chair with arm-

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_1

Table 1.1 Historical summary of the most relevant patents (modified from Rassweiler et al. 2017)

No	Inventors	Title	Owner	Registered	Expired	Comment
(a) Console-based robot-assisted laparoscopy						
US5631973 A	Green PS	Method for telemanipulation with telepresence	SRI International, since 7.5.2008 assigned by the NIH	05.05.1994	05.05.2014	Basis of Da Vinci console technology, designed for battle-field surgery
US 5997471	Gumb L, Schaf A, Trapp R, Buess G, Schurr M	Apparatus for guiding surgical instruments for endoscopic surgery	Nuclear Research Centre Karlsruhe, Germany	26.08.1997	24.12.2012 due to failed payment of maintenance fee	Basis of ARTEMIS Not commercially used
US6436107B1	Wang Y, Uecker DR, Laby PK, Wilson J, Jordan C, Wright J, Ghodoussi M	Method and apparatus for performing minimally invasive surgical procedures	Computer Motion, since 18.11.2004 assigned by Intuitive Surgical	03.03.1999	03.03.2019	Basis of ZEUS
US6312435B1	Wallace DT, Rosa DJ, Moll FH	Surgical instrument with extended reach for use in minimally invasive surgery	Intuitive Surgical	08.10.1999	08.10.2019	Endo-wrist technology of Da Vinci-system
US6459926 B1	Nowlin WC, Guthart GS, Salisbury K Jr., Niemeyer G	Repositioning and reorientation of master/slave relationship in minimally invasive telesurgery	Intuitive Surgical	17.09.1999	17.09.2019	Basis of Da Vinci-system
DE10314828B3	Braun M	Surgical instrument	Tuebingen Scientific Since 13.3. 2016 assigned by SOFAR, Italy	22.07.2004	22.07.2024	7DOF-instruments for TELELAP ALF-X
US8506555B2	Ruiz Morales, E	Robotic surgical system for performing minimally invasive medical procedures	EURATOM	02.02.2007	02.02.2027	Basis of TELELAP ALF-X manufactured by Sofar Aquired 2015 by Transenterix
US20070123855A1	Morley T, Wallace D, Maurer C	Bipolar cauterizing instrument	Intuitive Surgical	09.02.2007	09.02.2027	Improvement for Da Vinci S-system

US20120265176A1	Braun M	Surgical instrument with elastically movable instrument head	Tuebingen scientific	18.10.2012	18.10.2032	7DOF-instruments for TELELAP ALF-X
US20130204271A1	Brisson G, Mohr PW, Nixon TR	Systems and methods for controlling a robotic surgical system	Intuitive Surgical	31.01.2013	31.01.2033	Control system of Da Vinci XI
US20150150636A1	Hagn, U, Passig G, Lantermann S, Fröhlich F, Seibold U	Minimally invasive instrument for robotic surgery	German Center for air and space (DLR)	09.05.2012	09.05.2032	Basis for EINSTEIN (Patents from MIRO-DLR used by Medtronic-Covedien)
US20130165869A1	Blumenkranz SJ, Larkin DQ	Force sensing for surgical instruments	Intuitive Surgical	07.01.2013	07.01.2033	Option for Da Vinci XI
US20150005784A2	Seeber M, Karguth A, Trommer C	Device for supporting and positioning of a surgical instrument and/or an endoscope for use in minimal-invasive surgery and a surgical robotic system	E-sys medical assigned 4.12.2013 by Avateramedical	14.03.2013	14.03.2033	Basis of avatera system
US 9307894 B2	Von Grünberg H, Seeber M, Stolzenburg JU	Endoscope comprising a system with multiple cameras for use in minimal-invasive surgery	E-sys medical assigned 3.12.2013 by Avateramedical Since 11.02.2016 Stolzenburg added to inventors	18.03.2013	18.03.2033	Basis of avatera system
US20140249546A1	Shvartsberg A, Charles RA, Mc Caffrey RJ, Kennedy JJ	Apparatus and method for supporting a robotic arm	Titan medical	16.05.2014	16.05.2034	Basis of AMADEUS RSS (development actually stopped)
US20150157411A1	Choi SH	Surgical robot system und method for controlling surgical robot system	Meere Company This application claims benefit of Korean Patent Application No. 10–2013-0152632, filed on Dec. 9, 2013, in Korean Intellectual Property Office	5.12.2014	5.12.2034	Basis of REVO I platform a 4-arm system with console

(continued)

Table 1.1 (continued)

No	Inventors	Title	Owner	Registered	Expired	Comment
US20150157410A1	Kilroy PE, Egan TD, Shakespear Koenig K	Hyperdexterous surgical system	SRI International	9.10.2014	9.10.2034	Basis for Taurus dexterous robot
(b) Console-based devices for robot-assisted laparo-endoscopic single-port surgery (LESS)						
US8545515B2	Prisco GM, Gerby GR, Rogers TW, Steger JR	Curved cannula surgical system	Intuitive Surgical	13.11.2009	13.11.2029	VeSPA-system for robotic LESS
US8347754B1	Veltri JA, Schaible UD	Multi articulating robotic instrument	Titan medical	30.06.2009	30.06.2029	Basis of SPORT
US20070299387A1	Williams M, Stack R, Orth G, Smith G, Glenn R, Fifer D, Athas W,	System and method for multi-instrument surgical access using a single access port	Synecor Assigned 5.07.2010 by Transenterix	12.05.2007	12.05.2027	Basis of spider
US20110230894A1	Simaan N, Xu K, Goldman R, Allen P, Fowler D, Ding J	Systems, devices, and methods for providing insertable robotic sensory and manipulation platforms for single port surgery	The trusties of Columbia University in the City of New York assigned 10.07.2012 by NIH	07.10.2009	0.7.10.2029	Basis of IREP
FI2010A000076–77	Scarfogliero U, Piccigallo M, Quaglia C, Tognarelli P, Valdastri A, Menciassi A, Dario P	ARAKNES 1–3	Scuola Superiore Sant'Anna	26.04.2010	26.04.2030	Basis of SPRINT-robot (Italian patent) European consortium
US20130304084A1	Beira R, Clavel R, Bleuler H	Mechanical manipulator for surgical instruments	Ecole Polytechnique Federal de Lausanne	11.10.2011	11.20.2031	Basis of SPRINT-robot (US patent) European consortium

(continued)

US20130197697A1	Schaible U, Brocilo D, Harmen J	Force feedback system	Titan Medical	25.10.2012	25.0.2032	Optional for further Titan Medical devices (AMADEUS, SPORT)
US20150018841A1	Seo KH	Surgical robot system and control method thereof	Samsung Electronics	27.03.2014	27.03.2034	Control unit (master) as basis for Kyung Hee SR1 and single port system
US20150366625A1	Tognaccini ME, Gomez DH, Diolaiti N, Mustafa T, Mitra P, Liligan PE	Medical robotic system providing an auxiliary view including range of motion limitations for articulatable instruments extending out of a distal end of an entry guide	Intuitive Surgical	24.06.2015	24.06.2035	SP-system for Da Vinci XI for LESS
WO2016057989A2	Jay W, Penny MP	Electromechanical surgical system	Transenterix	12.10.2015	12.10.2035	Basis of Surgibot

Table 1.2 Historical development of surgical robots for laparoscopy. Apart from ARTEMIS all used clinically (modified from Rassweiler et al. 2017)

Device and patents	Telescope	Console	Robotic arms	Force-feedback	Degree of freedom (DOF)	Milestones
ARTEMIS (Nuclear Research Centre Karlsruhe, Germany)	3D–CCD-technology controlled by camera-arm (joy-stick)	3D monitor with polarized glasses 3 joy-sticks with armrest	2 cable actuated robotic arms plus camera-arm (FIPS) mounted to OR-table	No	7 DOF	1996 first robotic device used in experimental surgical models. Designed for abdominal and cardiac surgery
ZEUS (Computer Motion aquired by Intuitive Surgical)	2D/3D–CCD-technology (voice control)	2D/3D monitor with polarized glasses or helmet and microphone 2 handles (like chop-sticks)	2 motorized robotic arms plus the voice controlled camera arm (AESOP) mounted to OR-table	No	4 DOF	First coronary by-pass surgery in 1999 including harvesting of the left internal thoracic artery 1999 first experimental robot-assisted pyeloplasty 2001 transcontinental robot-assisted cholecystectomy (Lindbergh-operation) 2004 use abandoned (Computer Motion acquired by Intuitive Surgical)
Da Vinci 2000 (Intuitive Surgical)	3D–CCD-technology (manipulated by the two handles activated by foot-pedal)	3D–montor with mirror technology Two handles (loops) with Endowrist-technology foot-pedals for focussing, clutch, camera, monopolar cautery	2 cable-driven robotic arms plus the camera arm	No	7 DOF	1998 first robot-assisted cholecystectomy First coronary by-pass surgery in 1999 including harvesting of the left internal thoracic artery First robot-assisted laparoscopic radical prostatectomy in 2000

Da Vinci S (Intuitive Surgical)	3D–CCD-technology (manipulated by the two handles activated by foot-pedal)	3D–montor with mirror technology Two handles (loops) with Endowrist-technology foot-pedals for focussing, clutch, camera, mono- and bipolar cautery	2 cable-driven longer robotic arms plus the camera arm, optional 4th arm for retraction	No	7 DOF	Routine clinical use for robot-assisted radical prostatectomy
Da Vinci SI (Intuitive Surgical)	3D–HD-technology (manipulated by the two handles activated by foot-pedal)	3D–montor with mirror technology Two handles (loops) with Endowrist-technology Foot-pedals for focussing, clutch, camera, mono- and bipolar cautery, finger-tip-switch for individual clutching	2 cable-driven longer robotic arms plus the camera arm, optional 4th arm for retraction	No	7 DOF	2009 release of dual-console model da Vinci SI surgical system 2010 first use of VeSPA-system for robotic single-port surgery with only 4 DOF-instruments 2011 first use of infrared fluorescence imaging using indocyanine green dye
Da Vinci XI (Intuitive Surgical)	3D–HD-technology (manipulated by the two handles activated by foot-pedal)	3D–montor with mirror technology Two handles (loops) with Endowrist-technology Foot-pedals for focussing, clutch, camera, mono- and bipolar cautery, finger-tip-switch for individual clutching	4 cable-driven thinner robotic arms with additional joint each applicable as camera-arm (8 mm) Laser crosshairs aligning the patient cart with designated camera port In combination with Trumpf-medical OR-table no need to undock, when moving the patients	No	7 DOF	2014 used for robotic partial nephrectomy with improved docking and minimal instrument clashing 2014 first clinical application of **SP-system** for robotic single-port radical prostatectomy and partial nephrectomy 2016 introduction of 7DOF-instruments for the **VeSPA-system** for robotic single-port surgery

(continued)

Table 1.2 (continued)

Device and patents	Telescope	Console	Robotic arms	Force-feedback	Degree of freedom (DOF)	Milestones
Da Vinci X (Intuitive Surgical)	3D–HD-technology (manipulated by the two handles activated by foot-pedal)	3D–montor with mirror technology Two handles (loops) with Endowrist-technology Foot-pedals for focussing, clutch, camera, mono- and bipolar cautery, finger-tip-switch for individual clutching	4 cable-driven thinner robotic arms with additional joint each applicable as camera-arm (8 mm)	No	7 DOF	2ß17 CE-mark for this device mainly designed for hospitals not focusing on general surgery
TELELAP ALF-X/ SENHANCE (Sofar, Italy; aquired by Transenterix, US)	3D–HD-technology (eye-tracking system)	3D–glasses and monotor with eye-tracking system special handles providing haptic feedback	3 cable actuated robotic arms plus telescope arm arranged on 2 carts	Yes	7 DOF (provided by Tuebingen scientific, Germany)	2015 experimental use for robot-assisted nephrectomy 2016 first clinical application for robot-assisted hysterectomy based on CE-mark 2017 TELELAP ALF-X renamed in SENHANCE

rests controlling instruments of two robotic arms by use of chop-stick-like handles [10]. The robotic arms were mounted at the operating table (Fig. 1.2) including the camera-arm AESOP, which was controlled by the Surgeon's voice [11]. Unfortunately, the instruments provided only 4 degrees of freedom (DOF: jaw, pitch, insertion, rotation). A 2-D or 3-D-videosystem (with head-mounted screens) was used for visualization of the OR-field. The ZEUS-system was initially developed for cardiovascular surgery [10]. However, the most impressive demonstration of ZEUS represented the transatlantic laparoscopic cholecystectomy ("Lindbergh-procedure") by Marescaux [12]. Although the camera-arm AESOP found widespread application for laparoscopic urologic procedures [11, 13–15], ZEUS was used rarely in Urology: in experimental trials on robot-assisted pyeloplasty and clinical applications with pelvic lymph node dissection [16, 17]. Following some legal actions, the two companies announced in 2003, that they were merging into one company [18]. Consequently all further developments of ZEUS (i.e. 7-DOF-instrumentation) and AESOP were stopped (Table 1.2).

Fig. 1.1 ARTEMIS. (**a**) First experimentally used device for laparoscopic telesurgery (Institute for Nuclear Research Karlsruhe, Germany). In vitro-study of bedside master-slave system using one robotic arm. (**b**) Finally design of the robot with an open console, two manipulators and 3D–videosystem

Da Vinci Series

Da Vinci 2000

The da Vinci Surgical system (Intuitive Surgical, Sunnyvale, United States) was based on studies of SRI International (Menlo Park, USA), a non-profit research institute, who developed a robotic system for open surgery that caught interest of the Defense Advanced Research Project Agency (DARPA) due to its potential to operate remotely on soldiers wounded in the battlefield [19, 20]. In 1994, Frederic Moll became interested in the SRI-system with the idea to use it for robot-assisted laparoscopic surgery [21]. Even if some of the previous patents regarding *open tele-presence surgery* date back to 1994 (i.e. 3D–mirror technology), all principle patents for Da Vinci 2000 were registered in 1999 (Table 1.1).

Like ZEUS, the device was initially designed for robot-assisted coronary artery surgery starting clinically at the Heart Centre of Leipzig in Germany after gaining CE-mark in 1999 [22]. At this time the tele-presence effect was much more in the focus: When we visited the Heart Centre early in the year 2000, the surgeon was sitting at the console in a room next to the OR and all commands were transmitted via a microphone. In 2000, Binder pioneered the first robot-assisted radical prostatectomy in Frankfurt followed by other European groups [23–26], here the console was placed in the OR. In 2001, Menon et al. achieved the breakthrough in urologic surgery establishing a full-working clinical programme [27]. Subsequently, FDA approved the use of the system for prostatic surgery.

Already da Vinci 2000 addressed most ergonomic problems of classical laparoscopy sufficiently, such as limited depth perception,

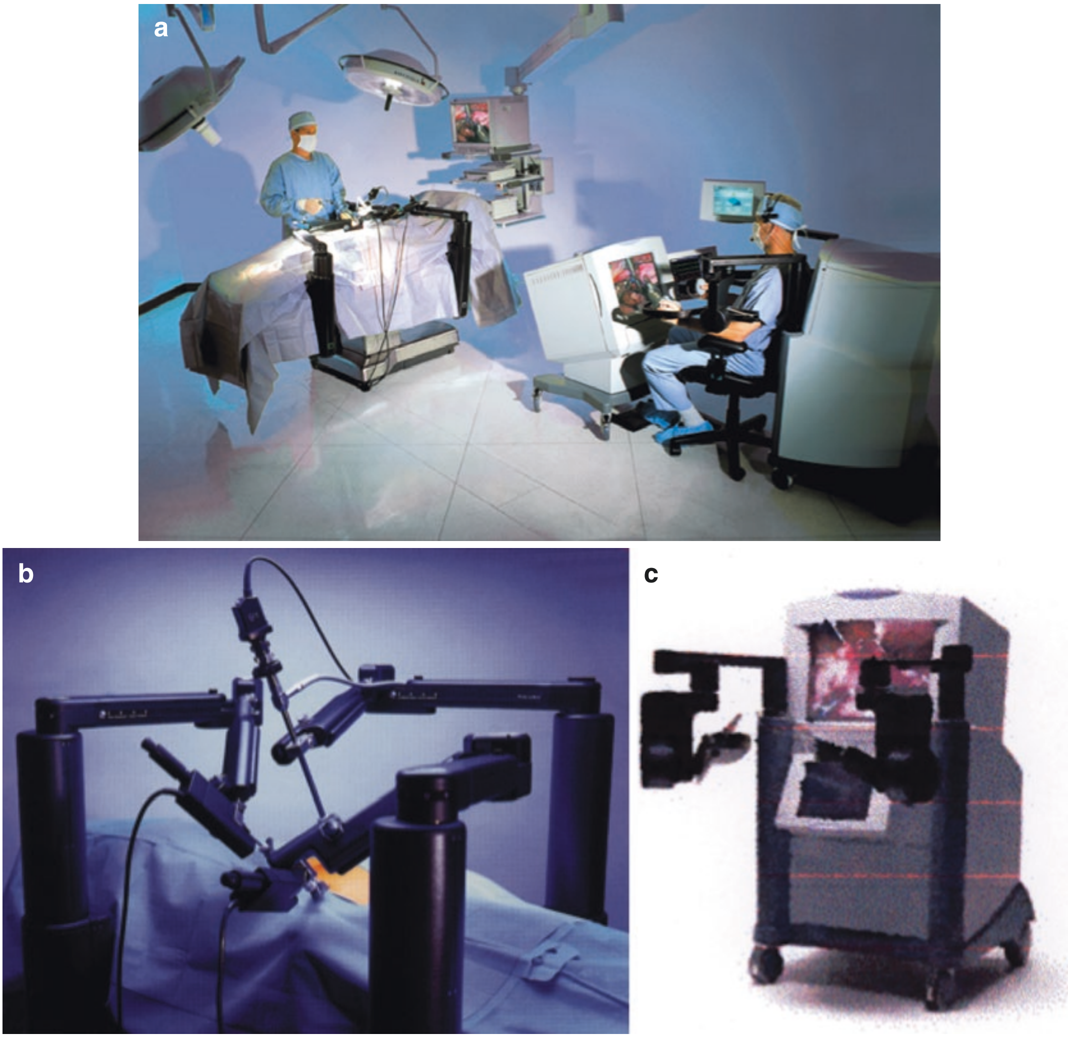

Fig. 1.2 ZEUS. Surgical device with voice-controlled camera-arm and two further robotic arms mounted on OR-table with laparoscopic instruments providing 4 DOF (Computer Motion, United States). (**a**) Overview of the system. (**b**) Three armes: voice-controlled camera-arm AESOP and two manipulators attached at the OR-table. (**c**) Open console with off-line view and chop-stick-like handles to manipulate the 4-DOF-instruments

eye-hand coordination, and range of motion by introducing the Endo-wrist™-technology (Fig. 1.3). Da Vinci provided a closed console offering a 3D–CCD-video-system with in-line view. The cable-driven instruments with up to seven DOF and loop-like handles enabled an ergonomic working position due to the clutch-mechanism [1, 28]. These slave manipulators (i.e. surgical arms) provide three degrees of freedom (i.e. pitch, jaw, insertion). The last elements are the surgical instruments (i.e. end-effector): At the tip of the instruments, a cable driven mechanical wrist (Endo-wrist™-technology) adds three more DOF (including rotation) and one motion for tool actuation (i.e. grip). However, initially, the device had some limitations: There were no bipolar instruments and the range of motion of the robotic arms was reduced providing only a three-arm-systems (Fig. 1.4). In 2015 Intuitive Surgical abandoned the production and technical support of the first generation [6].

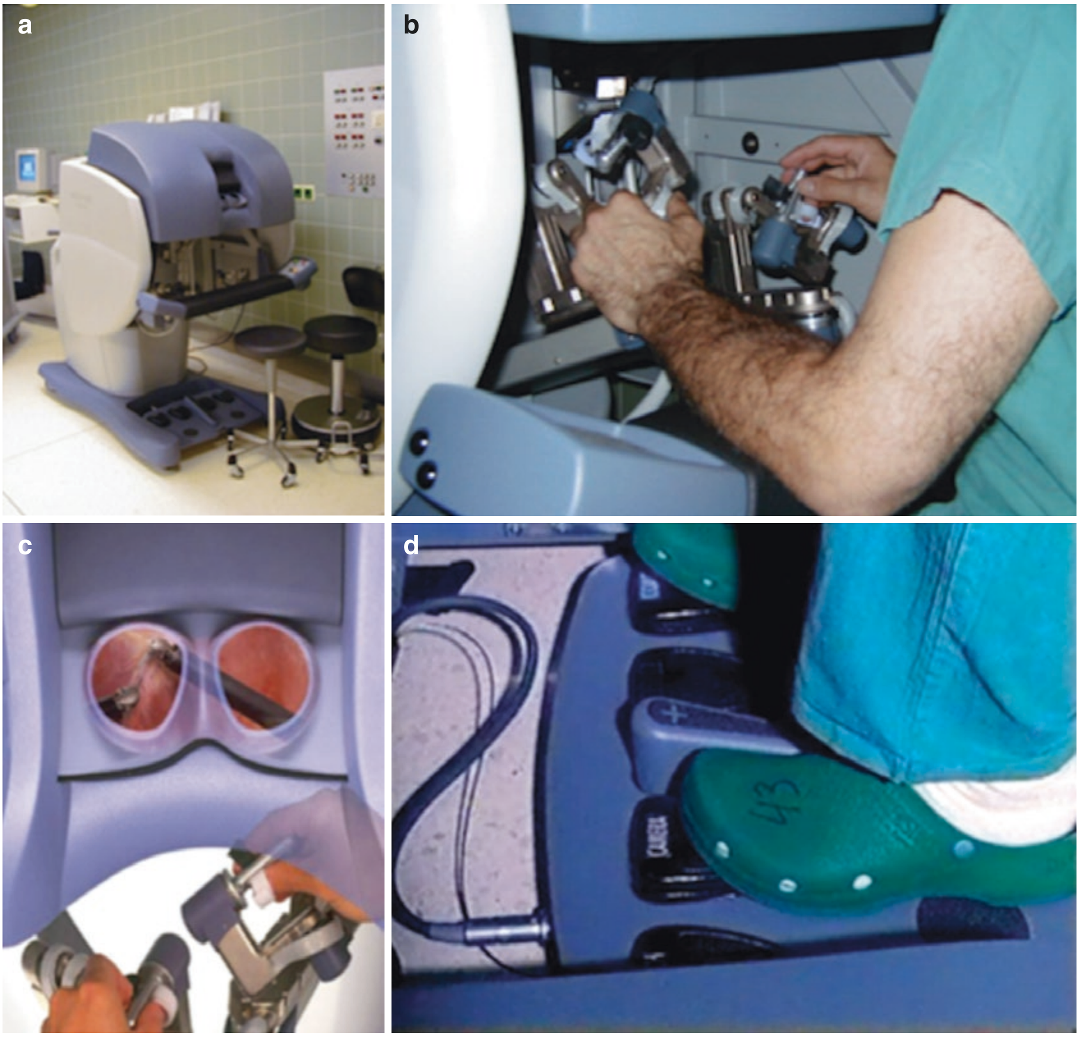

Fig. 1.3 Da Vinci 2000—first solution of ergonomic problems at console. (**a**) Master-Slave device with closed console for surgeon (Intuitive Surgical, United States). (**b**) Armrests and two loop-like handles for manipulation of 7-DOF-instruments (Endowrist™-technology). (**c**) 3D–CCD-camera with mirror-technology providing in-line-view on manipulators. (**d**) Foot-pedals for camera control, clutch, focussing of the lens, and mono-polar coagulation (initially no bipolar instruments available)

Da Vinci S

Da Vinci S introduced clinically in 2006 provided better range of motion, longer robotic arms and optional an HD-video-system respectively fourth arm together with implementation of bipolar energy devices (Fig. 1.5). This allowed performing further procedures like robotic bladder diverticulectomy [29] or even trans-axillary robotic thyroid surgery [30]. Although relevant patents were registered in 2007, technical support for Da Vinci S will end in December 2017 (Table 1.2).

Da Vinci SI

In 2009, the SI-system was launched offering integrated HD-videotechnology, finger-based clutch-mechanism and isocyanine-green fluorescence (Firefly™-technology) [5, 31, 32]. The Da Vinci Si dual console allows two surgeons to col-

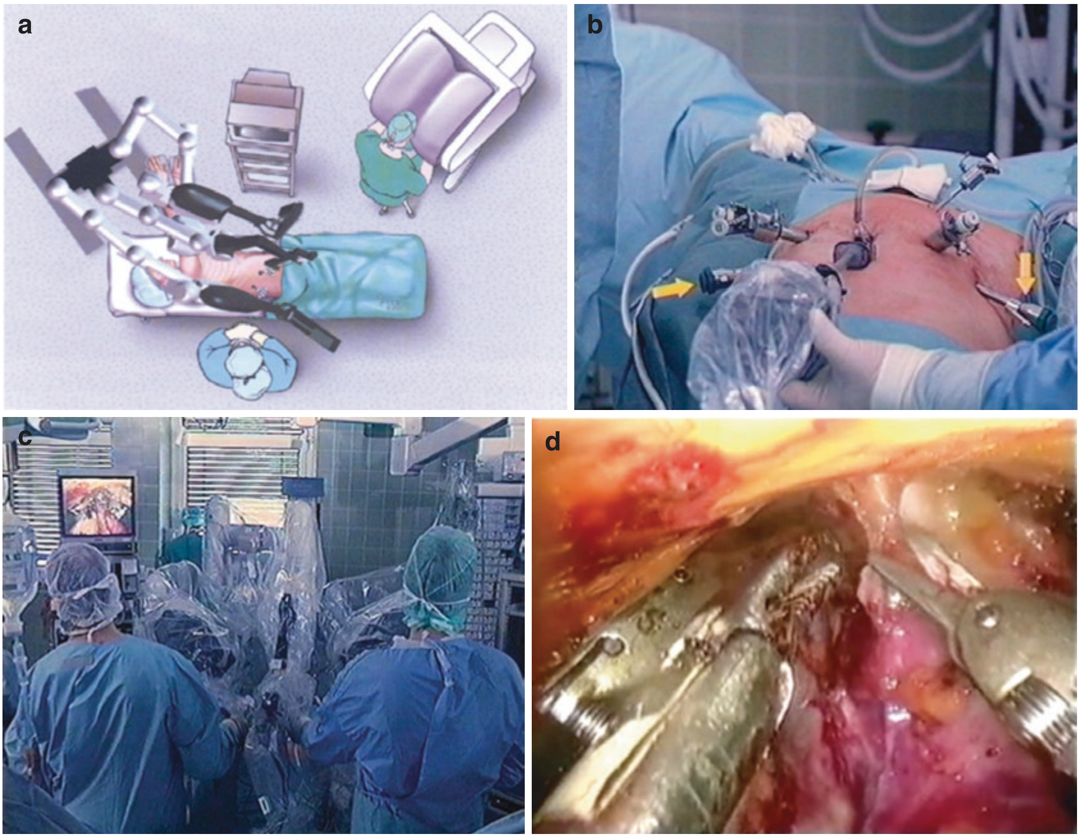

Fig. 1.4 Da Vinci 2000—ergonomic problems for assistant at OR-table. (**a**) Arrangement of robot cart and console for cardiac surgery. (**b**) Trocar placement for robot-assisted laparoscopic radical prostatectomy (*yellow arrows* = Da Vinci-trocars). (**c**) Arrangement of two assistants at the bedside, one has to use bipolar forceps. (**d**) Endoscopic view during apex dissection of prostate: two robotic instruments assisted by the bipolar forceps

laborate during surgery representing an ideal training platform (Fig. 1.6). Although proposed already in 2000 by Autschbach [33], it was realized clinically with introduction of Da Vinci SI (Table 1.2). Additionally, SI-system enabled the use of VeSPA-system for robotic single-sport surgery, however offering only 4 DOF-instruments [5, 34].

Da Vinci XI

In 2014, Intuitive Surgical launched the Da Vinci XI-system (Fig. 1.7) enabling the 8 mm-3D-HD-camera to be chosen liberally at all four ports. This feature is important for colonic and rectal robot-assisted laparoscopic surgery, and might be also helpful during a partial nephrectomy. The robotic arms are finer to minimize instrument clashing and the OR-table can be moved while the robotic arms are connected. Additionally, the system can provide a feature in combination with a specific OR-table (Trumpf-Medical, Germany), which enables to move the table without the need to undock the arms [6]. This is very important for abdominal surgery requiring dissection in different quadrants (ie. colon-surgery, Whipple-procedure). The design of the console is the same as for the SI-version (Fig. 1.6), but now it includes

Fig. 1.5 Da Vinci S—next step of robotic evolution. (**a**) Unchanged basic console design, but with integrated bipolar foot pedal, optionally HD-camera and fourth arm-pedal). (**b**) New robotic arms (three or four) with wider range of motion. (**c**) Better working ergonomics for the assisting surgeon(s) due to wider range of motion of robotic arms. (**d**) A variety of 7-DOF-instruments with monopolar and bipolar functions

always the Firefly™-option. The Da Vinci XI also provides the use of the new robotic SP 1098-platform for 7-DOF-robotic single-port-surgery [35]. Intuitive continues introducing technological advancement such as 7-DOF-stapling devices or 7-DOF-intruments for their VeSPa-single-port system.

Da Vinci X

Recently, the company introduced the X-system, which provides almost all features of the XI, except the table-motion without the need to undock, only access to two quadrants. The rest of the features and all instruments can be used. The new da Vinci X is designed to slip in between the SI and the XI-model, which is still the top of the line when it comes to surgery robots. The da Vinci X takes the thinner, more capable arms and instruments of the Xi and moves them onto a cart like the Si model. That means the system sacrifices some of the versatility of the higher-end model, like the ability to perform procedures in several parts of the body at once, but that's the trade-off for the lower price. Thus, the main purpose for introduction of this device is to reduce the costs for those Hospitals, where General Surgery does not play an important role with respect to robotics, because it seems to be very useful for urologic and gynaecologic applications. Intuitive Surgical has now received a CE mark for the da Vinci X, which promotes its use in Europe (Table 1.2). Before it can be rolled out in the US though, it will need to undergo FDA approval [36].

Fig. 1.6 Da Vinci SI—optimizing the design for urologic indications and robotic training. (**a**) New design of the console with clutch-mechanism also by finger tips—optional as double console. (**b**) 3D–HD-camera providing fluorescence filter for isocyanine green (Firefly™) enabling visualization of renal artery. (**c**) Simulator training system applicable with the Da Vinci SI-system. (**d**) VeSPA-system for single-port surgery with crossover programming of the handles, but only applicable for 5-DOF-instruments

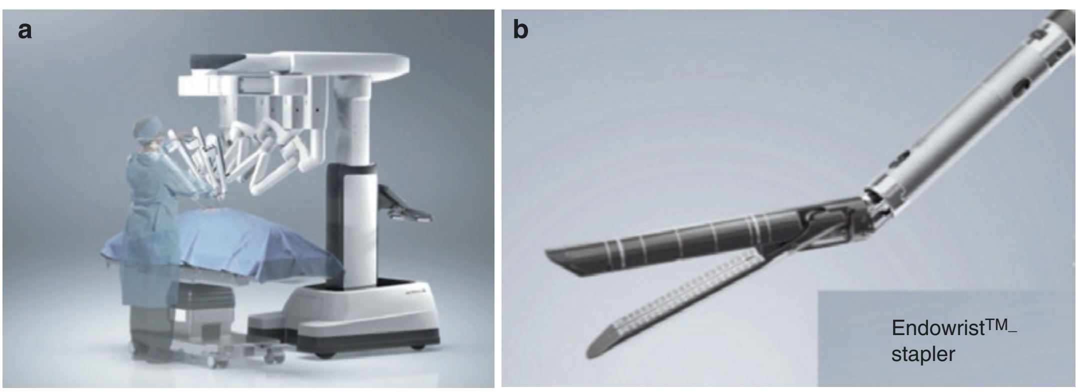

Fig. 1.7 Da Vinci XI—optimizing the design for interdisciplinary indications. (**a**) Finer design of robotic arms to minimize the risk of clashing of instruments with variable use of all four robotic arms (camera, instruments). (**b**) Use of 7-DOF-endoscopic staplers can be used with the device. (**c**) Optional module of a software enabling movement of OR-table without undocking the robot. The software works only with a specific OR-table (Trumpf-Medical, Germany). (**d**) Console enables control of the new robotic SP 1098-platform for 7-DOF-robot-assisted single-port-surgery

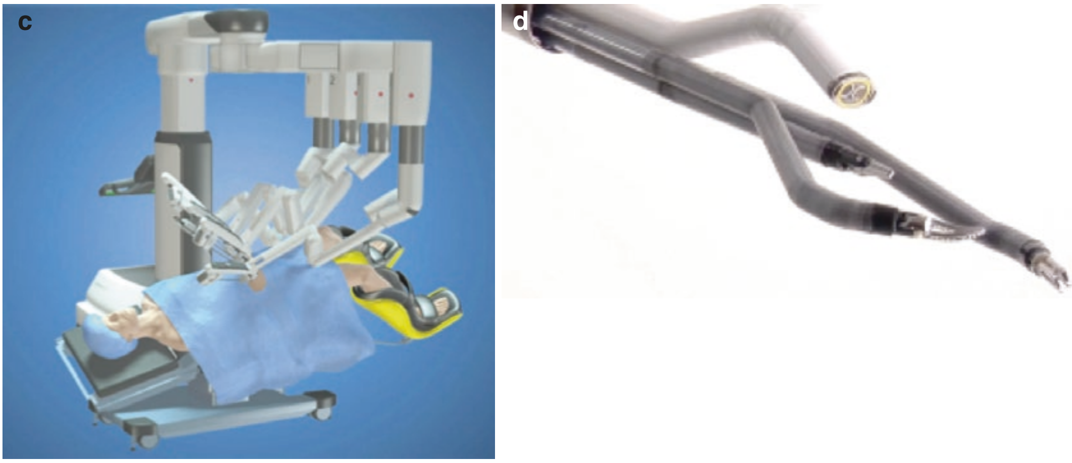

Fig. 1.7 (continued)

Alternative Robotic Systems

From 2004 to 2016, there was no active opponent for Intuitive Surgical based on the fact, that Intuitive acquired Computer Motion in 2004 assigning all patents concerning the principle of ZEUS. This may also concern future robotic devices featuring a similar design such as an open console or three robotic arms mounted to the operating table. Patent protections are critical to Intuitive Surgical's success: many are sought for defensive purposes to fend off patent trolls. Nevertheless, at least in the year 2019 some of the key-patents of Da Vinci 2000 and ZEUS expire. This should enable other companies to enter the market.

TELELAP ALF-X (SENHANCE)

Supported by the European Commission, the Italian healthcare company SOFAR (Milan, Italy) started to develop an alternative robotic device consisting of a remote control station and three robotic arms arranged on three separate carts ([37]; Fig. 1.8). The respective patents were registered in 2007 (Table 1.1). TELELAP ALF-X provides an open console with a 3D–HD-screen requiring polarized glasses. Two handles similar to those of laparoscopic instruments manipulate the instruments attached to the robotic arms (Fig. 1.8). Unique system features include haptic feedback and an eye-tracking system at the console. Tuebingen Scientific (Tübingen, Germany) developed the 4-DOF and 7-DOF-instruments based on Radius- technology [38]. Haptic feedback is realized by force-induced counter-movements of the laparoscopic handle at the console according to the application at tip of the instrument. An eye-tracking system controls the camera movement: e.g. the camera moves to the left, if the surgeon looks to the left of the screen and the image is zoomed, when the surgeon's head approaches the screen (Table 1.2). First experimental trials included also urological indications, such as nephrectomy and prostatectomy [39, 40].

In 2015, Transenterix (Morrisville, USA) acquired the Surgical Robotics unit of SOFAR for 99.8 million $ [41] and subsequently a patent for 7-DOF-instruments from Tuebingen Scientific (Table 1.1). In the following year first clinical reports of robot-assisted hysterectomies using a new robotic platform, TELELAP ALF-X, have been published [42, 43]. TELELAP ALF-X has CE-mark for indications in general surgery, gynaecology, urology and thoracic surgery. First devices have been sold in Italy. On their recent website, the robot is named SENHANCE [44].

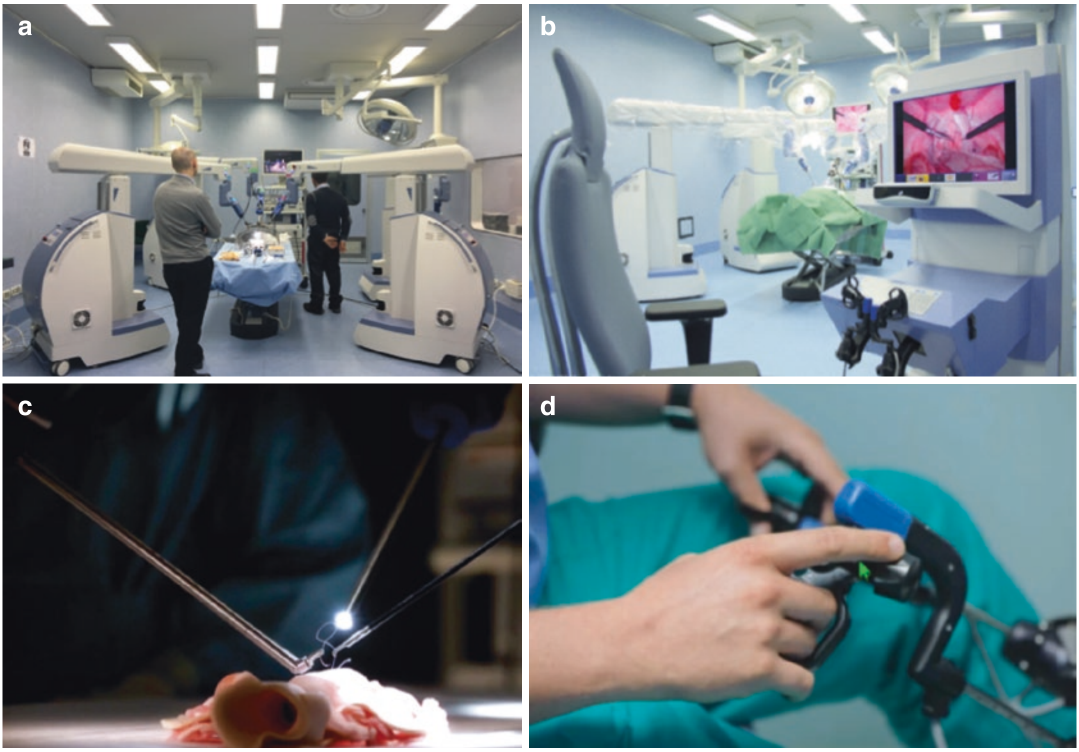

Fig. 1.8 TELELAP ALF X (Transenterix, US). (**a**) Robotic arms mounted on 3 individual carts. (**b**) Console with 3D–Monitor requiring polarizing glasses with eye-tracking. (**c**) 7-DOF-instruments based on Radius-principle (Tuebingen Scientific, Germany). (**d**) Laparoscopic handles to control instruments with 4–7 degrees of freedom

Medtronic

The Medtronic device is based on collaborations between three institutions. In 2010, the German Aerospace Centre (DLR, Oberpfaffenhofen, Germany) published first experimental results of their master-slave-system MIROSurge including the MICA-instruments [45, 46]. Key-patents were registered in 2012 and 2013 (Table 1.1). The original system used an open console with the surgeon sitting in front of an autofocussing monitor (Fig. 1.9). The slave part consisted of three light weighted arms mounted to the operating table. These robotic arms were composed of seven joints (A_1–A_7) with serial kinematics, comparable to a human arm enabling to manoeuver MICA-instruments driven by micro-motors with three joints (A_7–A_{10}) providing the option of tactile feedback, which was realized via potentiometers. Control of instruments is provided by Sigma7™-technology (Force Dimension, Nyon, Switzerland) using forceps-like handles [47].

In 2013, Medtronic (Dublin, Ireland) acquired the licence for commercial use from German Aerospace Centre (DLR) and included further developments in their two R&D-centres in the USA [48]. Since Medtronic completed already the Covidien-merger in 2015, the company is now able to develop all necessary instruments (ie. end-effectors). In the meantime, Medtronic is working on various prototypes of this project (Table 1.3). The company plans to initiate clinical trials in India and Europe according to less regularity restrictions there and seeks to launch the device in the US in 2019 [49].

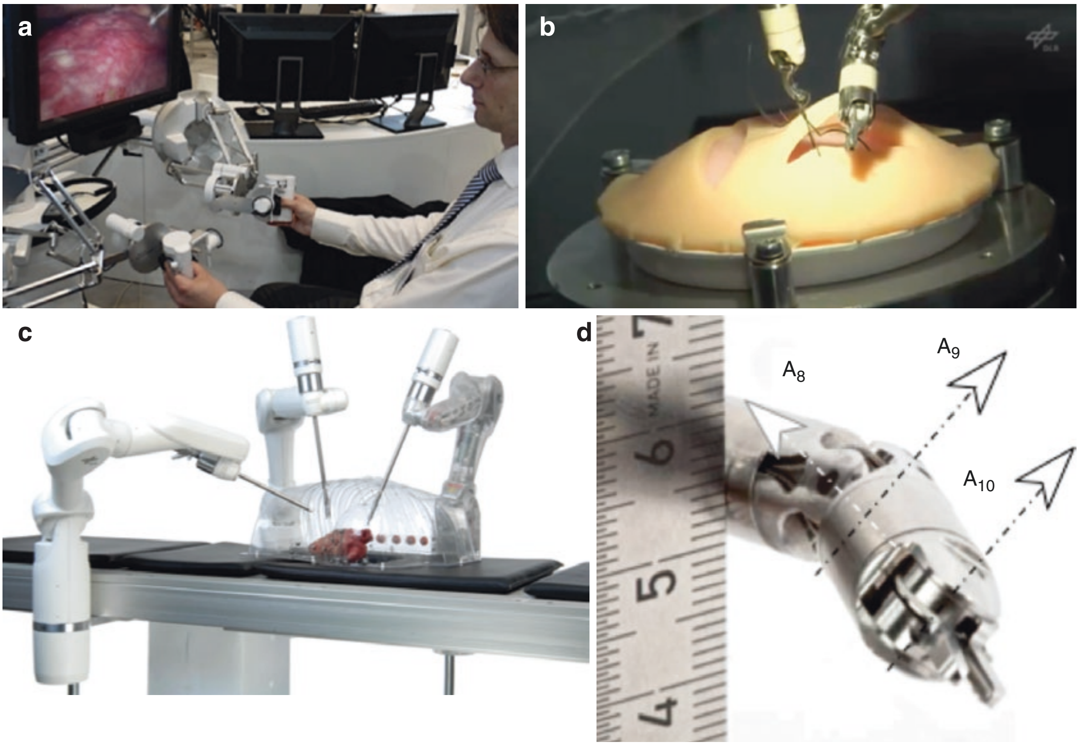

Fig. 1.9 MIRO Surge-robot for laparoscopic surgery (German Aerospace Centre, Germany; Medtronic, Ireland) as basis of the Medtronic-device. (**a**) Console with auto-stereoscopic monitor and handles with force-feedback using sigma 7-haptic technology (Force Dimension, Nyon, Switzerland). (**b**) Three lightweight robotic arms are mounted to the operating table with motorized MICA instruments. (**c**) MICA-instruments during simulation. (**d**) Design of MICA-instruments providing three articulations (A_8–A_{10}) moved my micro-motors with optional haptic feedback

AVATERA

Based on patents registered 2012 and 2013 (Table 1.1), Avateramedical GmbH (Jena, Germany) developed the robotic master-slave system AVATERA. The device consists of a closed console with an integrated seat providing in-line 3D–image with more than full-HD resolution based on a microscope-like technology using two oculars (Fig. 1.10). The robotic arms are mounted on a single cart [50]. The 7-DOF-instruments have been designed in collaboration with Tuebingen Scientific (Tübingen, Germany) offering an instrument diameter of 5 mm. Control of instruments is also provided by Sigma7™-technology (Force Dimension, Nyon, Switzerland) using forceps-like handles (Table 1.3). Until now, the device was used in experimental animal trials and has started the validation process for CE-certification [6].

REVO-I

In collaboration with Yonsei University and other Korean academic and industry groups, Meerecompany (Hwasong, Korea) designed the REVO-I-platform consisting of an open console and a 4-arm-system mounted on a cart (Table 1.3; Fig. 1.11). This represented a 10-year project from the prototype (Rebo, Eterne) to the final version, starting 2007 [51, 52]. In 2016, first results of trials in animal models have been published and Meerecompany received approval to start human trials in South Korea, which have been initiated in 2017 [53–56].

Table 1.3 Overview of new robotic devices for laparoscopy with potential to be used clinically in the future (modified from Rassweiler et al. 2017)

Device/Patents	Telescope	Console	Robotic arms	Force-feedback	Degrees of freedom (DOF)	FDA/CE approval	Comment
AMADEUS RSS (Titan Medical, Canada) Patents: US20140249546A1 Listed: 16.05.2014 US20130197697 A1 Listed: 25.10.2012	3D–HD-technology	3D screen with mirror-based technology and loop-handles	3 cable actuated robotic arms plus telescope arm arranged on a curved support	Yes	7 DOF	No	Development actually stopped due to patent problems
MEDTRONIC (MEDTRONIC-Covedien, Ireland) Based on MIRO surge (DLR, Germany, aquired by Medtronic, Ireland) Patents: US20150150636A1 Listed: 09.05.2012 US20150090063A1 Listed: 22.04.2013	3D–HD-technology	Open console with monitor and 3D–glasses Finger tip-controlled handles Clutch-mechanism Foot switches to activate bipolar energy	3–4 light-weighted motorized robotic arms mounted on separate carts	Not in prototype Haptic technology available	7 DOF including straight (4 DOF) instruments and deflectable staplers (tri-taplers) (instruments from Covedien-Medtronic, Ireland)	CE expected 2018	Planning of optimal trocar position Zero-space positioning [43] Only in-vitro studies, clinical studies expected in 2018
AVATERA (Avateramedical, Germany) Patents: US20150005784A2 Listed: 14.03.2013 US20140180309A1 Listed: 14.03.2012	3D–HD-technology	Closed console with 3D in-line screen (immersion) based on microscope-technology with two adjustable occulars Integrated seat with foot-switches	4 arms mounted on a superordinate carrying system including the camera	No	7 DOF (5 mm instruments)	CE expected 2017	Only experimental trials
REVO I (Meerecompany, Korea) US20150157411A1 Listed: 5.12.2014	3D–HD-technology (stereo-endoscope)	2D monitor with two handles and foot controller for clutch mode and cautery	4-arm system	No	7 DOF	Korean licence in 2017	Collaboration with Samsung First animal trials published 2016 Clinical trials starting in 2017
Japanese robot (Medicaroid, Kobe, Japan) No US patent	3D–HD-technology	Semi-open console with occular-like in-line technology, need of polarized glasses	3-arm system attached to OR-table	No	7 DOF	Japanese license expected in 2020	Collaboration of Sysmex and Kawaski heavy industries Clinical launch expected at 2020

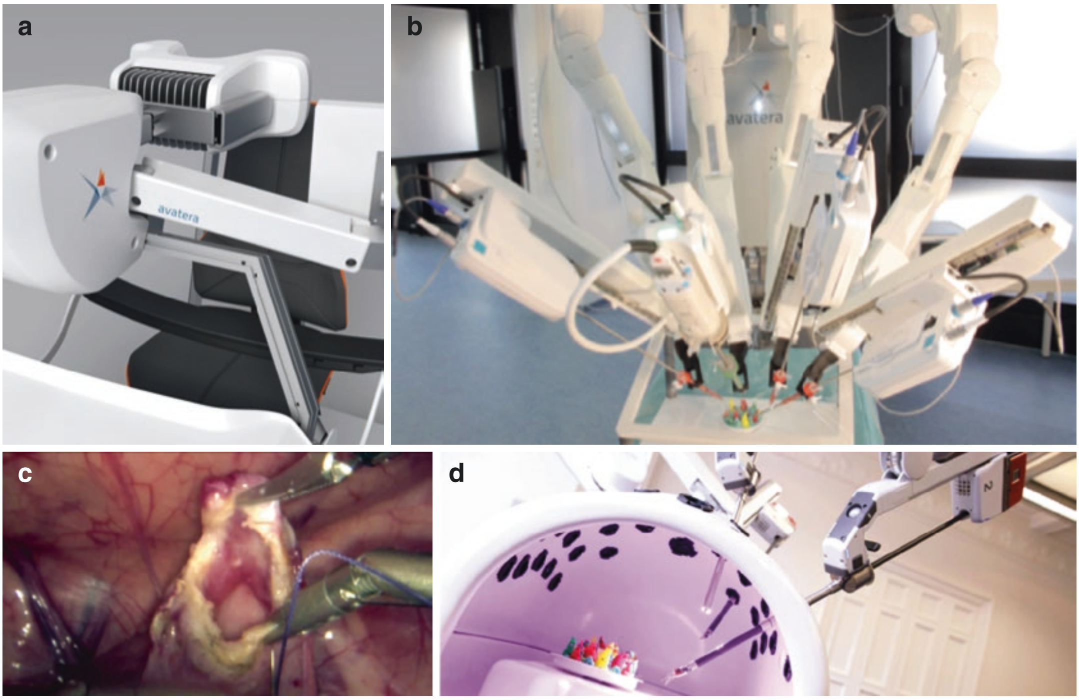

Fig. 1.10 AVATERA robot for laparoscopic surgery (Avateramedical, Germany). (**a**) Console with integrated seat, armrest and 3D–HD-videosystem using microscope-like technology with two adaptable oculars. Control of instruments by forceps-like handles using Sigma7-technology (Force Dimension, Nyon, Switzerland). (**b**) Four arm-system mounted on one cart using 5 mm instruments with 6 degrees of freedom. (**c**) Endoscopic view of the 7-DOF-instruments in porcine model (courtesy to J-U. Stolzenburg). (**d**) Arrangement and functionality of robotic arms with instruments using in-vitro-model

MEDICAROID

In 2016, Matsuda reported details of the "Japanese Robot" during AUA-plenary [56]. The device consists of three robotic arms attached to the operating table and a semi-open console using a microscope-like ocular, but the surgeon still needs polarized glasses (Table 1.3; Fig. 1.12). In January 2016, Medicaroid (Kobe, Japan) started a corporation in Silicon Valley based on previous collaboration of Sysmex and Kawasaki Heavy Industries to develop the US market for made-in-Japan medical robots [57]. The company's name is a portmanteau of "medical" and "android" [58]. The company expects to start with first clinical trials in 2018.

Verb Surgical

Verb Surgical was founded in 2015 with technology, expertise and funding from Verily (formerly Google Life Sciences) and Ethicon, a medical device company in the Johnson & Johnson family of companies. The company is building a surgical solutions platform that began several years earlier as a concept built between Ethicon and SRI International. Google has experience in the field of android robots by acquiring Boston dynamics [59] and Johnson & Johnson is one of the most important manufacturers of instruments for minimally invasive surgery. Verb intends to harness the unique capabilities of both companies to shape the future of surgery. Up to now, there is no exact information

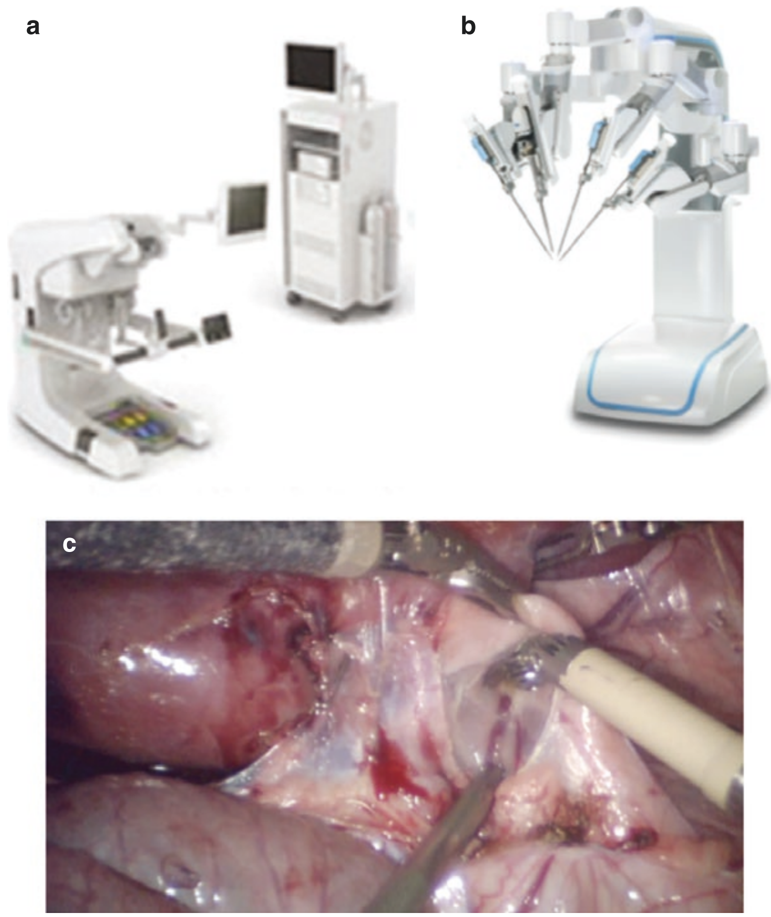

Fig. 1.11 REVO-I-platform for robot-assisted laparoscopic surgery (Meere Company, Seoul, Korea). (**a**) Open console with two handles, integrated foot pedals and 3D–HD-Monitor, surgeon needs polarizing glasses. (**b**) Four arm-system mounted on one cart. (**c**) Endoscopic view during porcine nephrectomy (courtesy to K. Rha)

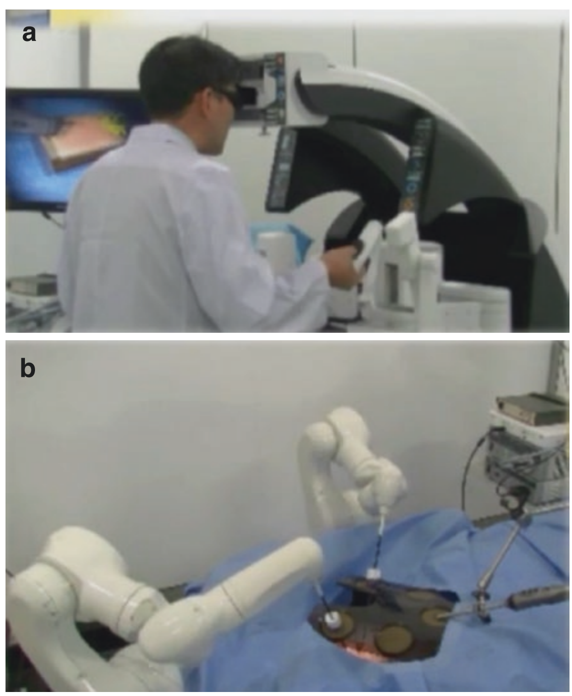

Fig. 1.12 Japanese robot (Medicaroid, Kobe, Japan). (**a**) Three robotic arms are attached to the operating table. (**b**) Surgeon sits at semi-open console using a microscope-like ocular, but still requiring polarized glasses

available about the final design of the robot. However, the idea is to integrate information and imaging into the surgical robot-assisted procedure based on five technology pillars — robotics, visualization, advanced instrumentation, data analytics, and connectivity [60–62]. The device could be based on the existing *Taurus Dexterous Robot* (SRI International, Menlo Park, USA) of which Ethicon owns the patent [63]. This device uses a closed console with in-line view. 7-DOF-instruments are controlled by Force Dimension-technology, however, until now only electromechanical end-effectors are shown (Fig. 1.13).

Experimental and Abandoned Projects

During the process of development other robotic devices have been developed, but did no reach further medical application due to various reasons ([5, 6]; Fig. 1.14).

AMADEUS RSS

AMADEUS RSS (Titan Medical, Toronto, Canada) was presented at an earlier stage on experimental level, which was based on a patent registered 2012 (Table 1.3; Fig. 1.14a). The device showed similarities to the Da Vinci-design with a closed console and 3 robotic arms aligned on a curved support [64]. This might be one of the reasons, why in 2013 Titan Medical stopped the development of AMADEUS RSS and focussed on development of the single-port robot SPORT™ ([65, 66]; Table 1.4).

Kyung Hee SR1

Kyung Hee SR1 developed at Seoul Yonsei University in collaboration with Samsung consisted of two industrial robots (AS2, Samsung Automation, Korea) providing 7 DOF and force-feedback mounted at bedside and a 2D standard laparoscope. Due to the relatively

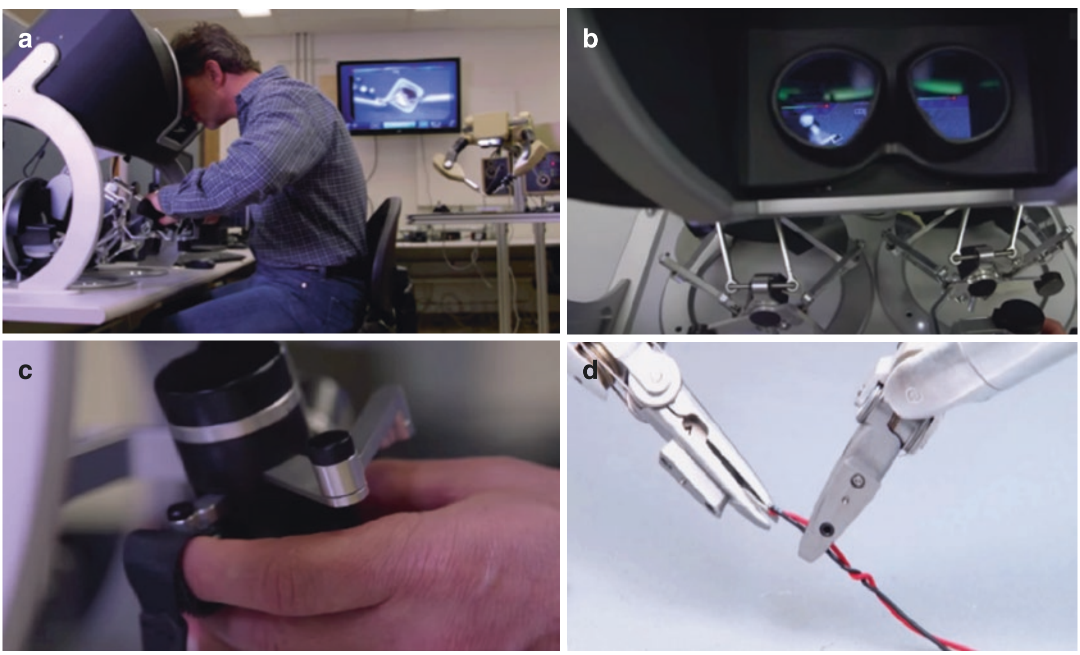

Fig. 1.13 TAURUS Dexterous robot (SRI International, Menlo Park, USA). (**a**) Closed console with in-line-view, in the laboratory version no arm rests provided. Three robotic arms are used. (**b**) In-line view with two oculars. (**c**) Control of instruments by forceps-like handles using ForceDimension-technology. (**d**) Electro-mechanical 7-DOF-end-effectors (i.e. cable-clamp)

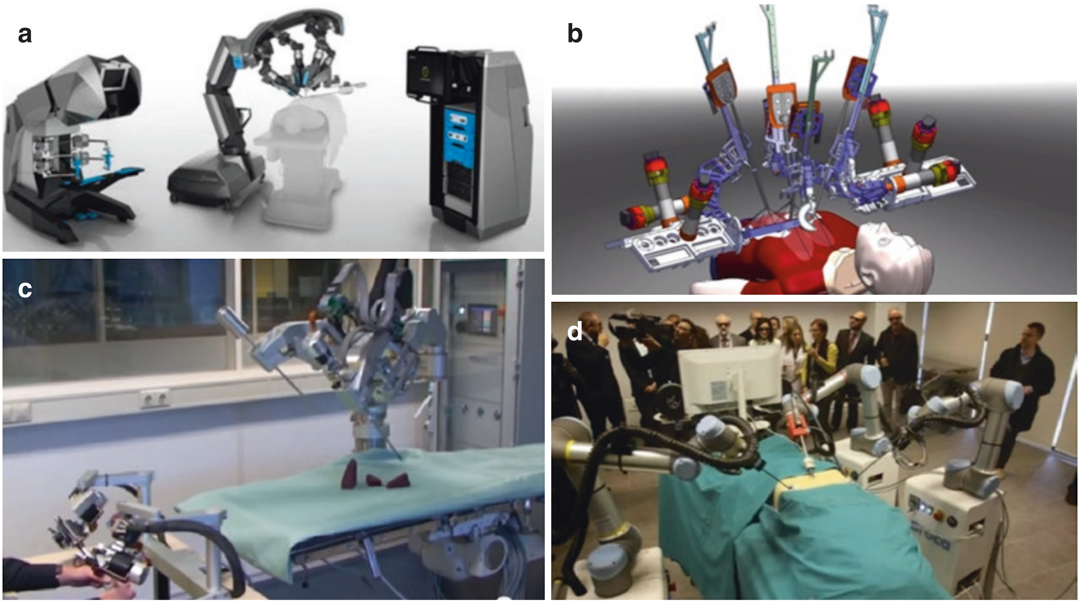

Fig. 1.14 Experimental and abandoned master-slave-devices. (**a**) AMADEUS RSS (Titan Medical, Toronto, Canada). Closed console, four robotic arms on a single cart with semilunar arrangement. Development stopped in 2013. (**b**) Raven Platform (Santa Cruz University, Berkeley University, Davis University) consists of an open console, portable surgical robotic arms controlled by an open source-software. (**c**) SOFIE (Surgeon's Operating Force-feedback Interface Eindhoven, University Eindhoven, The Netherlands) consists of an open console and maximally three robotic arms mounted at the OR-table. Until now no surgical applications. (**d**) BROCA-project (Maimonides Institute for Biomedical Research, IMIBIC, Cordoba, Spain). Three robotic arms on separate carts with an open console providing 3D–vision

simple design, this system allowed tele-presence surgery like ZEUS. The observed time delay during an in-vitro testing ranged from 20 to 40 ms [51]. However, the system was never used clinically.

Raven Platform

Raven Project represents the collaborative effort of three American universities (Santa Cruz, Berkeley, Davis) aiming to produce an open source system that might allow two surgeons to operate on a single patient simultaneously. The initial system included two portable surgical robotic arms, each offering seven DOF and a portable surgical console. Raven II is a two-armed surgical robot designed with one camera and may utilize 3-D ultrasound imaging [67]. Raven III includes four robotic arms and optionally two cameras (Fig. 1.14b). Raven platform is one of the most advanced surgical robotics research platforms. A lot of research is dedicated to battlefield and underwater remote surgery.

SOFIE

SOFIE (Surgeon's Operating Force-feedback Interface Eindhoven) provides a force-feedback interface with less space for robot consume. Two components (master and slave) are completely separated from each other, however all communication between the two takes place over data cables arranged in an overhead wiring boom [68]. Three different light-weighted robotic arms with maximally 8 DOF can be fixed to operating table (Fig. 1.14c). Until now no laparoscopic application has been published.

Table 1.4 Robotic flexible endoscopic multi-tasking platforms for single-port surgery with possible clinical future

Device/patents	Outer diameter (mm)	No. of instrument channels	Robotic arms	Length (cm)	Degree of freedom of movements (DOF)	Comment
SPORT surgical system (Titan Medical, Canada) Patent: US8347754B1 Listed: 30.06.2009	25	None	2 robotic arms with snake-like Plus deflectable telescope	30	Endoscope: 4 DOF[a] Instruments: 9 DOF[b] Due to snake design	Ergonomic console with HD-3D-monitor Patient cart to manipulate robot with various instruments for both arms For renal surgery additional instruments are necessary
SurgiBot (Transenterix, USA) Patent: WO2016057989A2 Listed: 12.10.2015	21	2 working channels tubes (2x5mm) plus 3D/HD flexible laparoscope (5 mm)	2 steerable tubes controlled by endomechanical vertebral arms (adjustable motion scaling)	30/50	Endoscope: 6 DOF[a] Instruments: 7 DOF[b]	Robotic arm holds the device 3D/HD-vision by polarized glasses motion of arms like laparoscopic instruments No console, no FDA-approval yet
SP 1098-platform (Intuitive Surgical, USA) US20150366625A1 Registered: 24.06.2015	25	Non	3 robotic arms with snake segments plus flexible 3D telescope	30	Endoscope: 6 DOF[a] Instruments: 9 DOF[b] Due to snake design	Controlled by EndoWrist-technology at the Da Vinci-console For prostate surgery additional instruments are necessary
Insertable robotic effectors platform (Columbia University, USA) US20110230894A1 Listed: 07.10.2009	20	None	2 flexible arms with snake segments design +3D telescope (paralleogram design)	22	Endoscope: 2 DOF[a] Instrument: 9 DOF[b] due to snake design	Operated by two hand-pieces and a 2D–monitor actually not comparable to a surgical console. Provides sensory feedback Still completely experimental

(continued)

Table 1.4 (continued)

Device/patents	Outer diameter (mm)	No. of instrument channels	Robotic arms	Length (cm)	Degree of freedom of movements (DOF)	Comment
SPRINT (ARAKNES, Italy, Switzerland, Germany) Patent: US20130304084A1 Listed: 11.10.2011 FI2010A000076–77 Listed: 26.04.2010	25	None	2 motor-driven robotic arms with joints for end-effectors (elbow, wrist)	30	Endoscope 4 DOF[a] Instruments: 7 DOF	Operated by two hand-pieces with haptic interface and a 3D–monitor with glasses actually not comparable to a surgical console Magnetically controlled endo-camera tested in vivo. No in-vivo tests of the device have been reported yet supported by the European Commission's Joint Research Centre Still completely experimental

[a]Endoscope up/down left/right rotation translation
[b]Instrument up/down left/right open/close translation rotation wrist of instrument

BROCA-Project

In 2016, first details of the BROCA-project have been published. BROCA has been the first pre-commercial public procurement project in the field of biomedicine in Spain, a new contractual arrangement form supported by the Ministry of Science and Innovation and ERDF to favour development of new technological products by private enterprises. In this case, the University of Cordoba was awarded funding to conduct this pioneering project with the key implication of the Maimonides Institute for Biomedical Research (IMIBIC) scientific board and the collaboration of Reina Sofia University Hospital. Finally, the robot prototype will be delivered to the University of Cordoba that will be in charge of future commercialization [69, 70]. The BIT-robot consists of three arms separately mounted on carts with an open console with 3D–video-imaging (Fig. 1.14d). The instruments may provide tactile sensations.

Console-Based Devices for Robot-Assisted Single-Port Surgery

Laparo-endoscopic single site surgery (LESS) further minimizes access trauma of classical laparoscopic or robot-assisted laparoscopic surgery as a potential step toward true natural orifice surgery (NOTES). However, classical LESS-technique is significantly impaired by suboptimal ergonomics with clashing of instruments. Robotic technology may overcome some of these problems [71].

SP 1098 Platform

Da Vinci XI system also allows the use of the robotic single-port SP 1098-platform (Table 1.4). The design of SP-platform includes a 3D/HD flexible telescope and two flexible instruments. Once introduced via umbilical incision, the flexible instruments with a snake style wrist separates to achieve triangulation (Fig. 1.7d). The device is controlled by use of EndoWrist™-technology at the console. In contrast to all other devices, based on CE-mark the SP 1098-platform has been already used successfully in clinical pilot studies focussing on robot-assisted single port partial nephrectomy, radical prostatectomy and radical perineal prostatectomy [35, 72, 73].

SPORT-Surgical System

Titan Medical focused on SPORT™-Surgical System as a platform for robot-assisted LESS consisting of a console with 3D–HD-vision and a manipulator at bedside to perform the procedure [65, 66]. The basic design of the platform is similar to other solutions including a 3D–flexible telescope with fibre-optic based illumination and two flexible instruments (Table 1.4; Fig. 1.15). The company made first public unveiling and demonstration of the device at SAGES-2016 in Boston. However, FDA-approval for the system is still pending [74, 75]. Main applications should be robot-assisted LESS-cholecystectomy. Recently, robotic single-port partial nephrectomy has been performed in the animal model requiring additional trocars for retraction [65, 66].

Experimental Devices for LESS

Based on research grants various institutions developed robotic devices for single-port surgery (Fig. 1.16).

ARAKNES

The ARAKNES Project (Array of Robots Augmenting the Kinematics of Endoluminal Surgery) was funded by EU-Programme to produce a micro-robotic-based smart operating system for advanced endo-luminal surgery ([76]; Table 1.1). The system is based on the common design of a remote console and two robotic arms with rotating grippers on the end (SPRINT robot) introduced via the umbilicus (Fig. 1.16a).

Fig. 1.15 SPORT™ Surgical System (Titan Medical, Canada) for robotic single-port surgery. (**a**) Console offering 3D–HD-vision, armrest, two handles, and foot-pedal to control monopolar and bipolar cautery. (**b**) Transfer of movements at the console with sigma-technology (Force Dimsension, Nyon, Switzerland). (**c**) Robotic arm to manipulate the three-arm-system consisting of 3D–flexible telescope with fibre-optic based illumination and two flexible instruments. (**d**) Endoscopic view of the instruments during laparoscopic partial nephrectomy in porcine model. Note the need of additional laparoscopic instrument for retraction

IREP

The IREP (Insertable Robotic Effectors Platform) is currently developed at Vanderbilt University consisting of a 3D–telecope and two flexible arms with snake segments design providing a passive and active segment. Enlargement of working space may be provided based on parallelogram instrument design ([77]; Table 1.4). The device is operated by two hand-pieces and a 2D–monitor not comparable to a surgical console (Fig. 1.16b).

University of Nebraska Robot System

The University of Nebraska [78, 79] in collaboration with Virtual Incision (Nebraska, United States) presented the prototype of a two-armed dexterous miniature robot system using inter-

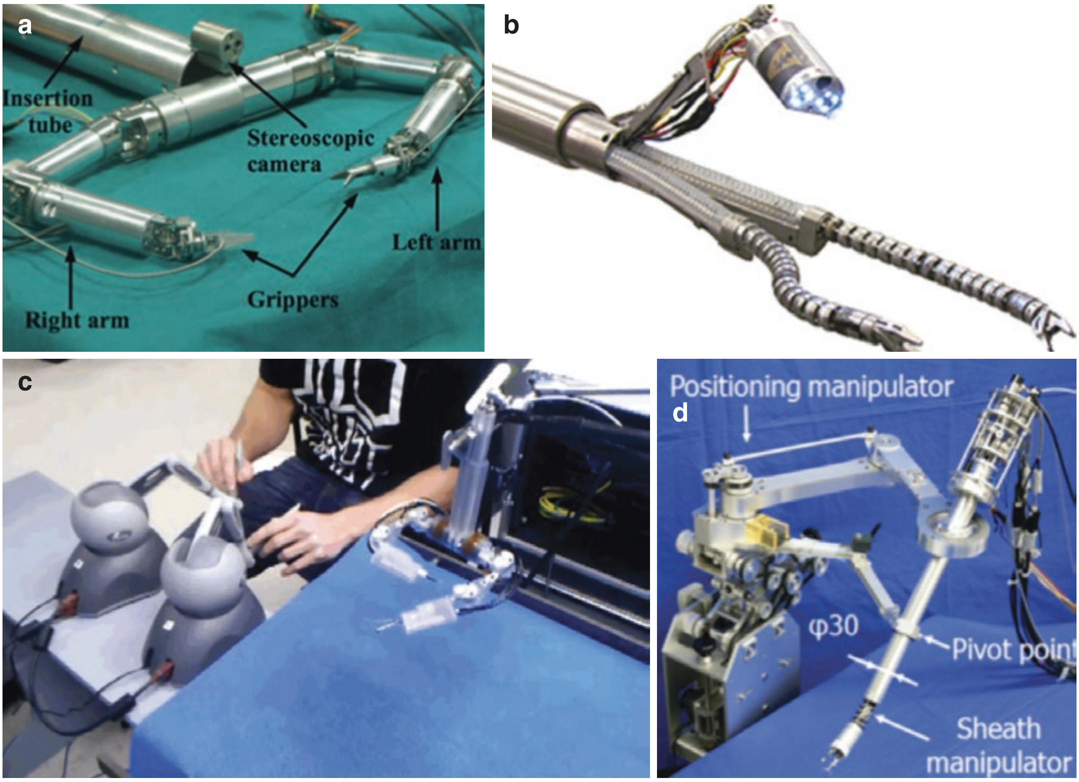

Fig. 1.16 Experimental master-slave-devices for single-port surgery. (**a**) ARAKNES (University of Lausanne, Switzerland). The system is based on the common design of a remote console and two robotic arms with rotating grippers on the end (SPRINT robot) introduced via the umbilicus. (**b**) The IREP (Insertable Robotic Effectors Platform) currently developed and tested at Vanderbilt University, United States consisting of a 3D–telecope and two flexible arms with snake segments design providing a passive and active segment. Enlargement of the working space may be provided based on a parallelogram design of the instrument. (**c**) University of Nebraska robot system in collaboration with Virtual Incision (Nebraska, United States). A two-armed dexterous miniature robot system using interchangeable end-effectors to provide mono-polar cautery, tissue manipulation, and intra-corporeal suturing capabilities. Instruments are controlled by two external handles. (**d**) Waseda-University device representing a single port-device, which is manipulated at bedside with a flexible tip of the device. At this tip, two small flexible instruments can be used

changeable end effectors to provide mono-polar cautery, tissue manipulation, and intra-corporeal suturing capabilities. The device is controlled by two external handles (Fig. 1.16c). The modules can separate for individual insertion, and the robot is externally supported by a mounting rod assembly.

Waseda-University Device

This robot has been developed at WASEDA-University, Japan. It represents a single port-device, which is manipulated at bedside with a flexible tip of the device. At this tip, two small flexible instruments can be used (Fig. 1.16d). The master-slave system included a six-degrees of freedom (DOFs) tool manipulator, an easy set-up mechanism, a flexible shaft drive with sufficient DOFs and a vertical arrangement for improved vision. The robot manipulates an endoscope within the body [80]. Evidently, this device has a very limited working space similar to early instruments designed for NOTES.

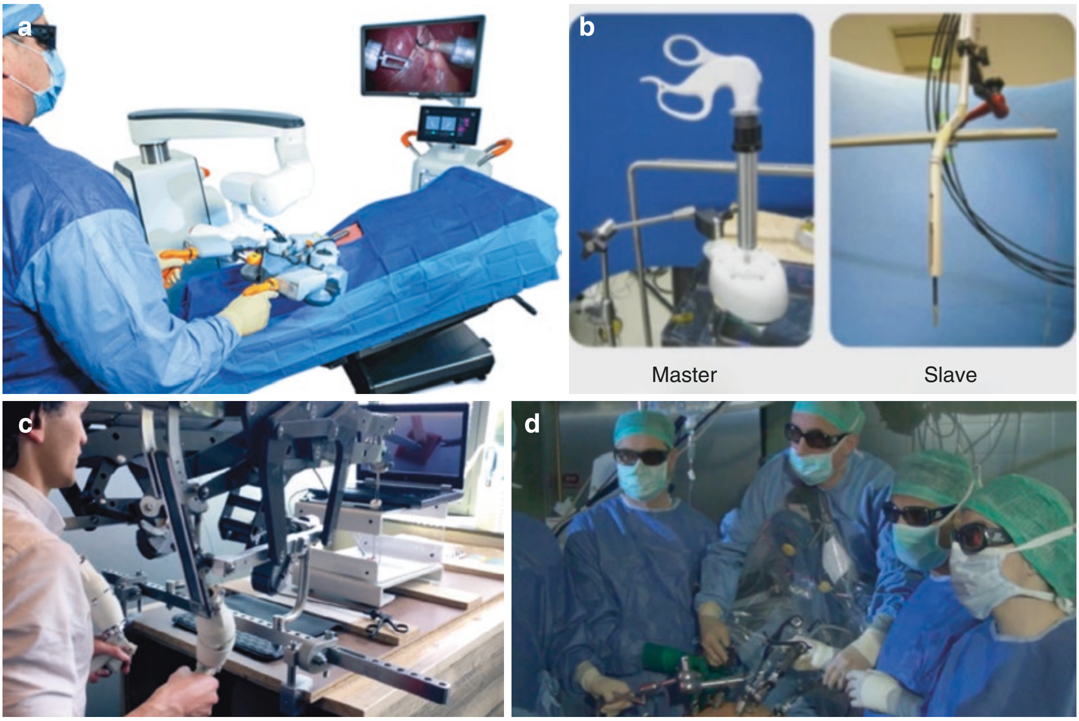

Fig. 1.17 Bedside solutions for robot-assisted surgery. (**a**) SurgiBot (Transenterix, USA): Platform developed for LESS based on tubes in which flexible instruments can be manipulated to perform laparoscopic single-port surgery. The robotic arm provides multiple features such as triangulation adjustment, multi-quadrant movement, robotic lateral movement and rotation, clutch of instruments in an ergonomic position, and a 3D–HD-videosystem. (**b**) LODEM (Osaka Institute of Technology, Osaka, Japan). A flexible locally operated end-effector manipulator developed for single-site laparoscopic surgery at the Osaka Institute of Technology. Only experimental studies. (**c**) MIM-system (LaparaSurgical, Utrecht, The Netherlands). Mechanic device, which enables instrument movement similar to the other robotic systems, owing to a parallelogram-based design. Used at bedside. Only experimental studies. (**d**) ETHOS-platform: Use of the ergonomic platform ETHOS™ in combination with motorized instruments offering 7 degrees of freedom

Bedside-Based Devices for Robot-Assisted Single-Port Surgery and Laparoscopy

SURGIBOT

Spider System (Transenterix) represents a platform developed for LESS based on tubes in which flexible instruments can be manipulated to perform laparoscopic single-port surgery. The initial device used wire-based manipulation only for 5 mm instruments requiring insertion of on additional trocar for ablative renal surgery [81]. Handling of instruments was difficult particularly concerning endoscopic suturing. Therefore, Transenterix improved the system considerably providing the robotic arm SurgiBot with multiple features such as triangulation adjustment, multi-quadrant movement, robotic lateral movement and rotation, clutch of instruments in an ergonomic position, and a 3D–HD-videosystem (Table 1.4; Fig. 1.17a). In 2015, Transenterix has submitted application for FDA-approval [82], however until now, this has not been granted.

LODEM

A flexible locally operated end-effector manipulator (LODEM) was developed for single-site laparoscopic surgery at the Osaka Institute of Technology (Japan). This device uses crank-slider and cable-rod mechanisms to achieve 5 degrees of freedom and an acting force of more than 5 N. The surgeon utilizes a robotic arm for endoscope and forceps together with classical laparoscopic instruments [83]. The device has been tested in-vitro and in-vivo for surgical indications (Fig. 1.17b).

MIM-System (Minimally Invasive Assistant = MIA)

The manually manipulated robot-like system MIM developed at the Universiy of Utrecht, the Netherlands is an interesting modification of bedside devices for laparoscopic surgery providing seven DOF [84]. This device enables instrument movement similar to the da Vinci® device, owing to a parallelogram-based design (Fig. 1.17c). However, the handling is still relatively clumsy and the device has been tested experimentally only. On the other side, the company Lapara Surgical (Amsterdam, Netherlands) has been founded to further developed this device to get on the market under the name MIA (minimally invasive assistant) [85].

ETHOS-Platforms Plus 7-DOF-Instruments

Another bedside-based alternative for laparoscopy could be the use of the ergonomic platform ETHOS™ in combination with motorized instruments offering 7 degrees of freedom such as Robot DEX (Dexterité, Annecy, France) or Kymerax (Karl Storz, Tuttlingen, Germany) and 3D–HD-videotechnology [86–88]. ETHOS™ chair (Ethos, Seattle, USA) enables avoidance of the torero position during suturing as the surgeon sits over the patient's head during pelvic surgery, rather than standing or sitting laterally. The surgeon has two adjustable armrests and footrests with integrated foot switches that enable electrically motorized movements of the chair (Fig. 1.17d). Compared to robotic systems using a console, such solutions are much cheaper (ie. 50.000–100.00 Euro vs. 1–1.5 Mio Euro). They can compensate for some of the deficiencies of laparoscopy particularly during reconstructive surgery, however a clutch-mechanism is still missing.

Robotic Device for Retrograde Intra-Renal Surgery

Robotic-master slave systems are not limited to multi-port or single-port laparoscopic surgery, but are also used already in endourology (Fig. 1.18).

Sensei-Magelan-System

In 2011, robotic flexible ureteroscopy was reported using as the Sensei-Magelan-system (Hansen Medical, Mountain View, USA) designed for cardiology by Frederick Moll, the inventor of the da Vinci-system. This device consists of four components: surgeons console, flexible catheter system, remote catheter manipulation system, and electronic rack containing computer hardware, power supplies and video distribution units (Fig. 1.18a, b). The robotic flexible catheter system consists of an outer catheter sheath (14/12F) and inner catheter guide (12/10F). A 7.5F fibre-optic flexible ureteroscope was inserted through the inner catheter guide. Remote manipulation of the catheter system manoeuvres the ureteroscope tip, which was glued in place to the inner guide. The tip of the outer sheath was positioned at ureteropelvic junction to stabilize navigation of inner guide inside the collecting system. This means that the ureteroscope is manipulated only passively [89].

Avicenna Roboflex

In 2015, Avicenna Roboflex (Elmed, Ankara, Turkey) was introduced to perform retrograde intrarenal surgery (RIRS). The surgeon sits at the console manipulating a standard flexible ureteroscope with HD-videotechnology. The hand-piece of the scope is attached to a robotic manipulator enabling rotation, insertion, and deflexion of the scope inside the collecting system. All movements can be graduated and fine-tuned up to a

Fig. 1.18 Robotic assisted flexible ureterorenoscopy. (**a**) Schematic drawing of the main parts of the Sensai System (Hansen Medical, United States) designed for interventional cardiology. (**b**) Sensai-System: Surgeons sits at console and controls the flexible ureterorenoscope, which is introduced in the steerable tube system. Transfer of movements at the console with sigma-technology (Force Dimsension, Nyon, Switzerland). (**c**) Schematic drawing of the main parts of the Avicenna Roboflex (Elmed, Ankara, Turkey) designed for retrograde intra-renal surgery (RIRS) with a console and the manipulator. (**d**) Avicenna Roboflex: Surgeon controls the handpiece of the flexible ureterosopce with two joy-sticks (for deflection, advancement and rotation). Additionally, he can control the position of the laser fibre and the force of irrigations system. Integrated foot-pedals for activation of fluoroscopy and laser lithotripsy

1:10 ratio. Irrigation, activation and control of the laser-fibre as well as fluoroscopy are provided by touch-screen functions or foot-pedals at the console (Fig. 1.18c, d). First multi-centric clinical experiences are very promising [90].

Discussion

End of Monopoly of Intuitive Surgical

Developments in robotic surgery were limited by the monopoly of Intuitive Surgical. Over the years Intuitive Surgical has built barriers to new entry, including superior product offerings, intellectual property protection, multiple regulatory clearances, a large installation base, worldwide training centres, strong customer relationships, and an excellent balance sheet [91]. Expiration of company's existing key-patents in 2019 poses a serious challenge (Table 1.1). Once these patents expire, competitors can utilize those technologies, and Intuitive Surgical's advantages might be lost. Speaking of competitors, several companies will be soon introducing their own robotic platforms [5, 6, 92]. However, FDA-approval still represents a significant barrier [6]. On the other hand several devices are developed in Europe and Asia and TELELAP-ALF-X (SENHANCE) has already received CE-mark [44].

Some Internet publications emphasized possible expiring of Intuitive Surgical's key-patents in 2014 [91, 92]. However, a recent research identified only a few early patents related to construction of a console for battlefield surgery [6]. All relevant patents of ZEUS and Da Vinci were listed in 1999 and will expire in 2019 (Table 1.1). This is one of the reasons, why Medtronic will

Table 1.5 Features of existing and upcoming robots and their possible advantages (modified from Rassweiler et al. 2017)

Feature	Description	Advantage
Closed console	Surgeon looks in window/occular of the console	Surgeon has imagination to immersed in the body No need of 3D–polarized glasses Additional imaging information can be dysplayed on the in-line screen
Open console	Surgeon sits in front of a monitor: using 3D–polarized glasses	Vision similar to laparoscopy Better contact to the OR-team Easy viewing if additional information (imaging, virtual reality) on separate screen Flexible for technical improvement (3D–monitors; ultra-HD-videotechnology
Camera control by handles and foot-pedal	Surgeon activates camera movement by foot-pedal and navigates the telescope via parallel move of both handles	The tip of both instruments are always lateral to the telescope enabling immediate continuation of the surgical step
Camera control by eye-tracking	Camera is navigated according to the eye and head movements of the surgeon	Automated process similar to the surgeons attitude (head closer to the monitor = zoom in) No need to activate camera navigation
Loop-like handle	Surgeon manipulates instruments with the finger-tips (thumb and index finger)	Full realization of the immersion-like endoscopic surgery (Endo-wrist-technology) Additional functions can be integrated lateral to the loops (clutch-function for each arm)
Laparoscopy-like handle	Surgeon manipulates instruments with laparoscopic handles (thumb and middle-finger)	Manipulation similar to laparoscopy Index-finger can be used for further functions (rotation, activation of haptic feedback) Easy integration of 4-DOF-instruments (advanced sealing devices, laparoscopic forceps) Good realization of haptic feedback

initiate early clinical trials in India, Transenterix focuses on first studies in Europe, and Meer Company has initiated human studies in Korea. Avateramedical is focusing on CE-mark to enter the European Market [50].

Relevance of New Features of Surgical Robots

There are several ways to improve or modify devices including design of console and robotic arms (Table 1.5). Clinical introduction of new robots will soon demonstrate relevance of the different features [6].

Closed Console Providing 3D-Video-In-Line-Pictures Versus Open Console Using Polarized Glasses

There are two concepts realized in the different devices. Intuitive Surgical and Avateramedical rely on the principle of in-line video-technology, where the surgeon is immersed in the operative field and does not need to use polarized glasses associated with loss of brightness of image. Advantages of an open console include better contact to the team at bedside and the flexibility of such systems to integrate future technologies: Ultra-HD (4 K)-video-technology may come with larger screens, higher resolution; full HD-3D-screens are already used in entertainment industries [6].

Movement of Telescope by Eye-Tracking or Voice-Control Versus Manually with Two Handles

Intuitive Surgical introduced navigation of telescopes by two handles, whereas Computer Motion started with a voice-controlled camera-system (AESOP) [11, 13–15]. Sofar-Transenterix developed an eye-tracking system to control the telescope [44]. According to personal experiences with voice-controlled and head-controlled laparoscopes versus the hand-controlled system of Intuitive Surgical, the advantage of handle-controlled systems represents the fact that the tips of both instruments are always in optimal distance to the telescope thus enabling immediate continuation of the surgical step [71].

Finger-Tip-Based Control of 7-DOF-Instruments Versus Use of Laparoscopic Handles

Fingertip-based controls of instruments (ie. by loops) use the index finger and thumb of the surgeon as well as the wrist. Laparoscopic handles control instrument by thumb and middle finger allowing the index finger to be used for further functions (activation of haptic feedback, rotation of instrument). Laparoscopic handles enable the use of instruments providing only 4 DOF (ie. Ligasure™, staplers, endo-dissect, endo-scissors), which may have an economic aspect. Until now, haptic feedback has been realized only for laparoscopic handles [39].

Importance of Clutch-Mechanism

Apart from this, the clutch-mechanism is most important for robot-assisted surgery. Only bedside devices, which provide such functions like the Surgibot may have a potential for clinical use [82]. According to our experience with the different generations of da Vinci devices, it plays no role how the clutch-function can be activated: finger-tip-based or foot-pedal.

Robotic Arms Fixed at OR-Table or Mounted on Cart(s)

Most companies have modified their prototypes putting robotic arms on carts and not fixing them to the OR-table. This enables more versatility for different applications. Future will show, whether this has really advantages compared to a four arm-arrangement on a single cart (Intuitive Surgical, Avateramedical, REVO-I). It seems to be very difficult to assemble four single carts around respectively four arms on the OR-table.

Single-Port Versus Multi-Port Robots

Easy procedures like robot-assisted laparoscopic LESS-cholecystectomy might be performed with all types of devices. However, comparable urological indications are infrequent. Using SP 1098-Platform, Kaouk et al. needed additional ports in 4 of 11 robotic LESS-prostatectomies [35]. Reduced working space in case of single-port surgery is another issue. One can hardly assume, that such devices will become routine for frequent urological indications like radical prostatectomy.

Importance of Joint Ventures

Initially, apart from 3D–videotechnology coming from Schoelly (Denzlingen Germany), Intuitive Surgical completely developed and produced of all parts of the robot and basic instruments providing Endowrist™-technology. Only for specific instruments (ie. stapler, harmonic scalpel, vessel sealer) Intuitive Surgical collaborated with referring manufacturers of such devices. Recently, they collaborated with Trumpf-Medical (Saalfeld, Thüringen) to adapt the XI-system to an OR-table (table motion technology).

Most of upcoming systems already represent joint ventures involving experts of robotics, video-technology and instruments. Tuebingen Scientific is involved in production of 7-DOF instruments for TELELAP-ALF X (SENHANCE) and AVATERA. Project EINSTEIN combines German robotic technology of MIROSurge with instruments of Covedien under the roof of robotic know-how by Medtronic. Such joint ventures present a future trend in robot-assisted surgery.

Costs and Benefits of New Robots

Costs for the new robots are expected to be significantly lower ranging about 800.000 USD compared to 2.1 USD for Da Vinci XI-system [91]. TransEnterix will most likely be Titan Medical's main competitor from the get-go, and because TransEnterix will have a head start in the US-market due to its expected timeline of milestone events [92]. However, both companies have not yet FDA-approval for their devices, but TELELAP-ALF X (SENHANCE) has CE-mark and has been already sold in Italy [44]. Intuitive Surgical has already reacted by implementing the X-system in between the SI and XI to still control the market [36]. The variety of new devices will definitively have an impact on the costs, including purchase and maintenance of the robot as well as instrument prices. Finally, the marketing effect of robotic surgery will decrease and cheaper bed-side-solutions might also become a valid alternative ([6]; Fig. 1.17).

Perspectives

Development of robotic technology will never stop: it may offer distinct features to the surgeon, such as haptic gloves, cellular image guidance [56]. Particular cooperation of Google and Johnson & Johnson aims to use cellular guided imaging in their robot, which would lead this device beyond a classical master-slave device. Verb Surgical was formed in August 2015 as an independent start-up company, backed by Google and Johnson & Johnson to bring this collaboration to life [60–62].

Beyond, surgical robots as master-slave devices, the role of robotics might be even extended: Shademan et al. [93] described in vivo supervised autonomous soft tissue surgery in an open surgical setting, enabled by a plenoptic three-dimensional and near-infrared fluorescent (NIRF) imaging system supporting an autonomous suturing algorithm. Based on expert human surgical practices, a computer program generates a plan to complete complex surgical tasks on deformable soft tissue, such as suturing an intestinal anastomosis [93, 94]. Despite dynamic scene changes and tissue movement during surgery, they could demonstrate that the outcome of supervised autonomous procedures was superior to surgery performed by expert surgeons and robotic-assisted techniques in ex vivo and in-vivo porcine model comparing metrics of anastomosis-including the consistency of suturing informed by the average suture spacing, the pressure at which the anastomosis leaked, the number of mistakes that required removing the needle from the tissue, completion time, and lumen reduction in intestinal anastomoses.

These results of STAR (Smart tissue autonomous robot) demonstrate the potential for autonomous robots to improve the efficacy, consistency, functional outcome, and accessibility of surgical techniques. Similarly, robot-assisted water-jet-ablation (Procept, Redwood Shores, United States) showed significantly better ablation efficacy compared to standard transurethral resection [95]. Thus, all proposed solutions have to be assessed critically. We need to develop specific robotic curricula for urologic indications. Next years will be fascinating to see answers to those questions and to evaluate the impact of robot-assistance for other surgical approaches in urology like robot-assisted flexible ureterorenoscopy [89, 90].

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2 Anesthesiological Considerations During Robotic Urological Surgery

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Introduction

Robotic-assisted surgery has become commonplace in medicine since FDA approval of the da Vinci Surgical System in 2000, and the number cases performed using robotic assistance continues to increase nationwide [1]. The benefits of robotic-assisted surgery include decreased blood loss, smaller incision sites, reduced hospital length of stay leading to lower total hospital costs, and possibly better patient outcomes [1]. While many fields now use robotic-assisted surgeries, the field of Urology remains at the forefront. Robotic systems, when compared to standard laparoscopy, access deep, small spaces in the pelvis with much better articulation. Common urologic robotic-assisted surgeries include radical and simple prostatectomy, nephrectomy (radical, simple, and partial), and cystoprostatectomy with reconstruction. In 2011, 80% of radical prostatectomies were assisted by robotic surgery systems, and to date, it is the most common procedure to utilize the da Vinci robotic system [2].

While robotic-assisted laparoscopic surgery has some clear benefits, it also creates additional challenges for both the urologist and anesthesiologist. Specific challenges include extreme patient positioning, pneumoperitoneum, and limited access to patients while the robotic system is docked [1]. Extremes in patient position and pneumoperitoneum cause unique hemodynamic and physiologic sequela. Anesthesiologists must learn to anticipate, prevent, and manage these unique complications and this requires careful patient selection and assessment, detection and management of complications intraoperatively [3]. These challenges make communication an important component for the entire surgical/anesthesia team. Therefore, it is important for the anesthesiologist to develop competency in caring for patients undergoing robotic-assisted surgery.

Preoperative Considerations/ Comorbid Conditions

Careful preoperative assessment, including a thorough patient history and physical examination, is important to screen for conditions that

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_2

may be exacerbated or complicated by the extreme body positioning (steep Trendelenburg position, or full flank position), prolonged pneumoperitoneum, and the longer operative times associated with robotic-assisted surgery [2]. Special attention must be paid to patients with cardiovascular and respiratory diseases as extremes in body position and increased intraabdominal pressure may cause significant alterations in cardiovascular and respiratory physiology [4]. Alternative surgical methods should be considered for patients with significant cardiovascular/respiratory disease.

Some procedure-specific considerations should also be made. For robotic-assisted surgeries in the pelvis, a light bowel prep is recommended to decompress the bowel and to decrease the risk of fecal contamination should bowel injury occur during surgery [2]. A formal bowel prep is ordered for cystoprostatectomy [2]. Anticoagulation is held preoperatively for most urologic procedures unless other conditions are present. However, both mechanical and chemical anticoagulation are often given during cystoprostatectomy due to the length of the procedure and risk for thromboembolic events. While type and screens are ordered, radical prostatectomy is associated with such minimal blood loss that it is often not ordered for this procedure [2].

Due to pneumoperitoneum and extreme positions associated with robot surgery a variety of co-morbidities which can be affected by these conditions must also be screened for with history and physical exam and are discussed in further detail below. See Table 2.1.

Comorbidities

Cardiac

Patients should be screened for CAD, heart failure, valve dysfunction. Preexisting cardiovascular pathology may be worsened with robotic surgery due to steep Trendelenburg which increases preload and pneumoperitoneum which can cause aortic compression increasing afterload. These effects cause decreased cardiac output and increased work of myocardium [1]. For this reason, a patient's cardiac symptoms, medications, and exercise tolerance should be evaluated. Refer to AHA guidelines to determine if the patient has been optimized for surgery. Generally, beta blockers may be continued perioperatively. Further consideration must be given to patients with cardiac stents, and the pros and cons of continued anticoagulation must be weighed. Echocardiogram and stress testing should be performed in high-risk patients [1].

Obesity

Obesity causes a multitude of airway changes and puts patients at increased risk for: restrictive lung disease, sleep apnea, delayed gastric emptying, difficult vascular access, difficulty with intubation and ventilation, cardiovascular disease, diabetes mellitus, degenerative joint disease, thromboembolic events, and reduced wound healing, and conversion to open procedures. These patients also have decreased functional

Table 2.1 Perioperative considerations

Preoperative considerations	Comorbidities	Intraoperative considerations	Postoperative considerations
Full history and physical Thorough review of cardiovascular and pulmonary systems Consider co-morbidities	Cardiovascular conditions Central nervous system conditions, increased intracranial pressure Increased intraocular pressure Obesity Diabetes Peripheral neuropathies Pulmonary conditions Cancer Renal conditions	Decreased access to patient Pneumoperitoneum and extreme positions cause hemodynamic shifts Prevention of nerve injuries Higher levels of monitoring if necessary	Early IV fluids if needed Look for signs of airway edema and follow strict extubation criteria Examine for signs of nerve injuries Monitor for signs of insidious hemorrhage Early ambulation

residual capacity, vital capacity, FEV1/FVC ratio, and increased shunting [5] . The combination of steep Trendelenburg, and anesthesia negatively impacts respiratory physiology and can worsen pulmonary function. For these reasons, obese patients are more prone to quick desaturation and atelectasis [5]. Delayed gastric emptying also causes concern for possible aspiration during steep Trendelenburg.

Pulmonary

Patients with normal lungs can tolerate the extremes in position and pneumoperitoneum associated with robotic surgery. However, pulmonary pathology may be exacerbated by the extreme conditions [1]. Patients must be screened for COPD, bullous emphysema and spontaneous pneumothorax, reactive airway disease, OSA, and other lung diseases [6]. Patients with lung pathology are at higher risk of developing, atelectasis and pulmonary interstitial edema. These patients are also at higher risk for acidosis and hypercarbia. An arterial line should be placed for frequent blood gas monitoring. Pulmonary function testing is recommended in any patient with possible chronic lung pathology.

Renal

Renal insufficiency must be considered as it is likely to be exacerbated by mechanical obstruction, patient positioning, and fluid restriction during robotic surgery. The patient should be renally optimized before surgery and protective strategies such as avoidance of hypo-perfusion and avoidance of nephrotoxic drugs [6].

Neurologic and Ocular

The extremes in body position that are required of robotic surgery can also elevate intracranial pressure. For this reason, patients must also be screened for diseases of central nervous system and conditions which cause increased intracranial pressure such as mass lesions, cerebral aneurysm, and cerebrovascular accident. Patients with shunts should have shunt patency confirmed before robotic procedures [1, 6]. Similarly, patients with glaucoma or other causes of increased intraocular pressures are at risk for complications as increases in intraocular pressure likely occur during robotic assisted surgeries. These patients are also at risk for retinal detachment and periorbital edema.

Cancer

Cancer must be screened for before undergoing robotic surgery. Renal cell carcinoma can be associated with paraneoplastic syndromes 10–40% of the time and paraneoplasms secrete hormones such as insulin, renin, or erythropoietin [1]. Of additional concern are cancer patients who have or are receiving radiation or chemotherapy. Cancer patients previously treated with radiation therapy are more likely to have difficulties with surgical resection due to fibrosis and bleeding. Chemotherapy can cause many other systemic complications that must be considered perioperatively. Chemotherapy patients may have weight loss, predisposition to clot/embolism formation, electrolyte abnormalities, anemia, hypothermia risk, malnutrition, and decreased protein [1]. Decreased protein binding and a smaller volume of distribution should be expected for medications. Exposure to agents such as bleomycin and doxorubicin can cause pulmonary fibrosis and cardiomyopathy, respectively. All candidates for robotic cancer surgery should have a chest radiograph, electrocardiogram, blood counts, coagulation studies, renal function, basic electrolytes, and blood type screen. All patients should also be given an ASA score, noting that a score of 4 or greater bears an increased risk for complications with robotic surgery. Prophylaxis for infection, DVT, and reflux should be considered with antibiotics within 1 h of the surgical incision, subcutaneous heparin/sequential compression devices, and non-particulate antacids [1].

Peripheral Neuropathy

A recent study found that 6.6% of patients who underwent robotic-assisted urologic surgeries suffered a nerve injury from improper positioning [7]. Of these nerve injuries, 23% persisted for greater than 6 months. Patients with co-morbidities of diabetes, vascular disease, ASA class 4, obesity, and anatomic abnormalities are at even greater risk for nerve injury. A preoperative neurologic exam is important for documentation of preexisting abnormalities [1].

Diabetes

Preoperative blood glucose should be attained. If a lengthy case is expected, intra-operative blood glucose monitoring may be required. As previously discussed, diabetic patients are at increased risk for peripheral nerve injury and should have proper neurologic exam before surgery [1].

Age

Age has not been found to be a significant risk factor for robotic assisted surgery, and should not be a contraindication to robotic surgery.

Intraoperative Considerations

The space required for the robot and equipment may reduce the ability of health care personnel to visualize placement pf IV lines, monitors, and the endotracheal tube. See Table 2.2. Standard ASA monitoring is appropriate for robotic urologic surgeries unless other patient conditions or health factors exist. Two large bore intravenous lines with adequate tubing length should be available to account for the space limitations once the robot is docked. Additional access should be considered as needed for surgical or patient concerns. ART lines should be considered for hemodynamic monitoring if necessary. ART lines are often used in robotic-assisted simple prostatectomies and partial nephrectomies as they carry a higher risk of significant bleeding [2]. Additionally, blood products should be readily available for partial nephrectomies.

A standard induction and airway control with a tracheal tube is appropriate and should be adjusted based on patient's medical conditions [4]. It is important to secure the endotracheal tube, monitors, and IV lines before the robot is docked, as access to these sites may be limited during this time. This will be discussed in detail in the next section. For surgeries involving the

Table 2.2 Robotic procedure specific considerations

Procedure	Chemical thrombo-prophylaxis	Additional monitoring	Position	Special considerations
Simple prostatectomy	No	Consider ART line	Lithotomy, steep Trendelenburg	
Radical prostatectomy	No		Lithotomy, steep Trendelenburg	Robot may be docked above patients head
Simple/radical nephrectomy	No		Full flank	Robot may be docked above patients head
Partial nephrectomy	No	ART line often needed	Full flank	Robot may be docked above patients head Have ready mannitol, and Lasix. Blood products should be available. Tight post-op blood pressure control
Cystoprostatectomy	Yes, often given		Lithotomy, steep Trendelenburg	

kidneys a full flank position is used, for surgeries involving structures of the pelvis, lithotomy, and steep Trendelenburg are utilized. Muscle relaxation is important as patients must remain immobile while the robot is docked. Non-depolarizing muscle relaxant by infusion or bolus is sufficient. Film dressing and ointment over the eyelids helps protect the patient from corneal injury and desiccation. Patients are also at high risk for aspiration of stomach contents causing facial/ocular burns. Gastric decompression with NG or OG tube helps reduce these risks. Many facilities use mechanical DVT prevention during procedures. Due to the prolonged nature of robotic surgeries, use of volatile agents with shorter half-life should be considered. Adjunct opioids such as a remifentanil infusion are well tolerated during robotic-assisted surgery and provide balanced anesthesia.

As previously mentioned, nerve injury from extreme prolonged positions is also a risk. Patients must be positioned securely with adequate padding where needed. Fluid management is important to minimize edema of face and airways. Additionally, surgical views during may be obscured by high urine output in certain procedures (e.g., vesicourethral anastomosis). Some institutions recommend keeping preoperative and intraoperative fluids to a minimum of fewer than 2 L of crystalloid for these reasons [8]. Urine output monitoring may be further complicated as many common procedures will cause leakage of urine into the abdomen. Close monitoring of hemodynamic status is required as low intravascular volume and the cardiovascular/pulmonary physiologic changes that occur during robotic surgery.

It is recommended that emergence from anesthesia should occur after the robot has undocked. Anesthetic and muscle relaxants levels should be maintained until this time. It is important to watch for signs of airway edema, and several reviews suggest conducting an airway cuff leak test before extubation. If patients do not meet, strict extubation criteria patients should remain intubated and given several hours for redistribution of fluids and excretion of anesthesia.

Postoperative Considerations

The incidence of postoperative complications is low. The most common complications are anastomotic leaks and ileus due to pelvic hematoma [4]. Airway complications include stridor, laryngeal edema, obstruction, and tracheal deviation which can result in respiratory distress requiring reintubation occurs in 0.7% of robotic surgeries. Blood transfusion in not commonly required as intraoperative blood loss is lower in robotic assisted surgeries. However, significant hemorrhage can occur and should be monitored for during the postoperative period. Pain management is accomplished with multimodal pain management and will be discussed in detail at the end of this chapter. Kidney function should be monitored with urine output with the goal of at least 0.5 mL/kg/h, and IV crystalloid should be considered if urine output is lower than such. Early ambulation should be encouraged to prevent deep vein thrombosis. Post-operative blood-pressure control is needed to reduce the risk of bleeding after partial nephrectomy.

Specific Anesthetic Considerations Associated with Robotic-Assisted Surgery

Restricted Access to Patients

As previously mentioned, one of the main disadvantages of robotic-assisted surgery is a restriction in access to the patient. Once the patient is positioned and the robot has been docked, the position of the patient cannot be modified without going to great lengths due to the locking of the robotic arms. This is a disadvantage for the anesthesia provider and care must be taken to prepare as thoroughly and completely ahead of time to mitigate risk. Once the robot is docked, monitors, lines, positioning, and protective equipment cannot be readily accessed without the robot being detached. This process can result in delays and possible complications. Also, un-docking the robot takes time, and other complications can arise from that. It is imperative that the anesthesia provider is vigil and recognize complications as soon as possible so correct steps can be taken to provide adequate patient care [9].

Patient Positioning

Positioning is of utmost importance in robotic-assisted surgery. A safe and effective compromise between the anesthesia provider, surgeon, and patient care must be established for the benefit of the patient [9]. Depending on the location of the procedure, patient access may be even more restricted to the anesthesia provider. Upper abdominal, thoracic, and head and neck surgeries require the airway to be away from the workstation making access to the airway nearly impossible [10]. Due to the restriction of access to the patient, patient positioning is of utmost importance because once the trocars are placed, and the robot is docked, the patient movement could be catastrophic and complications may arise. Taking that into consideration, anesthesia must be directed to inhibit patient movement with prolonged muscle relaxants and paralytics [4]. Also, it is important that the patient's arms be placed in a natural position with armboards up to 90° or wrapping the patient's arms with towels and gel. It is imperative that those assisting do not accidently change the position of the armboard as this can cause damage to the brachial plexus [9]. One of the most common complications in robotic-assisted surgery is corneal abrasion, thus eyes must be taped or goggles placed to minimize that risk. Most of these considerations are imperative to all laparoscopic surgery, all surgery in general, but special care must be taken due to the nature of extreme Trendelenburg that is common in robotic surgery. Gel mats should be placed between the patient and the table, or the angle reduced as tolerated. Some use restraining straps and shoulder supports. Shoulder supports are not best practice to anchor the patient into position due to the risk of brachial plexus injury if the patient slips. If used, a gap between the shoulders and the supports should be used to prevent wedging the patient into place [9].

Steep Trendelenburg

Steep Trendelenburg or, "head down" positioning, is critical for optimization of view during laparoscopic proceduresshsu [6]. While surgical exposure is optimized, this particular patient positioning can have physiologic effects that the anesthesia provider must be aware of. Namely, the cardiac, pulmonary, and nervous systems can be adversely affected in extreme Trendelenburg positioning. Steep Trendelenburg is not well defined, but it is regarded as between 30 and 45° with steeper angles in robotic-assisted surgery as opposed to strictly laparoscopic. There are multiple potential rare complications that can arise from being in steep Trendelenburg for prolonged periods of time. Those complications include increased intracranial and intraocular pressure, bilateral lower limb compartment syndrome in long surgery exceeding 4 h, occipital ischemic necrosis resulting in alopecia, hypercapnia and hypothermia, damage to skin, neurologic, and vascular systems, facial trauma and corneal abrasion, and facial and laryngeal edema which can be mitigated with judicious fluid management [3]. Prolonged periods of steep Trendelenburg can reduce pulmonary compliance as well as increase upper airway resistance due to upper airway edema. Both vital capacity and FEV1 are decreased and can have a more pronounced effect in those with COPD and other pulmonary diseases. This can have a direct effect on pulmonary ventilation, thus patients with pulmonary disease need to be carefully evaluated.

The patient also needs to be protected against possible nerve injury, particularly the brachial plexus, ulnar, and lateral femoral cutaneous nerves while in steep Trendelenburg lithotomy position for prolonged periods of time. Other rare complications in those placed in steep Trendelenburg include compartment syndrome, rhabdomyolysis due to hypoperfusion of the lower extremities in the lithotomy position, blood loss, and hypothermia. These manifestations are of concern in patients who are obese, coronary artery disease, peripheral vascular disease, diabetes, or heart failure [4, 11]. Since both ICP and IOP are increased in steep Trendelenburg, care

Table 2.3 Steep Trendelenburg

Steep Trendelenburg and pneumoperitoneum physiologic effects
– Neurologic—increased ICP and IOP
– Cardiovascular—increased SVR, MAP, CVP, decreased cardiac index
– Pulmonary—decreased FVC, VC, compliance. V/Q mismatch, hypercarbia, acidosis
– Gastrointestinal—increased intragastric pressure

must be taken in those patients who are at risk for permanent damage relating to those complications. Patients with glaucoma may be poor candidates for robotic-assisted surgery. That being said, not every patient needs an eye exam before surgery because the risk of permanent vision damage including posterior ischemic optic neuropathy is low [12]. Laryngeal edema is also a grave concern in those who are in prolonged steep Trendelenburg positioning. Edema of the vocal cords, epiglottis, and arytenoids can cause upper airway obstructions, so criteria for extubation should be carefully assessed to prevent the need for re-intubation. See Table 2.3.

Pneumoperitoneum

The presence of pneumoperitoneum is necessary for all laparoscopic procedures, including robotic-assisted laparoscopic procedures. However, with that comes physiologic changes affecting mainly the cardiovascular and pulmonary systems. Those physiologic changes are more pronounced in patients undergoing robotic-assisted surgery due to the necessity of steep Trendelenburg positioning for longer periods of time. Systemic vascular resistance, mean arterial pressure, and myocardial filling pressure are increased in laparoscopic surgeries while the cardiac index goes down with minimal change in heart rate. Pneumoperitoneum compresses the vasculature in the abdomen, including the inferior vena cava, which subsequently leads to an increase in SVR and afterload at low right atrial filling pressures. At high right atrial filling pressures, pneumoperitoneum can increase venous return. In addition to the mechanical effects of insufflation, CO_2 can have a direct physiologic effect as well. $PaCO_2$ can be increased and can result in acidosis and systemic vasodilation and myocardial depression. These effects are mild but can be more pronounced in those with severe cardiovascular disease and limited cardiovascular reserve. The pulmonary effects of pneumoperitoneum are also observed mainly related to mechanics and gas exchange. Functional residual capacity and lung capacity decrease while supine and are augmented with pneumoperitoneum and steep Trendelenburg. Atelectasis, V/Q mismatch, and hypoxemia are the side effects that can be abated with the application of PEEP for alveolar recruitment. As the abdomen is insufflated with CO_2, the CO_2 is absorbed and reaches an absorptive plateau in 10–15 min. Absorption is independent of the length of surgery, and $PaCO_2$ concentrations are non-contributory in healthy patients. Those with severe cardiopulmonary disease can be at risk to acidosis and hypercapnia. The neurologic effects of increased intracranial pressure are increased with pneumoperitoneum in addition to steep Trendelenburg. The theory being that increasing intraabdominal pressure causes and increase in intrathoracic pressure as well. There is also a reduction in CSF absorption. These combined result in a decrease in lumbar venous plexus drainage which causes an increase in intracranial pressure [13]. Also, CO_2 is a vasodilator and as a result, can increase ICP. Typically healthy patients tolerate the increase in ICP. Laparoscopic surgery should be avoided in those with disease states that manifest in increased ICP. CO_2 is the most common gas used for insufflation. It is ultimately eliminated in the lungs through gas exchange. Because CO_2 is increased, the lungs have to compensate for adequate elimination. This is done through increasing the minute ventilation while under general anesthesia. Usually, healthy patients can adapt to the hypercarbia even with increased minute ventilation, but there are some patients whose compensatory mechanisms may be diminished. Those patients are ones with severe lung disease including COPD, reduced cardiac output like CHF, or septic patients. These particular patients require vigilant monitoring of end tidal CO_2 and arterial pH to prevent untoward effects. Steep Trendelenburg with insufflation can cause increased intragastric pressure as well. Usually a nasogastric or orogastric tube is placed for decompression to prevent aspiration of gastric contents into the pulmonary system [13].

Fluid Management

Excessive fluid administration during robotic-assisted surgery is associated with facial edema and swelling of the airway and conjunctiva. According to Kalmar et al., crystalloids do not remain very long within the vascular space, and due to gravity in the steep Trendelenburg position, edema can develop quickly around the face, eyes, and upper airway [13]. Respiratory distress has also been shown to occur during extubation that can require emergency reintubation. Therefore it is recommended to restrict fluid replacement to no more than 1–2 L during the procedure, utilize colloids over crystalloids, and to make sure that the patient can breath with the endotracheal tube placement. However, it is still speculative whether or not colloids carry an advantage over crystalloids [10, 13]. Once the patient positioning is accomplished, hemodynamic properties must also be addressed. These include increased systemic vascular resistance, increased mean arterial pressure, increased filling pressures, and 50% decreased cardiac index all occur after the initial CO_2 insufflation. 10 min after CO_2 insufflation, cardiac index increases, and systemic vascular resistance decreases. These hemodynamic changes occur along with increases in intraabdominal pressure which have an effect on the diaphragm and leads to oliguria. This is why urinary output during robotic-assisted surgery is not a reliable indicator of volume status. Nonetheless, studies have shown a 10–30% decrease in cardiac output when patients are placed in the Trendelenburg and reverse Trendelenburg positions [14]. In conclusion, patients undergoing robotic-assisted laparoscopic surgery should have a more restrictive fluid management that allows for decreased length of hospitalization postoperatively.

Hypothermia

Many factors can contribute to rapid heat loss during robot-assisted surgery that can lead to hypothermia. Anesthetics induce vasodilation on the skin surface while also having a depressive effect on thermoregulatory centers in the central nervous system. The mode of heat loss through the skin is mostly through radiation and convection which can allow for drops in body temperature up to 2 °C. Prolonged surgical time and carbon dioxide insufflation during laparoscopic procedures also contribute to heat loss [15]. It is important to prevent these drops in body temperature to prevent associated complications of hypothermia during robotic-assisted surgery. These complications include delayed wound repair, decreased coagulation times, increased adverse myocardial events, reduced resistance to wound infection postoperatively, and postoperative shivering in the patient [15]. Therefore, it is recommended to maintain intraoperative body core temperatures higher than 36 °C to prevent the adverse complications associated with hypothermia intraoperatively. Methods to prevent hyperthermia during robotic-assisted surgery are actively monitoring the core temperature of the patient, warming intravenous fluids before delivery, using warm humidified anesthetic gasses, air-warming devices, and controlling operating room temperature [15]. See Table 2.4.

Pain Management

Opioid analgesics were originally considered the gold standard to minimizing postoperative pain. This approach is quickly being replaced by the multi-modal approach to pain management

Table 2.4 Complications associated with hypothermia during robotic-assisted surgery

1	Decreased wound repair
2	Impaired coagulation times
3	Increased adverse myocardial events
4	Reduced resistance to wound infection
5	Postoperative shivering

which utilizes NSAIDs, gabapentinoids, and acetaminophen, as well as alpha-2 agonists, ketamine, esmolol, and nonpharmacologic approaches in combination with one another to achieve just as much efficacy, if not better efficacy than opioids alone while also reducing postoperative nausea and vomiting [16]. This multi-modal approaches to pain management have been shown to decrease the length of hospital stay and decrease postoperative complications such as nausea and vomiting while ultimately improving patient satisfaction [16]. Use of acetaminophen and non-steroidal anti-inflammatory drugs, if no contraindication exists, are recommended. As needed opioids are acceptable if indicated. Epidural analgesia is not typically needed for robotic-assisted surgical pain [17]. Epidural analgesia is said to have no advantage for post-operative pain control following robotic-assisted surgery [17]. Epidural anesthesia should not be used intraoperatively since the steep Trendelenburg position can cause a high block and cardiovascular instability [8].

The Learning Curve

A univariate analysis by Buchs et al. has shown that cardiovascular and renal comorbidities, American Society of Anesthesiologists score ≥ 3, BMI <30, age $\geq$ 70 years, and malignant disease were among several factors associated with increased morbidity during robotic-assisted surgeries [18, 19]. In the future, a scoring system could be used to identify patients at risk before and during the surgery to help guide robotic-assisted surgery safely with low morbidity and mortality.

The learning curve is the time during which surgical team members utilize to train to use the robot before a surgical case. This training can take anywhere from months at a time to a year to complete training. Complications of robotic-assisted surgeries also involve variable learning curves to use the robot with varying complexities of each case. Therefore the Advisory on Robot-Assisted Surgery recommends that surgical team members utilize a longer training period for more advanced cases in which the robot is used. Nonetheless, the length of training for each surgical team member to be proficient with the robot is still unknown with most agreeing that it depends on the type of surgery performed and skill level involved.

Communication Amongst Team Members

The level of success and efficiency of robot assisted surgery largely depends on communication amongst the surgical team including the surgeon, anesthesiologist, OR nurses, and OR assistants. With the surgeon sitting behind the console of the robot and away from the rest of the team, effective communication between the anesthesia staff and operative assistants and nurses at the patient's bedside must be optimal to ensure the safety of the patient and success of the operation. And because the surgeon is placed behind the console, audio speakers are placed in conjunction with the video tower to facilitate transmission of the surgeon's voice [8]. Team members, however, use simulations and emergency training drills to prepare for the most adverse outcomes that could occur with the use of a robot and to better communication between team members before real cases. Studies have shown that these drills improve communication amongst robotic surgical team members and significantly reduce adverse complications [20]. Development of a perioperative protocol for all phases of anesthetic management is recommended for patients undergoing robotic-assisted surgery to help ensure patient safety and satisfaction as well as optimal clinical care and provider satisfaction [21].

Conclusion

Robotic-assisted urologic surgery is a minimally invasive laparoscopic technique using robotic technology. This type of surgery allows the surgeon and surgical team to work in very compact areas with great detail, precision, and accuracy. Robotic surgery has been utilized and used in gynecologic, urologic, abdominal, thoracic, and head and neck surgery. There are many advantages to robotic surgery including reduced pain, shorter hospital length of stay, and smaller incisions. There are also disadvantages including increased length of anesthesia, patient positioning, changes in physiologic hemodynamics, and inexperience due to the emerging technology. It is important that the anesthesia staff and surgical staff communicate to best prepare for the needs of the patient, including and special body positioning during the procedure. This communication will also prevent and problems with operating room organization involving IVs, tubes, the anesthesia cart, oxygen tanks and any other supportive equipment.

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3 Training and Education in Robotic Surgery: Recommendations of ERUS (EAU Robotic Urology Section)

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Introduction

The classic and well recognized Halstedian apprenticeship of "view one- do one- teach one" has come to its end in the surgical field. Nowadays learning curves in humans are unacceptable, not only due to ethical reasons and patient safety, but also because of the modern tools for surgical training that are available. Surgical simulators are a great example.

For 30 years, robots have been helping surgeons in their practice. Since then, we have performed a huge number of robot-assisted surgeries, most of them, thanks to the introduction of today's most commercialized surgical robot, the Da Vinci by Intuitive Surgical (Sun Valley, CA, USA) [1].

Compared to other surgeries, urological surgery and in particular pelvic surgery is very complex because of the deep, narrow and small operating field. Since the early 2000s robot-assisted radical prostatectomy (RARP) has been rapidly adopted in many hospitals of developed countries as the first choice surgical treatment for prostate cancer. Published data suggests that long-term oncological outcomes of RARP are comparable to those of open prostatectomy (OP) with a huge advantage of surgical outcomes such as estimated blood loss, complication rate, catheterization time and hospitalization. Furthermore, other surgical techniques such as robot-assisted partial nephrectomy (RAPN) and robot-assisted radical cystectomy (RARC) are also becoming very attractive for the robotic approach [2, 3].

With the fast development of technology and large demand for minimally invasive surgery, in particular robotic surgery, the question of how to train urologists arise. Many efforts have been made all around the world to create a standard and trustworthy curriculum able to provide the necessary education and skill acquisition, in order to allow a safe and efficient management

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_3

of patients with prostate cancer. However, to this date none of such programs has been universally recognized and adopted.

Virtual Simulation in Urology

Originally developed for gaming, virtual reality is now spreading in other fields. Thanks to the huge technological improvements of the last years, a wide array of surgical simulators based on virtual reality are available, finding their application in most of the surgical fields and in particular in urology. Many of them are designed for basic skill acquisition as for example needle driving, peg transferring, circle cutting, while others are designed for specific tasks acquisition as the transurethral resection, cystoscopy, ureterorenoscopy and renal percutaneous puncture models [4–6].

The introduction of virtual reality let us to acquire basic skills that are essential before starting dry and wet lab training. The newest simulators are able to recreate an entire surgical procedure as for example a RARP. It has been stated that virtual simulators improve surgical outcomes in a risk-free environment [7, 8]. Various virtual reality simulators with very different features are available on the market. Apart from the well known Da Vinci Skills Simulator (dV-SS), other companies such as Mimic Technologies (dV-Trainer), 3-D systems (Robotix Mentor™) and Simulated Surgical Systems LLC (New RoSS II) offers different options for this purpose [1, 9] (Fig. 3.1).

The latest *Robotix Mentor*™ (3-D Systems Beit, Golan, Israel) is a simulator that integrates basic tasks and also full clinical procedures simulation. The RoSS II (Simulated Surgical Systems LLC, San Jose, CA) features a portable, stand-alone console able to provide in-vivo virtual operative steps with different levels of complexity. The Mimic—da Vinci Trainer (Mimic Technologies Inc., Seattle, WA) powers the exercises that permits to create, import and export customized training protocols for different specialties.

Simulators should fulfill both, objective and subjective requirements. The subjective aspects generally consist of *face* and *content* validity. *Face* refers to the similarity and accuracy of the model to the real surgical procedure. *Content* refers to the usefulness of the performed tasks in a clinical scenario. The objective evaluation stipulate if the task is able to assess the participants' levels of expertise (*construct validity*), if the test scores reflects the performance in a real procedure (*concurrent validity*), and if it can foretell the operating room performance (*predictive validity*) [10, 11].

The Perspective in Creating a Universal Curriculum

In centers with an ongoing robotic program, heterogeneous scenarios are seen around the world. Ranging from modern and technologically-advanced robotic training centers to institutions with limited amount of resources or training spaces. A well known problem is the limited access and time-of-use of simulators due to the priority given to other daily surgical activities. The importance of scheduling a specific planned period at a certified training center before starting a robotic program is often underestimated. Nonetheless, available resources should be maximized in order to guarantee surgeons to start safely and effectively the robotic procedures [11–13].

The huge heterogeneity between the different available training programs is a major problem. In fact there are huge differences in terms of duration, structure and tasks used for training. Some courses are delivered in very short periods, as for example one weekend courses, providing to the trainee only basic information. Meanwhile other courses lasts longer and are structured in different modules in order to allow the trainee to acquire all the information and skills that are essential before starting with real cases [12, 14–16].

For the creation of a robotic program many aspects should be considered. Ahmed [17] proposed to summarize them as the 5 "**P**′s": "***Place***" which is a physical space equipped with a wide range of tools and resources with the possibility to be shared by a network of hospitals or academic institutions. ***People*** referring to human resources

Fig. 3.1 Current simulation consoles. (**a**) Da-Vinci Skill Simulator (*Upper left*). (**b**) Ross II (*Upper right*). (**c**) Mimic (*lower left*). (**d**) Robotix mentor (*lower right*)

starting with motivated trainees to a director who would ideally be an established urologist holding an extensive academic background and leadership. **P**ounds, the economical aspect, in fact training centers are usually expensive facilities and searching for sponsors or allies will be fundamental. ***P**rograms and **P**roducts* is the elaboration of a curriculum along with faculty and other clinical experts to set the specific end-points. ***P**ositioning,* acknowledging the importance of the program among the clinical, academic and hospital authorities is essential. The training sessions into resident's daily activities must be granted.

It must be made clear for all that investment in training hours and simulation facilities will translate in future savings by reducing complications, decreasing operating hours and increasing efficiency.

Curricula

Implementing a program with pre-defined tasks, and its repetition through time will benefit participants in acquiring skills and reducing time to perform them. Although very different in most of the structure, today's robotic programs share a common origin; some of them have emerged from Fundamental of Laparoscopic Surgery (FLS) [18] curriculum as its predecessor. The Fundamentals in Robotic Surgery (FRS) [19] is an example of multi-specialty, technical skills competency base curriculum divided in four different modules: introduction to surgical robotic systems, didactic instructions for robotic surgical systems, psychomotor skills curriculum and team training and finally communication skills. The Fundamental skills of robotic surgery (FSRS) [20] is a curriculum developed and based on the RoSS virtual reality simulator (Simulated Surgical Systems LLC, San Jose, CA) where three different tasks are performed and has showed significant improvement in robotic skills. The BSTC (Basic Skills Training Curriculum) [21] is a 4-week simulation program including an introductive part, a self-directed online modules, a da-Vinci skills Simulator (dVSS) sessions and a console hands-on trainings with the aim to provide a better acquisition of basic robotic surgical skills [22–25].

The surgical background of the trainee is also an important aspect when choosing the different types of exercises. For this reason, the trainer must take always under consideration the baseline expertise level of the trainee, understanding that in the case of an unexperienced surgeon, basic exercises will be sufficient. The proposed initial tasks can include: peg transfer, suturing and knot, pattern cutting, running suture and dome with four towers for ambidexterity. Then the participants can be introduced to the dry and wet lab training with unanimated and animated models and finally progress to clinical modular training with specific procedures of increasing complexity performed under supervision. Prior to perform a specific procedure, either in laboratory or in vivo may be useful to show a video or some photos with step by step explanations of the surgical technique to grant the trainee a valid reference. The bedside assistance experience improves even more the knowledge of the trainee that is approaching to the console modular training (Figs. 3.2 and 3.3).

Fig. 3.2 Dry lab for urethral anastomosis

To accomplish the goal of performing a robotic surgery the trainees could have two different types of mentors either a proctor or a preceptor. Proctor refers to an observer responsible for overseeing and assessing the skills and knowledge of the surgical trainees. The proctor also cares for safety and effectiveness of the procedure providing advices and guidance throughout the surgery but he has no active role during the performance of the procedure. On the other hand, the preceptor is an experienced surgeon that "scrubs" and supervises the surgery. He is the primary responsible for the well-being of the patient and must take over the procedure when the situation requires it [2, 9, 11, 13].

Dual console can be used in two different collaborative modes, either in swap nor in nudge mode. The "swap" mode allows two surgeons to simultaneously operate and actively swap control of the robot's four arms, and the "nudge" mode allows them to share control of two of the robot's arms. "*Telementoring*" represents an attractive option especially where limited human and

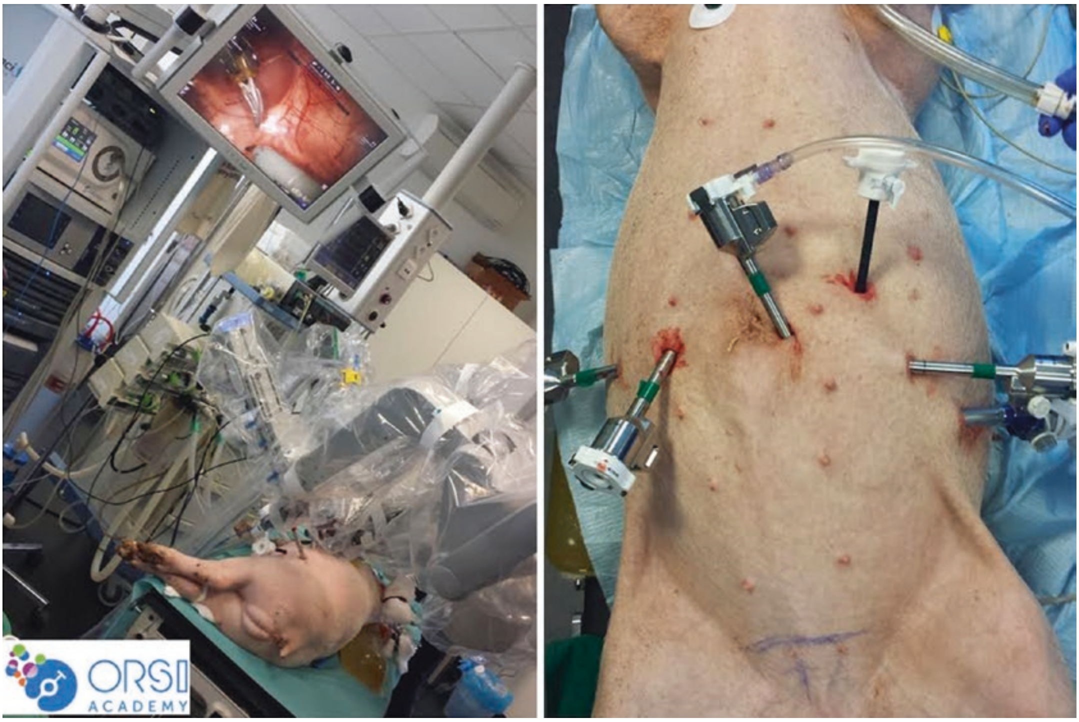

Fig. 3.3 Wet lab with animated model (pig)

Fig. 3.4 Dual Console for mentoring

economical resources exist. It can easily bring the surgeon and the proctor together. Recently new interphases are being created in order to allowed telementoring in a safe and effective manner [9, 11, 13, 26] (Fig. 3.4).

Evaluation

Continuous assessment of participants' performance and their improvement during the course is a fundamental step in any program. The surgeon needs to have continuous feedback, to be encouraged for keeping with the good practices and modifying the conducts that do not generate satisfactory results.

A comprehensive evaluation approach can be reached dividing the examination into preoperative, intraoperative and postoperative aspects [23, 27].

Preoperative issues should teach common features of the robotic device *per se* like getting familiarized with equipment (basically the da-Vinci robotic system). This can be supplemented with didactic lectures, online tutorials and functional aspects such as setting up the equipment and other activities before starting with console surgery [27].

The intraoperative section will focus on critical psychomotor skills, ideally performed in a 3D nature, with defined objectives similar to real-life tasks. Finally learning how to shut down the robot and to undock it will be considered the postoperative assessment [27].

Scores of the virtual reality tasks allows an objective technical evaluation of the participants and the measurement quantification of the improvement that the trainee has obtain since from the beginning till the end of the course [4–6].

For the practical evaluation, Alvin et al. have developed a standardized assessment tool for robotic surgical skills, the Global Evaluative Assessment of Robotic Skills (GEARS), which has been validated and adopted in many centers. It is based on a 5 point anchored Likert scale across six different domains that include; depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy and robotic control. This score was validated during prostatectomies demonstrating it is an optimal tool for measurement of progress and giving objective feedback [18].

Finally we cannot miss the importance of non-technical skills which have been related to patient safety and clinical effectiveness. The Non-Technical Skills for Surgeons (NOTSS) represent an effective tool to evaluate four different aspects; situation awareness, decision-making, communication and teamwork and leadership of the surgeon in the operating room [28, 29].

Is It Useful to Go Through Laparoscopic Training Before Robots?

For some aspects, evidence has shown that previous laparoscopic training is beneficial for surgeons starting a robotic curriculum because some steps are common for both techniques. This includes activities such as the trocar placement and bedside assistance with the responsibility of retracting, suctioning, grasping and the introduction of sutures or any other surgical supply. A previous laparoscopic background could be also beneficial for example in patients with previous surgeries where the laparoscopic adherensiolysis is needed in order to complete the robotic port placement.

Meanwhile, others underestimate the usefulness of a laparoscopic skills, thinking that is feasible to start directly with robotics without the need of a previous laparoscopic background. Some experts consider robotics a completely independent technique with unique features like 3-D view, seven degrees of motion, elimination of tremor and articulating instruments [9].

Certification and Credentialing

A lot of robotic training programs are available all around the world in several training centers and hospitals. Some hospitals require from their consultants to complete one of them in order to be allowed to start a robotic program. Most of these courses are proposed by the robot manufacturers and not by institutions with academic recognition.

Not all the hospitals require the completion of a well-structured and complete program including advanced tasks and also a procedure specific modular training [24, 30–33].

It is a fact that surgeons should be continuously evaluated to ensure their clinical competency by certification and re-certification processes. Credentialing is one of the nodular themes, but today there are plenty of unanswered questions: Who should be the corresponding authority to certify the correct acquisition of the skills and its correct implementation during clinical practice? What would be the selection criteria for a certified training center? Which are the criteria to define a high volume center?

So far there is no universal agreement to define the requirements to become a high volume center and the number of procedures to be performed by a surgeon in order to complete his learning curve in RARP or other procedures. What we can assume is that experienced surgeons have decreased odds of complications and shorten the hospital stay [34].

In 2007, Valvo and colleagues proposed a policy for performing RARP and suggested to evaluate each candidate according to his surgical background in terms of hours of robotic training, clinical experience, and also a minimum caseload suggested in order to obtain certification as a robotic surgeon. The policy contemplates the need of re-assessment if the surgeon interrupts his robotic practice for a periods longer than 6 months [35].

In summary there is a desperate need for an universal accreditation scheme to be developed by experts because of the extreme variability and inconsistency between the currently available programs. An academic driven more than an industry-driven governing body should be created in order to guarantee the quality of care during robotic procedures [12, 36, 37].

ERUS Program

ERUS-curriculum was developed by a panel of international experts. The program was validated by a pilot validation study, that included 12 surgeons and consisted of a 12-weeks length training course. It started with an online theoretical training module, followed by simulation, live case observation and a mixed setting of virtual reality simulation, also with dry and wet lab training. It included also active participation as a table assistant and sitting in the dual console while surgeries were performed. During the training participants' technical and non-technical skills were periodically evaluated by their mentors using the GEARS and NOTSS scales respectively. At the end, in order to get the certification, a complete procedure record underwent blind revision by a committee of expert surgeons. In the initial study up to 80% of the participants were able to perform a RARP independently at the end of the course. For this reason and in order to achieve the objectives in all participants, it was suggested to extend the length of program to 6 month [38].

The ERUS-curriculum is targeted for surgeons with all grade robotic experience and is conceived as a progressive and exhaustive training program. Its modular nature demands the trainee to complete a specific task in other to continue to the next more demanding step following a predetermined plan (Fig. 3.5) [38].

The curriculum starts with an **e-learning theoretical course** which is an online course that participants can complete independently at home.

The core of the course is the 5-day intensive **advanced robotic skills program** consisting of a **theoretical training course**, one day of **live case observation** and an intensive lab training.

The theoretical training course aims to provide the fundamental knowledge of robotic surgery. The main topics are the components and main features of the robotic system, principles of endoscopic surgery, surgical anatomy and an overall view of the main procedures. A multiple-choice examination is performed at the end of each chapter of the e-course to verify if the participant got the most important points.

Live case observation represent an essential step to better understand the relation between the

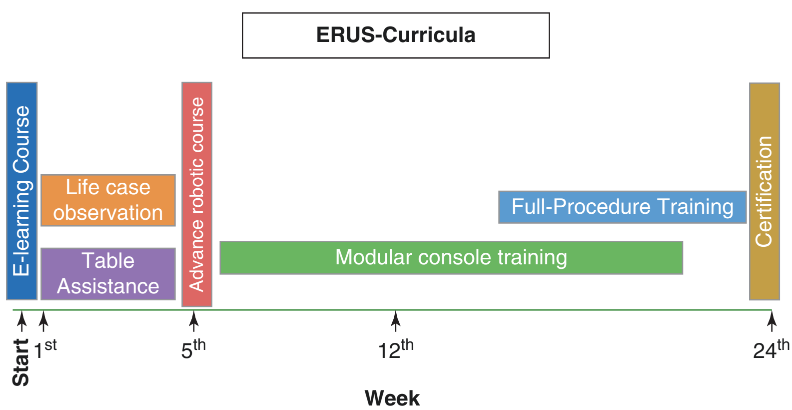

Fig. 3.5 ERUS curricula for RARP

Fig. 3.6 3-D Live case observation

theoretical and clinical aspects. It also enables to share opinions and opens the opportunity to debate with mentors and experts about clinical decisions. Dual console feature is important to allow the trainee to have the same 3D vision as the surgeon (Fig. 3.6).

During the **intensive lab training** various training methods are used from virtual reality simulation to wet lab and training on cadaveric models. During the first day an introductive course is given by a specialized technician who explains all the main features of the robotic system in order to familiarize the trainees with the equipment. Situations designed to face troubleshooting are also included. The program continues with the hands-on training, that permits to acquire directly on the field the features of the console like 3-D vision and the wristed instruments.

Virtual reality simulation is used for specific tasks to improve aspects like moving the camera and clutching, manipulating the endowrist, energy use for dissection and needle driving.

The dry lab section includes practice in synthetic models and animals models. Tasks such as peg transfer, vertical and horizontal suturing are performed under mentor's supervision. An anastomosis model using the Venezuelan chicken accurately simulate the human's vesicourethral anastomosis. Wet lab models as dogs or pigs are very useful for training because they provide a realistic setting for complex exercises despite the higher costs compared to other models [38] (Fig. 3.7).

For **non-technical skills**, the ERUS program incorporates cognitive skills training with decision-making and awareness exercises. It also encourages social skills encouraging communication, team working and leadership abilities development. The participants are continuously evaluated using the NOTSS (non-technical skills for surgeons) scoring system.

During the **modular training** the participant starts to perform surgical steps on the patient following a precise sequence. Only when he is able to perform the easiest steps safely and effectively he can progressively move to a more complex step.

The ERUS curriculum proposed an increasing complexity approach and considers a series of individual steps for RARP:

1. Bladder detachment
2. Endopelvic fascia incision
3. Bladder neck incision
4. Dissection of the vasa and seminal vesicles
5. Posterior prostatic release
6. Anterolateral release of the neurovascular bundles
7. Preparation and section of prostatic pedicle
8. Ligation of dorsal vein complex
9. Apical dissection
10. Urethrovescical anastomosis.

When the trainees are able to safely perform all the steps, they can proceed to perform the entire surgical procedure. The complete surgical procedure will be recorded and sum-

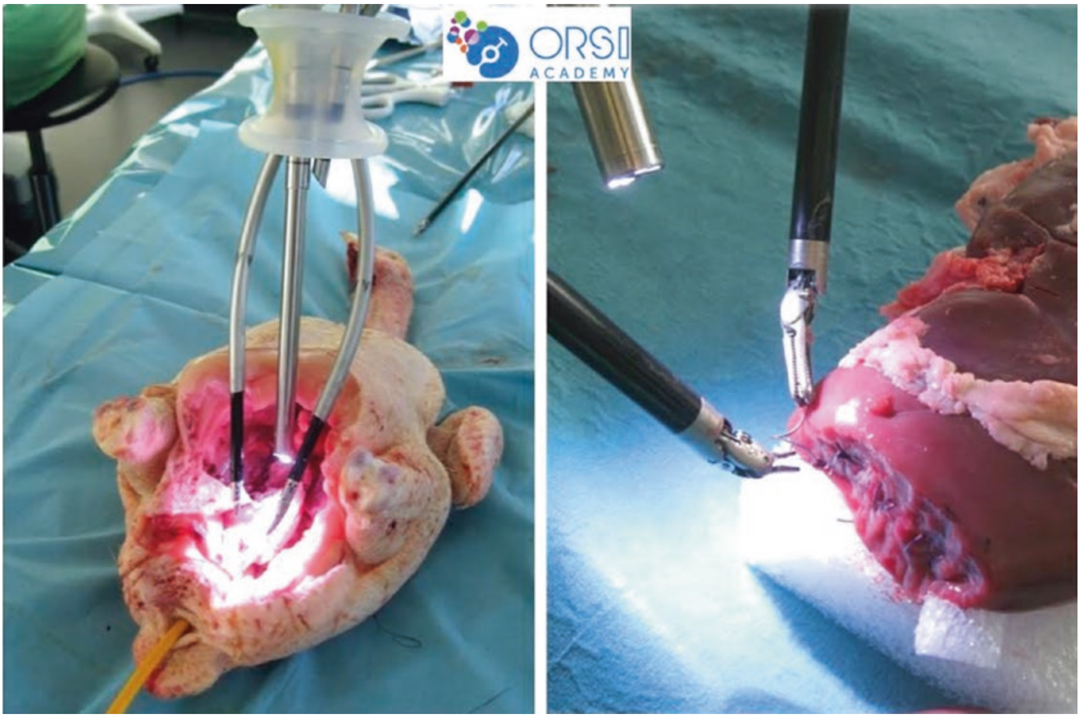

Fig. 3.7 Training models. Anastomotic model in Venezuelan Chicken (*left*) Kidney model for robot assisted- partial nephrectomy (RAPN), (*right*)

mited to a committee of experts for its blind evaluation.

Conclusion

The robotic era has brought outstanding changes in the surgical field. Advantages of investing in training facilities are nor seen just by patients and surgeons, but also by the institutions.

As a minimally invasive technique that has demonstrated comparable outcomes to open surgery, robotic surgery represents the preferred approach in many high volume centers. However some aspects are still pending concerning training uniformity, regulations and certification.

In order to have urologists with the same baseline knowledge and skills in clinical practice, it is essential to prioritize the implementation of universally validated curriculum. The ERUS-curriculum offers an attractive option that clearly covers each mandatory aspect of an ideal curriculum. It has an academic and pedagogical approach and its modular nature allows flexibility with increasing complexity of tasks that are encountered through the course.

In addition, the ERUS curriculum offers a well-structured platform for urologists in training, and can be considered as a standard. Its assessment process allows an objective comparison of candidates and identifies weak areas that need improvement.

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Part II

Kidney

4 Surgical Anatomy of Kidneys and Adrenals

Ibrahim M. Karam, Alexandre Oliver, and Jacques Hubert

Introduction

In this chapter, surgical anatomy of kidneys and adrenals is described in detail. Their anatomical relationships and preoperative evaluation of retroperitoneal anatomy are illustrated for providing anatomic information necessary to plan the surgical procedure. This evaluation is crucial, in robotic surgery, for detecting vascular anomalies and helps the surgeon to easier dissect atypical renal or adrenal vessels. We also describe the practical surgical options of dissection to give to the operator the capacity to anticipate difficulties and overcome them.

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Description and Anatomical Relationships

Retroperitoneum and Gerota's Fascia

The retroperitoneum is divided into the anterior pararenal space, the perirenal space, and the posterior pararenal space. The perirenal space is defined by the anterior and posterior layers of the perirenal fascia (Gerota). This fascial layer encloses the kidney and adrenal in their covering of perirenal fat (Fig. 4.1). It was originally described as being made up of two separate entities, the posterior fascia of Zuckerkandl and the anterior fascia of Gerota [1].

The Adrenal Glands

The adrenal glands are paired structures medially located to the upper poles of the kidneys. They are covered by the perirenal (Gerota's) fascia and are surrounded by an adipose and connective tissue that forms a pseudocapsula, facilitating surgical dissection [2]. The *right adrenal* is usually lower than the left. It lies above the upper pole of the right kidney, between the liver and the diaphragm, and forms the impressio suprarenalis on the liver surface, just to the right of the inferior vena cava. Surrounding structures include the liver anterolaterally, the duodenum anteromedially, and the inferior vena cava (IVC) medially. The *left adrenal* lies within the perirenal fat along the medial

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_4

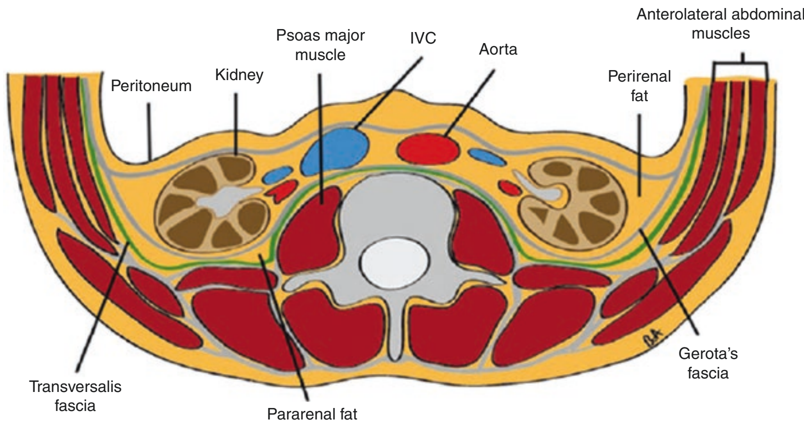

Fig. 4.1 Organization of the perirenal space and fascia

or superomedial border of the left kidney. It is more closely related to the kidney than is the right one, and it is more easily drawn down with the kidney because its central vein drains into the midpoint of the left renal vein, while on the right the central vein fixes the gland high on the inferior vena cava. It is more crescent-shaped and medial to the upper pole of the left kidney. The upper and anterior aspects are related to the stomach, tail of the pancreas, and splenic vessels.

The adrenal arterial supply originates from three sources: The inferior branches are issued from the ipsilateral renal artery, while the middle branches originate directly from the aorta, and finally the superior adrenal pole is irrigated by branches from the inferior phrenic artery (Fig. 4.2). The venous drainage varies by side, the left principal adrenal vein joins the inferior phrenic vein, and the other enters the cranial aspect of the left renal vein. On the right side, the adrenal vein enters the IVC directly on its posterolateral aspect.

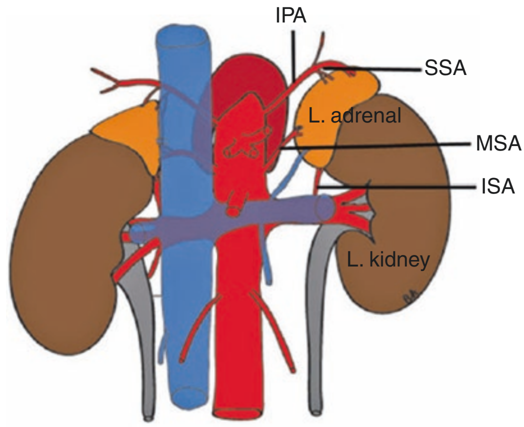

Fig. 4.2 The arterial supply to the adrenal gland originates from three sources: Superior suprarenal arteries (*SSA*) from the inferior phrenic artery (*IPA*), middle suprarenal arteries (*MSA*) originate directly from the aorta and inferior suprarenal arteries (*ISA*) issue from the ipsilateral renal artery

The Kidneys

The kidneys are paired retroperitoneal organs that parallel the psoas muscle on either side of the lumbar spine. The left kidney is usually slightly higher than the right one and is slightly more medially located. Posteriorly, the diaphragm covers the upper third of each kidney. Medially the lower two-thirds of the kidney lie against the psoas muscle, and laterally the quadratus lumborum and aponeurosis of the transversus abdominis muscle are encountered. Anteriorly, the right kidney is bordered by the liver and attached to it by the hepatorenal ligament. On the medial aspect, the descending duodenum is intimately related to the hilar renal structures. The left kidney is bordered superiorly by the tail of the pancreas and the splenic vessels adjacent to its upper pole. The splenorenal ligament attaches the left kidney to the spleen. It can lead to splenic capsular lesions if excessive downward pressure is applied on the left kidney. Superior to the pancreatic tail, the posterior gastric wall can overlie the kidney.

The renal arteries typically arise from the aorta slightly below the origin of the superior mesenteric artery. The right renal artery has a long downward course to the relatively inferior

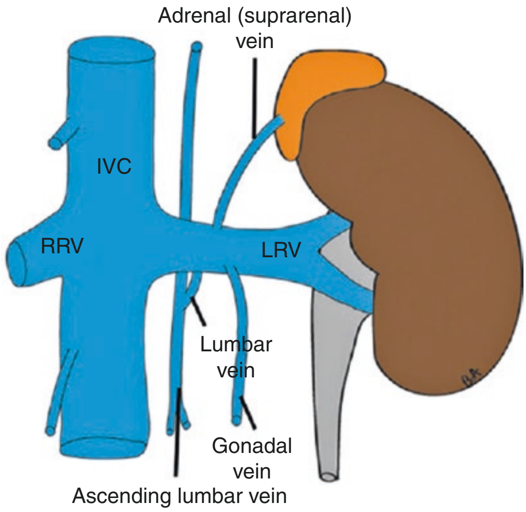

Fig. 4.3 Before joining the inferior vena cava (*IVC*), the left renal vein (*LRV*) receives the left adrenal vein superiorly, lumbar vein posteriorly, and left gonadal vein inferiorly. The right renal vein (*RRV*) typically does not receive any branches

right kidney, traversing behind the inferior vena cava. However, the left renal artery, which arises below the right renal artery and has a more horizontal orientation, has a rather direct upward course to the superiorly positioned left kidney. The renal vein usually lies anterior to the renal artery at the renal hilum. The left renal vein is almost three times longer than the right renal vein. It runs anteriorly between the superior mesenteric artery and the aorta before emptying into the medial aspect of the IVC. Unlike the right renal vein, the left renal vein receives several tributaries before joining the inferior vena cava. It receives the left adrenal vein superiorly, the left gonadal vein inferiorly, and a lumbar azygos vein posteriorly (Fig. 4.3).

Radiological Anatomy

CT angiography, performed with volume rendering and multiplanar reconstructions, is extremely accurate in the preoperative evaluation of renal vascular anatomy. It has replaced conventional angiography in most institutions. Comprehensive preoperative evaluation of retroperitoneal anatomy is crucial for detecting vascular anomalies and for providing anatomic information necessary to plan the surgical procedure [3]. The multidetector computed tomographic (*MDCT*) angiography presents a noninvasive imaging modality for the evaluation of adrenal and renal vascular anatomy. In addition to assessing the vessels, anatomic definition of the collecting system is important [4]. The number, size, branching pattern, course, and relationship of the renal arteries and veins are easily demonstrated by MDCT angiography [5]. The 3D imaging provides high-quality images that make intraoperative anatomic analyzes more accessible to those nonspecialized in imaging mainly urologists. Preoperative knowledge of minor venous variants such as a lumbar or gonadal vein may facilitate the dissection of these veins and help to avoid hemorrhagic complications during surgery. Dual-phase MDCT combined with maximum intensity projection (*MIP*) reconstruction can provide a minimally invasive, accurate preoperative evaluation of kidney donor candidates in a single study (Fig. 4.4).

The accuracy of MDCT angiography in detecting accessory arteries, early branching, and renal vein anomalies are 95, 90–95, and 95–100%, respectively [6]. The most common venous anomaly is a circumaortic left renal vein. The larger veins can be evaluated with the volume-rendering technique (*VRT*); however, to find all smaller veins, the multiplanar reformatting technique (*MPR*) is better and should employ axial, coronal, sagittal, and oblique planes. Retroperitoneal varices can be detected with this technique [7]. Recent studies have demonstrated that the best nephron-sparing approach can be based in reconstructed 3D renal arteriogram, fused with 3D image of surface-rendered renal tumor and semitransparent kidney to facilitate selective microdissection of tumor-specific arterial branches, even for intrarenal or central tumors [8].

The multiphasic acquisition with multislice CT scan 3D reconstruction permitted the establishment of an intraoperative cartography of the vessels number and situation resulting in an easier dissection in a reduced operative field. The 3D CT scan images and 3D robotic coupling lead operator to conduct a selective dissection of renal and adrenal vessels and overcome difficulties

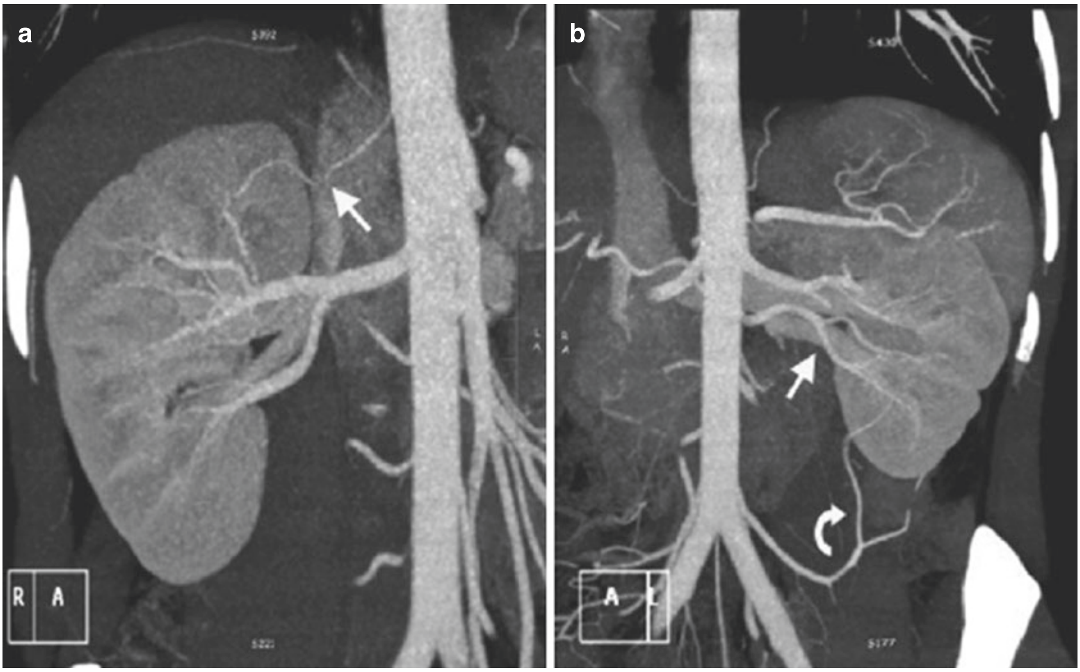

Fig. 4.4 Oblique maximum intensity projection images, of a man undergoing preoperative renal donor evaluation, show accessory polar renal arteries to the right (**a**) and left (**b**) kidneys (*arrows*). The superior branch of the inferior mesenteric artery (*curved arrow*), which courses toward the left kidney, mimic the appearance of an accessory renal artery

represented by the atypical anatomic configuration [9]. The identification of renal vascular variants is important in the preoperative evaluation, especially before donor or partial nephrectomy. Renovascular variations are common, occurring in 25–40% of cases.

Renal Arteries Variants

Accessory arteries are seen in about one-third of the population, while about 70% of the population have a single renal artery that originates from the abdominal aorta on each side [10]. They usually arise from the aorta or iliac arteries. Most commonly, the accessory arteries originate from the abdominal aorta and supply the inferior pole of the kidney (Fig. 4.5a).

In rare cases, they can arise from the lower thoracic aorta or from lumbar or mesenteric arteries. Bilateral multiple renal arteries occur in 10% of the population [11]. Double renal arteries are detected in 25% of cases, triple renal arteries in 4%, and quadruple renal arteries in 1% of the population (Fig. 4.5b). Accessory renal arteries are considered to be persistent embryonic lateral splanchnic arteries. Rarely, they can arise from the coeliac, mesenteric, lumbar, middle colic, or middle sacral artery [12]. The polar accessory renal arteries are usually smaller, but hilar accessory renal arteries are not always smaller than the principal renal arteries. Early branching of the renal artery is a variant in which any branch diverge from the lateral wall of the aorta in the left kidney or in their retrocaval segment in the right kidney.

Renal Vein Variants

The most common anomaly of the left renal venous system is the circumaortic renal vein, seen in approximately 2–17% of the population. Here, the gonadal vein will typically join the retroaortic limb and the adrenal vein will join the

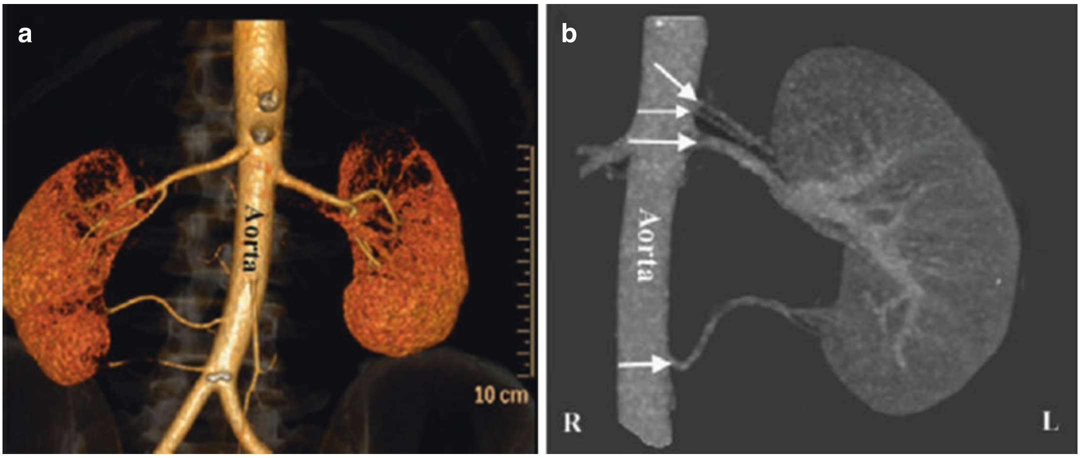

Fig. 4.5 (**a**) Coronal VR image shows two accessory polar renal arteries to the right kidney. (**b**) Coronal MIP image shows two upper polar arteries of the left kidney, the main left renal artery and a left inferior renal polar artery (*arrows*)

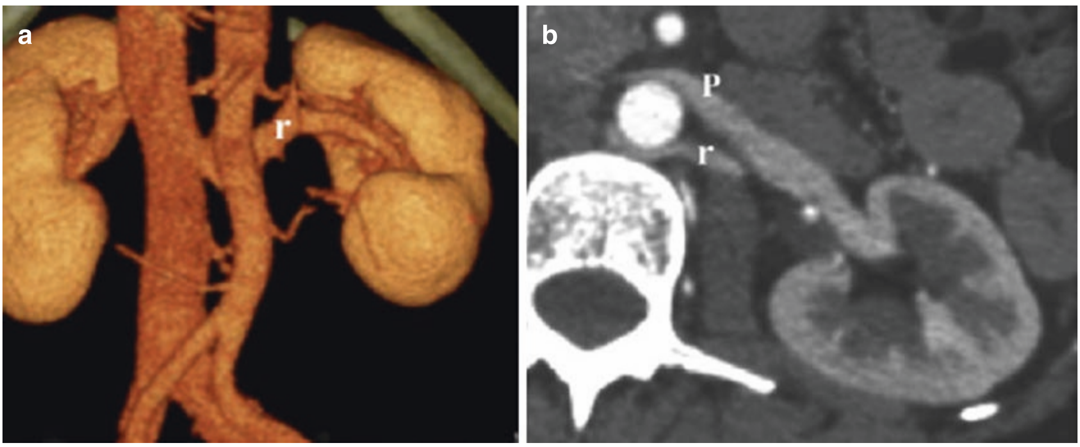

Fig. 4.6 (**a**) Coronal VR image shows triple right renal arteries and circumaortic left renal vein. (**b**) Axial MIP image demonstrates a "circumaortic left" renal vein with retroaortic (*r*) and preaortic (*p*) components

preaortic limb (Fig. 4.6). The completely retroaortic renal vein, is seen in 2–3% of patients. In this case, the single left renal vein courses posterior to the aorta and drains into the lower portion of the IVC (Fig. 4.7).

The left adrenal vein and gonadal vein enter into the left renal vein in almost all cases. However, on the right side, the gonadal vein and adrenal vein enter the right renal vein in only 7 and 30% of cases, respectively. Two left gonadal veins may be seen in about 15% of cases. In about 60–85% of the population, the retroperitoneal veins, including the lumbar, ascending lumbar, and hemiazygos veins, drain into the left renal vein [13].

Anatomical Landmarks and Surgical Dissection

The robotic-assisted laparoscopic surgery can be performed via a transperitoneal or retroperitoneal approach. The transperitoneal approach is a familiar one with quicker access to the renal hilum, easily recognizable anatomy and a much larger working space [14]. In this approach, the peritoneum is incised along the line of Toldt, and the bowel is mobilized medially, developing the plane between the anterior Gerota's fascia and the posterior mesocolon. Dissection is continued

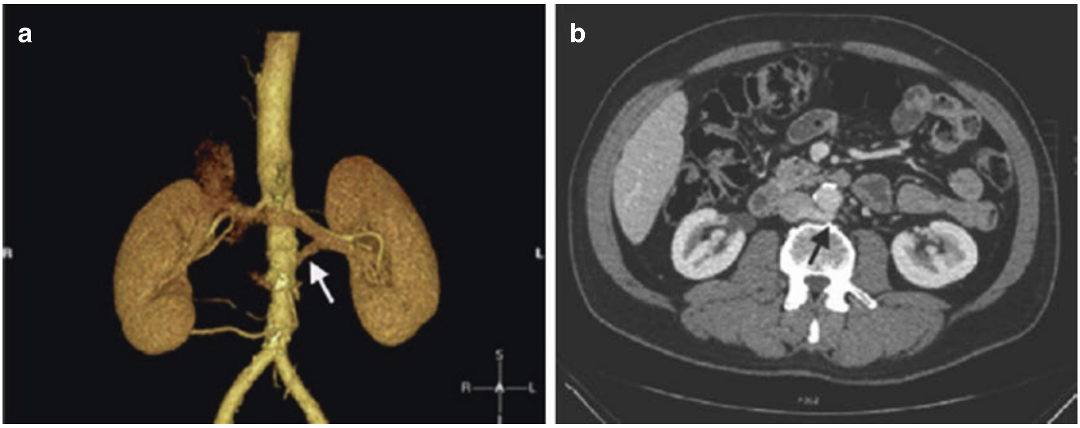

Fig. 4.7 (**a**) Coronal volume-rendering image, of a preoperative renal donor evaluation, shows the right renal arteries. The last pierces the lower pole of the kidney directly. (**b**) Axial slice shows a retroaortic left renal vein (*arrow*)

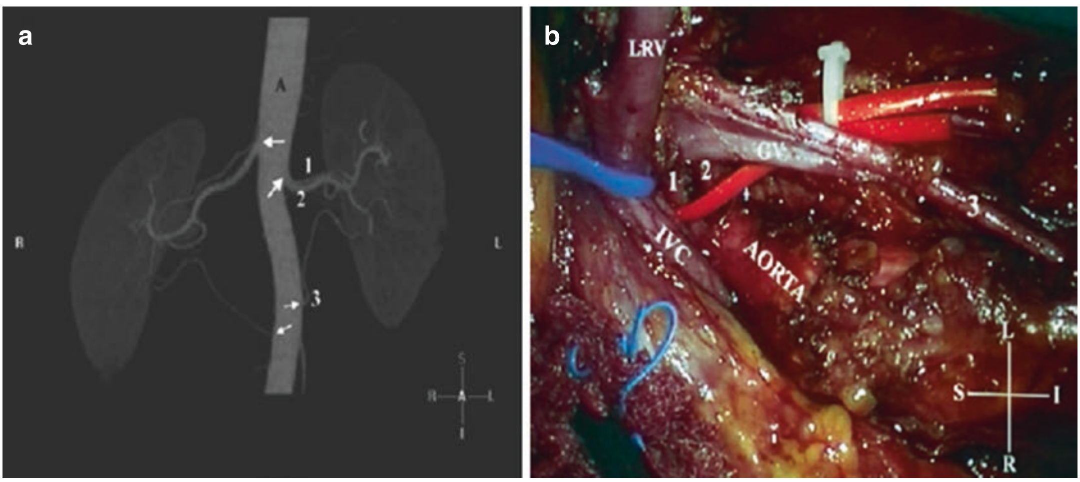

Fig. 4.8 (**a**) Oblique maximum intensity projection image shows an accessory renal artery to the lower pole of the right and left kidneys (*arrows*). (**b**) Intraoperative photography shows an early branching of the main left renal artery (*1*, *2*) and a left inferior renal polar artery (*3*)

along the upper pole of the kidney to mobilize the spleen or liver:

On the right, dividing the right triangular ligament is usually necessary to gain access to the Gerota's fascia and visualize the upper pole. *On the left*, the upper pole is well visualized after division of the phrenicocolic, splenocolic, and the splenorenal ligaments at the splenic flexure. The ureter and gonadal vein must be identified, and they can be followed superiorly to aid in hilar identification and dissection. At the level of the lower pole of the kidney and proximal ureter, the gonadal vessels are medial to the ureter, and a slight anterior elevation of the ureter and lower pole may be useful to identify the renal hilum and its vessels, including the anteroposterior lumbar vein. After the hilum is identified, it is dissected, and the artery and vein are controlled separately [15]. The 3D robotic vision and articulation lead operator to conduct a selective and meticulous dissection of renal vessels and overcome difficulties represented by the atypical anatomic configuration (Fig. 4.8).

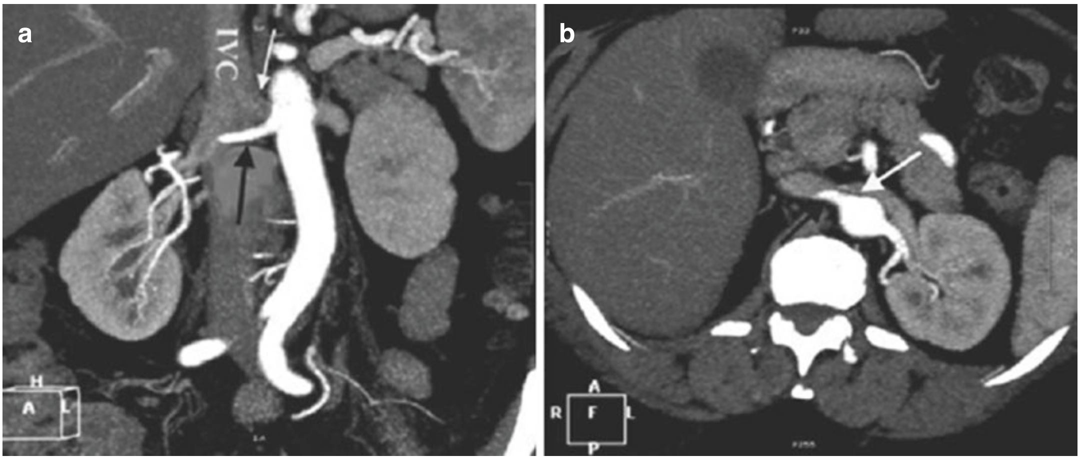

Fig. 4.9 Coronal MIP image (**a**) and axial MIP image (**b**) show renal vessels of a patient undergoing right partial nephrectomy. "In this anatomical situation: left renal vein (*white arrow*) is above the right renal artery (*black arrow*), interaorticocaval clamping of the right renal artery is made possible"

If a retroperitoneal approach is used for nephrectomy, Gerota's fascia is identified and the renal pedicle exposed. The renal artery and vein are identified and individually dissected. The remainder of the kidney is mobilized using sharp and blunt dissection. The ureter is identified inferiorly, clipped, and divided. Although adopted by some trained teams, the retroperitoneal approach offers only a reduced operative field, which complicates the robotic instrument's movements [16].

Partial nephrectomy requires complex dissection and intracorporeal reconstruction. There are technical challenges which include adequate intraoperative visualization and control of the vascular supply to realize a nephron-sparing procedure. Precise identification of all renal arteries is mandatory in order not to miss to clamp one collateral branch during renal excision. Knowledge of arteries and veins respective positions helps to the surgical strategy (such as finding the artery at the superior or inferior aspect of the vein, dissection of the interaorticocaval space for getting access to the right renal artery) (Fig. 4.9).

For adrenalectomy, it is important to recognize the lateroconal fascia (extending from Gerota's fascia to the lateral peritoneum). This fascia covers the space that contains the adrenal gland, and it must be opened to expose the adrenal gland and its vessels. Circumferential separation of adrenal after careful dissection of the gland from its adhesions is done by holding the fat overlying the adrenal. This avoids direct handling of the gland and facilitates the precise dissection of the adrenal arterial supply. The advantage of the retroperitoneal approach is that mobilization of other organs is unnecessary because the adrenal gland is approached in its proper anatomic plane [17]. A disadvantage of retroperitoneal adrenalectomy is the limited maneuvering space for the endoscopic instruments. Adrenalectomy involves delicate dissection alongside major vascular structures and viscera:

For left side, the mobilization of the left colon flexure is sometimes necessary; the plane of dissection is developed laterally and dorsally to expose the superior aspect of the kidney and the adrenal gland. Identification of the left adrenal vein and its confluence with the renal vein is essential to secure the left adrenal vein. It is followed by clipping and dividing the adrenal vein. The same is done with the suprarenal arteries. Thereafter the adrenal gland is completely dissected from its bed.

In the right side, after incising the precaval peritoneum, the upper pole of the kidney, the right adrenal, and the inferior vena cava (IVC) are visualized. The adreno-caval junction can be located by dissecting along the lateral border of the inferior vena cava. Following this lateral caval plane cranially, the adrenal vein or veins and arteries are identified, clipped, and divided. Although the right adrenal gland is readily accessible when the transperitoneal approach is used, exposure of the left adrenal gland can be difficult because it requires mobilization of the spleen, the splenic flexure of the colon, or the pancreatic tail [18].

Acknowledgment Acknowledgment to Dr. Al Said B. for the anatomical illustrations and Dr. Hubert N. for the preoperative pictures.

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5 Robotic Radical Nephrectomy

Ronney Abaza

Introduction

Robotic radical nephrectomy is now an established procedure with evolving indications. While early controversy regarding whether or not robotics is appropriate for nephrectomy may have obstructed its adoption, the procedure is gaining traction particularly for complex tumors and challenging patient anatomy [1]. Some advocates of laparoscopic surgery for straight forward nephrectomies and open surgery for very complex nephrectomies still challenge whether robotic radical nephrectomy is a reasonable procedure to perform either selectively or routinely.

Advocates of robotic nephrectomy have maintained that robotic surgery can be enabling of a minimally-invasive approach for complex tumors or anatomy when laparoscopy would be inadequate, such that the need for open surgery would be reduced or eliminated. Additionally, some have suggested that robotics is appropriate even for procedures that could be performed with standard laparoscopy as a measure to reduce safety and potential conversions to open surgery due to unexpected events or findings and also as a stepping-stone procedure to more complex robotic operations such as robotic partial nephrectomy that shares many steps [2]. Robotics may also allow a more thorough retroperitoneal node dissection in appropriate patients and management of complex cases such as vena caval tumor thrombi [3, 4].

While early reports focused on feasibility in small patient numbers, larger series have now been reported with excellent outcomes as compared with other techniques [5]. This chapter will outline the main background information and steps that a surgeon should understand to perform robotic radical nephrectomy.

Procedure

Indications

Radical nephrectomy is performed when a renal tumor mandates removal of the entire kidney, but determining when to do so in minimally-invasive, robotic fashion is still evolving. Robotic radical nephrectomy, with experience, has been applied to increasingly complex tumors and situations despite initial relative contraindications while the procedure was still being developed or by surgeons early in their learning curve.

Presently, robotic radical nephrectomy has been applied in complex scenarios that include vena cava tumor thrombus, invasion of contiguous organs like the liver or pancreas, or for extremely large tumors over 20 cm or larger [2]. The limitations will be at least in part dictated by

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_5

the surgeon's experience and robotic ability, but as the procedure has evolved there have been fewer and fewer renal tumors not amenable to robotic extirpation.

Patient Preparation

Patient preparation for robotic radical nephrectomy does not differ materially from that used for other robotic renal surgery (e.g. pyeloplasty, partial nephrectomy, etc) with few exceptions. Patients should be counseled preoperatively on the operative plan and potential triggers for conversion to open surgery or potential need for resection of contiguous organs if involved. Preoperative imaging to evaluate vascular anatomy, potential venous tumor thrombus, and possible metastases should be performed to ensure proper patient counseling preoperatively and as a guide for surgery.

General safety measures for any open or laparoscopic surgery are prudent and include holding anticoagulation when possible as well as measures to avoid thromboembolic events such as compression stockings and prophylactic doses of low molecular weight heparin and cessation of oral contraceptives in females. Other standard precautions should be taken such as intravenous antibiotics prior to incision.

Bowel preparation is used by some surgeons and omitted by others. Efforts to decompress the colon of stool may ease reflection of the colon, and when the possibility of direct bowel invasion by the tumor is suspected, bowel preparation would be advisable. Placement of a nasogastric or orogastric tube is typical and allows for more space by decompressing the bowel in transperitoneal procedures. For large, right-sided tumors, decompression of the duodenum through this measure is recommended.

Patient Positioning

For robotic radical nephrectomy, patients are positioned in similar fashion to what is commonly used for other laparoscopic or robotic kidney surgery. The flank position is used with the patient laying on the side that will elevate the involved kidney. Care should be taken to secure the patient and prevent pressure points with padding to prevent injury, particularly if a lengthy procedure is anticipated.

The laterality of the patient in flank position has been described to various degrees from 30 to 90° with some surgeons using 45 or 60° as their standard position. The closer the patient is placed to full 90° of laterality, the more gravity will aid in retracting the small bowel as well as organs after mobilization like the colon, duodenum or spleen by gravity alone without need of additional retractors.

Flexion of the operative table is optional and used by some but not all surgeons. Use of the kidney rest should be avoided entirely as this does not improve access to the relevant anatomy and may increase the risk of rhabdomyolysis or other injury by creating an undue concentration of pressure on the spine and perispinal musculature. A bladder catheter should be placed to decompress the bladder and avoid injury during placement of lower abdominal ports as well as to allow monitoring of urine output.

Robotic Ports and Docking

The operative room should be organized in a fashion that will allow the patient side cart of the robotic system to approach the patient from behind on the side ipsilateral to the involved kidney. If the daVinci® S or Si system (Intuitive Surgical, Inc., Sunnyvale, CA) is being used, the patient side cart can be driven towards the patient at an angle approaching from the shoulder rather than perpendicular to the bed so as to triangulate the robotic arms around the upper quadrant of the abdomen. When using the daVinci® Xi robot, the patient side cart can be brought in perpendicular to the bed and the tower holding the robotic arms can be rotated to the extent as desired.

A minimum of three ports will be needed to perform robotic nephrectomy, including a camera port and two ports for robotic instruments. The camera port can be placed adjacent to the umbilicus or in the midline along the linea alba or can be placed more laterally with the understanding that the more lateral the camera port, the less wide the field of view will be. When the camera port is placed in the midline, the 30° down lens can be used, but if a more lateral camera port position is chosen then the 0° lens should be used.

The right and left robotic ports can then be placed above and below the camera port location taking care to triangulate around the kidney in the upper quadrant particularly with older generation robots where this can be critical to avoid arm collisions. For more complex procedures (e.g. very large tumors or caval thrombi), for less-experienced surgeons, and for surgeon preference, additional ports can be placed for the robotic fourth arm or for a bedside assistant to provide suction or retraction. If not using an assistant port, vascular control can be performed by the robotic surgeon using robotic Hem-o-lok clips or the robotic stapler rather than having the assistant perform this. In right-sided nephrectomies, a port for placement of a liver retractor is optional and is recommended for newer surgeons. With experience, the robotic surgeon will be able to complete the procedure without a liver retractor by lifting the liver and keeping it above the shaft of the right arm instrument throughout the dissection of the hilum and upper pole.

Robotic Instruments

Typical instruments used for robotic nephrectomy include one instrument in the surgeon's dominant hand for tissue cutting such as the hook cautery or cautery scissor and a dissection and retraction instrument in the other hand such as the bipolar or Prograsp instrument. For straight forward nephrectomy procedures, two robotic instruments are adequate for the entire procedure in addition to the robotic Hemolock clips for the major vessels and the ureter. The author's preference is to use the fenestrated Maryland bipolar and cautery scissors.

If the robotic fourth arm is used, the Prograsp is typically the instrument of choice. If assistant ports are placed, this could replace the need for the fourth arm or robotic clip appliers if the assistant is used to control the major vessels.

Operative Steps for Right Nephrectomy

Step 1: Reflection of the Colon

In both right and left robotic nephrectomy, the first step after docking the robot is reflection of the colon reflection, although simpler on the right because the hepatic flexure of the colon is usually lower on the kidney and sometimes below the lower pole of the kidney altogether. In both cases, it is critical to identify the plane between the colon and associated fat/mesentery and the Gerota's fascia. An incision is made lateral to the Line of Toldt, and the colon is reflected medially extending the incision caudally enough and mobilizing the colon medially enough to allow gravity to keep it out of the field of view upon approaching the hilum.

Step 2: Kocherizing the Duodenum

In the course of reflecting the colon medially, the duodenum will invariably be seen along the medial aspect of the kidney, and care should be taken to identify it as early as possible to prevent potential injury by cautery or otherwise. As with reflection of the colon, identifying the Gerota's fascial layer and keeping intact during Kocherization of the duodenum is critical to maintain proper planes for the subsequent steps of the operation.

Adequate reflection of the duodenum medially will once again allow gravity retraction and no need for retraction by the robotic fourth arm or an assistant instrument. Immediately upon reflecting the duodenum, the vena cava will be seen below (Fig. 5.1). The vena cava can then be

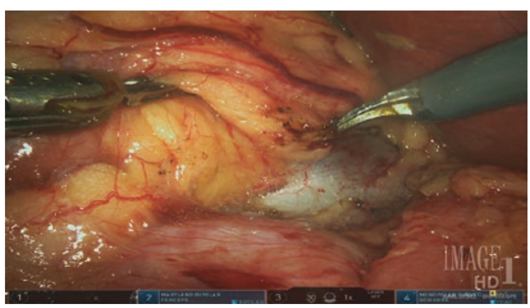

Fig. 5.1 Initial view of the anterior vena cava after completing mobilization of the colon and duodenum

cleared of any overlying anterior tissue (particularly in obese patients) until the junction of the right renal vein is located.

Step 3: Psoas Plane

On the right side, the psoas plane is typically easier to identify by dissecting directly lateral to the edge of the vena cava in a posterior trajectory beginning at a level near the lower pole of the kidney and away from the hilar vessels. The Gerota's fascia plane must be identified on the posterior aspect and left intact while lifting it up and away from the underlying psoas muscle. If the Gerota's fascia is not violated, the ureter will be within in and lifted away from the psoas as well so that injury will be impossible, which is important in other renal surgeries other than nephrectomy.

The kidney within the intact Gerota's fascia must be lifted so as to place the renal hilum on stretch as it is approached from the lower pole of the kidney. When neither the robotic fourth arm nor any assistant ports are used, the lifting of the kidney to keep the hilum on stretch during hilar dissection with two arms can be accomplished by clipping the anterior Gerota's fascia to the peritoneal side wall (Fig. 5.2).

Step 4: Vessel Ligation

Review of the vascular anatomy on preoperative imaging studies will identify the number and location of renal vessels, but the most common

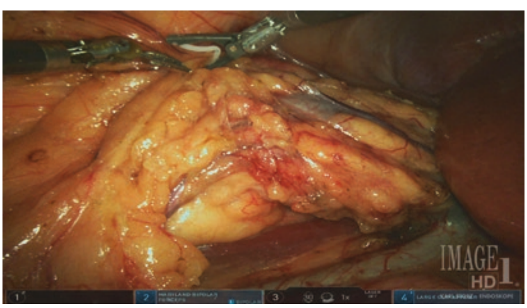

Fig. 5.2 Lifting the kidney and contents of Gerota's fascia away from the underlying psoas muscle can be accomplished with a clip so that the renal hilum will remain on stretch during the hilar dissection

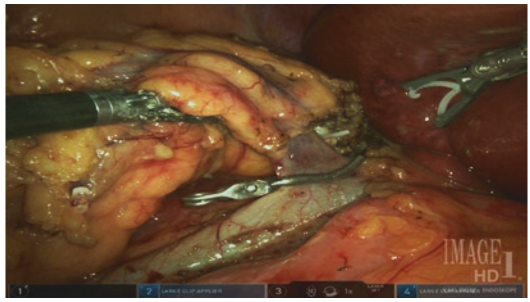

Fig. 5.3 Example of a variant anatomy with the renal artery located above the renal vein that has been clipped. A bulldog clamp was placed on the renal vein before clipping it to confirm that the kidney and vein did not become congested, which would have suggested a second renal artery

variant is one renal artery approaching the kidney posterior to the renal vein. The renal vein is approached along the lateral aspect of the vena cava with the kidney lifted anterolaterally as previously described until the renal artery is found in the fat behind the vein.

While the renal artery and vein can be stapled *en bloc*, typically they are dissected individually and ligated separately. After circumferentially dissecting the artery, a minimum of two clips should be placed on the aortic side of the artery if not stapling it. The renal vein can then be dissected circumferentially and clipped or stapled (Fig. 5.3).

Step 5: Upper Pole and Adrenal Gland

It is beneficial to perform dissection of the upper pole prior to detaching the kidney laterally so that the kidney will not fall medially and obscure visibility of the upper pole and adrenal fossa. The adrenal gland can be spared when uninvolved by the tumor such as when the bulk of the tumor is lateral or emanating from the lower pole. If the upper pole of the kidney is normal, dissection can be performed directly along the renal capsule to leave the adrenal and upper pole perinephric fat undisturbed as violation of the adrenal will often lead to troublesome venous bleeding (Fig. 5.4).

If the surgeon opts to remove the adrenal gland with the specimen due to suspicion of tumor extension or metastasis, the dissection must be continued along the lateral aspect of the

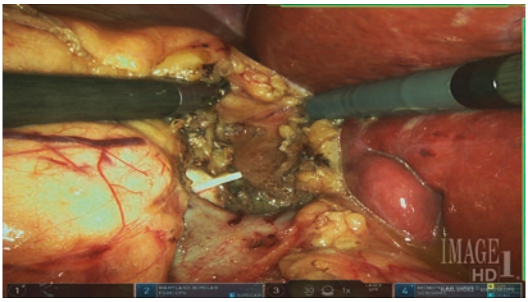

Fig. 5.4 Mobilization of the upper pole of the kidney leaving the adrenal gland *in situ*. Removal of the adrenal gland with the specimen would entail dissection immediately along the liver such that none of the fat from within Gerota's fascia as seen above along the liver would be left behind

vena cava until the adrenal vein is clipped and divided followed by upper pole mobilization with Gerota's fascia intact. Since the adrenal gland is within Gerota's fascia, complete removal will entail dissection immediately along the lower edge of the liver where it meets the posterior body wall.

Step 6: Completion

The ureter is clipped and divided followed by mobilization of the lower pole of the kidney, ideally respecting Gerota's fascia and removing this fat with the specimen so as not to leave a large amount of devitalized fat within the patient. The last step is to divide the lateral attachments of the kidney between the Gerota's fascia and body wall. The specimen is then placed in an extraction bag as used in laparoscopy and extracted through the linea alba around the umbilicus or in the suprapubic area.

Operative Steps for Left Nephrectomy

Step 1: Reflection of the Colon and Spleen

The first step in left nephrectomy is the same as the right side, but in addition to reflecting the colon medially, reflecting the spleen along with it will maximize exposure to the retroperitoneum.

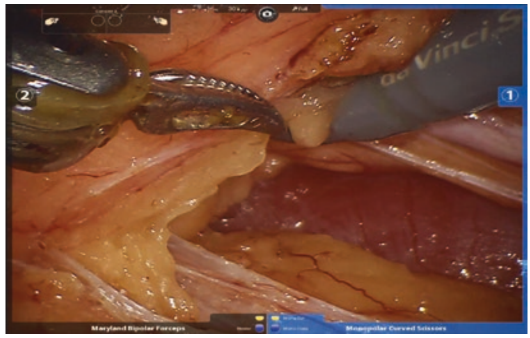

Fig. 5.5 The psoas plane is identified by lifting the left kidney within Gerota's fascia while remaining lateral to the periaortic nodal tissue as shown

In order to accomplish this, the incision in the Line of Toldt is continued cranially along the lateral aspect of the spleen so that the splenic flexure of the colon and spleen will reflect medially as one unit as well as the pancreas. This is in contrast to reflecting the colon alone and extending the incision between the splenic flexure and edge of spleen. Once again, care must be taken to respect the natural tissue planes and not violate Gerota's fascia.

Step 2: Psoas Plane

As in right nephrectomy, once the retroperitoneum is exposed, the kidney within Gerota's fascia should be lifted from the underlying psoas muscle before approaching the hilum. Unlike on the right side where the vena cava is used as a landmark to find the psoas plane and eventually the renal vein, on the left side the psoas plane is more difficult to identify. Care must be taken to remain medial to the ureter so as to ensure that the Gerota's is not violated and remain lateral to the aorta (Fig. 5.5).

Step 3: Vascular Dissection

Once the kidney within Gerota's fascia is lifted to place the hilum on stretch, the psoas plane can be followed cranially until reaching the renal hilum. If the gonadal vein can be seen within Gerota's fascia, it can be followed to where it drains into the renal vein. The renal artery typically can be found directly behind the renal vein as on the right side. Once the artery is clipped, even with

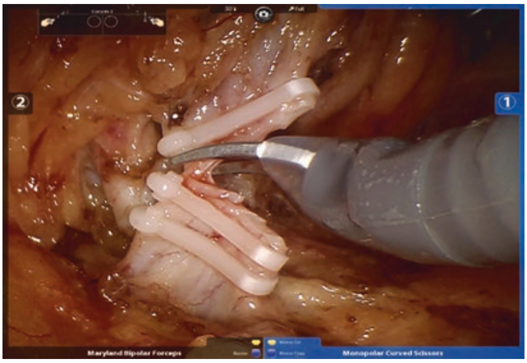

Fig. 5.6 With the kidney within Gerota's fascia lifted anteriorly, the renal artery is clipped prior to clipping and dividing the renal vein as shown

only one clip, the vein can be clipped and divided thereby improving access to the artery to complete clipping and division (Fig. 5.6). If the adrenal gland is to be spared, the renal vein should be clipped closer to the kidney than the root of the adrenal vein.

Step 4: Adrenal and Completion

As on the right, when the adrenal gland is being spared, Gerota's fascia is entered and the dissection plane continues along the capsule at the upper pole of the kidney to separate the adrenal gland and surrounding fat from the kidney to leave it *in situ*. The upper pole is then mobilized followed by division of the ureter and gonadal vein and lastly the lateral attachments.

Postoperative Care

Postoperative care after robotic nephrectomy is similar to that following other robotic or laparoscopic procedures. Immediate ambulation and regular diet is important to speed convalescence. The largest difference between robotic nephrectomy and other robotic procedures is the size of the extraction incision, particularly for large tumors. This might contribute to postoperative analgesic requirements.

The author's preference is to use the ON-Q® pain pump (Kimberly-Clark, Lake Forest, CA), which is a subcutaneous catheter for continuous delivery of local anesthetic at the extraction site, in order to allow complete avoidance of intravenous narcotics. Use of intravenous ketorolac and oral analgesics without intravenous narcotics allows faster return of bowel function and resumption of diet as well as avoidance of mental status changes in elderly patients.

As with robotic prostatectomy or partial nephrectomy, an overnight stay is typically adequate [6]. Use of a clinical pathway or "early recovery after surgery" protocol as well as setting expectations preoperatively is critical to allow this [7].

Complications

All of the complications that can occur after any robotic or laparoscopic procedure can occur after robotic nephrectomy, including anesthesia-related and access-related complications. Preoperative patient evaluation to anticipate cardiac, pulmonary or other comorbidities is critical. All of the typical precautions taken during the perioperative period for any surgical procedure should be followed despite the minimally-invasive nature of the operation.

Particular to robotic nephrectomy as compared with prostatectomy or other procedures is the potential for renal insufficiency or failure due to removal of one kidney. Ketorolac and other potentially nephrotoxic medications should be avoided in patients with preoperative renal insufficiency or dose-reduced as needed, particularly in elderly patients. A bladder catheter will allow monitoring of urine output intraoperatively and postoperatively, and postoperative laboratory assessment of renal function is helpful with selective involvement of nephrologists when required.

Infectious complications after robotic nephrectomy are rare and should raise suspicion of bowel injury if early in the postoperative period. Bleeding postoperatively is also rare with only occasional need for transfusions, most commonly in patients with preoperative anemia related to more advanced cancers. Surgeons should have a low threshold for appropriate imaging in the postoperative period when complications occur in order to recognize complications early.

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Partial Resection of the Kidney for Renal Cancer

6

Paolo Umari, Alessandro Volpe, and Alexandre Mottrie

Introduction

Partial nephrectomy (PN) represents the gold standard treatment for renal masses <4 cm (cT1a). A few studies support the expanded indication for PN in selected patients with tumors from 4 to 7 cm (cT1b) and larger (cT2) [1, 2].

Indications for partial nephrectomy can be divided in absolute, relative and elective. *Absolute indications* include a localized lesion in solitary kidney, bilateral renal lesions, or poor renal function. *Relative indications* include hereditary forms of Renal Cell Carcinoma (RCC) like Von Hippel–Lindau syndrome, hereditary papillary RCC, Birt–Hogg–Dubé syndrome, or tuberous sclerosis in which there is a high risk of future development of metachronous renal malignancies. Relative indications also exist for patients with unilateral lesion but with the risk of future renal insufficiency such as patients with hypertension, diabetes mellitus, nephrolithiasis or chronic pyelonephritis. *Elective indications* include the presence of renal tumor in patient with normal contralateral kidney [3].

Partial nephrectomy could be performed through traditional open or minimally invasive techniques such conventional laparoscopy and robot-assisted surgery.

Laparoscopic partial nephrectomy (LPN) is a technically demanding procedure with a step learning curve in order to reach acceptable perioperative outcomes as a short warm ischemia time (WIT) and low perioperative complication rates [4]. For this reason the guidelines of the European Association of Urology (EAU) are proposing this approach as an optional treatment for cT1 renal tumors only in highly experienced centers [1].

Robot-assisted partial nephrectomy (RAPN) represents the evolution of the LPN in fact in many specialized centers it has become an integral part of daily practice. The first RAPN series was reported by Getman et al. in 2004 [5]. The robotic technology offers several advantages over the conventional laparoscopy as the better visualization of the surgical field due to superior three-dimensional vision, a wide selection of wristed instruments with 7 degrees of freedom and the elimination of the tremor. This allows the surgeon to perform a very precise resection as the tumor can be approached from all desirable angles, while renorrhaphy can be performed with torque-free suturing simplifying the parenchymal reconstruction and accelerating the manoeuvres to achieve an adequate haemostasis of the

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_6

resection bed [6]. Furthermore it allows the resection of renal tumors greater than 4 cm and those with higher complexity [7, 8].

Lavery and colleagues suggested that prior experience of LPN shortens the learning curve for RAPN in terms of WIT and operative times [9].

Weinberg et al. in a population based study showed that acquisition of a surgical robot is associated with an increased use of nephron sparing surgery (NSS) for renal tumors and also an increase of renal surgery at hospitals with a robot due to referrals from nonrobotic to robotic hospitals [10].

Surgical Technique

Robot Installation

Due to large dimension of the daVinci robotic system, the correct disposition in the OR of the three main components (patient cart, vision cart and console) is essential. For kidney transperitoneal surgery patient cart is placed on the backside of the patient usually with the camera arm at the level of the target anatomy. Right-angle positioning of the robot to the backside of the patient is very important particularly for the Si system. The assistant is positioned on the opposite side of the robot and the assistant beside him on the same side as illustrated in (Fig. 6.1).

Patient Positioning and Port Placement

Patient positioning and port placement are indispensable conditions for a successful accomplishment of the procedure. In robot-assisted surgery the adequate distance between robotic arms and optimal placement of the patient cart beside the patient is essential for a straightforward docking.

Patient is placed in a modified lateral decubitus position with a 20–30° ipsilateral rotation of the shoulder and hip. The anterior abdomen is placed on the lateral edge of the bed to minimize interference with the operative table. Bending of the table at the level of the umbilicus is essential to achieve an adequate working space and avoid collisions between

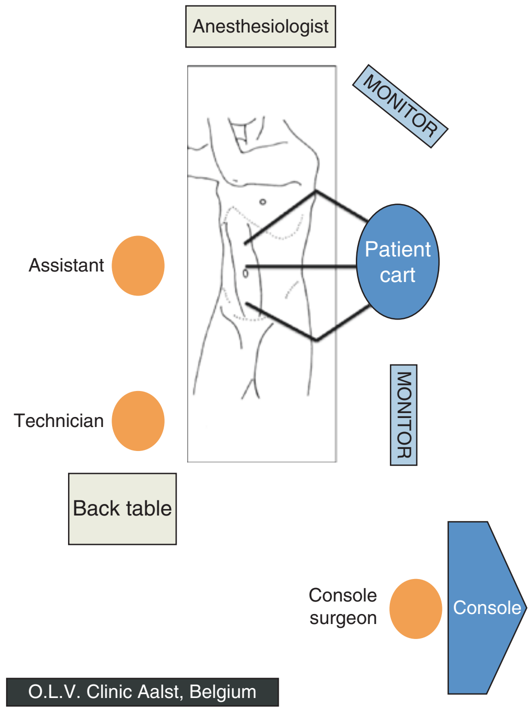

Fig. 6.1 Operating room set-up

robotic arms. The patient is secured on the table and all pressure points are padded. The complete ipsilateral flank is prepared ad draped (Fig. 6.2).

In our clinical practice the four-arm approach is preferred with the addition of one assistant trocar. We use a medial trocar configuration in which the camera is located medially near the umbilicus. The strengths of this approach include a wide viewing distance and the ability to track instruments being passed into the abdomen by the assistant (Fig. 6.3a). Alternatively, the lateral trocar configuration use a modified trocar arrangement, with the camera port placed more laterally and with two robotic trocars placed medially. This approach provide a closer view of the target structures at the expense of a wider viewing angle (Fig. 6.3b).

The primary access for the pneumoperitoneum is performed using a direct open access checking with the finger the incision of the fascia before the insertion of the trocar loaded with a blunt obturator. During trocar placement a pressure of 12 mmHg is used, while during whole surgery the pressure is adjusted to 5 mmHg in order to perform a low impact surgery. In our experience this

Fig. 6.2 Patient positioning

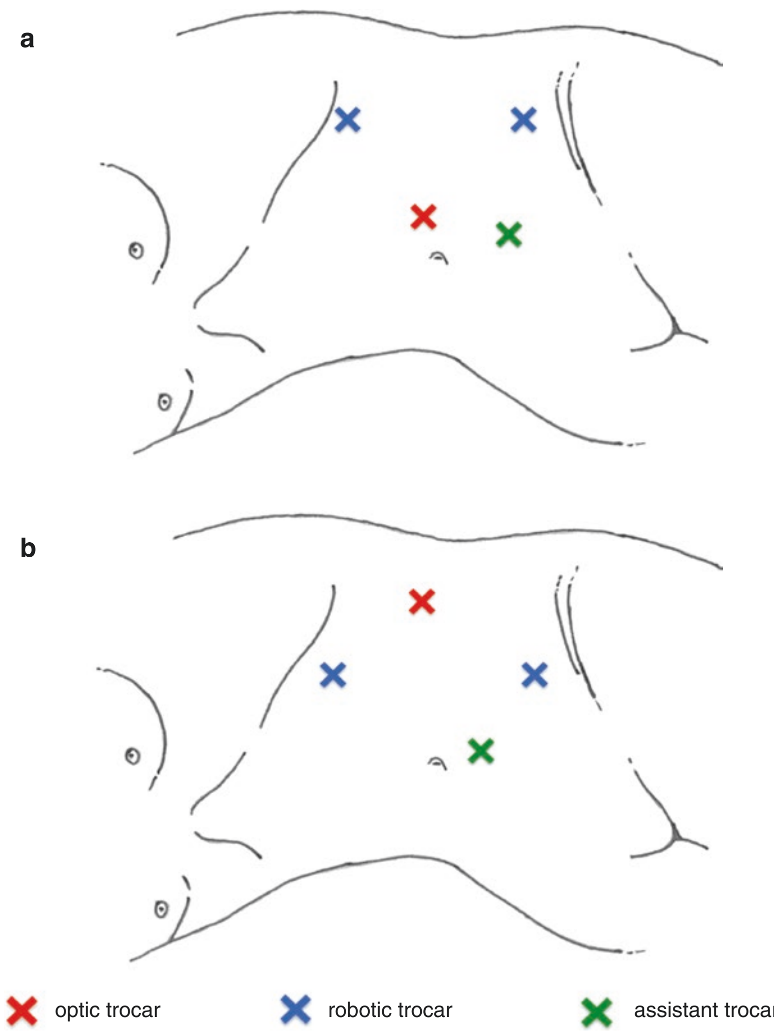

Fig. 6.3 Medial (**a**) and lateral (**b**) camera trocar arrangement

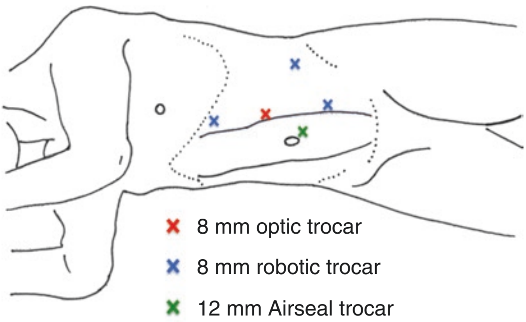

Fig. 6.4 Trocar placement for *left* robotic partial nephrectomy with the Si system

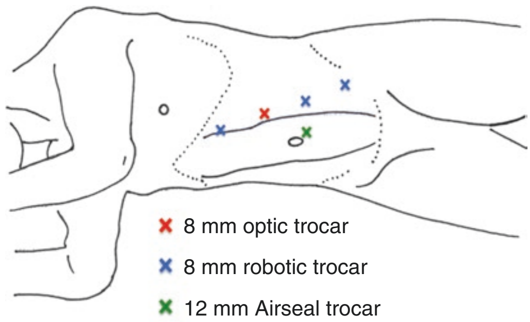

Fig. 6.5 Trocar placement for *left* robotic partial nephrectomy with the Xi system

is feasible in the majority of cases, however in patients with high body mass index the pressure must be maintained on 8 mmHg or above in order to gain a sufficient working space.

Using the Si system the 12 mm camera port is placed 2 cm cranial to the umbilicus on the pararectal line. Once the pneumoperitoneum is achieved additional robotic trocars are placed under direct vision using blunt tips. The cranial robotic trocar is placed subcostally on the pararectal line. The two caudal robotic trocars should be placed carefully to avoid collisions and maintain a sufficient mobility of the robotic arms. The most posterior one is placed approximately 2 cm caudal to the lower pole of the kidney and as lateral as possible. The medial one is placed in the lower quadrant of the abdomen 1 cm lateral from the pararectal line respecting a minimum distance of 8 cm from the previous one. A 12 mm AirSeal assistant trocar is then placed between camera trocar and the caudal robotic arm (Fig. 6.4).

The daVinci Xi surgical platform includes numerous technological enhancements. The patient cart features four robotic arms mounted on rotating overhead boom, which allows almost 360° of rotation and docking from any quadrant. Laser crosshairs on the boom facilitate aligning the patient cart with the camera port and the robotic arms are thinner with additional joints to allow rotation away from the patient (clearance feature). The endoscope has a diameter of 8 mm and can be placed into any working robotic port and finally the autotargeting feature allows the remaining robotic arms to autorotate on the boom to optimize the performance and minimize collisions.

The trocar placement for the Xi system is performed in a linear fashion at the lateral border of the rectus muscle. All the robotic trocars are placed under vision after placement of the Air Seal assistant trocar at the level of the umbilicus and pneumoperitoneum induction (Fig. 6.5).

Robot Docking

The daVinci Si robotic system is driven to the back of the patient with a right-angle positioning to the surgical table. During docking, there are some tricks that can be particularly helpful when using Si system; lifting up the camera arm after docking help to gain space in the operative field, turning inside towards the camera arm the elbow of the lateral caudal robotic arm improve its mobility range in the abdomen and finally moving the third robotic arm over the hip of the patient decrease the probability of external collisions with the caudal robotic arm.

When the Xi patient cart is driven for docking, the laser guidance is activated to facilitate the precise positioning of the rotating boom over the camera port. The camera port is the first to be mounted to the robotic arm and the camera is inserted. The autotargeting allows for optimal robotic arm placement, to maximize access and minimize collisions. After autopositioning, the remaining cannulas are docked and the robotic instruments are inserted. The robotic arms are moved in order to have at least

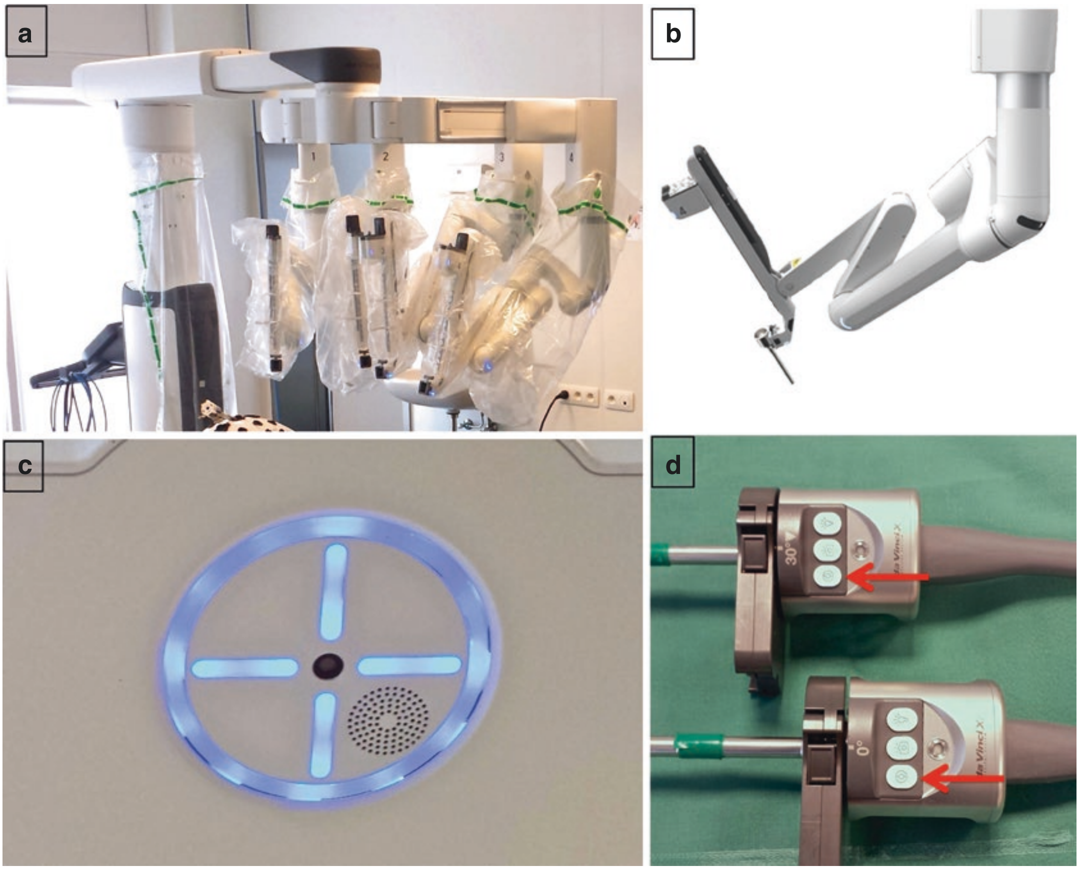

Fig. 6.6 Xi system peculiar features: rotating boom (**a**), additional joint with clearance facility (**b**), laser crosshair (**c**) and 8 mm lens with autotargeting feature (**d**)

the distance of a fist between them. The patient clearance facility could be used to further improve the arm movements (Fig. 6.6).

Conventional Multiport Versus Single Site RAPN

In the past few years, single-site surgery has been adopted to reduce port-related complications, increase recovery time, reduce pain and improve cosmesis [11]. A recent comparative study evaluating multiport versus single-port RAPN revealed significantly better outcomes for standard multiport RAPN in terms of operative time, WIT, and post-operative estimated glomerular filtration rate as well as trifecta outcomes. These findings suggest the limited role of the single-site surgery in RAPN with the current available daVinci platform [12].

Selection of the Robotic Instruments

A 30° lens is used throughout the case. The instruments usually used include a Monopolar Curved Scissors, a ProGrasp forceps and a Large Needle Driver. The large needle driver is often used as a grasper when positioned on the fourth robotic arm.

Transperitoneal vs. Retroperitoneal Approach

RAPN can be performed through a transperitoneal and retroperitoneal approach. Most of the robotic surgeons prefer the transperitoneal approach regardless the anatomical and topographic characteristics of the tumor.

Arguments in favor of the transperitoneal route are the lager working space allowing better maneuverability of the instruments and the more familiar anatomic landmarks improving the orientation of the surgeon. However it requires bowel mobilization and complete isolation of the kidney in case of posterior renal tumors. Bowel irritation due to mobilization and the contact with blood or urine can delay postoperative recovery.

The retroperitoneal approach allows direct access to the posterolateral surface of the kidney, as well as posterior hilar structures. The bowel mobilization is avoided, however the spatial limitations of the narrow retroperitoneal working space may cause disorientation and consequent inadvertent injury. Until now there are no evidences that one approach is preferable to the other and the choice is based on the surgeon's preference [13].

Personal Technique

Isolation of Renal Hilus and Tumor Identification

At our Institution the transperitoneal approach is the first choice. Primary access to the renal hilum is achieved leaving the kidney attached to the abdominal wall. On the right side the renal vein is usually identified following the inferior vena cava under the liver. On the left side the isolation of the renal vessels is performed starting from the kidney lower pole. Renal vein and artery are isolated by placing a vessel loop around them secured with a Hem-o-lok clip (Fig. 6.7). Then the Gerota's fascia is incised and the perirenal fat extensively removed to obtain an optimal tumor visualization and to mobilize the kidney until easy access to the tumor from all sides is achieved. The portion of perirenal fat that is in direct contact with the tumor is left on site to allow a correct pathological staging. Intra-operative ultrasound is not mandatory in the presence of predominantly exophytic neoplasms. It becomes of particular importance for tumors with large endophytic growth and/or hilar location. Robotic ultrasound probes that can be controlled directly by the console surgeon are available and the Tile Pro feature allows the surgeon direct visualization of intraoperative ultrasonographic image onto the console screen (Fig. 6.8). Under ultrasonographic guidance the tumor margin is demarcated using monopolar curved scissors a few millimetres away from the tumor circularly (Fig. 6.9).

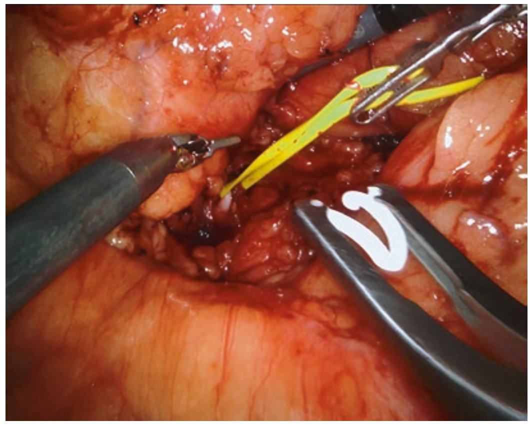

Fig. 6.7 Hilar control. A vessel loops is passed around renal artery and secured with an Hem-o-lok clip

Hilar Control and Tumor Excision

The most classic approach to RAPN involves clamping of the main renal artery until the end of the cortical renorrhaphy in order to reduce blood loss and ensure tumor resection in a bloodless field.

A lot of strategys have been developed and tested in order to eliminate global renal ischaemia and minimize the ischemic damage of the renal remnant. This is of particular importance in patients with relative and even more with absolute indications to PN.

Global renal ischemia time can be significantly reduced by the *early unclamping* of the main renal artery immediately after placement of the inner rennoraphy running suture. In this way the WIT can be reduced by more than 50% with

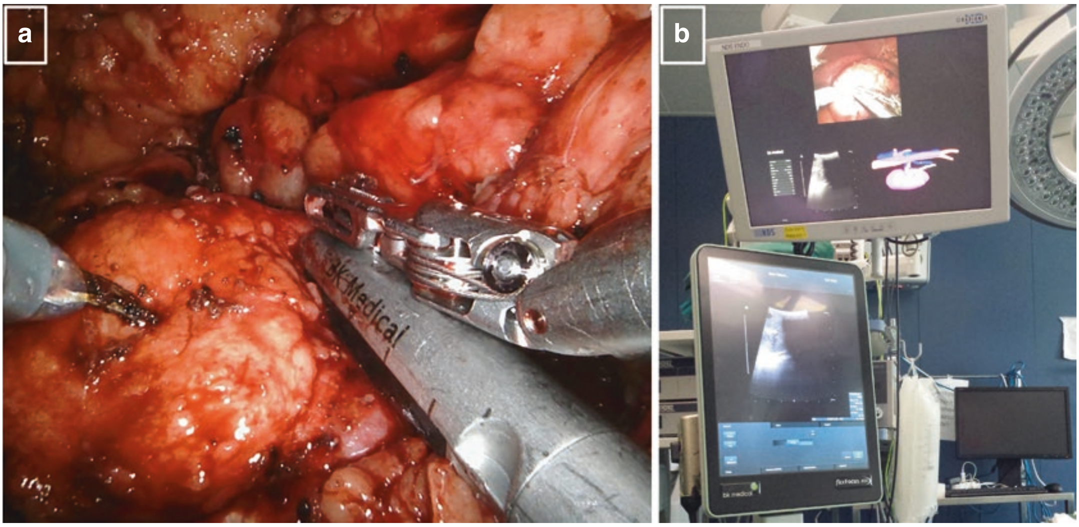

Fig. 6.8 Robotic drop-in ultrasound transducer (**a**) and Tile Pro function on daVinci Xi system (**b**)

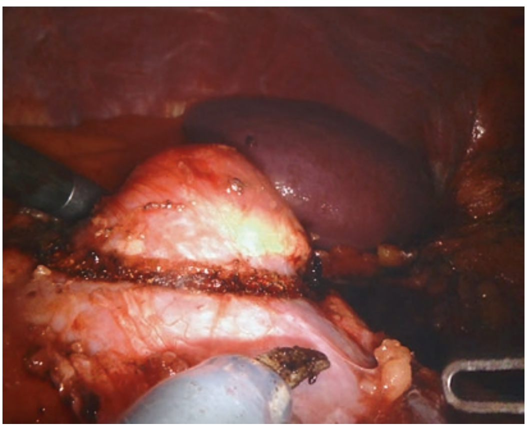

Fig. 6.9 Demarcation of the tumor by intraoperative ultrasound

similar estimated blood loss and bleeding complications [14].

The *selective clamping* technique was primarily used in minimally invasive PN to reduce the ischemic insult that result from clamping of the main renal artery. However in certain distances such as dense or adherent perirenal fat or short segmental arteries is not feasible [15].

If the tumor has favorable anatomic features as small size, exophytic lesion and low nephrometry scores, PN may be performed without any vascular clamping (*off-clamping*). Tumor excision and renal reconstruction are performed completely unclamped [16].

Finally the induction of hypothermia has also been proposed either by transarterial cold perfusion of the kidney or by retrograde ureteral cooling, or more recently by covering the kidney with ice slush during ischemia time [17].

Many surgeons prefer to use mannitol and/or furosemide during PN, however recent studies have shown that there are no significative advantages [18].

The issue of improving renal functional outcomes by decreasing warm ischemia time is not yet settled. Several studies indicate that the amount of renal parenchyma preserved, but not the type or duration of ischemia, is significant in multivariate analysis [19].

In our everyday clinical practice the arterial clamping is achieved using the robotic bulldog clamps. Usually, only the main renal artery is clamped. However, in larger or centrally located tumors, both renal artery and vein are clamped due to the high risk of main renal vessels injury. In selected cases, a selective clamping of secondary or higher-order arterial vessels going to the tumor is performed followed by a perfusion assessment using the fluorescence imaging (FireFly). 1.5–2 mL of indocyanine green (ICG) is injected intravenously and in a few seconds the main renal vessels and the perfused parenchyma are visualized in green with the exception of the area perfused by the clamped higher-order arterial vessel (Fig. 6.10). If the non perfused area corresponds with the tumor, excision can be performed using the selective arterial clamping technique, vice versa the best strategy will be to clamp another higher-order artery or a lower-order arterial vessel or even the main renal artery. Good vision at the level of the resection bed is mandatory to follow the correct dissection plane avoiding the risk of tumor violation and local dissemination.

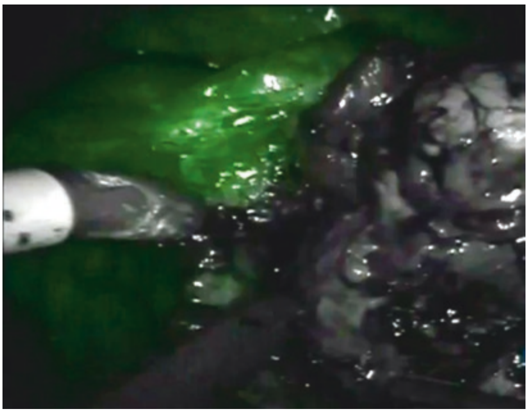

Fig. 6.10 Perfusion assessment using Fire Fly fluorescence imaging shoving the normally perfused parenchima (*green*) and the non perfused area due to selective arterial clamping

The borders of the tumor are defined and the demarcation line is then entered a few millimeters into the kidney cortex with blunt dissection before clamping. Clamping is usually performed with robotic bulldog (Scanlan International) (Fig. 6.11). In case of an off-clamping procedure the tumor excision is performed without bulldog placement.

The tumor excision is performed mainly using cold scissors and ProGrasp forceps are used to gently spread the tissue to aid the dissection (Fig. 6.12). In this way the surgeon can judge the quality of the incised tissue avoiding cutting into the tumor and thus avoiding positive surgical margins. During this step the role of the assistant controlling the suction device is essential. In fact he has to facilitate the tumor excision by gently pushing the parenchyma in order to expose optimally the dissection plane to the surgeon. In case of little opened vessels in the tumor bed the assistant has to perform a gently compression or put a clip. Once the dissection is completed, the specimen is placed above the liver or spleen for an easier later retrieval.

Renal Reconstruction

Renorrhaphy is typically performed with the sliding-clip technique, originally reported by Benway et al. [20]. For the renorrhaphy all

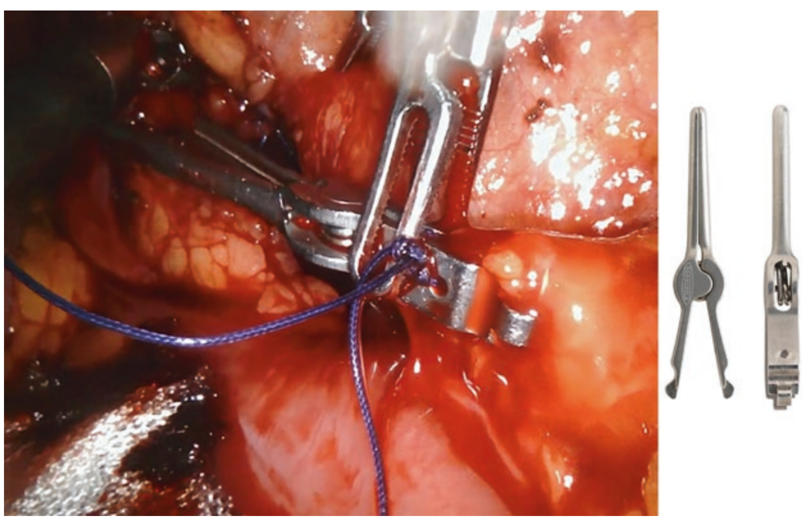

Fig. 6.11 The renal artery is clamped using the bulldog directly by the robotic surgeon

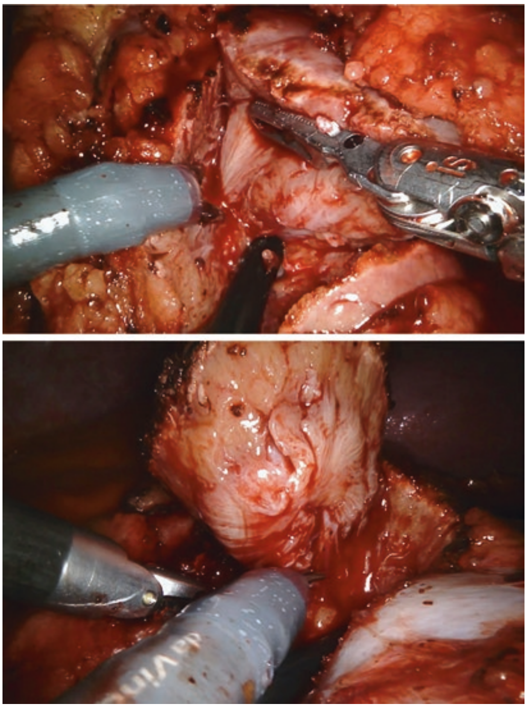

Fig. 6.12 Tumor excision using Monopolar curved scissors on the *left*, ProGrasp forceps on the *right* and Needle holder on the fourth robotic arm

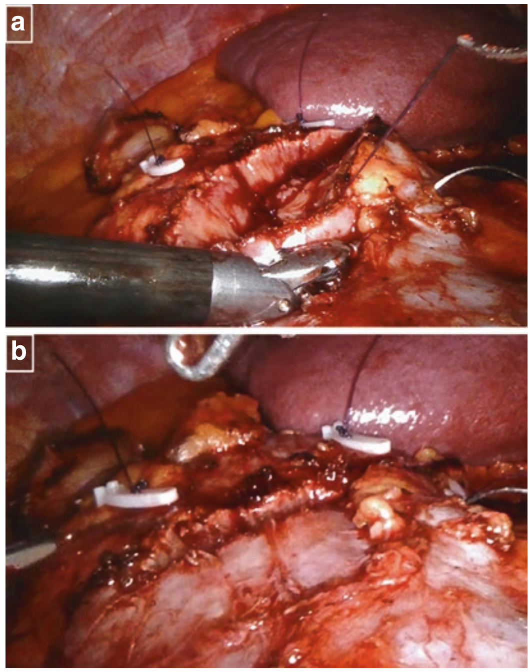

Fig. 6.13 Inner renorrhaphy performed using 3-0 Monocryl running suture

sutures should be first prepared on the back table before the beginning of the surgery. A knot is tied at the end of a 18 cm suture and a Hem-o-lok cip is placed above the knot. The robotic monopolar scissors are exchanged for a robotic large needle driver and the inner defect closure is performed with a running Monocryl 3-0 suture preloaded with a Hem-o-lok clip (Fig. 6.13). The suture is brought from outside to inside the parenchyma in order to have the clip outside the defect. Care is taken to close all the retracted calices and vessels with the running suture to avoid further complications. At the same time too deep bites should be avoided in order to prevent injury to deep larger vessels lying just under the defect. The Monocryl suture is then passed from inside to outside through the parenchyma and secured with another Hem-o-lok clip. The combination of monofilament suture and Hem-o-lok clips allow to brought the right tension on this suture and also to further regulate the tension.

After completion of the inner renorrhaphy, usually the bulldog clamp is removed according to early unclamping technique and the kidney is checked for any bleeding.

The outer renorrhaphy is performed using the sliding clip technique with a Polyfilament 1-0 sutures with CT needles (Fig. 6.14). The running suture is used, and at each bite, the thread is secured with a Hem-o-lok clip and proper tension is given on the tissue. After that the inner renorrhaphy is put under tension again, because of the pressure of the outer closure. Using the LapraTy clips this is not possible because an excessive force is needed to move the clip over the suture with the risk of tearing it especially during further regulations of the tension. Finally a second Hem-o-lok clip is placed on all ends of the sutures to prevent involuntary sliding of the previous clips. To minimize the risk of involuntary sliding of the clips is recommendable to "hook" the suture with the clip, which means to place the hook end of the second clip on the suture (Fig. 6.15). If necessary, additional sutures or various fibrinogen coagulation

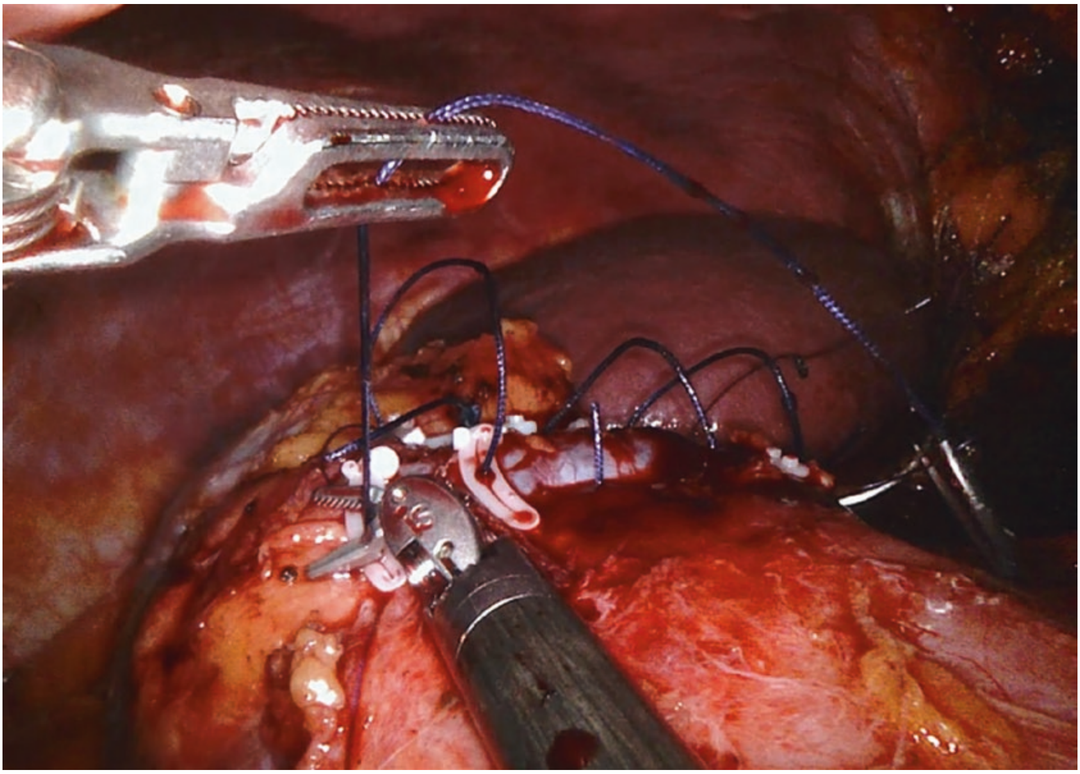

Fig. 6.14 Outer renorrhaphy performed using a Polyfilament 1-0 sutures with CT needles and the sliding clip technique

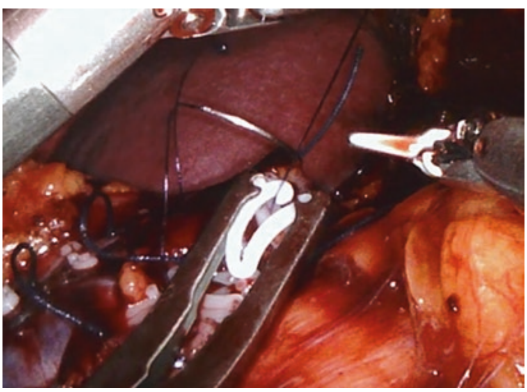

Fig. 6.15 To minimize the risk of involuntary sliding of the clips is recommendable to "hook" the suture with the clip, which means to place the hook end of the second clip on the suture

enhancers and tissue sealants can be applied on the defect. However, their usefulness is still under debate.

The specimen is placed in a retrieval bag and needles, bulldog clamp and vessel loops are removed (Fig. 6.15). Gerota fascia is closed, and the robot undocked. A wound drain is introduced through one of the 8 mm trocars under direct vision. The specimen is usually retrieved through the camera port which may be enlarged if necessary. The fascia at the extraction site is closed with a thick dissolvable suture. The remaining trocar sites do not require fascial closure, as the risk of herniation is low.

Other Approaches

Retroperitoneal Approach

This approach have been described and shown by James Porter during several live surgery procedures.

Patient is placed in a full flank position with the ipsilateral side up relative to the renal tumor. The ipsilateral arm is secured with an airplane-style arm-holder and the dependent arm is padded and secured close to face to avoid conflicts with the robot. The bed is fully flexed to provide maximal space between the ribs and the iliac crest. The anestesiologist is placed far from the patient's head to accomodate docking of the robot over the patient's head. A long circuit is attached from the endotracheal tube to the ventilator to ensure an adequate ventilation of the patient during all anesthetics.

A four-port configuration (one camera trocar, two robotic ports and one 12 mm assistant trocar) is routinely used for retroperitoneal robot-assisted partial nephrectomy (RP-RAPN).

The retroperitoneal space is created by placing a balloon dilator in an incision in the midaxillary line 1–2 cm above the iliac crest. After full expansion the ballon is removed and the 12 mm trocar is inserted for insuflation of the retroperitoneum with 15 mmHg of carbon dioxide. The first 8 mm robotic trocar is placed in the posterior axillary line in a horizontal plane approximately 2 cm cephalad to the 12 mm camera port. A second 8 mm robotic trocar is placed in the anterior axillary line in a horizontal plane approximately 1 cm caudad to the first robotic trocar. After that the peritoneum is reflected 2 cm medially to the anterior superior iliac spine and a 12 mm assistant trocar is inserted at this location. A 0° robotic laparoscope is most commonly used, but on occasion, a 30° up lens is needed to avoid camera conflict with the iliac crest.

The fenestrated bipolar forceps is used to lift the kidney upward to facilitate the dissection through the perinephric fat onto the pulsations of the renal artery. The artery is skeletonized to allow subsequent selective versus nonselective clamping. The renal vein is not routinely dissected out and clamped with the exception of very central renal tumors encroaching on the venous vasculature. Defatting of the kidney begins under the upper Gerota fascia cut edge, which is used as a landmark to avoid inadvertent peritoneotomy (Fig. 6.16).

Fig. 6.16 The excised renal tumor is placed in the endocatch bag

The laparoscopic ultrasound is used to identify and confirm tumor location, and cautery is used to circumscribe the planned renal capsule incision. After clamping the main renal artery or an arterial branch, the tumor is excised with cold scissors. The renal defect is reconstructed by first closing the collecting system, if it is entered. 4-0 absorbable Monofilament is used to repair collecting system and to oversewn individual vessels. The inner renorrhaphy is performed with 3-0 Monofilament absorbable suture in a running fashion and secured on the outside of the kidney with locking clips. The renal cortex is then closed using 2-0 absorbable, braided suture using the sliding-locking-clip technique.

The tumor is placed in an endoscopic entrapment sac and a 15 French round drain is placed through the more anterior 8 mm robotic trocar [21].

Zero Ischemia

Zero ischaemia was introduced as a technique to eliminate the renal ischaemia induced by hilar clamping. This is of particular importance especially for minimally invasive techniques such laparoscopic and robot-assisted partial nephrectomy, where a prolonged WIT is often mentioned as a criticism in comparison with open approach. It was first described by Gill et al. in 2011 in association with controlled hypotension to 60 mmHg of arterial pressure during the excision of the deep part of the tumor [22]. Since then, novel techniques, as early unclamping, off-clamp surgery, segmental arterial clamping, vascular microdissection and other approaches have been developed and tested in order to eliminate global renal ischaemia and maximize function of the renal remnant.

In order to facilitate the resection of medial tumors with zero ischemia laparoscopic or robot-assisted technique the anatomic renal artery branch microdissection have been proposed. The main renal artery and vein are mobilized and individually encircled with mini-vessel loop. Then the hilar microdissection is performed in a medial-to-lateral direction to identify the specific arterial branch or branches supplying the tumor. If necessary a small 1–2 cm radial nephrotomy incision is performed to expose specific arterial branches. Transient test placing a disposable bulldog clamp could be performed to confirm tumor devascularization. In case of hilar tumors that are in contact with renal artery and vein it should be peeled away preserving intact the big vessels. The hemostasis in the PN bed is performed using a combination of clips and intracorporeal suturing. Any pelvic-calyceal opening is repaired with sutures. If needed the arterial pressure may be pharmacologically decreased transiently to minimize renal parenchymal bleeding.

A precise understanding of the renal anatomy and vascularization is mandatory before proceeding with the surgery. Bi- or triphasic contrast-enhanced CT of the abdomen with slice thickness of 5 mm or less is the reference standard to delineate the relationship of the mass to adjacent normal structures and demonstrate the vascularization of the tumor. Three-dimensional CT reconstructions of the renal mass and vascularization are very useful for the surgeon to guide PN surgery, especially in complex cases. In fact they allow to reliably predict the tumor proximity to vascular structures and collecting system (Fig. 6.17).

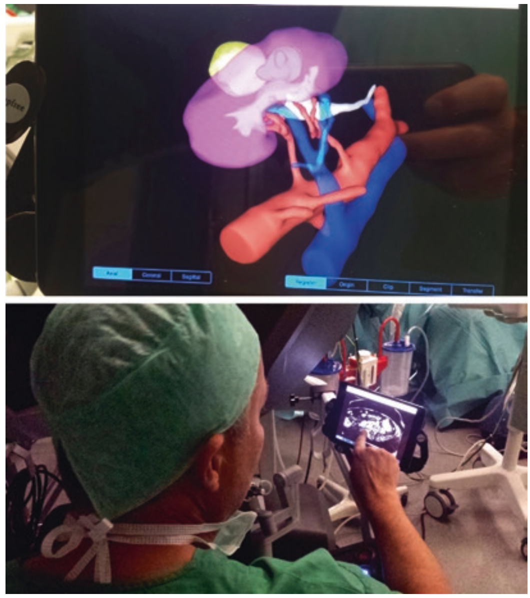

Fig. 6.17 3D reconstructions allow to reliably predict kidney vascularization and the conformation of the tumor

Also in our experience the number of RAPN performed with zero ischemia technique is growing even for complex and medial tumors.

Perioperative Outcomes

Since Gettman and colleagues published the first RAPN series in 2004, several case series and comparative studies have been published suggesting promising results.

Dulabon et al. in a large multi-institutional series of 446 patients with 41 hilar and 405 nonhilar tumors, reported a mean operative time of 196 and 187 min, a mean WIT of 26.3 and 19.6 min, a mean estimated blood loss of 262 and 208 mL and a mean hospitalization of 2.94 and 2.87 days respectively. Complication and conversion rates were 5.2 and 2.2% and perioperative transfusions were 2.4 and 4.2% for the hilar and nonhilar tumor cohort respectively [23].

It has been suggested that prior robotic experience with the robotic platform is important for successful application of RAPN. Mottrie at all

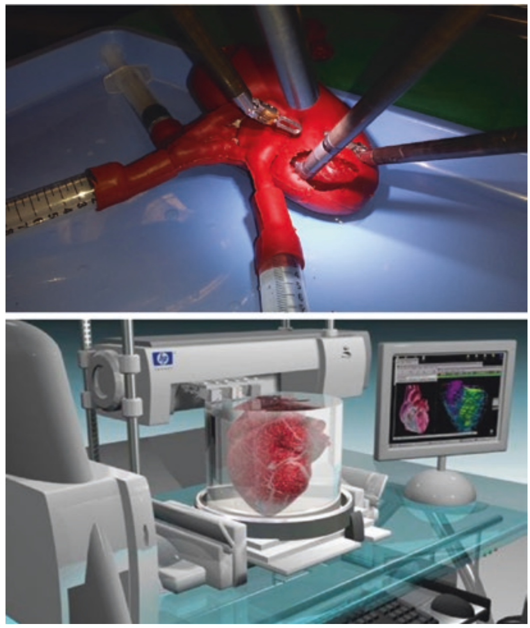

Fig. 6.18 Specific tissue-like 3D-print kidney models created with advanced three dimensional printing technology

demonstrated that, in the hands of an expert robotic surgeon dealing with other robotic procedures, RAPN is safe, requiring a short learning curve to reach satisfying results in terms of WIT, console time, blood loss, and complication rates. The WIT <30 min was reached after the first 20 cases and a WIT <20 min after the first 30 procedures. In this single-centre series, they observed only 2 (3.2%) grade 3 complications according to Clavien classification [6]. Paulucci and colleagues in a multi-institutional study concluded that although RAPN can consistently be performed safely with acceptable outcomes after a small number of cases, improvement in trifecta achievement, WIT, EBL, blood transfusions and a shorter hospitalization continues to occur up to 300 procedures [24].

More recent studies showed a further significant improvement in the peri-operative outcomes after RAPN and the feasibility of this new approach also in complex cases.

Ficarra et al. in a recent multicentric, international study analyzed retrospectively the clinical records of 349 consecutive patients and reported a median WIT and console time of 20 and 120 min respectively in patients with intermediate and high-risk tumors according to PADUA score [25].

Currently, in our experience, the operative time ranges between 80 and 120 min, the median WIT using the early unclamping technique is 9 min (range 5–15 min) and estimated blood loss between 100 and 150 mL. The overall complication rate resulted 21% with 8% of Clavien grade ≥2 and 3% of grade ≥3 complications. No positive surgical margins were observed after the first 62 patients analysed to evaluate the learning curve period [6].

In our everyday practice we use early unclamping technique in most of the cases. When feasible a selective clamping of higher-order arterial branches is performed, however this approach may result complex requiring long operation time also in hands of a very expert robotic surgeon. Recently the number of cases performed without any vascular clamping is increasing due to a better patient selection and advanced preoperative imaging as the 3D computed tomography reconstructions and patient-specific tissue-like 3D-print kidney models created with advanced three dimensional printing technology (Fig. 6.18).

Few data are available about the application of RAPN in the treatment of >4 cm tumors.

Two recent studies investigate the feasibility of RAPN on T1b renal tumors comparing the trifecta and pentafecta rates between T1a and T1b renal masses. They roled out that the rate of pentafecta after RAPN was comparable between T1a and T1b renal masses [26] and that RAPN allows significantly lower WIT and estimated blood loss with higher rate of trifecta achievement compared with LPN [27].

Petros et al. in a series of 83 patients with mean tumor size of 5 cm reported a mean operative time, blood loss and WIT of 177 min, 200 mL and 24 min respectively with low risk of intra-operative and post-operative high-grade complications (0% and 8% respectively) [28].

In a recent metaanalysis authors ruled out that PN is a viable treatment option for larger T1b and also T2 renal neoplasms, as it offers acceptable surgical morbidity, equivalent cancer control, and better preservation of renal function, with potential better long-term survival than radical nephrectomy. They concluded that for T2 tumors, the use of PN should be more selective, and a higher risk of perioperative complications should be taken into account [2]. However the role of minimally invasive PN for T2 renal tumours is not yet known.

Studies comparing RAPN to LPN showed a significant shorter WIT in the RAPN groups. Moreover, some studies documented a statistically significant advantage in favour of robotic procedure also in terms of reduction of blood loss and in-hospital stay duration [29].

Ficarra et al. showed that RAPN can attain equivalent perioperative and functional outcomes as OPN in patients with cT1 renal tumors, being a less invasive approach and offering a lower risk of bleeding and postoperative complications. However, the OPN is associated with a shorter WIT and a higher percentage of unclamped procedures. The overall renal function evaluated at 3 months after surgery seemed to be equivalent between the approaches [30].

Functional and Oncologic Outcomes

Available functional outcomes indicated excellent preservation of renal functional reserve after RAPN. However, the majority of these studies are based on the evaluation of creatinine levels (mg/dL) and/or estimated glomerular filtration rate (eGFR) values. Therefore, the real impact of the surgery on the renal function could be masked by the normal contralateral kidney function. Only a few studies evaluated the renal function of the treated kidney after RAPN using the renal scintigraphy. Zagar et al. studied the individual renal unit function after RARP in a cohort of 99 patients with the aid of nuclear renal scan. They ruled out that the ipsilateral renal function preservation was significantly lower than total eGFR preservation (72% vs. 83.83% respectively) and that baseline renal function, BMI, WIT >30 min and the amount of resected healthy renal parenchyma represent the factors with a significant impact [31].

Considering the short follow-up reported in the majority of available series, only early and intermediate oncologic outcomes can be evaluated after RAPN. In literature, in most recent series the risk of positive surgical margins (PSM) ranges between 2 and 4%. This preliminary results can be considered overlapping with the percentages previously reported after open or traditional laparoscopic partial nephrectomy.

Khalifeh et al. reported intermediate-term oncologic and functional outcomes on a series of 134 patients. The overall survival (OS) was found to be 97.0% at 3 years and 90.2% at 5 years, while the cancer-free survival (CFS) was 98.9% at 3 years and 5 years. With only one renal cell carcinoma (RCC) recurrence the OS and CFS at 3 and 5 years were comparable to similar studies describing laparosocopic, open and radical nephrectomy [32]. In another study with a multi-institutional cohort of 943 patients, the same authors reported a PSM rate of 2.2% and a 5-year recurrence-free and metastasis-free survival of 94.8% and 97.5% respectively with a mean follow-up of 64 months [33].

Complications and Management

Complication rates can be used to evaluate the safety of novel surgical procedures. Initial RAPN series reported complication rates from 0 to 20% and notably higher complication rates were demonstrated for tumors of increasing complexity.

Hemorrhagic complications are among the most common and can rappresent potentially life-threatening during PN requiring immediate treatment with blood transfusions, interventional embolization or operative reexploration.

Urinary leak is also a common complications after RAPN. It can be prevented by close inspection of the resection bed and accurate closure of the calycs during inner renorrhaphy. In case of a postoperative recognition of a urinary leak the decompression of the urinay tract is indicated in order to maximize healing of the collecting system.

Promt recognition of bowel injury is essential to avoid future severe complications. If a small laceration is noted, it can be repaired intraoperatively with a 4-0 Vicryl suture. In case of a larger laceration, it may require bowel resection and necessitates general surgeon involvement.

Rhabdomyolysis may occur due to compression at pressure points related to patient positioning on the operating table. Male sex, high body mass index, prolonged operative times and lateral decubitus position are all risk factors. Serum creatinine phosphokinase and creatinine should be trended to follow the clinical course. Management includes intravenous fluid hydration and if a compartment syndrome occurs, fasciotomy may be necessary.

Renal insufficiency (RI) due to nephron loss is significantly reduced with partial versus radical nephrectomy. In case of a postoperative RI close monitoring of urine output and serum creatinine should be performed. A postrenal etiology including clot obstruction must be roled out and if renal function further deteriorates or persists, a nephrology consultation should be asked.

Tanagho et al. performed a multi-institutional analysis of complications in 886 patients undergone RAPN at five high volume United States centers. Intraoperative complications occurred in 23 patients (2.6%) and 139 postoperative complications occurred in 115 patients (13.0%) for a total complication rate of 15.6%. Most (77.0%) were Clavien grade 1 and 2 and were managed conservatively [34].

At our institution we recorded an all grade complication rate of 21% with only 3% of Clavien grade 3 and no grade 4-5 complications.

Conclusions

Robot-assisted partial nephrectomy (RAPN) represent the evolution of conventional laparoscopy with the advantage of a new sophisticated technology. The improved vision associated with wristed instruments allows a decreased ischemia time, which is basically related to the length of the tumor dissection and suturing phase. Furthermore allows average surgeons with or without previous laparoscopic experience to overcome the learning curve in a reasonable time. It allows us to operate more comfortable on complex tumors respecting the oncologic principles and preserving as much renal function as possible. As reported by some Authors, it allows also to manage large and complex renal masses, including endophytic, central, and hilar lesions. Today a major problem remain the costs related to this technology. Maybe in the future, with the advent of new robotic systems from different companies, the costs will progressively decrease.

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7 Warm Ischemia During Robotic Partial Nephrectomy

Francesco Porpiglia, Daniele Amparore, and Riccardo Bertolo

Introduction

The last two decades have seen the sunset of the radical nephrectomy era in favor of nephron sparing techniques for the surgical treatment of renal masses, especially for T1 renal tumors. The rationale of this evolution was based on the evidence of similar oncological results with a better postoperative renal function in case of nephron sparing approach [1]. Simultaneously the new minimally invasive techniques, such as pure and robot-assisted laparoscopy, have been developed and used as the preferred approach to nephron sparing surgery [2]. Particularly, the three-dimensional visualization and the optical magnification allowed by robotic technology haveincreased the indication to nephron sparing surgery regardless the surgeon experience, shortening the learning curve of beginner surgeons. In experienced hands, robotic approach has pushed forward the limits of nephron sparing surgery with the aim of saving renal units the more as possible [3, 4].

Robotic technology, thanks to the intrinsic characteristics, allows for a more precise approach to nephron sparing surgery. The use of robotics is nowadays sponsored by the evidences that various factors can influence the postoperative renal function after a nephron sparing procedure: excluding the unmodifiablebaseline renal function, the volume of healthy renal parenchyma preserved, the duration of ischemia time (WIT) during the surgery and the suture techniquecan be influenced by the use of such an approach [5].

The aim of the chapter will be to cover the topic of warm ischemia during robotic partial nephrectomy (RPN). Following a general introduction about warm ischemia, some technical aspects were discussed in details and some experiences will be reported.

Warm Ischemia

The kidney is injured by ischemic damage when the hilar vessels are clamped. Clamping of hilar vesselsis mandatory in order to obtain a bloodless field during resection of the tumor and renal reconstruction [6]. If baseline renal function is considerable unmodifiable and the volume of renal parenchyma preserved can be shortly modulated, the warm ischemia time is a surgeon-dependent factor that can be minimized [7]. The concept has paramount importance in a minimally-invasive surgery setting such as robotics is, because prolonged ischemia time is often mentioned in Literature as a drawback of laparoscopic and robotic approaches in comparison with traditional open partial nephrectomy [8].

Over the last 15 years the duration of ischemia time beyond which the kidney function was

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_7

considered irreversibly damaged moved from 55–40 min to 30–20 min [9, 10]. However some Authors suggested that even a transient ischemia can be detrimental on renal function, especially in elderly patients,with comorbidities and low preoperative renal function. Some Authors stated that every minute counts when renal flow to the kidney is interrupted [11].

Starting from this principle many ideas were proposed in the Literature, aimed to reduce or minimize the ischemia time.

In the following paragraphs,all the different surgical techniques to manage the renal pedicle with the aim of reduce the ischemia time during partial nephrectomy will be presented and explained, specifically focusing on the robotic approach.

The topic has been often evaluated in the Literature, but no consensus exists in terms of definitions and descriptions of the different techniques for managing the renal pedicle [12, 13].

The classification of the available techniques it is necessary, starting fromthis concept: renal ischemia can be modulated working on the duration of the pedicle clamping rather than working on the percentage of the kidney parenchyma that undergoes ischemia. The first idea is independent from the anatomy of the kidney and solely based on thetime the renal artery is clamped. This will be referred as “Time-Based Management of Renal Pedicle” category.The second one is based on the anatomical distribution of the renal vasculature, regardless the time. This will be referred as “Vascular Anatomy-Based Management of Renal Pedicle” category.

Time-Based Managements of Renal Pedicle

Standard Clamping of Mainrenalartery

The standard renal artery management during partial nephrectomy (PN), regardless the approach (open, laparoscopic or robot-assisted) consists of the main renal artery dissection and its temporary clamping during the extirpative and reconstructive phase of the surgery (Fig. 7.1). This will allow a bloodless field during tumor excision and parenchymal defect suture. Robot-assisted nephron-sparing surgery was developed as an evolution of the traditional laparoscopic surgery. The robotic approach, thanks to the magnification of the image, the three-dimensional visualization and the endo-wrist technology, seems to allow better results in terms of surgical outcomes [14]. Indeed it has the potential to exceed the technical challenges of laparoscopic surgery, obtaining improvements of functional postoperative outcomes thanks to the more precise excision of the tumor and resection bed suture but also due to a decrease of warm ischemia time during the surgery [15]. Literature reviews that compared LPN with RPN confirmed that the two procedures are similar in terms of perioperative outcomes, except for WIT, that was found to be significantly shorter in RPN groups [14, 16].

Kaouk et al. analyzed the factors that can influence the postoperative renal function after RPN, and identified WITover 30 min, larger tumor size and lower baseline eGFR, as the main predictors of a sustained decrease of renal function [17].

Wiener et al. demonstrated that even in case of lower WITs (>22 min) a greater decline of eGFR can occur [18]. Independently from the type of the approach, many studies showed that limited WIT periods (<20–25 min) during PN might have negligible effects on postoperative renal function [19]. However, the ideal WIT safety threshold remains a matter of debate. In fact, some papers demonstrated that every minute of ischemia could have an impact on postoperative renal function [11]. According to this principle, the renal ischemia, above all when produced to the whole kidney, has to be limited as much as possible in order to minimize the postoperative renal damage [20].

Early Unclamping Technique

The early unclamping technique consists of a premature unclamping of the main renal artery when the reconstructive phase is still ongoing: usually the suture of the resection bed has already been finished but the parenchymal defect closure has to be completed. The concept was introduced

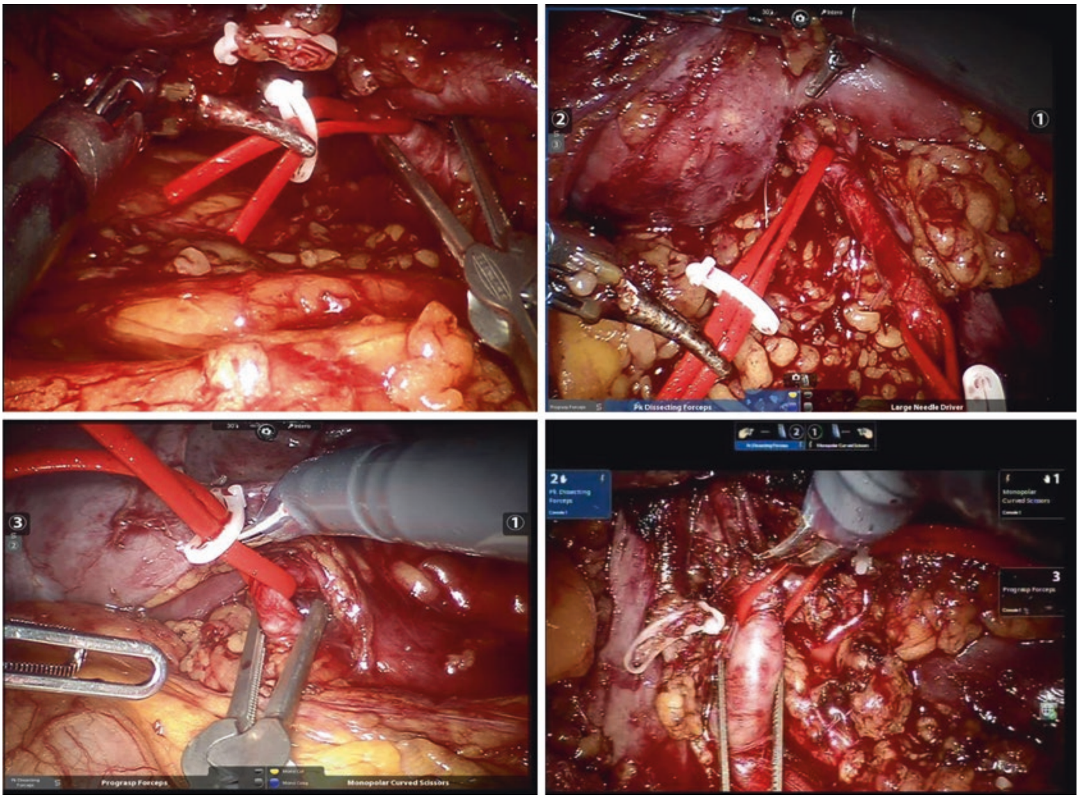

Fig. 7.1 Examples of main renal artery dissection and clamping with bulldog clamps

in laparoscopic PN era by Baumert et al. [21] with the aim of reducing ischemia time during laparoscopic PN. This technique had a little diffusion in the robotic era, and a few data are available in the Literature about the early unclamping in the robotic setting.

In a match-paired analysis of surgical outcomes comparing LPN with RPN published by Aron et al. in 2008, Authors stated that the role of such a technique in reducing WIT was not clear when employed for RPN [22].

A little sample size of patients treated with early unclamping RAPN was presented by San Francisco et al. in 2011 but in this study only the feasibility of the technique was assessed [23].

A multi-institutional retrospective study was conducted in 2014 by Peyronnet et al., comparing the outcomes obtained with the use of early unclamping versus standard clamping in 430 RPNs. The mean WIT recorded in the early unclamping group was significantly lower than the one in the standard clamping group (16.7 min vs. 22.3 min); conversely, the estimated blood losses were found to be higher when the renal artery was unclamped before the parenchymal defect closure. Notwithstanding this difference the complications rate, specifically the transfusions, was similar between the groups. At multivariate analysis, the early unclamping technique was predictive of a lower WIT, but the functional outcomes, expressed as eGFR decrease at 1 month postoperatively, were not significantly different between groups [24].

Clampless/Off Clamp/No Clamp/Unclamped Technique

The clampless technique, also known as off-clamp or no clamp or unclamped technique, can be considered the extreme evolution of the time-based management of renal pedicle during PN. In fact, with this technique, the renal artery is dissected but the clamping is not performed at all during the whole surgical procedure. Please note that some Authors with consistent experience avoid the dissection of renal pedicle in all the cases as clampless technique is always performed [25].

A huge surgical expertise is requested before embarking in clampless approach because of the likelihoodof persistent bleeding during the extirpative and reconstructive phases [12]. For this reason, such an approach is more indicated for low complexity renal masses, especially at the beginning of the dedicated learning curve [26]. Even if a higher blood loss rate can be expectable,this technique completely avoid any exposure of the kidney to the clamping-related ischemic damage.It was reported that can be a valuable choice in case of impairment of preoperative renal function [19]. As the previously mentioned clamping approaches, the off-clamp technique can be performed regardless the surgical approach. Indeed, Literature offers many examples of the feasibility and functional results of this technique in open, laparoscopic and robotic setting [13].

Focusing on the robotic approach, in 2013 Kaczmarek et al. presented the results of a large multi-institutional study of RPN without hilar clamping for the treatment of small renal masses. The aim of the study was to determine the risks and benefits of the off-clamp approach in comparison with a clamped approach. The results of the study showed that off-clamp RPN was associated with higher blood losses if compared with clamped RPN (228 mL compared with 157 mL, $p = 0.009$), with the advantages of shorter operative times (156 min compared with 185 min, $p < 0.001$) and smaller decrease in renal function (2% compared with −6%, $p = 0.008$). The Authors demonstrated the feasibility of such a technique, underlying that tumor characteristics and surgeon experience have a great importance for the success of the surgery [27].

In 2015, also Satkunasivam et al. evaluated the feasibility and the efficacy of the off-clamp technique focusing on the surgeonsexpertise. They considered the surgical and functional outcomes of patients treated with super-selective clamping technique vs. super-selective clamping technique performed by surgeons with high expertise vs. off-clamp technique. The median operative time and 30-days complications were similar among the groups, as well as the median percentage reduction in eGFR after 30 days from surgery (−7.6%, 0%, and −3.0% $P = 0.53$); however, new-onset of chronic kidney disease (CKD) stage >3 occurred significantly less frequently in the off-clamp group (23% and 10% vs. 2%; $P = 0.003$) [28].

No conclusive data are available about the superiority of such an approach in renal function preservation with respect to others renal artery managements in RPN setting.To date, in the laparoscopic setting Porpiglia et al. published a comparison between clampless and clamped (<25 min) PNs in a laparoscopic series. Renal scan parameters such as effective renal plasma flow and split renal function were evaluated preoperatively and 3 months after surgery in order to assess the loss of renal function. Data from this study showed that the percentage reduction of renal scan values was not significantly different between the groups [19].

A really important randomized multicentre study is ongoing comparing off-clamp versus clamped RPN. Preliminary results of the study stated that the approaches are equally safe in terms of oncological outcomes and complications. However, even for tumors with a low/intermediate complexity, at high-volume Centres and for skilled surgeons, despite the setting of a randomized controlled trial, in a relevant rate of cases off-clamp PN was not feasible due to bleeding while only in a few cases clamping the artery was deemed as redundant. This is why the enrolment phase of the study is still open [29].

Vascular Anatomy-Based Management of Renal Pedicle

Selective Clamping

The selective clamping technique is based on the concept that renal vasculature distribution, originating from one or few main renal arteries, progressively splits into peripheral branches that

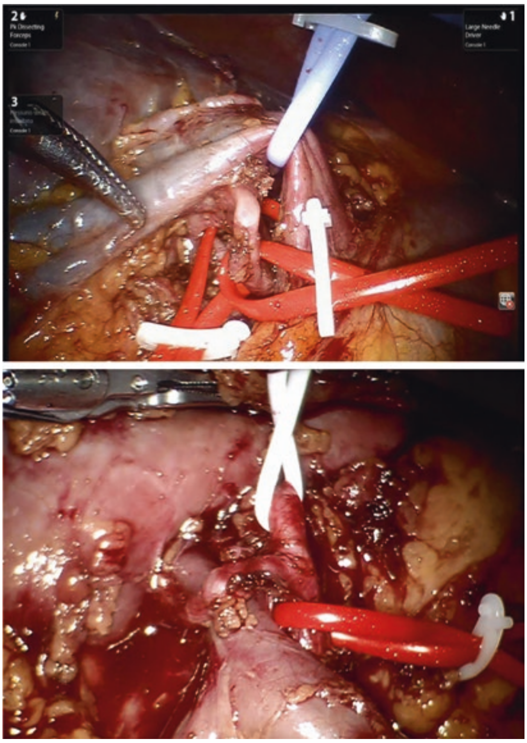

Fig. 7.2 Examples of arterial branches exposure of right kidney pedicles after isolation with dedicate vessel loops

vascularize a specific region or area of the kidney [30]. Starting from this anatomical principle, when performing a PN, it is possible to identify and progressively dissect that branches (Fig. 7.2), in order to ideally clamp only the one that vascularize the region of interest in which the tumor is located (Fig. 7.3).

With the development of minimally-invasive surgery, the selective clamping technique experienced a large diffusion, due to the miniaturization of instruments, allowing a more precise microvascular dissection of the renal artery branches (Fig. 7.4) [12].

One of the first experiences available in Literature concerning selective parenchymal clamping in RPN was published in 2008 by Aron et al. Authors compared perioperative outcomes of a group of patients treated with RPN with hilar clamping to a group of patients who underwent selective regional parenchymal clamping. The regional parenchymal clamping group showed better preservation of immediate postoperative glomerular filtration rate, but this difference from baseline did not persist at a median follow-up of 6 months [22].

Viprakasit et al. described their multi-institutional experience of selective regional clamping during RPN, aimed to the ischemia of the soletumorarea. They demonstrated the feasibility of such a procedure but underlined that a careful preoperative selection of patients is needed in order to obtain better postoperative results [31].

In 2012 Martin et al. compared patients treated with minimally-invasive PN with total hilar clamping, selective arterial clamping and off-clamp technique with 12 months follow-up. The functional results, evaluated as eGFR decrease 1 year after the procedure, did not demonstrate significant differences [32].

In 2014 McClintock et al. evaluated once again the role of selective arterial clamping in RPN. They described the use of near-infrared fluorescence (NIRF) guidance during selective arterial clamping for attempting to preserve kidney function. The rationale was based on the concept that, if selectively devascularized, when using a dedicated optical system, the tumor and the surrounding tissue appear unfluorescent with respect to the normal renal parenchyma. Outcomes of patients who underwent RPN with NIRF-guided arterial clamping were compared with those of a matched cohort of patients who underwent RPN without the use of selective arterial clamping or NIRF imaging. The matched-air analysis revealed that the use of selective NIRF-guided clamping resulted in significantly improved kidney function at discharge, (eGFR 78.2 vs. 68.5 mL/min/1.73 m^2; $P = 0.04$) and a significantly absolute reduction in eGFR (−2.5 vs. −14.0 mL/min/1.73 m^2; $P < 0.0.01$). The trends persisted at 3 months follow-up but were not statistically significant [33].

Data from Literature about selective clamping seem to suggest that this technique allows for a better preservation of functional results in an early postoperative period if compared with hilar clamping, but this advantage is not maintained over time.

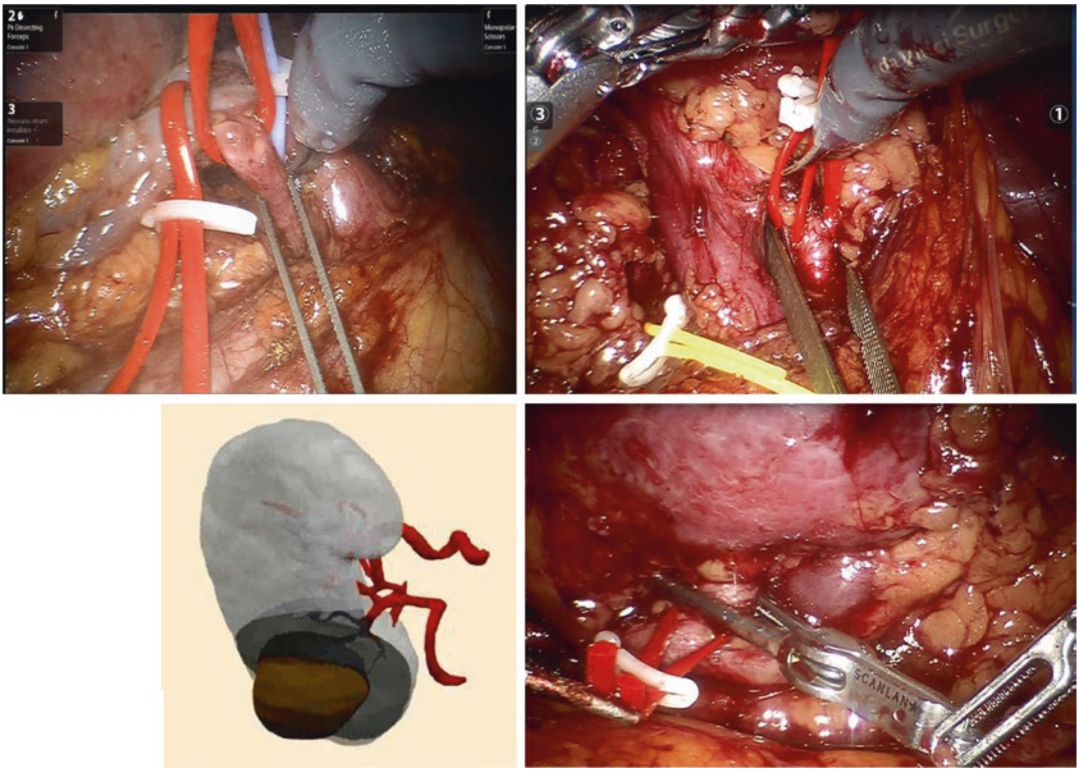

Fig. 7.3 3D virtual model simulation and intraoperative examples of selective clamping of a secondary order renal vessel with bulldog clamps

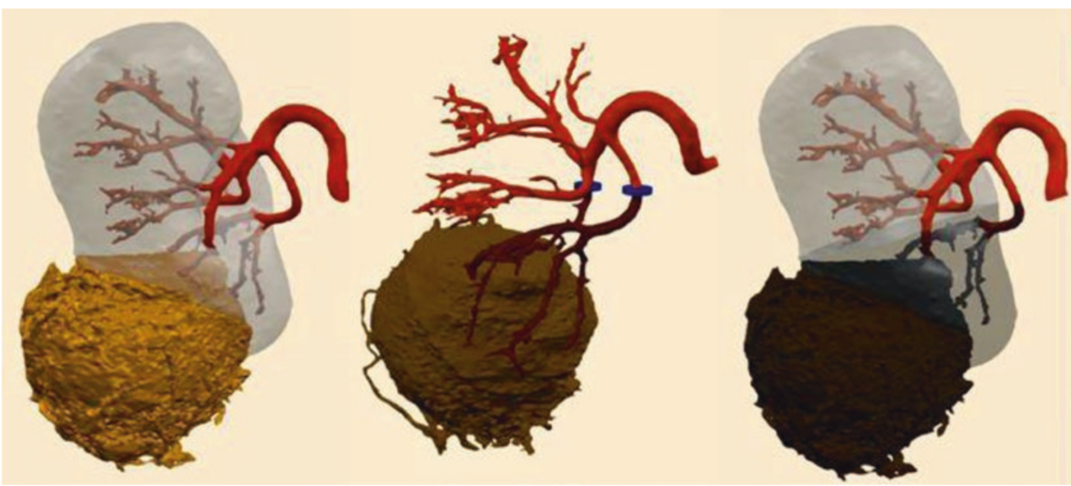

Fig. 7.4 3D virtual model simulation of secondary order arterial vessels and virtual simulation of the parenchymal exposure to the ischemic damage

Superselective Clamping/"Zero-ischemia" Technique

The super-selective clamping technique is based on the principle that it is possible to dissect and clamp or clip selectively only the feeding artery/-ies of the tumor, avoiding to expose the whole healthy renal tissue to the ischemic damage (Fig. 7.5). Following this theoretical idea,

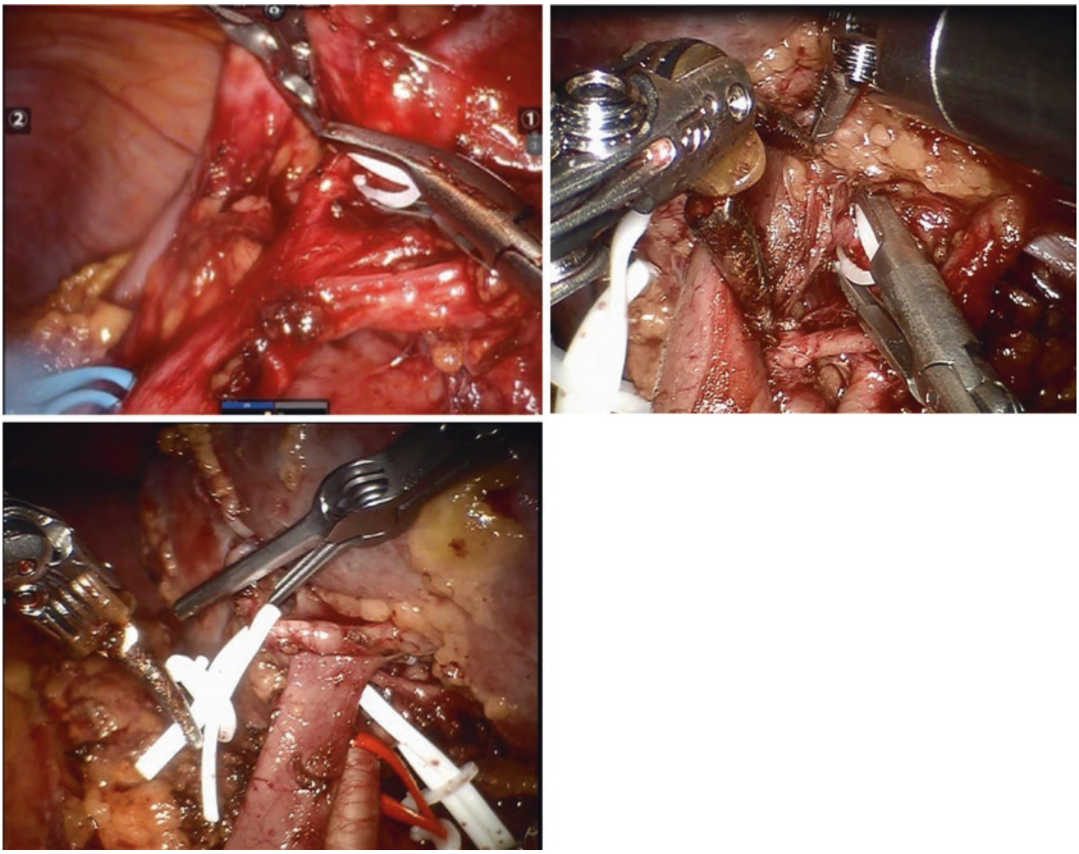

Fig. 7.5 Examples of super-selective clipping or temporary clamping of the feeding artery of intraparenchymal renal tumors

many techniques were developed, in order to find the one able to really limit the ischemia to the tumor tissue, the so-called "zero-ischemia" technique. The concept was firstly developed by Gill et al. that in 2011 described their novel technique [34]. This technique, performable both with pure laparoscopic or robot-assisted approach, was based on four main maneuvers: (1) the preoperative virtual reconstruction of renal vascular anatomy by contrast enhanced Computed Tomography scans, (2) the anatomic micro-dissection of targeted tumor feeding tertiary or higher order renal vessels, (3) the super-selective tumor devascularization by using microsurgical bulldog clamps from neurosurgery (Fig. 7.6) and (4) the transient, controlled, reduction of blood pressure during the excision of the deepest part of the tumor.

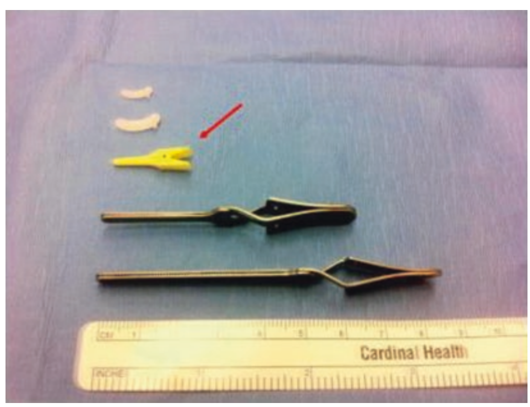

Fig. 7.6 Neurosurgical aneurysm micro-bulldog clamp (*arrow*). These dedicate, disposable plastic bulldog clamps (Bear) are similar in size to Hem-o-lok clips and are significantly smaller than conventional bulldog clamps. From Zero ischemia anatomical partial nephrectomy: a novel approach by Gill et al. J Urol. 2012;187(3):807–14

After the demonstration of the feasibility of such a technique in patients with low-complexity renal tumors,further researches conducted by the same Authors showed its feasibility also in patients with complex renal masses [35].

Increasing the experience with the zero ischemia technique, controlled hypotension was abandoned because it was deemed unnecessary. Moreover, controlled hypotension was indicated to be potentially dangerous, especially in patients with cardiovascular comorbidities, as exposing to the risk of major organs hypo-perfusion.

Hence, Gill et al. described their "novel zero-ischemia technique" in 2012; it was composed by microvascular dissection and super-selective clamping of tumor feeding arteries without any controlled hypotension during RPN. In the preliminary study the feeding vessels of the tumor were clamped with micro-bulldogs with the assistance of a preoperative 3D contrast enhanced CT-scan based reconstruction and/or intraoperative ultrasound guidance to identify specific segmental or interlobar arteries [36]. This first study demonstrated the feasibility of such an approach, but results were confirmed in a further publication in 2014, when the Authors retrospectively compared this group of patients with a control group in which RPN was performed with main renal artery clamping. In the super-selective group they confirmed the correct arterial control by using NIRF or color-doppler ultrasound guidance. Super-selective clamping group showed longer median operative time and transfusion rates but similar estimated blood losses, perioperative complications, and hospital stay. Concerning the functional outcomes, patients treated with super-selective arterial clamping RPN experiencedlower decrease of estimated glomerular filtration rate either at discharge (0% vs. 11%, $p = 0.01$) orat fourth monthfollow-up (11% vs. 17%, $p = 0.03$). Comparing preoperative and 6 months postoperative computed tomography volumetric assessments, these patients trended towards a greater parenchymal preservation (95% vs. 90%, $p = 0.07$), despite the larger tumor size and volume at baseline imaging [37].

In 2014 Shin et al. published their experience with super-selective clamping technique during RPN. As in the studies on zero ischemia by Gill et al., a preoperative 3D reconstructed CT scan with angiography was performed in order to identify the tertiary arterial branches supplying the tumour.In this series, a curved conventional laparoscopic bulldog clamp was used for the super-selective clamping of the feeding arteries beforetumour resection. Authors compared results of a super-selective clamping cohort with a global-clamping control group: results demonstrated a shorter operative time and a better post-operative eGFR in patients who underwent super-selective clamping RPN, although these patients also had higher blood losses. No significant changes in the mean eGFR were observed 3 months after surgery, if compared with preoperative values [38].

Another variation of the super-selective clamping technique was describedby Ng et al. In their study, the micro-vascular dissection was obtained, according to the tumor location, extending the dissection intrarenallyby a 1–2 cm long radial micro-nephrotomy on the hilar edge of the kidney, directly overlying the anterior portion of the specific vascular branch suspected to feed the tumor. That branch was selectively clamped with a neurovascular microsurgical bulldog clamp. A controlled hypotension was used during resection of the deepest part of the renal mass, when needed. The micro-vascular dissection RPN group was compared with a control RPN zero ischemia group without micro-vascular dissection. Functional outcomes, evaluated as eGFR decrease at discharge and at 2 months after surgery were similar between the groups.Anyway, the micro-vascular dissection group demonstrated great usefulness for the treatment of complex, endophytic or central tumors if compared to the "standard" zero ischemia technique [39].

To assess once again the efficacy of the super-selective clamping with micro-vascular dissection, some authors tested the role of NIRF in this setting (Fig. 7.7). Borofsky et al. published their pilot study of NIRF-assisted RPNs matching this group of patients with a main artery clamping RPN group. Also in this study, after vascular micro-dissection of the arterial branch of interest, obtained with a small nephrotomy when

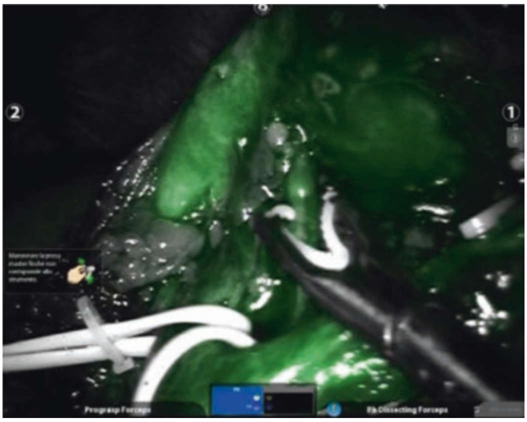

Fig. 7.7 Near Infrared Fluorescence guidance for the identification of the feeding artery of the tumor during robotic partial nephrectomy

requested, the vessel was selectively clamped with a neurovascular microsurgical bulldog clamp. NIRF was useful after super-selective clamping as confirmation, allowing to perform 79.4% of procedures with the "zero-ischemia" technique. Focusing on early functional outcomes, the zero-ischemia cohort demonstrated a lower decrease in eGFR if compared with main renal artery clamping group (−1.8% vs. −14.9% respectively) [40].

The concept of selective isolation and clamping or clipping of the feeding vessels of the tumor experienced many variations and evolutions in the Literature, with the aim of increasing its reproducibility, while ensuring safety and efficacy. Notwithstanding the published different declinations of the technique, the majority of the studies were focused on the feasibility and the early functional results and considered a small sample size of patients. Big sample size and functional results with longer follow-upare needed in order to assess the superiority of superselective clamping in comparison with others renal pedicle approaches.

Discussion

In recent years, increased interest has grown around the modulation of renal pedicle managementduringPN.Withtheintroductionofminimally-invasive surgical approaches such as robotics, many novel techniques have been developed, all focused on the minimization of the ischemic damage. This goal was mutuatedfrom the literature about open and laparoscopic approaches demonstrating the detrimental role of WIT in influencing postoperative functional outcomes [13].

However,a validated definition and classification of all the described different approaches to the renal artery management is still lacking.

A macroscopic stratification, as above-mentioned, could be time-dependent vs. anatomy dependent renal artery management. Another one could be the global ischemia vs. non-global ischemia techniques.

In 2015 Simone et al. tried to overcome the matter including together in one group all the different renal pedicle managements focused on the reduction of ischemic damage, using the terminology"minimally ischemic partial nephrectomy" [12]. Nowadays the difficulty in classifying the different techniques is related to the improperdefinition of the type of vascular clamping used by the Authors in their papers.

Moreover, there are substantial variations in the patients' functional outcomes definition; most of the studies evaluated serum creatinine levels and/or eGFR to assess renal function. These parameters can be inaccurate in determination of postoperative functional impairment, especially when a little renal injury is expected and in cohorts with bilateral kidneys. In addition, the huge variability of the follow-up periods among the different studies makes more difficult to compare functional results of the different vascular approaches. Anyway,a few articles reported 12 months postoperative functional outcomes, underlying that most of the studies are focused only on the feasibility of the approaches rather than on their efficacy over time. Furthermore, when considering comparative studies with shorter follow-up, the functional postoperative results, initially better for one approach or the other, trended to align over the postoperative months, regardless the type of arterial pedicle management. This evidence suggested that, notwithstanding the minimization of ischemia, even a little amount of renal impairment, possibly related to the ischemic damage performed by the suture of the resection bed or to the thickness of healthy parenchyma excised with the tumor, have to be expected. Lastly, when comparing different techniques, the studies not considered the tumor surgical complexity. Functional postoperative outcomes can be strongly influenced by tumor characteristics: the lacking of a stratification of the surgical approaches according to validated tumor complexity scores limits once again the standardization of the vascular management techniques.

Anyway, the functional benefits of the minimization of ischemia shouldalways be balanced with a relatively higher risk of technical intraoperative difficulties, such as a compromised visualization of the surgical field due to the parenchymal bleeding. This aspect is being consistently showed by the multicenter randomized experience by Antonelli et al. [29].

The unexpectedly high rate of conversions from no-clamped to clamped RPN in this serie proves that the unclamped technique is extremely challenging even in experienced hands.

High expertise of the whole surgical teamis mandatory before embarking in such a complex techniques. The complexity of the procedure itself is one of the factors that still limitits widespread diffusion and lowers the level of the available evidences.

Conclusions and New Perspectives

In the partial nephrectomy scenario the diffusion of minimally invasive approaches focused on the reduction of the postoperative functional damage has promoted the development of many techniques for the management of renal ischemia, one of the main surgeon-dependent and modifiable factors in the “economy” of nephron-sparing surgery.

Even if the feasibility of these techniques was widely demonstrated in the urological Literature, the efficacy of many of them is difficult to be standardized. By the moment, as for the resection techniques during nephron sparing surgery, an overall classification of the different approaches seems to be hard to be produced.

Considering their intrinsic, variable complexity, this still makes these procedures not easily generalizable.

Robotic approach, thanks to its technological advantages, allows overcoming some limits of these challenging techniques. Future improvements in 3D virtual navigation and surgical technology could yield larger accessibility and greater diffusion of these procedures (Figs. 7.8 and 7.9).

More homogeneous data collection will be able to increase the level of evidences and ideally establish a standardized classification of the different shades of renal arterial vasculature managementaimed to minimize ischemic damage during RPN.

Take Home Messages

- The Role of ischemia
- Renal ischemia figures among the important modifiable factors influencing early and long-term renal function in patients who undergo PN even if available studies are controversial in their conclusions.
- Warm/Cold Ischemia?
- Warm ischemia is the gold standard technique.
- In the era of minimally-invasive surgery, cold ischemia is complex to be reproduced but could be considered as an option when longer ischemia time is expected (absolute indications to PN).
- Global vs. non-global clamping
- The clamping of the renal artery is the gold standard. No advantages are reported with clamping of the entire renal hilum.Global ischemia allows performing the tumor resection in a bloodless field. Off-clamp and selective clamping techniques are more challenging and demanding. Consistent experience is required before embarking in this kind of techniques.

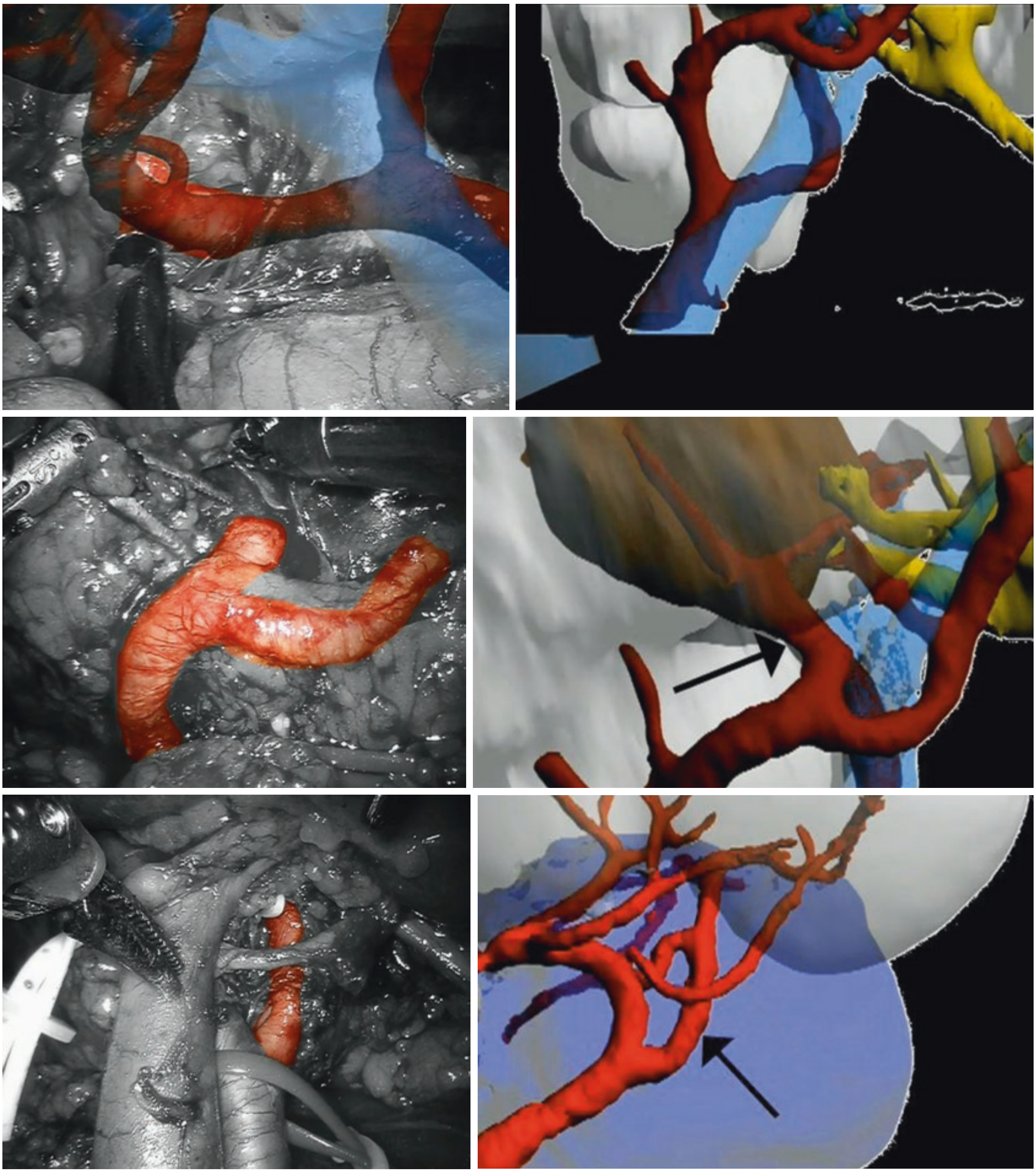

Fig. 7.8 3D virtual reconstructions of the arterial branches of the renal pedicle. To note the concordance in the overlapping of the virtual models on the intraoperative images

- Moreover, no definitive clinical data are available supporting the non-global ischemia techniques.
- Intraoperative fluorescence guidance has not increased the use of selective clamping technique, as it remains still empirical.
- Selective clamping technique should be planned prior to the intervention.
- An accurate study of the renal arterial vasculature via CT scan with angiography and precise 3D rendering should be required.

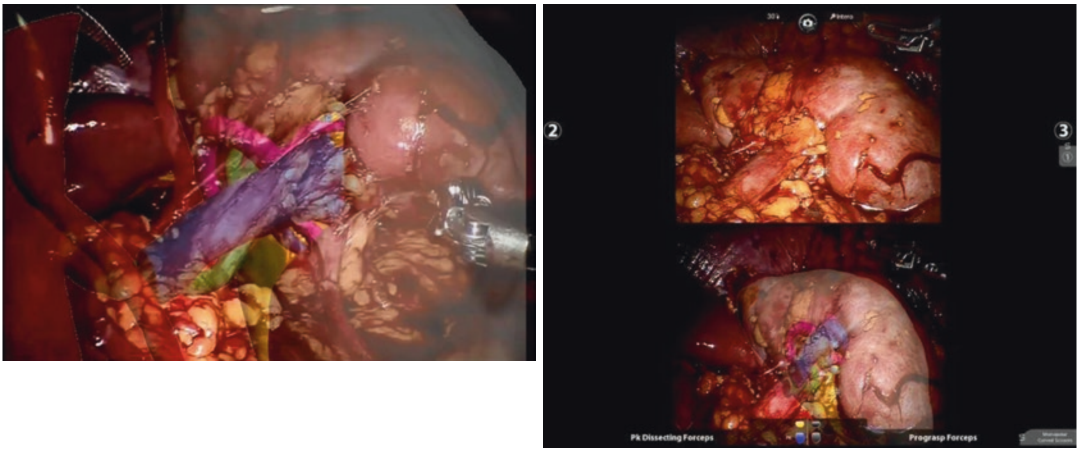

Fig. 7.9 3D virtual model inraoperatively allowing the identification of the location of the renal pedicle during the exposure of the kidney. This experimental technology can be used “tile-pro” like

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8 Fluorescence in Partial Nephrectomy

Nina Harke and Jorn H. Witt

Introduction

Since first described in 1991, laparoscopy has become highly approved in renal surgery, particularly in laparoscopic radical nephrectomy [1]. In addition to the steep learning curve, one major point of criticism in laparoscopic partial nephrectomy is the prolonged warm ischemia time [2]. Hence, several techniques like early unclamping of the renal hilum were established to reduce ischemic injury to the kidney. Also the use of the enhanced instruments and improved vision in robotic surgery has an influence in reducing warm ischemia time. However, those above-mentioned laparoscopic techniques continued to require disruption of the entire arterial blood flow during tumor resection. An additional point of criticism is the missing haptic feedback. While tumor identification can also be challenging in more endophytic renal tumors in open surgery, the lack of a tactile senor system in laparoscopy and robotic surgery may lead to an even more difficult definition of the exact tumor boundaries. Use of intraoperative ultrasound can help for further discrimination of different tissue properties but conventional laparoscopic ultrasound probes impair the surgeon's autonomy [3].

To address these issues in robot-assisted surgery, one innovation over the last years was the introduction of real-time imaging with inclusion of near-infrared fluorescence (NIRF) and the contrast agent indocyanine green (ICG).

Indocyanine Green (ICG)

In 1957, Fox et al. first introduced ICG for measuring of cardiac output [4]. Since then it has been used in different fields, mainly for assessment of circulation and vascularization [5, 6] but recently also for lymph node detection [7].

Indocyanine green is a dye of minor toxicity with only sporadic reports of allergic reactions [8]. Still, in patients with known allergies to iodine or conventional contrast agents as well as hyperthyroidism, standard robot-assisted partial nephrectomy should be considered for safety reasons. Due to the exclusive hepatobiliary elimination, renal insufficiency is not an absolute contraindication for application but a maximum cumulative dosage of 2 mg/kg should not be exceeded [9].

ICG as a relatively instable water-soluble agent is diluted in a 2.5 mg/mL solution and can afterwards be stored for up to 6 h. After intravenous application, ICG immediately binds to serum proteins (Fig. 8.1) and stays within the vascular compartment with a half-life of 150–180 s and a plasma life of 3–5 min [10].

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_8

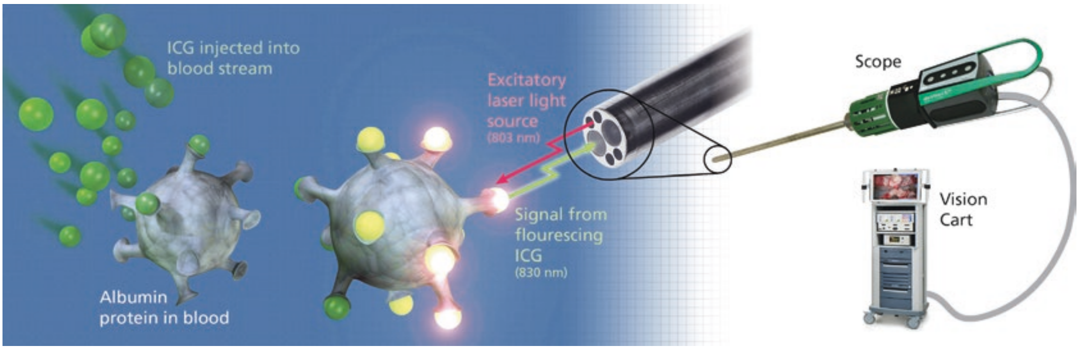

Fig. 8.1 Albumin binding and signaling from ICG under laser light (©2017 Intuitive Surgical, Inc.)

To activate fluorescence, a light source emitting a near-infrared wave length of 780 nm is needed, fluorescence then can be visualized with a camera capturing signals at a wave length of 805 nm (Fig. 8.1).

Since 2010, the near-infrared fluorescence capable Firefly™ fluorescence technique can be added to the da Vinci Si robot and is nowadays already integrated in the da Vinci Xi system. The alternating lighting modes of the scope (white light and fluorescence) can be changed via the console without interruption of the surgery while the 3D-view remains unaffected. After switching to NIRF, the surgical field is illuminated in shades of black and grey, the fluorescent dye is overlaid in bright green.

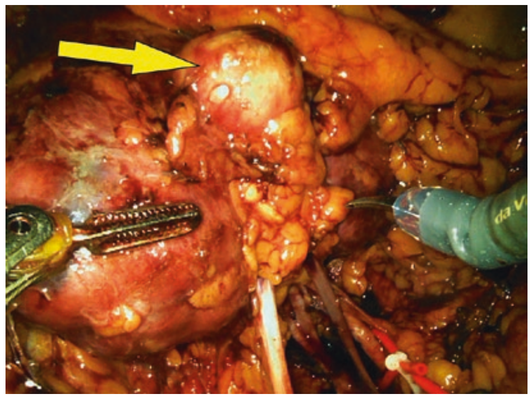

Fig. 8.2 Small exophytic renal mass (*arrow*) close to the hilum under white light

Differential Fluorescence for Tumor Identification

Due to the lack of haptic feedback, tumor identification may be more challenging in robot-assisted partial nephrectomy compared to open surgery. Utilization of NIRF can improve discrimination of normal and altered tissue especially in cortical renal tumors and therefore support definition of surgical margins. It is hypothesized that contrary to unaffected proximal tubulus cells, a reduced or missing expression of the ICG carrier protein bilitranslocase can be found in renal tumors leading to impaired tissue fluorescence [11]. Angiomyolipoma as well as cysts and cystic tumors remain afluorescent, but the dignity of other tumor subgroups cannot reliably be predicted. Special attention has to be kept on oncocytomas; the tumor might be isofluorescent due to the possible continued expression of bilitranslocase also in altered tumor cells [11].

Several studies investigated the benefits of ICG for tumor identification with varying results. In summary, the specificity is too low for precise differentiation of malignant and benign lesions and histopathologic examination cannot be waived. However, most of the renal masses are hypofluorescent compared to the surrounding tissue; this may facilitate improved determination of tumor boundaries [12, 13]. Figures 8.2 and 8.3 is given an example for an non fluorescent small renal mass close to the hilum under white light and with near infrared laser light.

Adequate ICG dosing is essential to achieve discriminating fluorescence—especially over-dosing of the dye may result in hyper- or isofluorescence of both the tumor and the remaining parenchyma. To avoid these difficulties, a test dose of 1.25 mg ICG can be administered before clamping of the renal hilum. Depending on the fluorescence of the kidney and the tumor, re-dosing can be necessary prior tumor excision. It should be kept in mind that ICG washout can take up to 20 min, a fact that must be considered when planning a selective arterial clamping procedure.

After clamping of the main renal artery and its branches, renal arterial washout of ICG is suppressed until tumor resection and the subsequent reestablishment of the renal blood-flow. Once ICG accumulated in tumor tissue, fluorescence in its boundaries can repeatedly be assessed after excision intracorporally as well as after removal of the specimen.

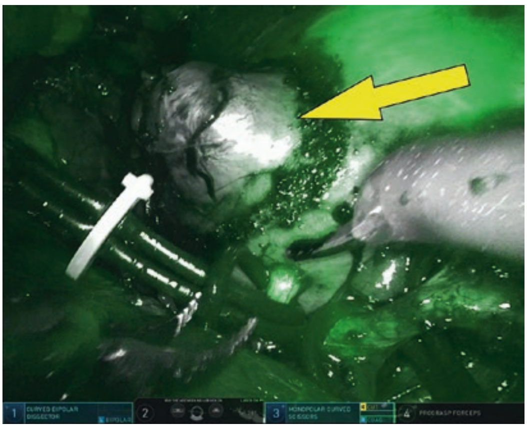

Fig. 8.3 Small exophytic renal mass without fluorescent (*arrow*) close to the hilum under firefly™ mode

Identification of Vasculature

After intravenous administration 98% of the dye binds to serum proteins (Fig. 8.1), unbound ICG undergoes almost immediate hepatic elimination. Therefore, indocyanine green is exclusively found intravascularly and near-infrared fluorescence can be utilized for intraoperative identification of renal vasculature [14].

Intravascular fluorescence can be detected between 5 and 60 s after intravenous application followed by staining of the renal parenchyma within 1 min after injection lasting for 10–15 min [11].

In our experience a bolus of 5 mg ICG diluted in 2.5 mg/mL is sufficient for identification of the arterial and venous vessels. Figure 8.4

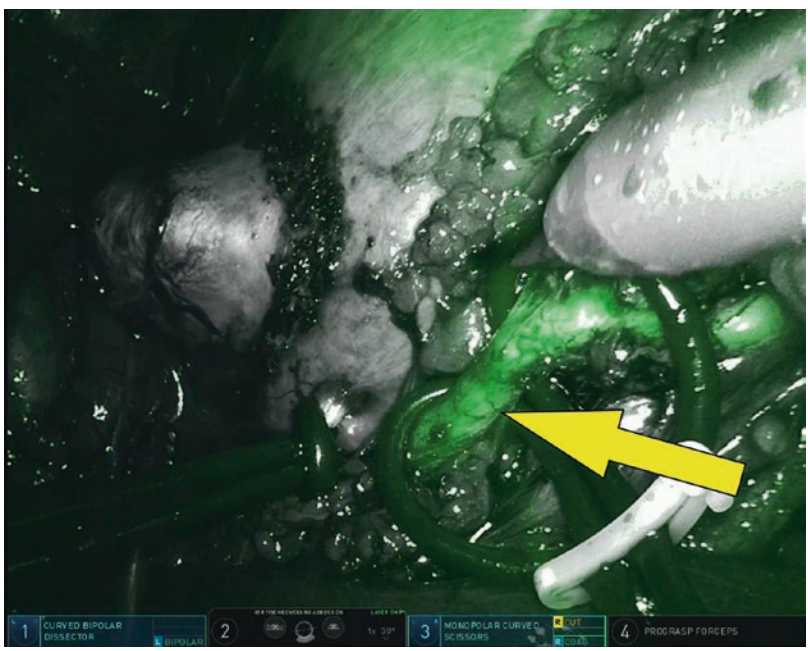

Fig. 8.4 Renal artery 40 s after ICG injection

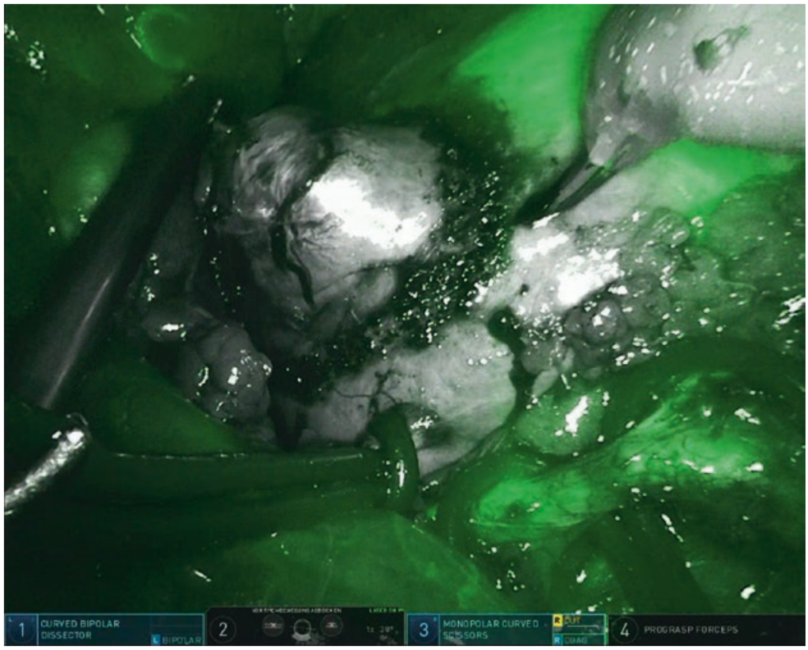

Fig. 8.5 Increasing fluorescence of the renal parenchyma 70 s after ICG injection

demonstrates the renal artery with fluorescence 40 s after ICG injection, the renal parenchyma is increasingly showing fluorescence 70 s after ICG injection (Fig. 8.5), after 90 s only the tumor is without fluorescence (Fig. 8.3).

Selective Arterial Clamping

The primary criteria for a successful partial nephrectomy are negative surgical margins and the maximal preservation of kidney function. For the latter, ischemia time and tissue volume loss are of utmost importance. Several approaches to reduce warm ischemia time have been introduced in the last years including early unclamping [15] or off-clamp resection. A significantly higher postoperative eGFR after 6 months can be observed after off-clamp resection compared to global ischemia partial nephrectomy [16]. However, off-clamp nephron-sparing surgery may lead to an impaired view of the surgical site due to more excessive bleeding, possibly resulting in positive margins or unnecessary resection of unaffected renal parenchyma.

In 2011, the research group led by Inderbir S. Gill first published a novel approach to minimize the ischemic injury in robot-assisted nephron-sparing surgery: the “zero-ischemia” robot-assisted partial nephrectomy [17]. By microdissection of the renal vessels up to the hilum and into the parenchyma, clamping of the tumor feeding artery can be performed without global ischemia. In the following years, the feasibility of selective, super-selective and “zero-ischemia” arterial clamping was confirmed with short selective ischemia times and at least improved short-term renal function [18, 19].

Preoperative magnetic resonance imaging or computed tomography with arterial and venous phases is mandatory for preoperative understanding of the renal vasculature. Additional three-dimensional reconstruction with 0.5–1.0 mm cuts may enable improved discrimination of the tumor feeding vessels especially in central or hilar tumor constellations.

Intraoperatively, complete dissection of the renal hilum with identification of potential accessory branches is followed by preparation of the main renal artery up to tertiary and quaternary vascular branches. Conventional laparoscopic or robot-assisted drop-in ultrasound support determination of the tumor boundaries, especially in patients with intrarenal tumors. After preparation of the tumor feeding vessels, the main as well as the supplying artery are encircled by loops. Doppler sonography identifies the disrupted blood flow of the tumor surrounding area after transient clamping or traction on the loop. Specific tumor feeding branches can be clipped directly. In our institution, we prefer drop-in bulldog clamps over the use of a tourniquet, which is also an appropriate alternative mainly for the main renal artery and its first branches. Redundant clamps and suturing material should be prepared and can be placed close to the surgical field in case of need for expeditious global ischemia due to bleeding. To avoid prolonged ischemia time, the estimated tumor boundaries on the renal cortex can be delineated with hot shears prior to clamping.

A drop-in bulldog clamp can be precisely positioned on the predetermined arterial branch. In case of more than one feeding artery or uncertainty in the exact tumor blood supply, multiple clamps can be used. Repeated sonography verifies devascularization of the tumor area without collateral ischemia.

Indocyanine green is diluted to 2.5 mg/mL; the first solution is given intravenously as a bolus of 5 mg by the anesthesiologist directly after clamping of the artery.

After administration of the dye, the light can be toggled between white light and NIRF. The pass of ICG can be observed in the main renal artery and subsequently in the renal vein after approximately 2 min and an exact discrimination between vascularized (green) and devascularized (black) areas can be achieved (Fig. 8.6).

The tumor is excised using minimal electrocautery and mainly cold scissors to enable an optimal pathologic examination of the surgical margins afterwards.

One central running suture in the tumor bed ensures reduction of hemorrhage. The bulldog clamp can be removed, followed by precise suturing of visible bleeding and repair of pelvicalyceal system, if necessary.

For further improvement of hemostasis, hemostyptic agents may be used. Employing the sliding-clip technique, renorraphy closes the defect which sometimes can be waived in patients with

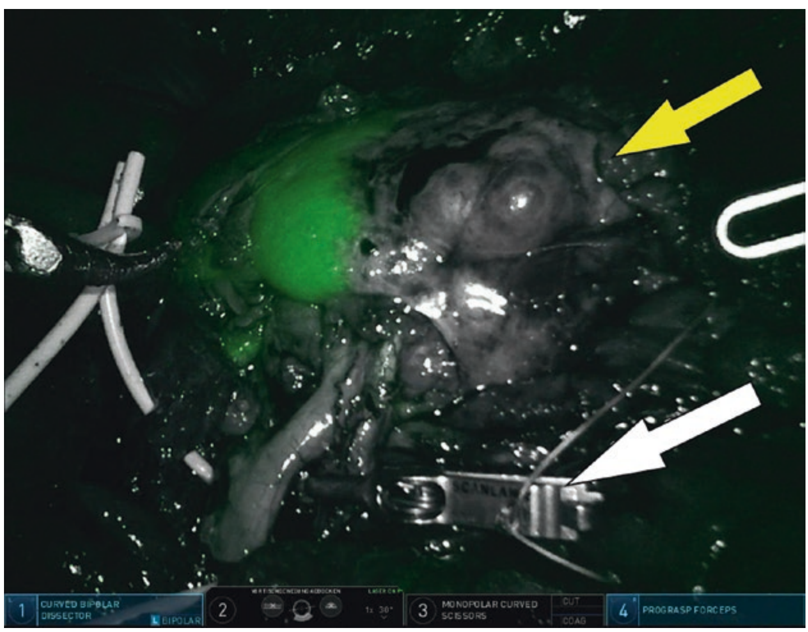

Fig. 8.6 Selective clamping of a lower pole artery (bulldog clamp, *white arrow*). Lower pole parenchyma (*yellow arrow*) showing no fluorescence

hilar tumors due to the immediate proximity of the vessels.

After renorraphy, a repeated ICG injection confirms unobstructed perfusion of the kidney and helps to rule out eventual unintentional vessel injury.

Costs

The Firefly™ fluorescence technology is already integrated in the da Vinci Xi and X system or can be added to the da Vinci Si system for approximately $100.000.

One vial with 10 mL of indocyanine green can be obtained for $80–$100. After dilution, stability of the dye is guaranteed for up to the 6 h; hence, utilization of one vial for more than one case is possible [12, 13].

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9 Robotic Nephroureterectomy

Mouafak Tourojman and Craig G. Rogers

Introduction

Upper urinary tract urothelial carcinoma (UTUC) represents approximately 5–10% of all urothelial cell carcinomas, and 10% of renal tumors [1, 2]. Nephroureterectomy, with excision of the ipsilateral bladder cuff, has been considered the standard of care for patients with UTUC.

In 1991, Clayman et al. [3] reported the first laparoscopic nephroureterectomy (LNU). LNU has demonstrated improved short-term perioperative outcomes with equivalent short-to-intermediate-term oncologic outcomes compared to open nephroureterectomy (ONU), at least for organ-confined disease [4, 5]. Given the evidence accumulated so far, LNU has proven to be equivalent or non-inferior in terms of recurrence-free survival (RFS) and cancer-specific survival (CSS) to ONU [6]. Jian-Ye et al. [7] showed no statistically significant differences in oncological outcomes between laparoscopic and open nephroureterectomy, with a 5-year intravesical RFS (88% vs. 79%), overall RFS (59% vs. 47%), CSS (70% vs. 63%), and overall survival (OS) (55% vs. 61%). Berger et al. [8] presented long-term oncological outcomes for LNU that are comparable to ONU, with a 5-year CSS of 80, 70, and 68% for pTis/Ta, pT1, and pT3 disease, respectively. LNU can be technically challenging, particularly the dissection of the distal ureter, excision of the bladder cuff, and suturing and reconstruction of the bladder. RNU helped with the technical challenges of LNU because of the benefit of improved visualization and precise articulating instruments. In this chapter, we discuss the indications, preoperative evaluation, procedural steps, and complications of RNU, with a brief discussion of the current literature on minimally invasive nephroureterectomy.

Indications and Contraindications

Indications for LNU and ONU are also indications for RNU for treatment of UTUC. Bleeding diathesis is a contraindication for RNU. Patients with prior abdominal surgery are a relative contraindication, especially early in the learning curve of the operating surgeon.

Preoperative Evaluation and Preparation

The diagnosis of UTUC is usually established with a combination of radiographic tests and endoscopic biopsy/cytology. Tumor staging should

Electronic Supplementary Material The online version of this chapter (doi:10.1007/978-3-319-65864-3_9) contains supplementary material, which is available to authorized users.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_9

include a chest X-ray and abdominal CT/MRI to evaluate for metastatic disease. Preoperative laboratory studies include renal function tests, liver function tests, and coagulation profile. All food and liquid intake should be stopped after midnight on the day before surgery.

Patient Positioning and Trocar Placement

The patient is positioned with the shoulders in flank position and the hips slightly leveled. We do not routinely perform intraoperative cystoscopy, but if the need for this is anticipated, the legs can be positioned to provide access to the urethra. Pressure points are carefully padded, and the patient is secured to the table. Pneumoperitoneum is obtained, and trocars are placed under direct vision. Figure 9.1 shows the placement of the various ports for both the da Vinci Si and Xi systems. With the Si system, we place a 12-mm camera port laterally at the level of the umbilicus. Robotic ports are placed forming two triangles centered on the camera port, with one triangle angled toward the renal hilum and the other triangle angled toward the pelvis. The port for the third robotic arm is placed in a medial and caudal position. An assistant port is placed medially in a periumbilical position to allow access to both the kidney and the renal pelvis. During the pelvic portion of the case, the caudal robotic working arm is changed to the third robotic arm port. The robot is docked perpendicular to the patient. Although it is possible to do a single docking strategy [9–11], if collisions become problematic, we suggest undocking, leveling the hips, placing the patient in reverse Trendelenburg position, and redocking at an angle over the hip. Another option for the bladder cuff portion is to reposition the patient supine in reverse Trendelenburg position and to place a right-sided robotic trocar and dock similar to that of a prostatectomy.

With the Xi system, we utilize four robotic ports positioned in an oblique line, starting with a robotic port located two finger breadths below the costal margin lateral to the rectus abdominis muscle, with a distance of 6–8 cm between ports. The second caudal port is designated to be the camera port for the bladder cuff part of the procedure, whereas the second cephalad port is used as a camera port for the nephrectomy part. A 12-mm assistant port is placed medially near the umbilicus. A 5-mm port may be placed below the xiphoid for liver retraction for right-sided RNU.

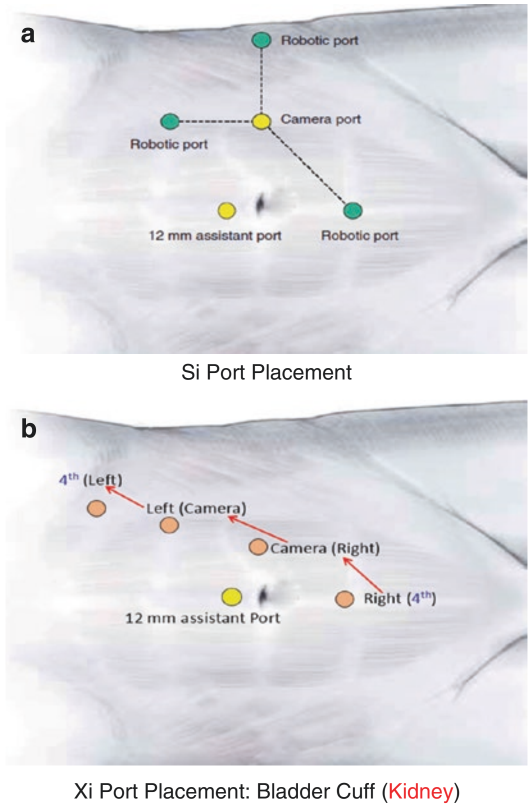

Fig. 9.1 Port placement for left robotic nephroureterectomy using da Vinci Si (**a**) and Xi (**b**) systems. With the Xi system, we prefer to do the bladder cuff dissection prior to the nephrectomy. Instruments are shifted for the nephrectomy (*parentheses*)

Operative Steps

Distal Ureteral Dissection

When using the da Vinci Xi system, we prefer to do the bladder cuff resection first, followed by the nephrectomy part of the procedure. However, the nephrectomy can also be done first per surgeon preference. The ureter is dissected caudally, and the distal ureter is clipped (Fig. 9.2). Distal dissection of the ureter is continued to the ureterovesical junction. Ligation of the obliterated umbilical ligament and the superior vesicle artery may help expose the distal ureter for bladder cuff dissection. Detrusor fibers are exposed circumferentially around the ureter prior to excision of the bladder cuff.

Excision of Distal Ureter and Bladder Cuff

The detrusor muscle is dissected circumferentially around the ureter. We place stay sutures on the bladder with barbed suture (V-loc™, Covidien, Mansfield, MA., 3–0 CV-23, 6 in.) outside the intended resection line for traction and for subsequent bladder closure. The bladder cuff is excised (Fig. 9.3) sharply to ensure complete removal of the ureteral orifice with an adequate bladder cuff margin. Closure of the bladder defect is performed in two layers using the barbed tacking sutures. The barbed suture allows for two-handed suturing without slippage or the need to tie knots (Fig. 9.4). The bladder can be filled to test the closure for leaks.

Colon Mobilization

An incision is made on the posterior peritoneum along the line of Toldt to displace the colon medially (Fig. 9.5). A plane between the Gerota's fascia and the posterior mesocolon is developed. The renal attachments to the liver or spleen are released.

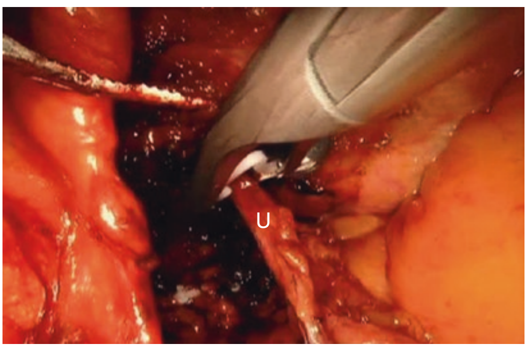

Fig. 9.2 Clipping of the ureter (**U**) using Hem-o-lok clips prior to dissection of bladder cuff in order to prevent tumor seeding or spillage

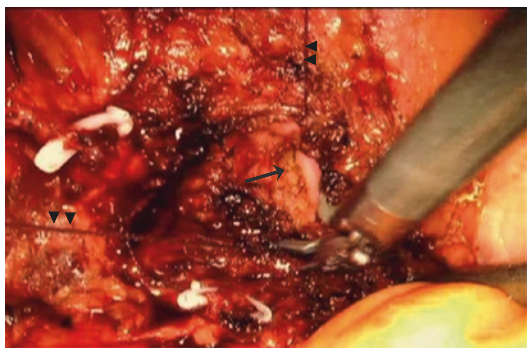

Fig. 9.4 Bladder defect (*arrow*) closed in two layers using barbed suture (*arrowheads*)

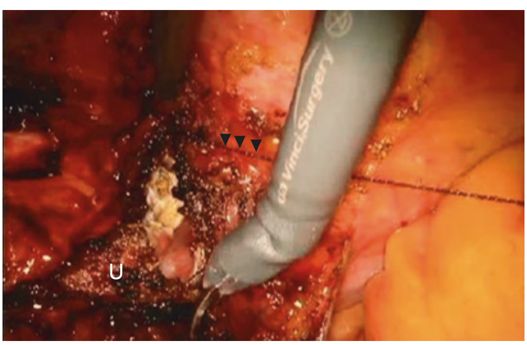

Fig. 9.3 Sharp excision of ureter (**U**) with adequate bladder cuff. A barbed stay suture (*arrowheads*) has been placed on the bladder outside the intended resection line for subsequent closure of the bladder defect

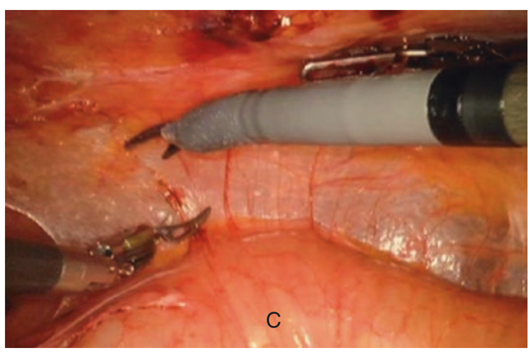

Fig. 9.5 Colon mobilization. The peritoneal reflection is incised, and the colon (**C**) is reflected medially

Nephrectomy

Following medial reflection of the colon, the ureter and gonadal vein are identified. The ureter and lower pole of the kidney are elevated anteriorly off the psoas muscle to place the renal hilar vessels on stretch. Dissection proceeds in a proximal direction toward the hilar vessels. The renal artery and vein are then dissected in preparation for hilar ligation. The lumbar, gonadal, and adrenal veins may be ligated as needed, and the kidney is adequately mobilized. The renal hilar vessels may be ligated using an endovascular stapler (Fig. 9.6) or Hem-o-lok clips. Following hilar ligation, all remaining renal attachments are released. The adrenal gland is spared unless it is clinically involved.

The nephroureterectomy specimen is placed in a retrieval bag for extraction. The Foley catheter is left in place. A drain may also be considered.

The da Vinci Xi system facilitates a single-docking technique [12, 13]. Our preference is to do the bladder cuff resection first, close the bladder defect, and then do the nephrectomy part of the procedure. The patient is placed in modified flank and mild reverse Trendelenburg position throughout the case and the ureter is identified and clipped prior to bladder cuff excision. We use a 3-way Foley catheter and instill Mitomycin-C into the bladder during the nephrectomy portion.

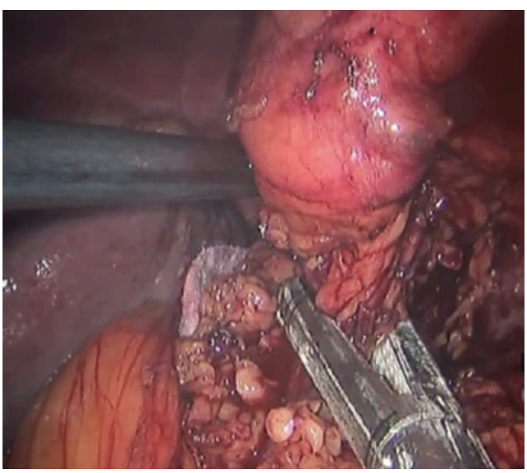

Fig. 9.6 Stapling of renal hilar vessels using an endovascular GIA stapler during left robotic nephroureterectomy

Moriarty et al. [14] reported that intraoperative intravesical instillation of cytotoxic chemotherapy at the time of nephroureterectomy is safe and feasible, without intraoperative or postoperative complications attributable to the instillation.

Postoperative Management

Diet is gradually advanced, and ambulation is encouraged. Our average hospital stay is 2 days. If a Jackson-Pratt drain is placed, it is removed prior to discharge. The Foley catheter is generally removed within 1 week.

Complications

Potential complications associated with RNU include bleeding, bowel injury, and urine leak.

Hemorrhage

Inadvertent injury to the renal vasculature or other abdominal vessels can result in significant bleeding. Pressure with a sponge or laparoscopic pad and an increase in pneumoperitoneum may help tamponade and resolve venous bleeding. While electrocautery or clips may be useful for small bleeding vessels, suture repair may be needed for injury to larger blood vessels. Conversion to open surgery is considered if there is intractable bleeding. Postoperatively, a decrease in hemoglobin values and hypovolemia signals the onset of hemorrhage, and transfusions are usually adequate. If the bleeding is not self-resolved, then explorative laparotomy may be indicated.

Bowel Injury

Injury to the bowels or other intra-abdominal organs can result from either inappropriate port placement or from cautery. A general surgery consultation is indicated for intraoperative repair of any noticed bowel injury. Nausea, fever, increased drain output, and abdominal pain in the postoperative course should raise the suspicion of a bowel injury, which may then be confirmed using a CT scan.

Urine Leak

If the patient has a persistent drain output and high drain creatinine values, the drain should be left in situ. Clinical suspicion of a urine leak can be confirmed with a CT cystogram to identify the leak, as well as any undrained collection. Collections that do not spontaneously resolve can be percutaneously drained and patients followed up to confirm resolution.

Literature Review

Over the last decade multiple studies have shown the feasibility of RNU. Nanigian et al. [15] used the da Vinci robot for the management of the distal ureter and bladder cuff in ten consecutive patients who underwent LNU for UTUC. Hu et al. [16] reported a similar series of nine patients. Rose et al. [17] used robotic assistance for the performance of nephrectomy in a retroperitoneal manner but performed the ureterectomy using the open technique. Park et al. [18] reported their initial experience with RNU using a hybrid-port technique. Other studies have looked at the oncologic outcomes after RNU. Eandi et al. [19] reported oncological outcomes for patients undergoing RNU. Of the 11 patients, four developed recurrence, and two died of metastatic disease at a mean follow-up of 15 months. Pugh et al. [20] reviewed a multi-institutional series of RNU for management of UTUC with respect to technique and perioperative outcomes. Over a mean follow-up of 9.6 months, 9 out of 43 patients had recurrences, 6 of which were within the bladder, 2 within the retroperitoneum (both in patients with high grade pT3 disease), and one in the contralateral collecting system. Zargar et al. [10] reported 9 out of 31 patients had local or distant recurrences over a mean follow-up of 8 months. Seven recurrences occurred in the bladder and four patients developed metastatic disease (liver, lung, retroperitoneum, and pelvic lymph nodes). Three of these patients had pT3 disease and one had low-grade disease, but this was a recurrence after previous distal ureterectomy. Four patients died during the follow-up period, two of them from UTUC (pT3N0). Lim et al. [21] reviewed 32 consecutive adult patients with UTUC who underwent RNU; of these patients, 11 died, including seven cancer-related deaths. Recurrences developed in 15 patients at a median of 8 months. Of the recurrences, ten were urothelial at a median of 9.5 months and ten were nonurothelial at a median of 11 months. Four patients had nonurothelial local recurrences: one had paraaortic lymph node recurrences, two had renal bed recurrences, and one had recurrence at the pelvic side walls. All four patients with nonurothelial local recurrences eventually developed distant metastases and six patients presented with distant metastases to bones, liver, or lungs. Two patients underwent adjuvant systemic chemotherapy and nine underwent salvage radiotherapy and/or chemotherapy at recurrence. At 2 and 5 years, the OS rate was 81.3% and 60.9%; the CSS rate was 87.3% and 75.8%, respectively. The 2- and 5-year nonurothelial RFS rate was 71.5% and 68.1%; the urothelial RFS rate was 68.0% for both.

Conclusion

Robotic nephroureterectomy is an established technique for the minimally invasive management of upper tract urothelial cancer. Robotic assistance provides three-dimensional visualization and more efficient intracorporeal suturing which is useful for the more difficult steps of the procedure, namely, dissection of distal ureter and excision of the bladder cuff. Short-term outcomes from initial series are promising, and longer-term data on oncological control and functional outcomes are needed.

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Part III

Adrenal

10 Robot-Assisted Laparoscopic Adrenalectomy

Pascal Mouracade and Jihad Kaouk

Introduction

Prior to the relatively modern techniques of adrenal imaging and hormonal biochemical testing, indications for adrenalectomy were limited to large symptomatic tumors. Currently, most adrenal masses are diagnosed incidentally "incidentaloma" on imaging studies.

The first surgery of the adrenal glands was performed via a transabdominal incision. It soon became evident that these approaches were less than ideal due to superior retroperitoneal location of the adrenals high up under the costal margin. In order to gain better access a posterior transdiaphragmatic approach through a long, oblique, posterior intercostal incision, was described in 1932 by Lennox Broster of London [1]. The flank approach was popularized by George Crile of the Cleveland clinic [2] in 1923, and Charles Mayo of Rochester described removing a pheochromocytoma via a flank approach just a few years later in 1927 [3]. In 1936, Hugh Young of Johns Hopkins [4] described a posterior approach for exposure of both adrenal glands a method to avoid an abdominal anterior incision. This wide array of patient positioning and method of access to the adrenal glands continued in its evolution throughout the latter half of the twentieth century.

As these glands are small and deeply located, exposure and visualization were of paramount importance. The very turning point was in 1992, when Gagner et al. [5] described a transperitoneal laparoscopic approach to the adrenal glands. In 1995, Mercan et al. [6] introduced the endoscopic retroperitoneal approach in clinical practice. While the transperitoneal approach allows excellent visualization of the adrenal glands and the vascular pedicles both sides, particularly the adrenals veins, the retroperitoneal approach has now become established approach. An understanding of the retroperitoneal anatomy is crucial when attempting this surgical approach.

The mini invasive approach has been associated with less pain, a shorter hospitalization, faster return to unrestricted activities, and less morbidity than open adrenalectomy. Late complications such as incisional hernia and chronic incisional pain are also less common with the mini-invasive approach.

After many decades, the gold standard seems to have been achieved. The main drawbacks of the conventional laparoscopic surgery include limited range of movements of the distal working element, two-dimensional (2D) image without depth perception, and a camera which is held by an assistant and which can be prone to unsteady control. The da Vinci surgical robot system offers articulated instruments, three-dimensional (3D) vision, filtering of tremors, and a stable camera.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_10

Additionally, the surgeon can operate in a comfortable sitting position.

Since the first robotic adrenalectomy by Horgan et al. in 2001 [7], several other groups have successfully adopted the robotic approach. Nowadays robotic assisted adrenalectomy has become an alternative to conventional laparoscopic adrenalectomy. However, evidence on the possible advantages of robotic assisted adrenalectomy remains still limited.

Embryology of the Adrenal Gland

The adrenal glands can be separated into two distinct areas both histologically and physiologically: The cortex which is mesodermal in origin and the medulla which is ectodermal in origin. The adrenal glands develop from two cell types. The cells of the cortex derive from mesodermic celomic epithelium of the posterior abdominal wall near the site of the developing gonad, at the cranial end of the mesonephros. The cells of the medulla derive from the neural crest in conjunction with the sympathetic ganglia. This group of neural cells migrates along the adrenal vein to invade the cortex and becomes the completed adrenal gland.

The adrenal cortex is the site of production of mineralocorticoids, glucocorticoids, and sex steroids. The medulla contains chromaffin cells, which secrete the catecholamines namely, epinephrine and norepinephrine and also dopamine.

The fetal adrenal gland is exceptionally large 10–20 times larger than adult adrenal gland because of the size of the cortex which regresses after birth. Substances secreted from the adrenal glands are involved in the maturation of other systems of the embryo, such as the lungs and the reproductive organs.

Anatomy of the Adrenal Gland

Because the adrenal glands are situated deeply in the retroperitoneum, and because primary diseases that require adrenalectomy are rare, surgeons tend to be less familiar with the anatomic relationships of these glands. Additionally, adrenal tumors can distort these relationships. On both sides, they cap the kidneys and are contained within a compartment of the fascia investing the kidney (Gerota's fascia). However, their position is not determined by the kidneys in that if the kidneys are in an abnormal position, the adrenal tend to be in their normal position. Their relationship to the inferior vena cava (right gland) and aorta (left gland) are the constants in their position. Each gland weighs approximately 4–5 g in the adult and has a golden yellow-orange color distinct from the pale yellow retroperitoneal fat.

The right adrenal gland is pyramidal in shape with its base lying against the upper pole of the kidney and usually well superior to the renal vasculature. The plane of the gland is well posterior to the IVC. The upper part of the gland lies partially behind the inferior vena cava, against the bare area of the liver, and on the diaphragm. The principal venous drainage is through the adrenal vein, which is short and wide and which exits the gland just below its apex to enter the inferior vena cava on its posterior surface and is the only vein to enter the inferior vena cava posteriorly along its retrohepatic course. Accessory adrenal veins entering the vena cava or hepatic veins may be present on the right side.

The left adrenal gland is lower than the right. It is more crescenteric in shape and lies on the diaphragm and is covered on its anterior surface by peritoneum superiorly and by the pancreas on its lower portion. The adrenal vein exists near the lower border of the gland, often to join with the inferior phrenic vein to empty into the renal vein.

The arterial blood supply to the adrenal glands is derived mainly from the inferior phrenic (superior adrenal artery) and renal artery (inferior adrenal artery) as well as directly off the aorta (middle adrenal artery). Lymphatic drainage from the adrenal gland is into adjacent pericaval (right gland) and periaortic (left gland) lymph nodes.

Indications for Adrenalectomy

Indications for adrenalectomy, can be either benign or malignant tumors. By far the most common indications for adrenalectomy are benign endocrine tumors or lesions suspected of being endocrine tumors.

The indications include a functional tumor (pheochromocytoma, primary aldosteronism, hypercorticolism), growth of an adrenal mass of 0.5 cm in 6 months based on imaging, masses with concerning radiographic characteristics, adrenal tumor greater than 4–5 cm, adrenocortical carcinoma and isolated metastatic disease [8].

Indications for Robot-Assisted Laparoscopic Adrenalectomy

Indications for robotic adrenalectomy mirror those of laparoscopic adrenalectomy and include most adrenal tumors, except those concerning adrenocortical carcinoma, which should still be approached preferably with open surgery (Table 10.1).

For adrenocortical carcinoma, the best determinant of patient outcomes is an appropriate oncologic resection that includes *en bloc* resection of any contiguous involved structures and regional lymphadenectomy. Thus, an open approach to resection may be best.

For larger tumors found to be locally invasive or otherwise concerning for adrenocortical carcinoma during minimally invasive adrenalectomy, most investigators recommend an open conversion.

Absolute contraindication for laparoscopic adrenalectomy include general patient comorbidities such as unacceptable cardiopulmonary risk and untreated or uncorrectable coagulopathy or obviously locally invasive cancer.

Relative contraindications include large size tumors. The upper size limit of lesions that can safely be removed with robotic adrenalectomy is related to type of tumor, safe handling of the tumor without violation of the capsule and surgeon's experience. In general transperitoneal resection can be performed safely for tumor up to 10–12 cm, while retroperitoneal resection can be performed for tumors up to a size of 8 cm.

Table 10.1 Indication for robotic adrenalectomy

Functional tumors	Pheochromocytoma Aldosteronoma Cortisol, sex-steroid, mineralocorticoid secreting tumors
Nonfunctional tumors >4–5 cm	With no signs of malignancy With no sign of local invasion
Metastasis	Mainly solitary
Myelolipoma	
Ganglioneuroma	
Adrenal cyst	

Minimally invasive adrenalectomy is associated with a learning curve that may be difficult to overcome given the paucity of these cases in general practice. Dedicated, advanced training should be pursued by surgeons unfamiliar with this technique. Until proficiency with laparoscopic adrenalectomy is attained, consideration should be given to referral to a center with expertise in minimally-invasive adrenal surgery.

Selection of Operative Approach: Transperitoneal and Retroperitoneal

Surgical approach is determined by surgical goals, patient medical and surgical history and surgeon experience. In studying minimal access adrenalectomy techniques, the effect of operative volume and experience of the surgeon needs to be taken into consideration.

A major benefit of the retroperitoneal approach is avoidance of intra-abdominal dissection of adjacent organs and adhesions to expose the adrenal gland, as this technique offers independence from prior abdominal surgeries and direct access to the retroperitoneum, but an understanding of the retroperitoneal anatomy is crucial when attempting this surgical approach, since the retroperitoneal space provides fewer landmarks than the intraperitoneal space. The drawback of the retroperitoneal approach is that the upper size limit of lesions that can safely be removed is 8 cm, since the retroperitoneal space is too small to conduct safe dissection of large tumors.

There may be circumstances where one approach may be preferable, which suggests that both techniques should be included in the armamentarium of surgeons who perform adrenalectomy routinely.

Surgical Management

Cooperation between the surgeon, anesthesiologist and endocrinologist is paramount for accurate diagnosis and proper preoperative management in order to minimize morbidities.

Preoperative Assessment

In general, a multidisciplinary management plan involving an endocrinologist is followed in a patient presenting with an adrenal mass. The adrenal gland is evaluated with a computed tomography (CT) or magnetic resonance imaging to assess the location, size, and functional characteristics of the mass. The primary goal of imaging is to distinguish among adrenal adenoma, adrenal carcinoma, pheochromocytoma, and metastatic lesions. It is important to emphasize that imaging cannot reliably distinguish between functioning and non-functioning adrenal adenomas. An adenoma can be identified by measuring contrast-washout kinetics on CT. Lesions that have an attenuation value below 10 HU on noncontrast CT scan are adenomas. Adenomas constitute about 70% of adrenal masses seen in the clinical setting. The differential diagnosis can be further delineated by CT scans done immediately after intravenous administration of a contrast agent and then again after a 10- to 15-min delay. Benign adrenal lesions will commonly enhance up to 80–90 HU and wash out more than 50% on the delayed scan, whereas lesions such as metastatic tumors, carcinomas, or pheochromocytomas will not [8].

Metabolic parameters (serum levels of aldosterone, cortisol, and catecholamines, as well as urine levels of metanephrines) are assessed to identify functional masses.

In cases of pheochromocytoma, patients are prescribed a preoperative 2 week course of oral α-blocker and addition of a β-blocker if necessary. Approximately 15% of incidenteloma are hormonally active (Table 10.2).

All patients should be counseled about standard surgical risks including infection, bleeding, and damage to surrounding structures and possible conversion to an open procedure.

Table 10.2 Preoperative assessment

Radiological assessment	• CT imaging is the ideal for diagnosis, assess extent, involvement, nodal status • MRI can be used if indicated • CT chest is done to check metastasis
Biochemical assessment	• 24 h urinary catecholamines, metanephrines, aldosterone, free cortisol • Plasma metanephrine, VMA • Plasma aldosterone concentration to plasma renin activity (PAC/PRA) • Plasma cortisol level • Plasma DHEA (dehydroepiandrosterone) • Dexamethasone test
Correction	• Hypokalaemia • HTA • Hydration
Medication	• Aldosteronoma: Oral postassium, spironolactome • Pheochromocytom: α-blocker, phenoxybenzamine, β-blocker • Cushing's syndrome: IV steroid

In general, anesthesia for non-functional adrenal tumors follows the principles for general laparoscopic abdominal surgical cases.

In the operating room, place sequential compression devices and a Foley catheter. For transperitoneal cases, a nasogastric or orogastric tube may be helpful. Ensure that pressure points are properly padded and administer perioperative antibiotic prophylaxis.

Robotic Adrenalectomy

Robotic Instrumentation

The da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) is used in a three-arm configuration, and the following robotic instruments are used:

- 30° down scope,
- ProGrasp forceps,
- Hot Shears (monopolar curved scissors),
- Robotic clip applier.
- A monopolar cautery hook and Harmonic ACE curved shears (Ethicon Endo-Surgery Inc., CA,

USA) can be also used when deemed helpful by the surgeon. We do not routinely use a bipolar energy source.
- 10 cm spherical dissecting balloon for retroperitoneal access.

Assistant Instruments

Laparoscopic instruments are handled by the bedside assistant including:

- Laparoscopic needle driver,
- Laparoscopic scissors,
- Blunt tip grasper,
- 5 mm Allis locking grasper for liver retraction,
- Weck Hem-o-Lok clip applier (Teleflex Medical)
- A suction device.

Trocars

Four to five trocars are used:

- 12 mm trocars: 1 for the camera and 1 for the assistant.
- 8 mm robotic trocar (×2)
- 5 mm trocar for liver retraction for the right side transperitoneal technique (×1)

Ultrasound

Laparoscopic ultrasound with a 5–7.5 MHz transducer. Using the TilePro™ (Intuitive Surgical, Inc., Sunnyvale, CA) feature of the da Vinci® S, the console surgeon is able to display the live intraoperative ultrasound images as picture in picture image on the console screen.

Patient Positioning

Transperitoneal approach: The patient is placed in a 60° flank position. Tapes are used to secure the patient to the surgical table, which is mildly flexed at the level of the kidneys and positioned in a slight Trendelenburg position. Extreme care is taken with pressure points and correctly padding them with pillows and foams. The patient's arms are in a comfortable position, either both over a double arm board or one placed along the side of the body (Fig. 10.1).

Retroperitoneal approach: The patient is placed in a full flank position. The flank should be directly over the table break. The table is flexed adequately to open the space between the 12th rib and the iliac crest. The patient's arms are in a comfortable position, either both over a double arm board or one placed along the side of the body the same as for the transperitoneal approach (Fig. 10.2).

Port Placement

Similar to laparoscopy, precise port placement is essential to maximize exposure and ease of surgery.

Transperitoneal approach: After creating pneumoperitoneum by using a Veress needle, a 12-mm port is inserted above and lateral to the umbilicus, at the lateral border of the abdominal rectus muscle across from the 12th rib. Through this first port, the robotic scope is inserted and the

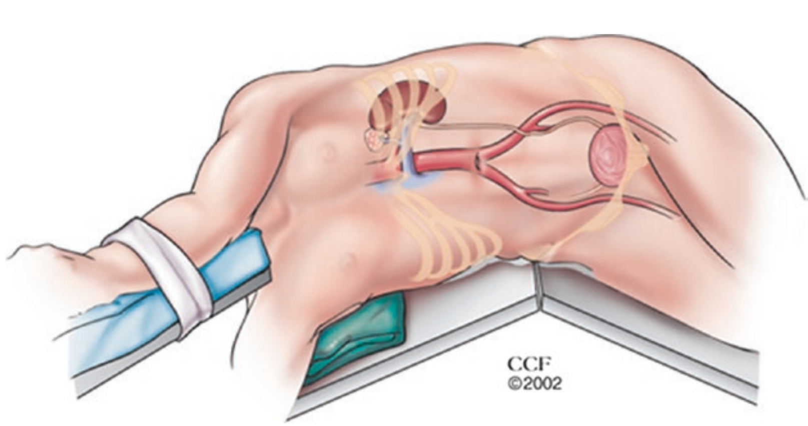


Fig. 10.1 Patient positioning: Transperitoneal approach

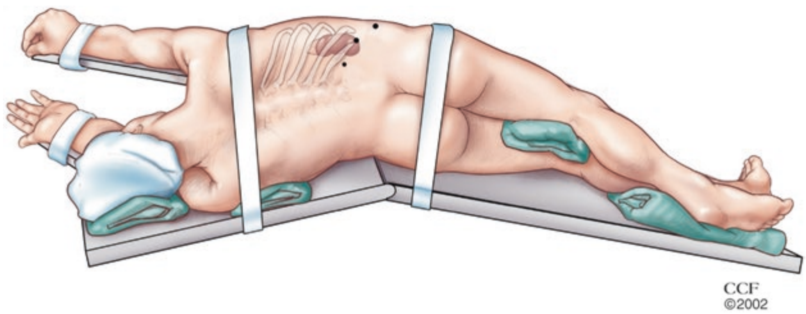


Fig. 10.2 Patient positioning: Retroperitoneal approach

abdomen is carefully inspected to rule out any accidental injuries. Then the remaining ports are placed under vision including an 8-mm robotic port at the lateral border of the ipsilateral rectus muscle about 1 in. below the costal margin, a second 8-mm robot port about 2 in. cephalad to the anterosuperior iliac spine, and a 12-mm assistant port along the lateral border of the rectus muscle, halfway between the camera port and the lower robotic port. For the right-side cases, an additional 5-mm port is placed below the xiphoid process in the midline, to help retract the liver by using an Allis locking clamp. To avoid clashing between the robotic arms, the ports must be appropriately spread, about 8–10 cm distant from each other. In case of obese patients, ports need to be shifted laterally and cephalad to appropriately access the adrenal gland. This move is to avoid abdominal contents obstructing the view (Fig. 10.3).

Retroperitoneal approach: A small 1.5 cm incision is made 1–2 cm below the tip of the 12th rib in the mid axillary line and is used to access the retroperitoneal space. Access to the retroperitoneum is gained by perforating the dorsal lumbar fascia. Blunt finger dissection is useful to create the working space anterior to the psoas. Caution is recommended to avoid entry to the peritoneal cavity. The operative space in the retroperitoneum is then developed with a balloon dilator. By generating this space, intraperitoneal structures such as liver, spleen, and colon are deflected medially. The camera is then placed to inspect the retroperitoneal space. Two 8-mm incisions for the robotic working arms are made medial (along the lateral border of the paraspinous muscle) and lateral (inferior to the 11th rib), to the camera port. In case of obese patients, ports need to be shifted laterally and cephalad.

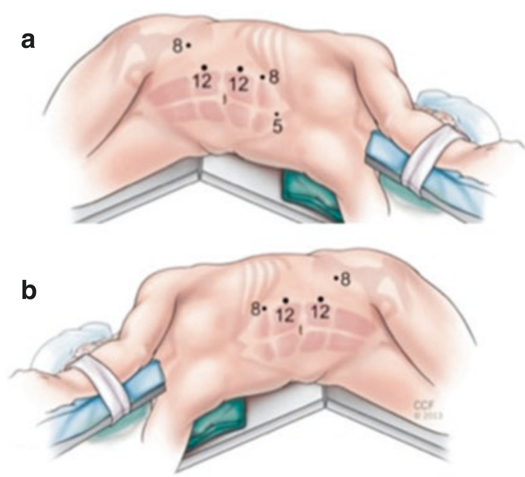


Fig. 10.3 Port placement: transperitoneal approach. (**a**): Right side. (**b**): Left side

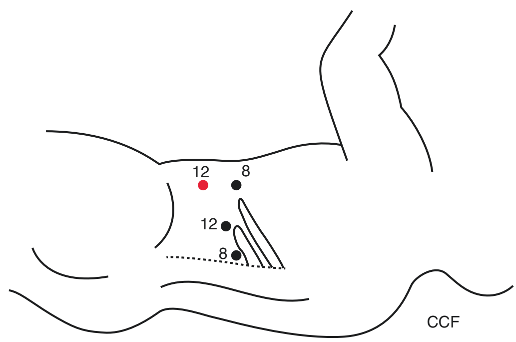


Fig. 10.4 Port placement: Retroperitoneal approach. Assistant trocar: Red

The assistant 12 mm trocar is placed inferior and medially to the anterior robotic port and should be no closer than 6 cm to avoid conflict with the anterior robotic arm. Pneumoperitoneum is maintained at a pressue of 15–20 mmHg (Fig. 10.4).

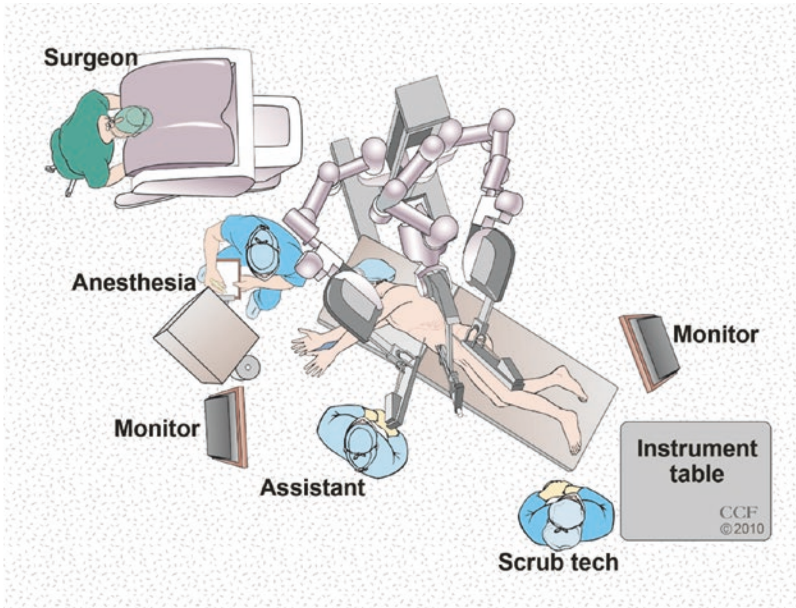


Fig. 10.5 Robot docking: Transperitoneal approach

Robot Docking

Transperitoneal approach: Similar to a robotic partial nephrectomy procedure, the robot is docked over the patient's shoulder so its axis makes an obtuse angle in relation to the patient's axis (Fig. 10.5).

Retroperitoneal approach: The robot is docked over the patient's head parallel to the spine.

Exposure of the Adrenal Gland

Intraoperative ultrasound may assist in staging and other aspects of minimally invasive adrenalectomy. Its potential uses include helping to locate the gland, confirm pathology, and identify the adrenal vein.

Transperitoneal approach: ***On the left side***, complete medial bowel mobilization is needed to allow gland exposure. The lateral attachments of the spleen, as well as splenorenal ligaments, are divided. The spleen, bowel, and the pancreas are mobilized medially until the adrenal gland is clearly visualized. Attention must be paid to the tail of the pancreas because it can be mistaken for the adrenal gland (Fig. 10.6).

On the right side, the triangular liver ligament is divided as cranially as possible to release the liver, and the locking grasper (placed through the subxyphoid trocar) is used as a liver retractor. The posterior peritoneum overlying the upper pole of the adrenal can also be incised to release the liver, which can then be retracted more superiorly (Fig. 10.7). After properly retracting the liver, the right adrenal can be accessed with minimal colon mobilization. For a better exposure of the inferior vena cava (IVC), the duodenum can be medially mobilized as well. If this is the case, the use of cautery needs to be minimized to avoid duodenal injuries.

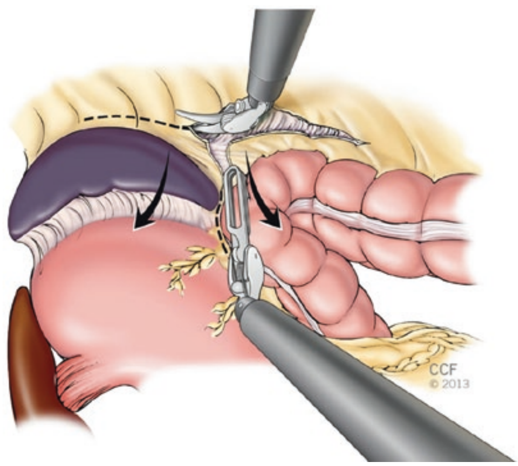


Fig. 10.6 Exposure of the left adrenal gland

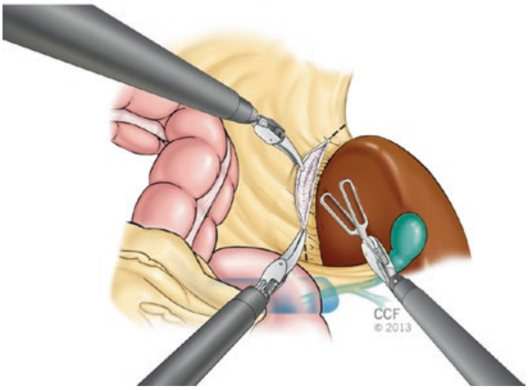
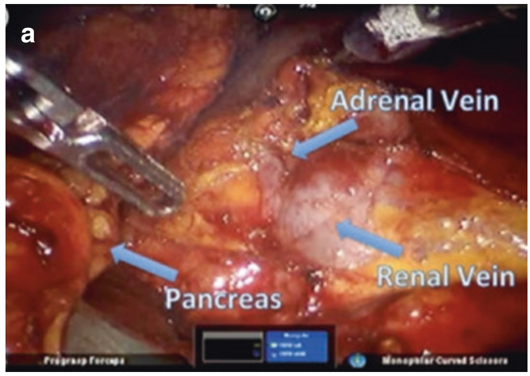


Fig. 10.7 Exposure of the right adrenal gland

Retroperitoneal approach: For proper orientation, the psoas muscle should be identified posteriorly, and the kidney should be displaced anteriorly and medially.

On the left side, the first step of the retroperitoneum approach is medial reflection of the peritoneum which in turn reflects the spleen, and the descending colon.

On the right side, the first step of the retroperitoneum approach is medial reflection of the peritoneum which in turn reflects the liver and the ascending colon.



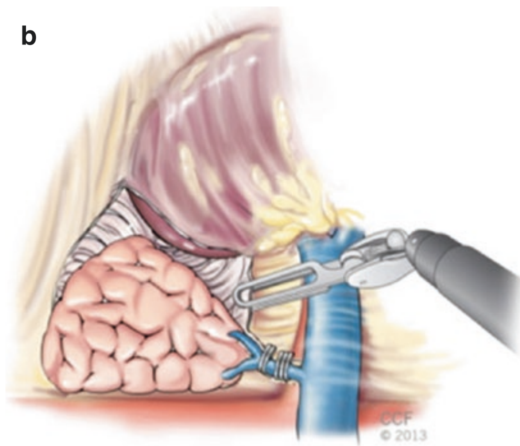


Fig. 10.8 Transperitoneal control of the right adrenal vein. (**a**): Camera view. (**b**): Illustration

Identification and Control of the Adrenal Vein

Transperitoneal approach: ***On the left side***, the renal hilum is identified, either by accessing it directly or after identifying and following the gonadal vein cephalically. It is necessary to identify and dissect the left renal vein because the adrenal vein is a tributary branch of it. Then the adrenal vein is carefully dissected and clipped by using the robotic clip applier, when available, or standard laparoscopic Hem-o-Lok clips placed by the bedside assistant (Fig. 10.8).

On the right side, after the duodenum is medially mobilized, the lateral border of the inferior vena cava (IVC) and the renal vein are identified. Dissecting cranially along the lateral border of the IVC, the right adrenal vein is encountered, dissected, clipped, and resected (Fig. 10.9).

Retroperitoneal approach: ***On the left side***, an initial incision is made transversely along the fascia of Gerota toward the renal upper pole. The perirenal fat is cleaned from the adjacent structures. The plane between the upper pole and adrenal gland is identified and developed with superior retraction of the gland and inferior retraction of the kidney. Dissection is continued with the identification of the renal hilum. The renal artery retracted caudally and blunt dissection helps to identify the left adrenal vein which is a branch of the renal vein. The vein is then carefully dissected, isolated and divided.

On the right side, the adrenalectomy begins with identification of the renal artery, next the IVC, superior to the renal artery is identified. The fibroadipose tissue overlying the vena cava is carefully dissected. During this dissection, multiple small aortic and renal hilar branches to the adrenal gland are controlled. Dissection continues cephalad along the surface of the vena cava. The main adrenal vein is identified on the posterolateral aspect of the IVC high under the liver edge. The vein is isolated and divided.

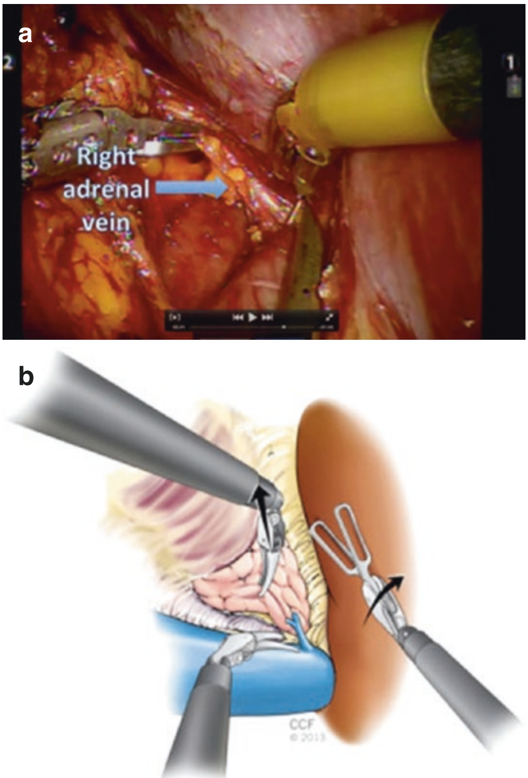


Fig. 10.9 Transperitoneal control of the left adrenal vein. (**a**): Camera view. (**b**): Illustration

Circumferential Dissection of the Adrenal Gland

At all times, care should be taken to avoid direct handling of the gland, as this often results in bleeding. En bloc mobilization of the adrenal gland and the surrounding peri adrenal fat helps the surgeon avoid grasping the gland itself.

Once the adrenal vein is properly controlled, the adrenal gland is circumferentially mobilized, beginning at the upper pole of the kidney, progressing to the medial surface of the diaphragm with ligation of adrenal branches of the inferior phrenic vessels which may obscure the operative field if not controlled appropriately, and finding a plane between the posterior surface of the adrenal and the psoas muscle. Care must be taken during this step to control arterial blood supply, which can be done using clips or the Harmonic ACE. Layers of fat are left on the surface of the adrenal gland to use as a handle, thereby minimizing manipulation of the gland and avoiding fracturing it (Fig. 10.10).

Specimen Retrieval and Closure

After checking the hemostasis by lowering the pneumoperitoneum, a laparoscopic entrapment sac is introduced by the assistant and the specimen is placed into the sac. All ports are

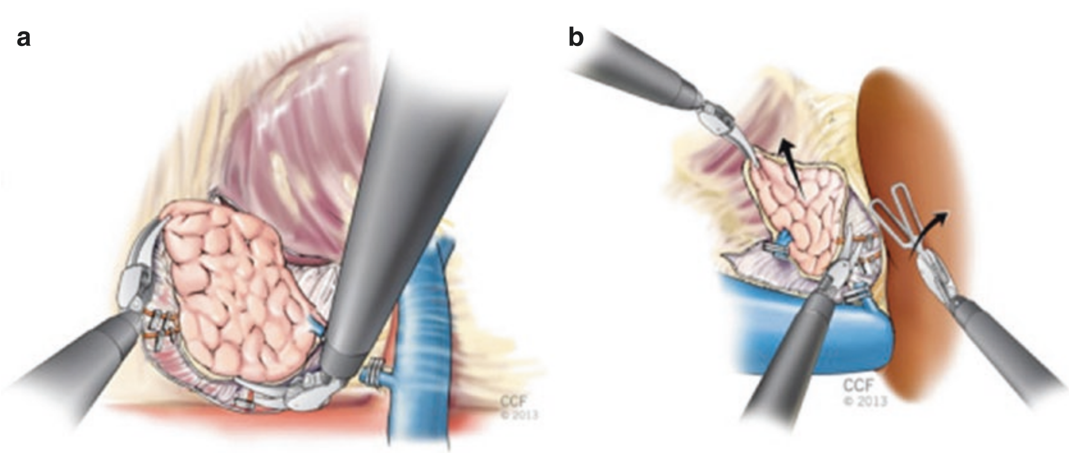


Fig. 10.10 Dissection of the adrenal gland. Transperitoneal view. (**a**): Right adrenal gland. (**b**): Left adrenal gland

removed under direct vision. After undocking the robot, the bagged specimen is extracted by extending the incision at the level of the assistant port. A Carter-Thomason device (Inlet Medical Inc., Eden Prairie, MN, USA) is used to close the 12-mm incisions. No drain is left in place.

Postoperative Care

Postoperative care varies depending on the type of tumor being treated. Intravenous fluids, analgesics, antibiotics, and prophylaxis for deep vein thrombosis are given per institutional protocol. Hemoglobin levels and hematocrit are monitored. Careful postoperative metabolic surveillance is essential in secreting tumors. The patient is encouraged to ambulate gradually, and diet is advanced. The patient is discharged on the first or second postoperative day.

Complications

The types of complications after robotic surgery are similar to those encountered in the conventional laparoscopic approach. Among the vast spectrum of complications reported, intraoperative and postoperative hemorrhagic complications are the most common noted during minimally invasive adrenal surgery.

Access Related Complications

Obtaining safe access is of paramount importance during laparoscopic surgery. Access related complications can be caused during insertion of the Veress needle or during placement of the initial trocar. Injury to the liver, spleen, pancreas, bowel and great vessels are the most commonly encountered injuries. In the transperitoneal approach, the liver and the spleen are at higher risk for entry related complication due to their location in the upper abdomen.

While robotic assisted adrenalectomy shares the same potential complications as conventional laparoscopic adrenalectomy, there are few potential hazards unique to the robotic approach. Collisions of the robotic arms outside of the body can limit the maneuverability of instruments within the surgical field, and therefore robotic trocars should be sufficiently distanced to avoid this problem. Additionally robotic assisted adrenalectomy necessitates an assistant who is comfortable with laparoscopic surgery.

Peroperative Complications

Manipulation of the adrenal tumor in pheochromocytoma, may lead to hypertensive episodes [9]. Insufflation of the peritoneum frequently contributes to cardiovascular lability. Usually cessation of manipulation or insufflation is sufficient to improve the hemodynamic function.

Intraoperative hemorrhage represents the most serious and life threatening complications of adrenal surgery. Even small amount of bleeding can hinder visualization during laparoscopic adrenalectomy. Bleeding complications are responsible for open conversion in 1.6% [10].

The adrenal glands are intimately associated with large vascular structures that may be inadvertently clipped or ligated during surgery namely renal vascular injury, mesenteric vascular injury and splenic vascular injury.

Adjacent structures may be injured during laparoscopic adrenalectomy, diaphragm, spleen, pancreas, liver, stomach, colon and kidney. Pulmonary damage observed in the laparoscopic approach is injury to the inferior aspect of the diaphragm during dissection. Overall, the rate of conversion to open surgery is 3.6% [10].

Postoperative Complications

Adrenal cortical function is vital and postoperative adrenal insufficiency can be fatal. The acute manifestation of adrenal insufficiency include sepsis, fever, metabolic disturbance, abdominal pain and death.

Many of the postoperative complications are not unique for robotic adrenalectomy. However, several complications are decreased with the laparoscopic approach such as pneumonia, atelectasis, wound infection, and hernia.

Overall complication rate is 10.9% in laparoscopic series. The mortality rate is 0.3% for laparoscopic adrenalectomy [10].

Results

Patients undergoing a laparoscopic procedure had significantly lower postoperative morbidity with less blood loss, less ileus, decreased pain, faster convalescence, and shorter length of stay than patients undergoing an open procedure after adjustment for patient and procedure related factors. Similar findings were demonstrated for all indications, including malignancy. No significant differences in mortality have been demonstrated for a procedure that in general is associated with very low mortality. Some series report longer times with the laparoscopic approach, others report similar duration, and others shorter duration compared with the open approach, mainly related to the surgeon's experience [11–26].

A recent retrospective analysis performed by Brandao et al. also compared transperitoneal robotic and laparoscopic adrenalectomy. They included 30 robot-assisted and 46 conventional laparoscopic adrenalectomies. There was a significantly lower reported blood loss in the robotic group (median, 50 vs. 100 mL, $p < 0.02$). However, there was no difference in operative time (median, 120 vs. 120 min, $p = 0.59$), length of hospital stay (median, 2 vs. 2.5 days, $p = 0.170$), conversion rate (0% vs. 2.3%, $p = 0.59$), 30-day-readmission rate (3.3% vs. 6.5%, $p = 0.48$), postoperative complications rate (20% vs. 10.9%, $p = 0.32$), and transfusion rate (10% vs. 13.1%, $p = 0.9$) [27].

Brunaud reported the largest series to date of lateral transabdominal robotic adrenalectomy and found that after a learning curve of 20 cases, tumor side, previous clinical experience, and the first assistant's skill are the main predictors of operative time in Robotic adrenalectomy. The authors also reported that robotic adrenalectomy might be especially useful for patients with a high BMI (>30–35 kg/m^2) and large tumors (>5.5 cm). Similarly, Nordenstrom and colleagues reported advantages in obese patients and large tumors in their series with robotic adrenalectomy [28, 29].

A Systematic review and a meta-analysis of current evidence show that robot-assisted adrenalectomy can be performed safely and effectively with operative time and complication rates similar to laparoscopic adrenalectomy. In addition it can provide the potential advantage of a shorter hospital stay and less blood loss. These findings seem to support the use of robotic surgery for the minimally invasive surgical management of adrenal masses [30].

Future Directions: Single Port

Laparoendoscopic single-site surgery (LESS) has been developed to further minimize the morbidity associated with laparoscopic surgery. By reducing the number and length of skin incisions, it was hypothesized that this would lead to less pain, faster convalescence and improved cosmetics following minimally invasive surgery. The first LESS procedure was reported by Hirano et al. [31] in 2005. They performed a retroperitoneoscopic adrenalectomy through a single incision with standard laparoscopic instruments.

The application of robotics to LESS (R-LESS) has addressed many of the limitations seen with the conventional technique. The endowrist technology allows for superior dissection, triangulation and intra-corporeal suturing. However, R-LESS was limited by the absence of robotic platform designed for LESS. Recently, a purpose-built single-port robotic System has been introduced [32]. The device delivers a 3D-HD camera and three fully articulating instruments through its 25 mm cannula. The EndoWrist Single port Instruments used by the system have two more degrees of freedom than the da Vinci Single-Site instruments previously available, allowing substantially more control for the surgeon.

Conclusion

The laparoscopic technology has presented new frontiers to adrenal surgery thus enabling modification and refinement of established conventional procedures. The integration of robots into adrenal surgery has made it feasible to offer alternatives to patients requiring surgical treatment of adrenal disorders. The robotic assistance may allow more surgeons, with limited conventional laparoscopic experience to offer to their patients a mini invasive approach. This technique is a safe procedure still, evidence on the possible advantages of robotic assisted adrenalectomy remains limited.

The greatest clinical limitation of robotic adrenalectomy is the cost. In today's healthcare system, with limited resources, the high price of the equipment and replacement instruments could be a barrier to the expansion of this technique. Such limitations should be quickly eliminated to merit continued development of these surgical techniques.

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Part IV

Pelvis

11 Surgical Anatomy of Pelvic Lymph Nodes

Martin C. Schumacher

Lymphatic System

In order to better understand the concept of nodal metastases from any primary tumor, including a pelvic tumor, it is important to understand the underlying mechanism of tumor cell dissemination via the lymphatic system.

The lymphatic system begins to develop at the end of the fifth week of pregnancy, approximately 2 weeks later than the cardiovascular system. One view states that the lymphatics develop as diverticulae (sac-like structures) of the endothelium of veins; another states that, like other blood vessels, they develop from clefts in the mesenchyme that connect with the venous system secondarily. Thus, the cells lining the mesenchymal clefts assume an endothelial shape and subsequent sprouting of these cells causes the clefts to fuse and form the lymphatic channels.

The lymphatic system is an endothelial-lined network of blind-ended capillaries found in nearly all tissues. These capillaries are made of a single-cell layer of extensively overlapping endothelial cells with endothelial cell leaflets linked by discontinuous button-like endothelial cell-cell junctions which open in response to increased interstitial fluid pressure [2]. Due to the lack of a basement membrane and supporting smooth muscle cells, lymphatic capillaries are highly permeable to the protein-rich lymph fluid. Lymphatic capillaries possess specialized structures called anchoring filaments, which are extracellular fibrillar structures, which help to keep the lymphatics open in response to increasing interstitial pressure [3]. The lymphatic capillaries converge into pre-collecting lymphatic vessels, which carry lymph to the main collecting trunks, such as the thoracic duct, for return to the venous circulation via the anastomosis with the cardinal vein. Unlike lymphatic capillaries, pre-collecting and collecting trunks contain smooth muscle cells and pericytes. Collecting lymphatics have valves to prevent retrograde flow of lymph fluid. Lymph fluid is moved along the lymphatics by contraction of an “intrinsic” muscle pump, under adrenergic, cholinergic and peptinergic control, as well as by the “extrinsic” pump which consists of compression of the lymphatics by adjacent muscle contractions and surrounding interstitial pressure [4].

The lymphatic drainage system is important in immune mediation because it channels lymphocytes and antigen-presenting cells to their corresponding lymph nodes. On the other hand it acts also as an important pathway for tumor cell dissemination. Several factors facilitate the entry of tumor cells into the lymphatic system:

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_11

First, because lymph vessels are relatively larger in caliber than small capillaries. Second, the lack of a basement membrane and fewer intercellular junctions may aid tumor cells to enter the lymphatics. Third, the flow velocities in the lymphatics are slower than in capillaries thus cells are less at risk to sheer stress. Fourth, lymph fluid is similar in its constituents and chemistry to interstitial fluid, which in turn promotes cell viability [5]. Lymph nodes are the main site for the development of antibody-producing B-lymphocytes, and produce also monocytes and plasma cells, in response to the lymph fluid [6]. Lymphatic vessels are known to contain a specific vascular endothelial growth factor (VEGF) receptor, VEGF-3 [7]. This specific receptor responds to stimulation from VEGF-C and VEGF-D to form new lymphatics. Certain tumors may use this mechanism to help the process of tumor cell dissemination by de novo formation of lymphatics. Experimental studies in mice have shown that blockage of VEGF-C and VEGF-D can reduce tumor cell dissemination [8].

Anatomy

A proper understanding of the location of lymph node groups in the pelvis is mandatory for formulating an appropriate treatment strategy in cancer patients. The present work gives a fine description of lymphatic vessels and nodal stations in the pelvis according to the important pioneering work by Cunéo and Marcille more than a century ago [9, 10]. Relevant single nodes are grouped according to their anatomical region and in relation to pelvic organs.

Divided into a *parietal* and *visceral* lymph system, all the lymphatics of the pelvis drain into successive groups of nodes located at the level of the pelvic inlet, along the arcuate line (on the internal surface of the ilium) and anterior of the fifth lumbar vertebra. Mainly in close proximity to the iliac vessels and their braches, they form several ascending lymph chains which include the external iliac, internal iliac, common iliac and sacral node groups. Their corresponding collecting ducts terminate in the inferior part of the lateral aortic chain on the corresponding side (Figs. 11.1 and 11.2) [11].

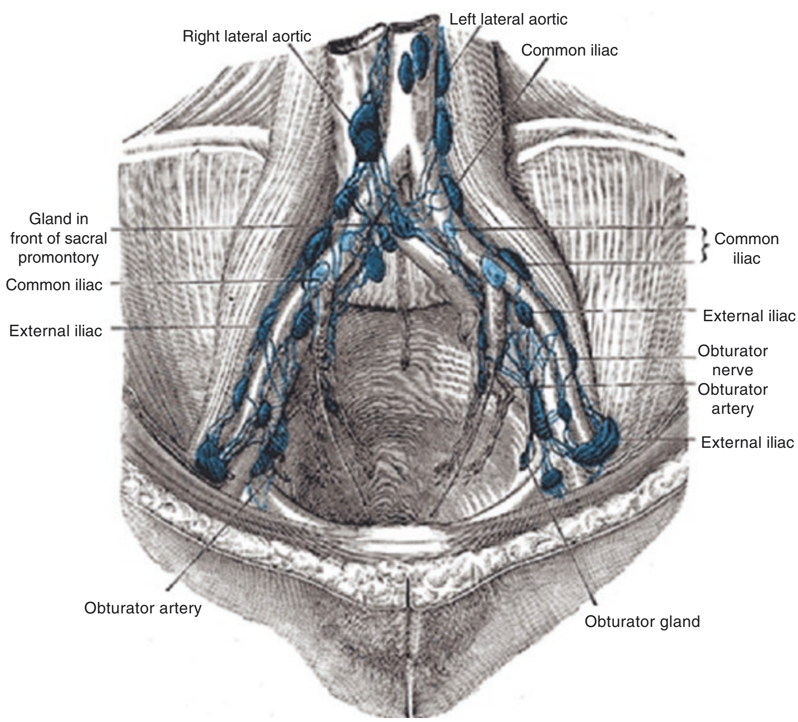

Fig. 11.1 The parietal lymph glands of the pelvis. (Cunéo and Marcille)

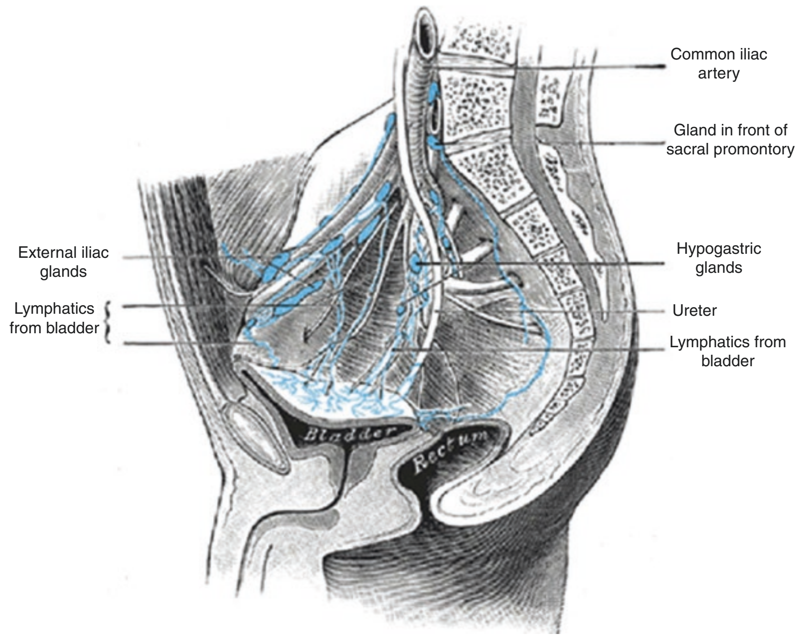

Fig. 11.2 Lymphatics of the bladder. (Cunéo and Marcille)

Parietal Lymph Vessels and Nodes

The *parietal* lymphatics drain lymph from the anterior, lateral, posterior and inferior walls of the pelvis and included a *superficial* and *deep* lymphatic network:

- The *superficial parietal* lymph vessels drain only the pelvic floor. It comprises all soft tissues of the perineum below the outer fascial sheet of the urogenital diaphragm, including the distal part of the vagina, and the inferior part of the anal canal below the ano-cutaneous line [12].
- The *deep parietal* lymph vessels follow the vascular structures of the external and internal iliac vessels, and drain into the inferior epigastric, circumflex iliac and sacral nodes [13]. They can be described as follows (Figs. 11.1, 11.2, 11.3, and 11.4):
  - The *deep inferior epigastric nodes* consist of three to six nodes located over the lower third of the inferior epigastric artery behind the rectus abdominis muscle. Their efferent lymphatic vessels terminate in the lateral chains of the external iliac nodes.
  - The *deep circumflex nodes*, two to four nodes, are frequently absent and drain also into the external iliac nodes.
  - The *sacral groups of nodes* are situated around the lateral and median sacral arteries, and form three groups of ascending lymph chains, running along the lateral borders of the sacrum and in front of its anterior aspect on the midline. These nodes drain the presacral space between the anterior aspect of the fascia recti and the posterior sacral space. Their efferent vessels drain into the internal iliac nodes and subaortic nodes in the midline. The largest node located on the anterior aspect of the intevertebral disc L5-S1 is known as *promontorial node* [14].

Visceral Lymph Vessels and Nodes

The *visceral lymph vessels* of the pelvis are first located close to each pelvic organ (viscera), then around the different vascular pedicles of each organ and finally along the iliac vessels. From there they form rich lymph plexuses and ascending pathways which finally converge to the lateral lumbar aortic node groups (Fig. 11.1).

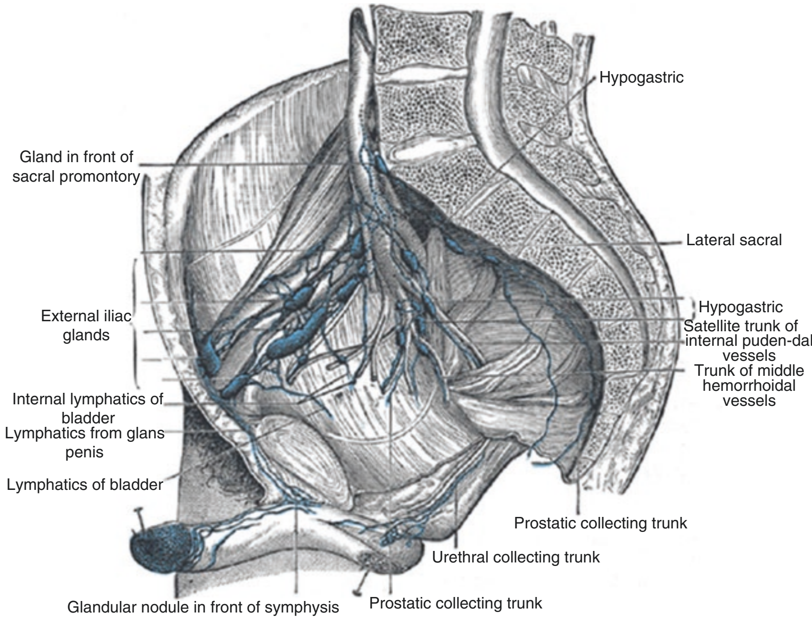

Fig. 11.3 Iliopelvic glands (lateral view). (Cunéo and Marcille)

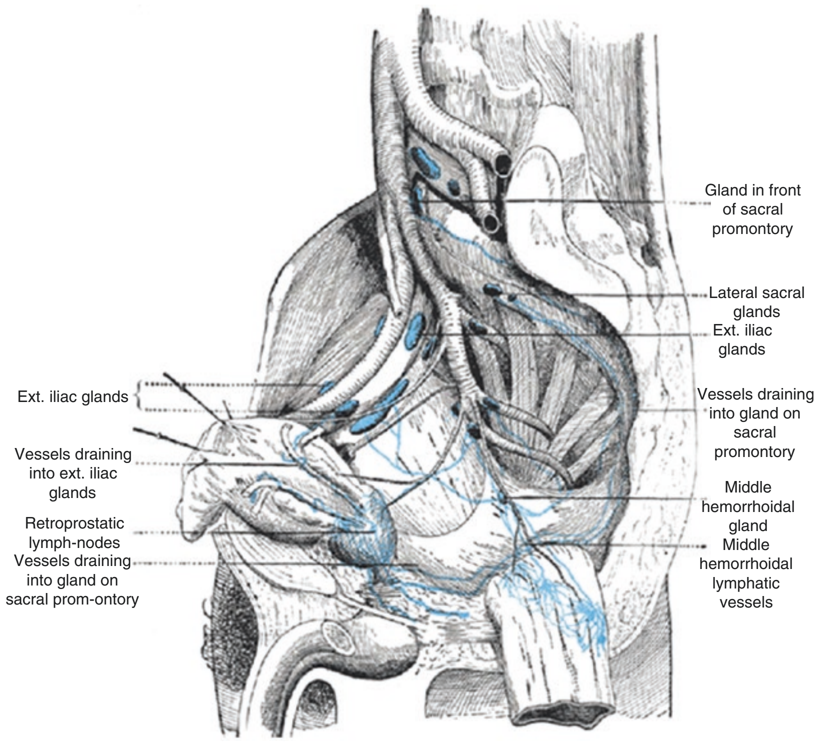

Fig. 11.4 Lymphatics of the prostate. (Cunéo and Marcille)

The *juxtavisceral nodes* can be described according to their locations as follows:

- *Anterior-, lateral-, posterior- and subvesical lymph nodes* are located on the corresponding site of the urinary bladder in the pelvis.
- *Paravaginal and parauterine lymph nodes* are situated lateral to the vagina and cervix in the female pelvis.
- *Pararectal lymph nodes* are located lateral on each side of the rectum in the pelvis.

These above mentioned node groups receive via afferent vessels lymph fluid from their corresponding viscera, while their respective efferent lymph vessels transport lymph to the external iliac, internal iliac or presacral lymph chains.

External Iliac Nodes

These nodes are grouped around the external iliac vessels, are usually nine to ten in number and have a constant arrangement, thus forming three distinct lymph node chains, each consisting of about three nodes, namely the lateral, middle and medial groups of external iliac nodes (Fig. 11.3).

- The *lateral external iliac node chain* are located between the psoas muscle and the lateral side of the external iliac artery. The node situated under the inguinal ligament is known as the lateral lacunar lymph node [15].
- The *middle external iliac node chain* lie on the anterior aspect of the external iliac vein along the medial side of the external iliac artery.
- The *medial external iliac node chain* is situated on the medial side of the external iliac vein, against the lateral pelvic wall above the obturator nerve [14]. The lower node of this group is located behind the femoral septum in contact with Cloquet's deep inguinal node and commonly termed medial lacunar lymph node [15]. It has been shown that these nodes are functionally linked to the external iliac chain of node groups [12]. From the surgeon's point of view, these nodes are commonly called *obturator nodes* due to their proximity with the obturator nerve. However, this terminology is misleading as stated by Sappey, as the small obturator node occupies the internal foramen of the obturator canal in the lower part of the obturator fossa (Fig. 11.1) [16].

  The efferent lymph vessels of each external iliac lymph chain converge into the lower nodes of the common iliac chains. The three different chains form an extensive network between these lymph chains, which are mostly located on the anterior surface of the blood vessels, though some connecting vessels cross also posteriorly.

Internal Iliac Nodes

These nodes are often described in the literature as hypogastric nodes, and surround the internal iliac vessels and are often situated in proximity with their different vascular branches (Fig. 11.2). Afferent vessels of the internal lymph nodes originate from the pelvic organs, namely from the posterior part of the prostate, the lateral and lower parts of the urinary bladder, the membranous and prostatic urethra, the seminal vesicles, the middle and lower part of the vagina, the body of the uterus, and the middle part of the rectum [13, 17, 18]. The lowest parts of the prostate, vagina and rectum is drained via the internal pudendal lymphatic vessels which then join the nodes of the internal iliac chain. The efferent vessels of the internal iliac node chain follow cranially within the hypogastric lamina and pass underneath the common iliac vein and terminate in the intermediate group of common iliac lymph nodes [16].

Common Iliac Nodes

The common iliac nodes are grouped around the common iliac vessels, ranging from four to seven nodes in number, and according to the afferent lymph vessels can be divided into the lateral, middle and medial groups of nodes (Fig. 11.1).

- The lateral lymph chain usually comprises two large nodes interposed between the lateral side of the common iliac artery and the medial border of the psoas muscle. These nodes drain the lymph from the lateral external iliac nodes and end in the lateral lumbar aortic node chain.
- The middle chain consists usually of three to four nodes located on the posteromedial side of the artery. On the left side they can be situated on the anterior aspect of the common iliac vein. These retrovascular nodes are located in Cunéo's and Marcille's triangular lumbosacral fossa, which is filled with adipose tissue and contains the nodes superiorly and the obturator nerve inferiorly [9].
- The medial chain runs along the inner side of

the common iliac artery, and its nodes (subaortic nodes) are found just below the aortic bifurcation.

Interestingly, the lateral and middle common iliac lymph chains do not receive any direct afferent vessels from the pelvic organs. However, some lymphatics coming from the bladder neck, cervix uteri and posterior aspect of the rectum drain directly into the subaortic group of nodes. From these nodes lymph chains continue cranially towards the preaortic, retroaortic and lateral aortic node groups. The lateral aortic lymph node group is the most important group, comprising typically 15–20 lymph nodes on each side.

Bladder Cancer

The pioneering work in describing the anatomical lymph chains and nodes by Cunéo and Marcille have since then be confirmed when reporting sites of lymph node metastases at radical cystectomy [9]. Indeed, one of the first anatomical lymph node mapping studies at radical cystectomy by Smith and Whitmore concluded that nodes along the external iliac vessels, obturator fossa and common iliac vessels were frequently involved in patients with muscle-invasive bladder cancer [19]. Their results have been corroborated by complex surgical and radiological means in radical cystectomy patients by others [20, 21].

Anatomic Lymph Node Mapping Studies

In order to achieve optimal treatment results in genitourinary cancer patients, detailed knowledge of the anatomic lymph-node distribution is mandatory. In recent years, single photon emission computed tomography (SPECT) sentinel lymph node data were used to develop a realistic anatomic atlas of pelvic lymph nodes in prostate cancer patients [22]. With current positron emission tomography (PET) imaging technology using various tracers such as Choline or PSMA-ligands, the exact localization of each individual lymph node can potentially be visualized prior treatment [23]. This may offer new possibilities for treatment strategies in the near future.

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Surgical Anatomy of the Bladder

12

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Introduction

Advancing from open to endoscopic surgery and continuing to robotic-assisted endoscopic surgery does not change the anatomical facts, but visual perspective changes literally. Both the angle of view of topographic relations between anatomical structures and the attention to details have been modified and enhanced by the technical development. Magnification and stereoscopic view along with the possibility of reduced tremor and precise preparation opened up these real-time insights into human pelvic anatomy. The following chapter addresses the macroscopic and microscopic anatomy of the urinary bladder with regard to special needs of a surgeon working endoscopically. In addition to basic anatomical knowledge, this chapter emphasizes the topographic female and male anatomy of the pelvis, the urethral sphincter mechanisms, and the continuously evolving field of genitourinary tract innervation. Whereas gross anatomy is substantially investigated and well known, microscopic anatomy, especially the complex pelvic neural network and the ultra structure of the rhabdosphincter, is still in the spotlight of scientific interest. The prostate and the periprostatic nerve courses are excluded and focused on in another chapter. The combination of new findings with traditional anatomical knowledge into urological practice will improve the treatment success for our patients after robotic pelvic surgery.

The Anatomy of the Urinary Bladder: A Look Back into History

A catheter made of bronze draining the urinary bladder was described for the first time in Egypt about 1000 B.C., and bladder stone surgery also seems to have been practiced. Classifications of functional diseases of the urinary bladder have been described by Hippocrates of Cos (about 460–370 B.C.) based on observational studies. Herophilus of Chalcedon demonstrated the existence of the prostate for the first time with human cadaver studies in 300 B.C. Precursors in human anatomy especially with regard to the urogenital tract were Leonardo da Vinci (1452–1519), Andreas Vesalius (1514–1564) from Brussels, and their successor Eustachi (1500–1574) after a widespread rejection of anatomical studies up to the Middle Ages. The anatomy of the urogenital tract was further characterized with the description of the seminal vesicles by Étienne de la Rivière of Paris, the investigation of the renal function by Marcellus Malpighi (1628–1694), and the description of the renal tubules by Lorenzo Bellini (1643–1704). The enhanced technical possibilities of microscopic pathologi-

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_12

cal examination advanced the basic anatomical knowledge. Mery described the existence of the bulbourethral glands, which was later attributed to Cowper in 1684. Giovanni Battista Morgagni (1682–1771) is presumed to be the founder of the study of the pathology of the urinary tract based on his work “De sedibus et causis morborum.” He is also considered the first to describe prostatic hyperplasia. One of the milestones in urology—urological endoscopy—goes back to Phillip Bozzini of Frankfurt who invented the first endoscope using candlelight in 1806. This made possible the exploration of the internal anatomical details of a living individual [1].

The Anterior Abdominal Wall: Anatomical Landmarks

Knowledge about the different anatomical structures of the anterior abdominal wall is crucial for laparoscopic and robotic-assisted surgery. Trocar positioning and the first steps of intrapelvic preparation require orientation at the different anatomical landmarks. Figure 12.1 illustrates a projection of the main structures onto the skin of the anterior abdominal wall, whereas Fig. 12.2 presents a combined realistic and delineated laparoscopic insight into the male pelvis at the beginning of robotic-assisted pelvic surgery. Five tissue folds subdivide the anterior abdominal wall. The median umbilical ligament raising the median umbilical fold between the apex of the urinary bladder and the umbilicus originates from the former embryonic urachus (connecting the urinary bladder to the embryonic allantois) and is located between the transversalis fascia and the peritoneum. The medial umbilical folds on both sides of the median umbilical fold accommodate the remnants of the fetal umbilical arteries. The excavation in between is called the supra-vesical fossa. The medial umbilical ligaments are guiding structures during cystectomy to identify the upper vesical pedicle including the superior vesical artery. Both inferior epigastric arteries form the lateral umbilical folds. Hernia classification is defined by the reference of the location of hernia passage to the lateral umbilical fold. Medial to the lateral umbilical fold, the medial inguinal fossa represents the passage of direct inguinal hernias. The lateral inguinal fossa is idem to the deep inguinal ring—the entry to the inguinal canal. An indirect inguinal hernia could accompany the components of the spermatic cord through the inguinal canal. The iliopectineal arch subdivides the space below the inguinal ligament, which connects the anterior superior iliac spine to the pubic tubercle and is formed by the external abdominal oblique aponeurosis. The muscular lacuna laterally contains the iliopsoas muscle and the femoral nerve, and the vascular lacuna medially includes the external iliac vessels. The lacunar ligament is directly located medial to the external iliac vein connecting the inguinal ligament to the superior pubic ramus and represents the caudal extent during lymphadenectomy for prostate or bladder cancer (Fig. 12.3) [2–4].

Anatomical Topography of the Female Pelvis

A plain sacral promontory and wide-open iliac wings characterize the female pelvic bone. Main organs of the peritoneal and subperitoneal pelvic cavity are the urinary bladder, the ureters, the uterus, the vagina, the ovaries, the oviducts, and the rectum. The parietal peritoneum covers approximately the upper half of the urinary bladder, the uterus, the adnexa, and the anterior wall of the rectum, which results in varying peritoneal conditions. The position of the uterus between the urinary bladder and the rectum develops the rectouterine excavation (Douglas’ fold) and the vesicouterine excavation. Different ligaments retain the uterus in its position: the cardinal ligaments (transverse cervical ligaments) contain the uterine arteries, the uterine venous plexus, and the parts of the distal third of the ureters and connect the cervix to the lateral pelvic wall. The bilateral peritoneal duplication between the uterus and the pelvic wall in cranial continuation to the cardinal ligaments is called ligamentum latum (broad ligament) although it is not a ligament in the anatomical sense. The suspensory ligaments contain the ovarian vessels and connect the ovaries to the lateral wall of the pelvis. In the other direction the ovarian ligaments connect the ovaries to the

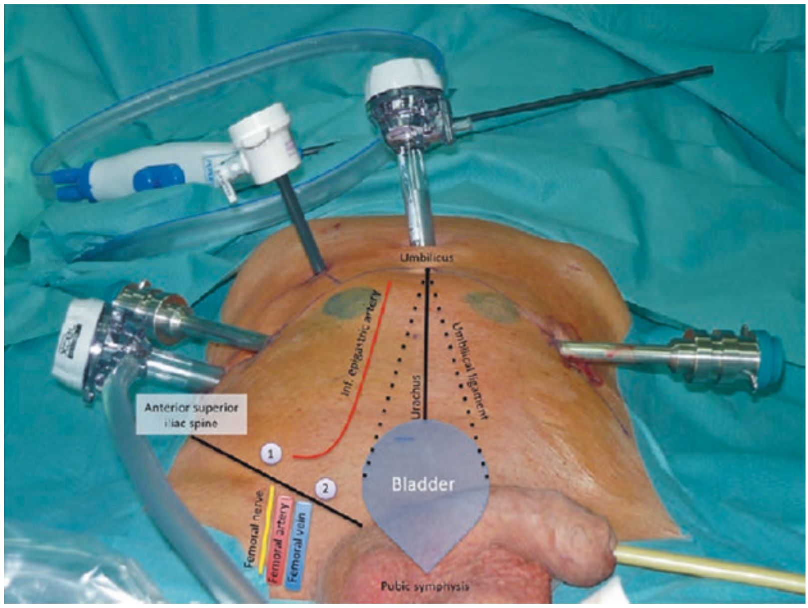

Fig. 12.1 Anatomical landmarks in projection on the external abdominal wall (internal inguinal ring (*1*), external inguinal ring (*2*), trocar positioning for robotic-assisted radical cystectomy)

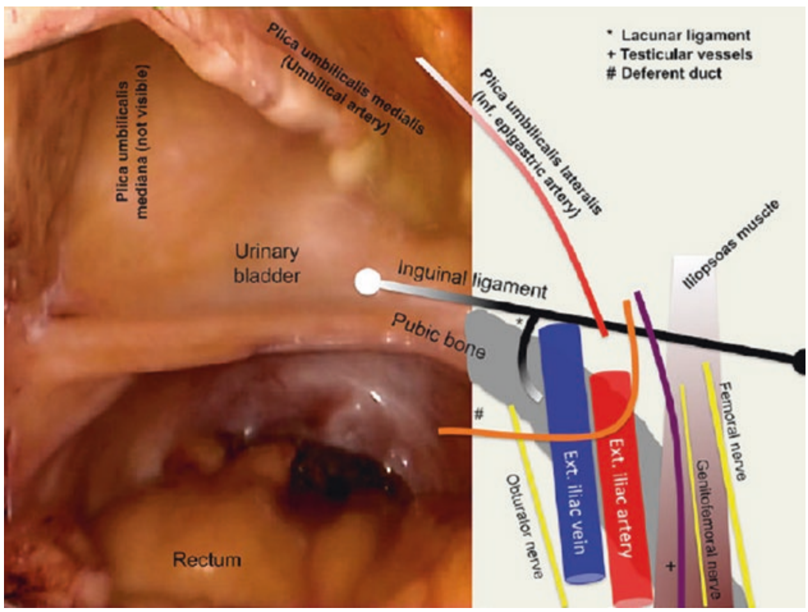

Fig. 12.2 Intrapelvic anatomical landmarks. *Left*: laparoscopic view into the male pelvis (trocar position below the umbilicus). *Right*: anatomical structures of the inguinal region and the internal abdominal wall (additional annotation: deferent duct (#, *orange*), testicular vessels (+, *violet*), lacunar ligament (*))

uterus—additional vessels originating from the uterine arteries are included in these structures. The round ligaments represent connections between the deep inguinal rings and the uterine horns. The recto-uterine folds mark the borders of the rectouterine excavation—they consist of fibrous tissue and smooth muscle fibers and also include the inferior hypogastric plexus (Fig. 12.4). The pelvic fascia (endopelvic fascia) subdivided into the parietal and the visceral layer covers the borders of the subperitoneal space (also called cavum retzii) and forms the superior layer of the fascia of the pelvic diaphragm. The urinary bladder is attached to the symphysis pubis via the pubovesical ligaments with lateral connections to the superior layer of the fascia of the pelvic diaphragm [2–5].

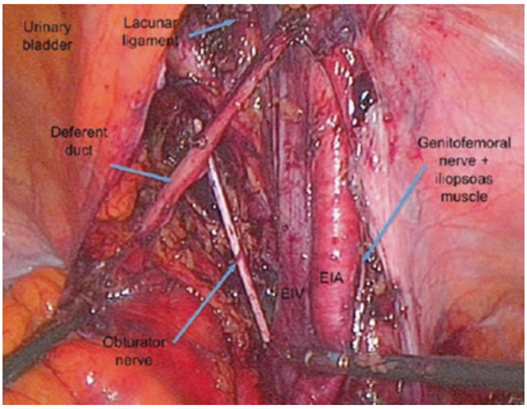

Fig. 12.3 Situs after laparoscopic lymphadenectomy for prostate cancer; *EIV* external iliac vein, *EIA* external iliac artery. The lacunar ligament is the distal extent of pelvic lymphadenectomy

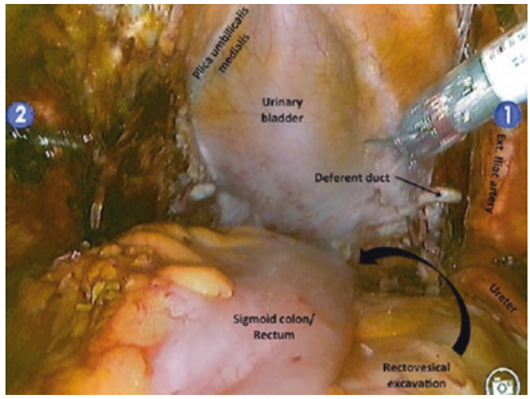

Fig. 12.5 Anatomical landmarks during robotic-assisted laparoscopic cystectomy after the first step of lymphadenectomy

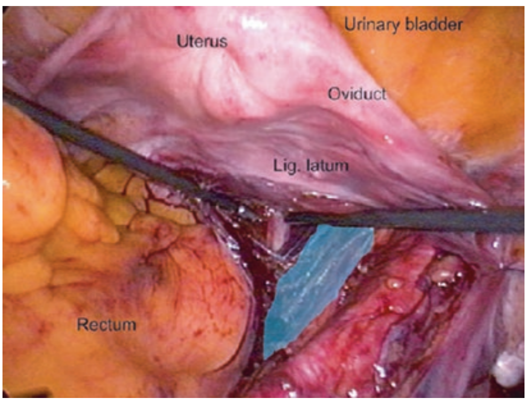

Fig. 12.4 Laparoscopic insight into the female pelvis during sacrocolpopexy. The rectovaginal fold including the inferior hypogastric plexus (*right side*) is marked lucent *blue*

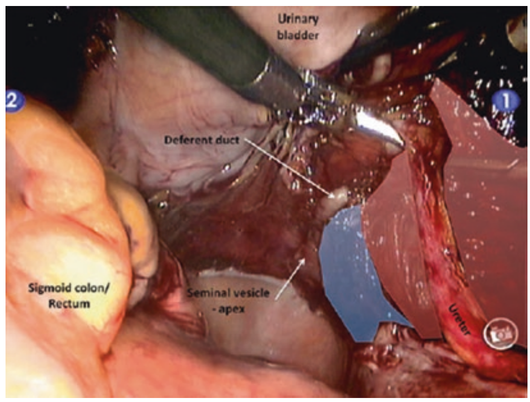

Fig. 12.6 Topographic anatomy during mobilization of the ureter and the vascular pedicles of the urinary bladder (marked lucent *red*) in robot-assisted laparoscopic radical cystectomy; the inferior hypogastric plexus (lucent *blue*) is located medial to the ureter and lateral to the apex of the seminal vesicle

Anatomical Topography of the Male Pelvis

Compared to the female pelvis, in male humans the pelvic bone is narrower and marked by a more protruding sacral promontory resulting in a heart-shaped pelvic entry. The pelvis comprises the urinary bladder, the ureters, the prostate, the seminal vesicles, the deferent ducts, and the rectum. The lowest point of the abdominal cavity between the urinary bladder and the rectum is called the rectovesical excavation (Fig. 12.5). The rectovesical fold borders the excavation laterally and includes the inferior hypogastric plexus (Fig. 12.6). The deferent ducts shape the paravesical fossa by raising a peritoneal fold. The current literature presents an inconsistent description and nomenclature of the subperitoneal fasciae especially on closer inspection of the periprostatic fasciae and the rectoprostatic septum, which separates also the urinary bladder and the rectum starting from the rectovesical excavation ("cul-de-sac"). Comparable to female anatomy, the pelvic fascia also consists of two elements: a parietal layer, which covers the lateral wall of the pelvis, and a visceral layer (clinically "endopelvic fascia") overlaying the pelvic organs. The inter section of both layers is called the tendinous arch of pelvic fascia. It remains still under discussion if the prostates' own fascia separates the gland. The fact of an absent fascia in the apical region of the prostate and the formation of the so-called puboprostatic ligaments by an aggregation of the endopelvic fascia suggest that the visceral layer of the pelvic fascia and the fascia of the prostate correlate. Possibly, muscle fibers (smooth or striated) also contribute to the configuration of the puboprostatic ligaments. Similarly, the configuration of the Denonvilliers' fascia is not clarified in the literature. The anatomical nomenclature utilizes the description rectoprostatic septum as a membranous separation between the rectum and the ventrally located urinary bladder with the prostate. The fascia emerged from two layers of a peritoneal cul-de-sac ranging from the deepest point of the rectovesical excavation to the pelvic floor. Currently, it is assumed that microscopically the rectoprostatic septum consists of two former peritoneal layers, which in the majority of cases cannot be divided bluntly. It is assumed that authors illustrating techniques of fascia separation are referencing the space between Denonvilliers' fascia and the rectal fascia propria (a part of the visceral layer of the pelvic fascia) [2–4, 6–12].

Macroscopic and Microscopic Anatomy of the Urinary Bladder

The urinary bladder is a muscular, distensible organ for urine collection and controlled micturition. Macroscopic anatomy subdivides the urinary bladder into the apex, the corpus, the fundus, and the collum (with the trigone) (Fig. 12.7). The average filling volume ranges between 300 and 500 cm^3. The interureteric crest raised between the obliquely passing ureters characterizes the trigone. The urinary bladder wall is structured into the mucosa (transitional cells), the submucosa, the detrusor muscle (three layers), and the surrounding adipose and connective tissue (Fig. 12.7). A direct adhesion of the mucosa to the submucosa exists in the trigone area; the other parts of the urinary bladder demonstrate a loose connection between these two layers. The detrusor muscle is subdivided into three layers: an external and internal longitudinal muscle layer and an interjacent circular layer. The circular layer does not reach the bladder neck including the trigone. The longitudinal muscle fibers (also forming the Waldeyer's sheath of the ureterovesical junction) in conjunction with the extending longitudinal fibers of both ureters extend below the bladder neck and reach the muscular layers of the urethra. In male humans these structures reach the point of the seminal colliculus.

Table 10.1 gives an overview of pelvic and especially genitourinary arterial blood supply. The urinary bladder generally receives two main branches of each of the internal iliac arteries: the superior vesical artery and the inferior vesical artery (clinically the superior and inferior

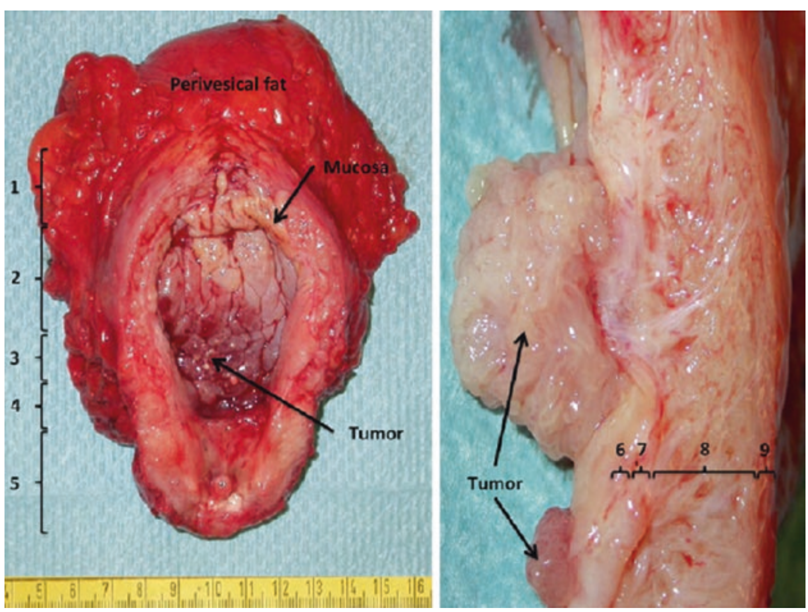

Fig. 12.7 Macroscopic anatomy of the urinary bladder. *Left*: male cystectomy specimen ventrally incised; *1* apex, *2* Corpus, *3* Fundus, *4* Collum/Trigone, *5* Prostate with verumontanum. *Right*: Cross section of cystectomy specimen with muscle bladder cancer; *6* mucosa, *7* submucosa, *8* detrusor muscle (three layers), *9* adventitia with perivesical fat tissue or serosa (peritoneum)

Table 10.1 Pelvic vascularization: main arteries with origin, branches and supplied organs [2]

Artery	Origin	Main branches	Blood supply to (lead structure)
Testicular/ovarian	Abdominal aorta	–	Testes (spermatic cord)/ovaries (suspensory ligament)
Inferior mesenteric	Abdominal aorta	Left colic art	Descending colon
		Sigmoid branches	Sigmoid colon
		Superior rectal art	Rectum
Middle sacral	Abdominal aorta	–	Sacral nerves, coccygeal glomus
Common iliac	Abdominal aorta	External iliac	(Ureter crosses iliac bifurcation)
		Internal iliac	
External iliac	Common iliac	Inferior epigastric	Rectus abdominis muscle (lateral umbilical fold)
		Deep circumflex iliac	Surrounding muscles/structures
		Femoral	Leg (vascular lacuna)
Internal iliac	Common iliac	See below	See below
Iliolumbar	Internal iliac (parietal branch)	…	Iliopsoas and quadratus lumborum muscle, spinal cord
Lateral sacral	Internal iliac (parietal branch)	…	Erector spinae muscles
Obturator	Internal iliac (parietal branch)	Pubic branch	Surrounding tissue (anastomosis to inferior epigastric art.—corona mortis)
		Anterior branch	Anterior adductor muscles
		Posterior branch	Posterior adductor muscles
		Acetabular branch	Femur head
Superior gluteal	Internal iliac (parietal branch)	–	Gluteal muscles (suprapiriform foramen)
Inferior gluteal	Internal iliac (parietal branch)	–	Gluteal muscles (infrapiriform foramen), hip external rotators, ischial nerve
Umbilical	Internal iliac (visceral branch)	Obliterated distal part	(Medial umbilical fold)
		Superior vesical art.	Urinary bladder, prostate, ureter
		Art. of the vas deferens	Vas deferens
Inferior vesical	Internal iliac (visceral branch)	–	Urinary bladder, prostate, seminal vesicles/vagina
Uterine	Internal iliac (visceral branch)	Vaginal branch	Vagina
		Arcuate vessels	Uterus (broad ligament)
		Ovarian branch	Ovary (ovarian ligament)
		Tubal branch	Uterine tube
Middle rectal	Internal iliac (visceral branch)	–	Rectum and surrounding organs
Internal pudendal	Internal iliac (visceral branch)	Inferior rectal art.	Rectum
		Perineal art.	Perineum
		Posterior labial/scrotal branch	Labia/scrotum
		Art. of the bulb of vestibule/penis	Urethra, bulb of vestibule/corpus spongiosum
		Dorsal art. of clitoris/penis	Corpus cavernosum clitoridis/glans penis
		Deep art. of clitoris/penis	Corpus cavernosum clitoridis/penis

… = different small branches, *art*. = artery vesical pedicle). The superior vesical artery descends from a common branch with the former umbilical artery proceeding in the medial umbilical ligament. The inferior vesical artery arises from a common branch of the middle rectal artery. Prostatic branches generally derive from the inferior vesical artery. Venous drainage of the urinary bladder is secured through varying distinct venous plexuses on both sides of the vesical base. These venous vessels communicate extensively with the prostatic venous plexus in male and the vaginal venous plexus in female humans.

A complex neural system facilitates a correct functioning of the urinary bladder to control urine storage, continence, and micturition. Interactions between independent reflex pathways and arbitrary actions are necessary for a precise process. Both the autonomous and the somatic nervous system contribute to lower urinary tract innervations to facilitate bladder filling and emptying. Table 10.2 systematically illustrates the nerves and plexus of the pelvis including their neural function.

Parasympathetic and sympathetic nerve fibers reach the urinary bladder and adjacent organs through the inferior hypogastric plexus (pelvic plexus). Anatomically, the inferior hypogastric plexus derives from the singular superior hypogastric plexus, which reaches the pelvis proximally and medial to the crossing of the distal ureter and the common iliac artery on both sides (Fig. 12.8). The inferior hypogastric plexus is part of the rectouterine or rectovesical fold as described previously (Figs. 12.4 and 12.6). The plexus extends laterally to the rectum, the vagina (in females, Fig. 12.9), the bladder neck, and the seminal vesicles (in males) in a sagittal direction (Fig. 12.10). An allocation of nerve fibers within the plexus to innervated targets seems to be possible. Roughly, the anterior part is responsible for urogenital innervations, and the posterior part serves the rectum.

The sympathetic fibers of the inferior hypogastric plexus arise from two superior retroperitoneal sympathetic chains called sacral splanchnic nerves, which pass topographically through the superior hypogastric plexus. Sympathetic excitations lead to urinary bladder filling based on an inhibition of the detrusor muscle and a stimulation of the smooth muscle sphincter cells at the bladder neck and the urethra. Parasympathetic fibers within the pelvic splanchnic nerves from the sacral spinal cord (S2-S5) exit through the foramina of the sacral bone and reach the bladder by passing the inferior hypogastric plexus. Both urinary bladder sensation (and presumably of the proximal urethra as well) and contraction of the detrusor muscle are mediated through the parasympathetic nervous system. The pudendal nerve is part of the somatic nervous system and innervates the striated parts of the external urethral sphincter among others. After distribution of the lumbosacral plexus, the pudendal nerve leaves the pelvis by surrounding the ischial spine and proceeds through the pudendal canal (Alcock's canal) at the bottom of the inferior pubic bone. Stimulation results in increased contraction of the external urethral sphincter and adjacent segments of the levator muscle. Complex interconnections on different sections of the central nervous system including the Onuf's nucleus (located in the sacral part of the spinal cord), the periaqueductal gray, the pontine micturition center, and the frontal lobe of the cerebrum are involved in the process of filling and emptying [2–4, 13, 15–17].

Anatomic Abnormalities of the Urinary Bladder

Unexpected intrapelvic anatomic anomalies or alterations have not been exposed preoperatively in all cases depending on the treated disease and the guideline-based extend of preoperative staging diagnostics. The following changes in human pelvic anatomy should be expected more or less frequently. Urinary bladder diverticula can be subdivided into congenital and acquired forms. The prevalently bilateral para-ureteral diverticulum (Hutch diverticulum) is most often congenital and results in the majority of cases in vesicoureteral reflux. Acquired diverticula occur due to infravesical obstruction and can develop to considerable dimensions. Anomalies of urachal obliterations could be found only in rare cases.

Table 10.2 Main nerve pathways of the pelvis [2]

Nerve	Spinal origin	Intermediary trunk	Innervation
Iliohypogastric	L1	Lumbar plexus	M: transversus abdominis and internal oblique muscle
			S: hip and lower abdominal wall
Ilioinguinal	L1	Lumbar plexus	M: abdominal muscles
			S: inguinal region, penile root, proximal medial femoral skin, scrotum/labia majora
Genitofemoral	L1/2	Lumbar plexus	M: cremaster muscle
			S: tunica vaginalis, tunica dartos, hiatus saphenus
Lateral femoral cutaneous nerve	L2/3	Lumbar plexus	M: –
			S: anterolateral femoral skin
Femoral nerve	L2/3/4	Lumbar plexus	M: iliopsoas/pectineus/sartorius/quadriceps femoris muscle
			S: anteromedial femoral skin, anteromedial crural skin, medial forefoot skin
Obturator	L2/3/4	Lumbar plexus	M: external obturator/pectineus/adductor brevis/adductor longus et magnus et minimus/gracilis muscle
			S: distal medial femoral skin
Inferior gluteal	L4/L5/S1	Lumbosacral plexus	M: gluteus maximus muscle
			S: –
Posterior femoral cutaneous	S1/2/3	Sacral plexus	M: –
			S: gluteal skin, posterior scrotal/labial skin
Ischial	L4/S1/S2/S3	Lumbosacral plexus	M: ischiocrural and forefoot muscles
			S: crural and forefoot skin (except medial)
Pudendal	(S2)/S3/S4	Sacral plexus	M: levator ani muscle, external urethral sphincter and urogenital diaphragm
			S: skin above the ischial tuberosity, labia (majora and) minora and clitoris, penile skin with glans and prepuce
Coccygeal	S5/Co1	Coccygeal plexus	M: –
			S: anococcygeal skin
Sacral splanchnic	Sympathetic trunk	Superior hypogastric plexus	Sympathetic: urinary bladder, internal sphincter complex, ejaculation reflex
Pelvic splanchnic	S2/S3/S4	Inferior hypogastric plexus—prostatic plexus—cavernous nerve	Parasympathetic: erectile function

M motoric, *S* sensory

Four different types of malformation can be distinguished: (1) persistent urachus with continuous urine leakage, (2) urachal cyst located in the course of the medial umbilical ligament, (3) umbilical-urachus sinus with obliteration toward the urinary bladder, and (4) vesicourachal diverticulum with obliteration toward the umbilicus [2, 3, 18].

Pelvic Floor

Two distinct fibromuscular layers complete the inferior pelvic aperture: the pelvic diaphragm and the urogenital diaphragm. The pelvic diaphragm consists of the coccygeal muscle and the levator ani muscle, which in turn consists of the following structures, named according to their

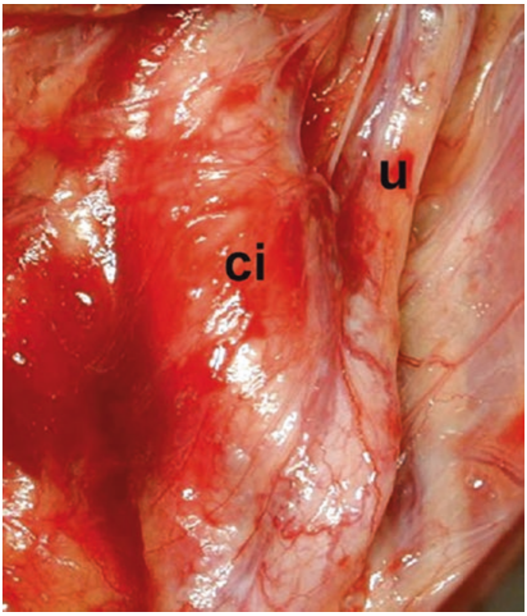

Fig. 12.8 Nerve course of the sympathetic fibers deriving from the superior hypogastric plexus (*ci* common iliac artery, *u* ureter) (Schilling et al. [13])

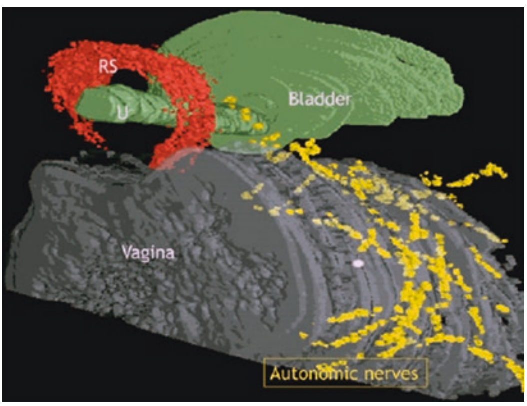

Fig. 12.9 Fetal female pelvic study illustrates 3D distribution pattern of autonomic nerves between the rhabdosphincter, the urethra, the urinary bladder, and the vagina (Colleselli et al. [14])

origins and insertions: the pubococcygeal muscle, the iliococcygeal muscle, and the puborectalis muscle. The endopelvic fascia forms the superior layer of the levator ani fascia, and a separate layer covers the caudal part; the pelvic insertion of the levator ani muscle is called the tendinous arch of levator ani. The levator ani

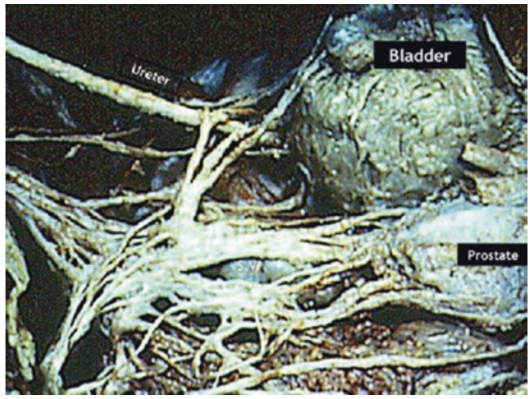

Fig. 12.10 Human male cadaver study to illustrate topographical relation of the complex intrapelvic nerve plexus to the urinary bladder, the ureter, the male adnexa, and the prostate. The superior vesical artery crosses the ureter almost orthogonally (Colleselli et al. [14])

muscle forms an archway-shaped opening for the anus and urethra in males and the anus, the vagina, and the urethra in females. The innervations derive principally from the sacral plexus (S3 and S4); some nerve fibers reach the puborectalis muscle via the pudendal nerve. Even though the contributions of the shape topography and the contraction of the pelvic diaphragm to anal continence seem to be proven, it is still unclear to what extent these anatomical structures also affect urinary continence. Recent publications have reported the muscular independence between the pelvic diaphragm and the striated external urethral sphincter, whereas an association by connective tissue forming a tendinous connection starting from the inferior part of the external urethral sphincter in females could be demonstrated. Due to these interactions, authors suggest the necessity of an intact pelvic diaphragm for urinary continence.

The urogenital diaphragm is not part of the anatomical nomenclature, and the exact anatomical and histomorphological constitution is still under investigation. Anatomical atlases report that the urogenital diaphragm consists of the deep transverse perineal muscle (less developed in females) with a superior and inferior urogenital fascia. Additionally, the superficial transverse perineal muscle inserting at the perineal body (central tendon of the perineum), the striated external urethral sphincter, and the surrounding connective tissue completes the traditional view of the urogenital diaphragm. Some authors report the existence of a deep transverse perineal muscle, but most of the recent studies could not verify this conclusion. The urogenital diaphragm is described as layers of connective tissue embedding the external urethral sphincter in conjunction with the perineal body, the inferior pubic bone, and the superficial transverse perineal muscle. The internal pudendal artery and the pudendal nerve are located directly below the urogenital diaphragm. The bulbourethral glands (Cowper's glands) are situated laterally to the membranous urethra integrated inside the urogenital diaphragm [2, 3, 19–25].

Male Urethra

The male urethra is subdivided into the intramural preprostatic urethra at the bladder neck, the prostatic urethra, the membranous urethra, and the spongy urethra. Transitional cells form the mucosa of the proximal parts, whereas the distal section toward the navicular fossa is marked by a stepwise transition over stratified columnar to stratified squamous cells. The muscular layer is subdivided into an inner longitudinal, an intermediate circular, and an inconsistently described outer longitudinal stratum. The bulbourethral artery originating from the internal pudendal artery provides blood supply and enters the spongy urethra at the level of the penile bulb [2–4].

Female Urethra

The female urethra measures about 4 cm starting from the urinary bladder neck to the vaginal vestibule. The muscular layer consists of an inner longitudinal and a surrounding circular oriented stratum. Figure 12.11 illustrates the innervations and blood supply of the female urethra, which is guaranteed by the internal pudendal artery and the pudendal nerve [2–4].

Sphincter Mechanisms

The voluntary, striated, external urethral sphincter (rhabdosphincter) located in the urogenital diaphragm and the autonomous, smooth internal sphincter (lissosphincter) located in the bladder neck have been reported to be responsible for urinary continence in the past. Extensive investigation led to substantial change of the anatomical and functional understanding of the sphincter complex (Fig. 12.12). Although there is discussion about the detailed anatomical formation and the interaction, three components of the sphincter

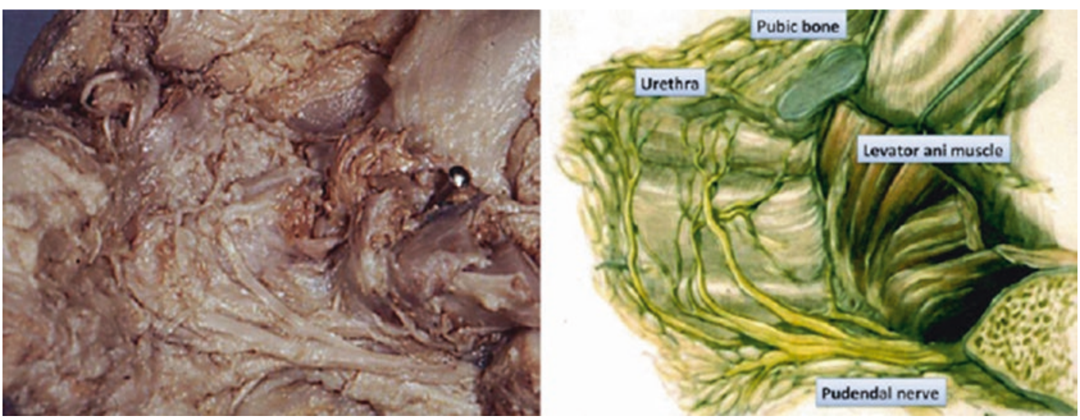

Fig. 12.11 Human female cadaver study illustrating the pudendal nerve arising from the Alcock's canal to innervate the distal third of the urethra including branches to the rhabdosphincter (Colleselli et al. [14]; additional annotations have been made for clarification)

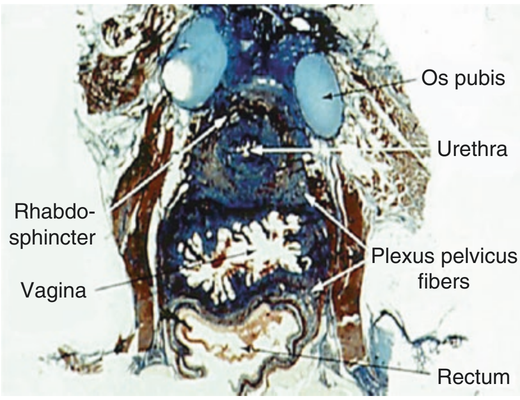

Fig. 12.12 Fetal female pelvis illustrating the omega-shaped rhabdosphincter surrounding the urethra and the topographical location of pelvic plexus (Colleselli et al. [14])

complex are commonly accepted: the smooth detrusor muscle fibers of the bladder neck including the trigone, the intrinsic smooth muscle fibers of the urethral wall, and the external urethral sphincter.

The Bladder Neck Component

The existence of an isolated, circular oriented smooth muscle sphincter at the internal urethral orifice has been denied by different authors over the last two centuries, regardless many anatomical atlases still illustrate a typical inner urinary bladder sphincter. In fact, a complex network of smooth muscle strands is formed at the bladder outlet, where detrusor muscle fibers condense toward the trigone, longitudinal fibers proceeding from the ureteral orifices and smooth intrinsic fibers of the urethral wall arrange a muscular compartment innervated by the autonomic nervous system. In male humans, muscle fibers originating from the ureteral orifices distend downward into the verumontanum.

The Urethral Wall Component

The smooth muscle fibers of the urethral wall are integrated continuously from the bladder neck component into the urethral closure mechanism. The urethral muscular element consists of inner longitudinal and surrounding circular oriented muscle fibers. Inconsistently, an outer longitudinal muscular layer has been described. Also these smooth muscle fibers receive autonomic innervations (Fig. 12.11).

The External Urethral Sphincter

To date, a generally accepted anatomical and functional concept of the external urethral sphincter complex is still outstanding. Consensus exists regarding the three dimensional profile of the external urethral sphincter, which is described to be omega or horseshoe shaped in male as well as in female humans (Fig. 12.12). Consequently, muscle fibers are located at the anterior and lateral part of the urethra. Fibrous tissue completes the horseshoe shape dorsally by an interconnection of the posterior muscular ends of the external urethral sphincter. It is under discussion if the external urethral sphincter is actually part of the urogenital diaphragm and hereby embedded into the doubtfully existing deep transverse perineal muscle. More and more it becomes obvious that the external urethral sphincter should be interpreted as an independent complex, which is supported by only fibrous connection to the surrounding tissue, especially the pelvic diaphragm with the puborectalis muscle. Similarly, the vertical extent and the histological constitution of the external urethral sphincter are under intensive investigation. In male humans it is assumed that the striated muscle fibers of the pronounced anterior part of the sphincter disperse below the puboprostatic ligaments over the anterior face of the prostate. A communication of the striated muscle fibers with structures of the urinary bladder neck is still not clarified. In females it could be demonstrated that parts of the striated external sphincter could only be found in the two distal thirds of the urethra. It has been well established for a long time that striated muscle fibers mainly participate in the configuration of the external sphincter. Regarding functional aspects the external sphincter has to secure continence continuously by a static closure pressure as well as during stress episodes with rapidly increased demand of urethral obstruction. The existence of two specified striated muscle fibers, "slow twitch fibers" for basal pressure and "fast twitch fibers" for rapid pressure increases, as well as the existence of a smooth muscle component ("lissosphincter") located within the main part of striated fibers (named the internal urethral sphincter) are two possible explanations to fulfill the intention of continence. The pudendal nerve comprises the axons for somatic innervations of the voluntary susceptible striated external sphincter (Fig. 12.11). Whether autonomous fibers deriving from the inferior hypogastric plexus with potential impact after nerve sparing ablative pelvic surgery are involved in the sphincter innervations is still under investigation [2–4, 9, 14, 19, 21, 22, 24–27].

Summary

Robotic-assisted surgery of the pelvis facilitates above all a stereoscopic and more detailed view of anatomical structures, which could not be realized by the naked human eye during open surgery. Therefore, robotic-working surgeons benefit especially from submacroscopic and microscopic anatomical knowledge to reach the optimal oncological and functional outcome for their patients. Special attention has to be paid to the distinct vascular and neural structures with the most pronounced impact on urinary continence and erectile function.

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13

Surgical Anatomy of the Prostate

Arnauld Villers and Jochen Walz

Introduction

Clear understanding of the periprostatic fascia helps in identifying the correct planes of surgical dissection and in communication between surgeons. Results are related to the identification of the multilayered prostatic fascia (PF), which permits definition of dissection planes for complete oncologic excision of the prostate and preservation of both the external urinary sphincter responsible for urinary continence and the autonomic nerves responsible for erectile function and urinary control [1]. Recent updates provide additional, detailed information about the surgical anatomy [2] and terminology [3] of the prostate and adjacent tissues involved in RP and were incorporated in this chapter.

Pelvic Fasciae, Parietal and Visceral, and Their Surgical Importance

General Considerations

The pelvic fasciae are either parietal or visceral. The visceral fascia comprises the connective fatty tissue, with neurovascular supply located medial to the parietal/pelvic fasciae. It covers and is adherent to all surfaces of bladder, prostate, seminal vesicles, rectum, and pudendal vasculature. Its thickness varies according to the amount of vessels and nerves it contains. Consequently, this so-called visceral fascia is not a discrete structure but rather a connective and mainly adipose thick structure which does not fulfill the fascial definition. A fascia is defined as a discrete organized structure which can be grasped, identified on dissection, and separated as a whole from adjacent tissues. It has a function of covering, of enveloping membrane. It is made of connective layers of mesenchymal tissue (muscle and fibrous fibers). It is different from a sheath of adipose tissue surrounding neurovascular structures (as in the retroperitoneum or pelvic spaces). Surgical anatomy is based on gross tissue identification.

The parietal fascia, e.g., endopelvic fascia, fulfills the fascial definition. It can be divided sharply and released as a whole from adjacent structures. Whereas referring to this adipose multilayered tissue of the so-called « visceral fascia » as a fascia is not very convincing, it cannot be released as a whole from adjacent structures since it is adherent to the visceral pelvic organs such as bladder wall or prostatic stroma without entering into their muscular and fibrous fibers stroma. In that sense, one can refer to the so-called visceral fascia as an adipose meso- or visceral fibrofatty sheath containing neurovascular supply to intrapelvic organs and corpora cavernosa. However, a consensus in the surgical litter-

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_13

ature is in favour of using the word fascia for visceral adipose multilayered periprostatic tissue (Figs 13.1, 13.2, 13.3, 13.4, 13.5, 13.6 and 13.7).

Parietal Pelvic Fasciae

The fascial tendinous arch of the pelvis (FTAP) (arcus tendineus fasciae pelvis, TA) results in a thickening of parietal and visceral components of the pelvic fascia and stretches from the pubovesical (puboprostatic) ligaments to the ischial spine. When the levator (parietal or endopelvic) fascia is incised just lateral to the fascial tendinous arch of the pelvis, the bare levatormuscle that overlies the obturator internus above and the ischioanal fossa below appears laterally.

Visceral Prostatic Fasciae

The fascia covering the glandular surface of the prostate has been referred to as lateral pelvic fascia by Costello et al. [4], Takenaka et al. [5], and in the past by Walsh and Partin [6]. Myers and Villers [7], Stolzenburg et al. [8], and Tewari et al. [9] called the fascia next to the prostate the periprostatic fascia (PPF); Graefen et al. [10] and Budaus et al. [11], the parapelvic fascia; and Menon et al. [12], Secin et al. [13], and, more recently, Nielsen et al. [14], the prostatic fascia. Located underneath the remnant levator fascia on the lateral surfaces of the prostate, the prostate visceral fascia where it is multilayered contains fat, smooth muscle, and collagen fibers. It is easier to identify grossly when nerves and vessels run among its layers. It consists of three parts (according to its location):

Anterior prostatic fascia. This element fused to the endopelvic fascia is associated with the anterior surface of the prostate where it covers the detrusor apron, contains the dorsal vein plexus, and is fused in the midline with the anterior fibromuscular stroma of the prostate. A recent study by Ganzer et al. demonstrated that 37 and 30% of the cross-sectional urethral

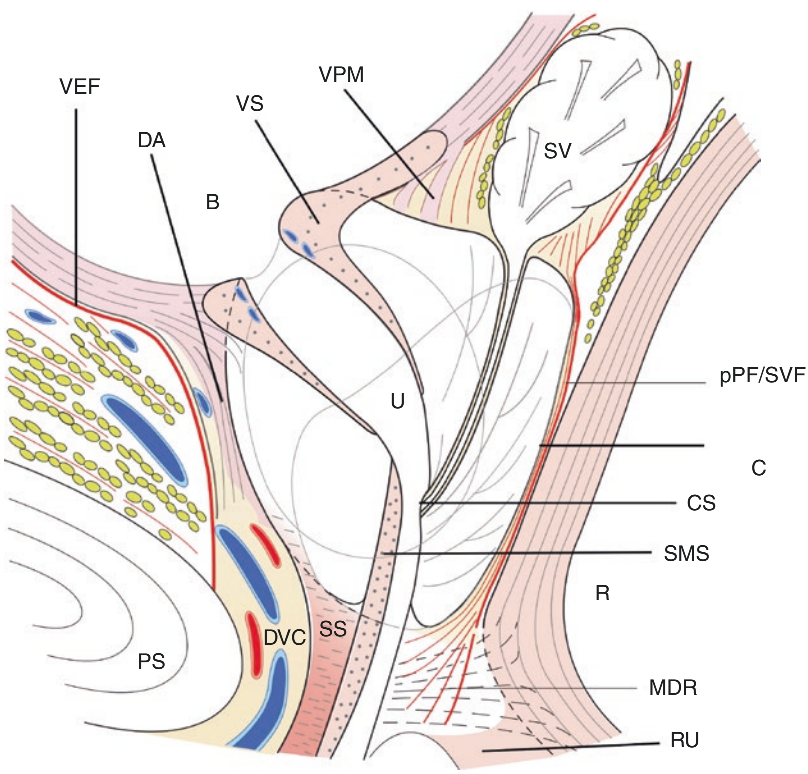


Fig. 13.1 Midline sagittal section of prostate, bladder, urethra, and striated sphincter. *B* bladder, *C* capsule of prostate, *CS* colliculus seminalis (verumontanum), *DA* detrusor apron, *DVC* dorsal vascular complex, *MDR* medial dorsal raphe, *PS* pubic symphysis, *pPF/SVF* posterior prostate fascia/seminal vesicle fascia (Denonvilliers' fascia), *R* rectum, *RU* recto-urethralis muscle, *SMS* smooth muscle sphincter, *SS* striated sphincter, *SV* seminal vesicles, *U* urethra, *VEF* visceral endopelvic fascia, *VPM* vesico-prostatic muscle

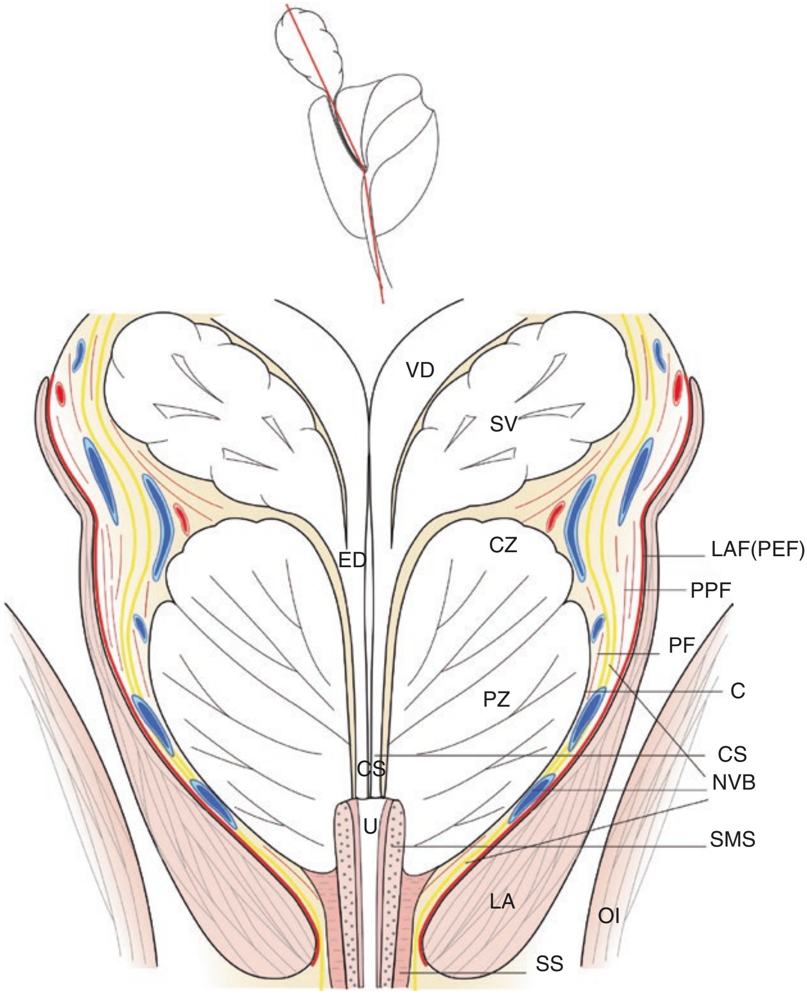


Fig. 13.2 Coronal section of prostate, sphincteric urethra, peri-prostatic fascias, and associated musculature. *C* capsule of prostate, *CS* colliculus seminalis (verumontanum), *CZ* central zone, *ED* ejaculatory duct, *LA* levator ani muscle, *LAF* levator ani fascia, *NVB* neurovascular bundle, *OI* obturator internus muscle, *PF* prostate fascia, *PPF* periprostatic fascia, *PZ* peripheral zone, *SS* striated sphincter, *SMS* smooth muscle sphincter, *SV* seminal vesicle, *U* urethra, *VD* vas deferens

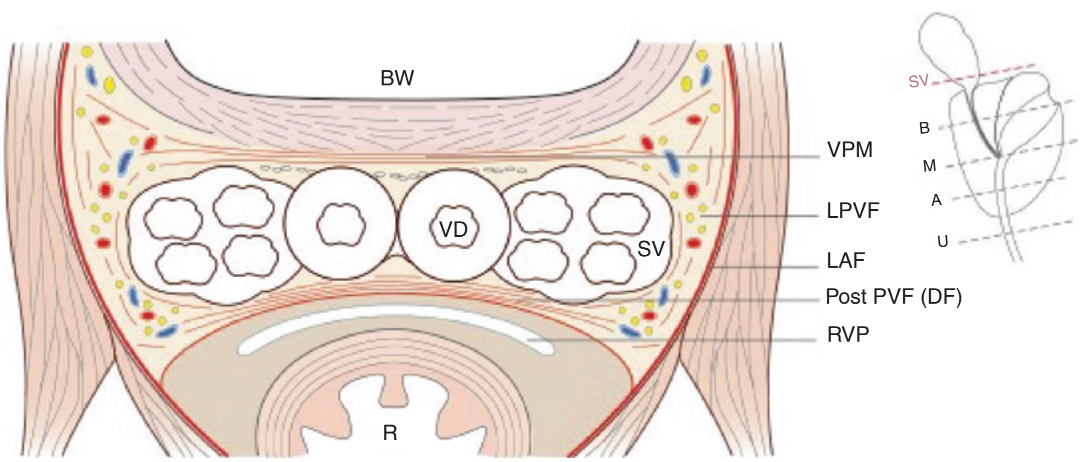


Fig. 13.3 Transverse section of seminal vesicles, bladder and surrounding fascias. *BW* bladder wall, *VD* vas deferent, *SV* seminal vesicles, *LA* levator ani, *LAF* levatorfascia, post*PPF/DF* posterior prostatic fascia/seminal vesicle fascia (Denonvilliers' fascia), *R* rectum, *RVP* rectovesical pouch, *VPM* vescio prostatic muscle

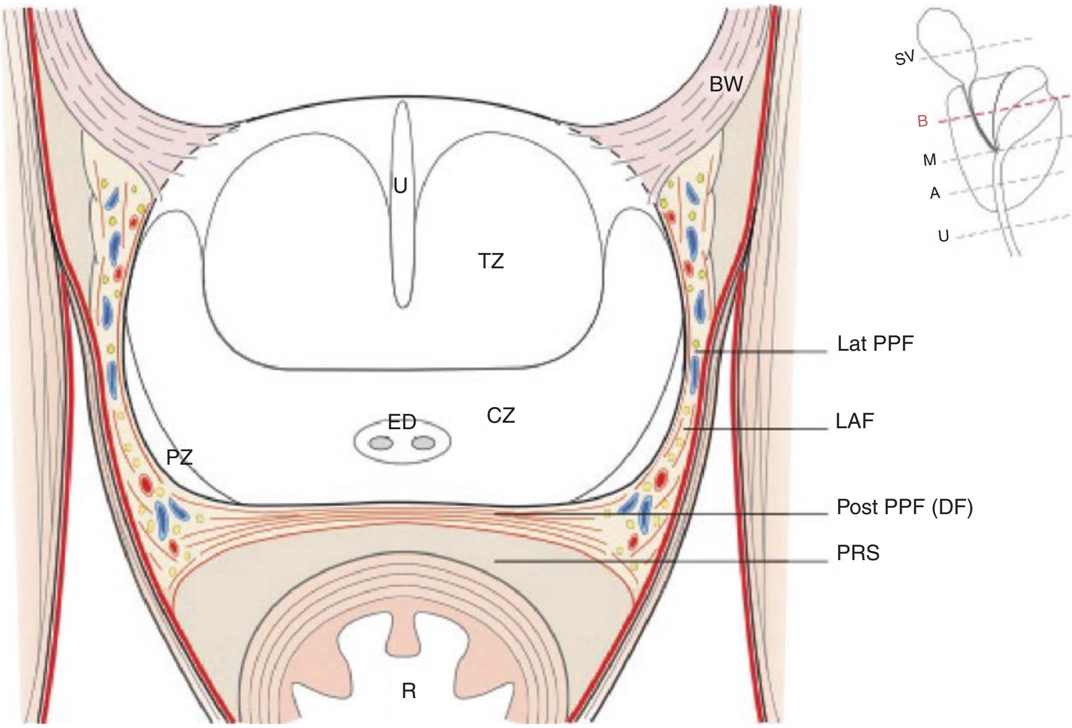


Fig. 13.4 Transverse section of prostate and periprostatic fascias at the level of the prostatic base. *BN* vesical sphincter, *U* urethra, *BW* bladder wall, *ED* ejaculatory ducts, *CZ* central zone, *PZ* peripheral zone, *TZ* transition zone, *LAF* levatorfascia, post*PPF/DF* posterior prostatic fascia/seminal vesicle fascia (Denonvilliers' fascia), *PRS* prerectal space, *R* rectum

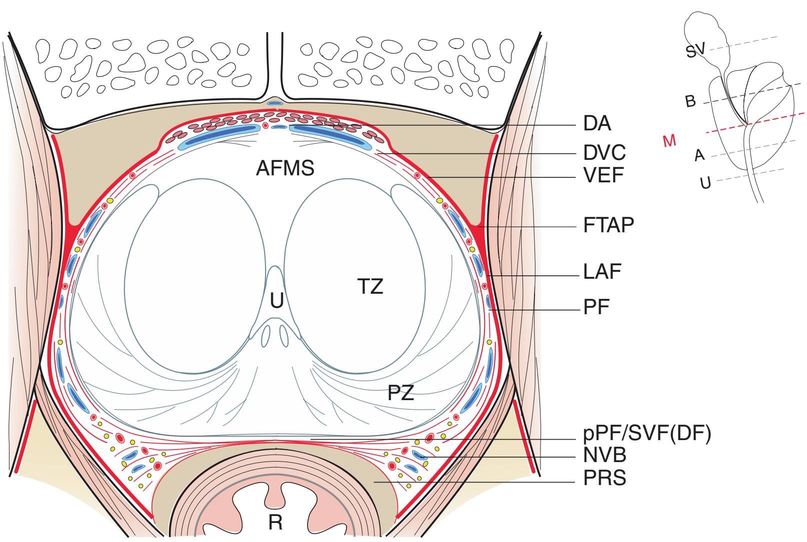


Fig. 13.5 Transverse section of prostate and periprostatic fascias at the level of mid prostate. *ED* ejaculatory ducts, *AFMS* anterior fibromuscular stroma, *PZ* peripheral zone, *TZ* transition zone, *U* urethra, *DA* detrusor apron, *DVC* dorsal vein plexus, *EF* endopelvic fascia, *FTAP* fascial tendinous arch of the pelvis, *LA* levator ani, *LAF* levatorfascia, *NVB* neurovascular bundle, *latPPF* lateral prostatic fascia, p*PF/SVF* posterior prostatic fascia/seminal vesicle fascia (Denonvilliers' fascia), *PRS* prerectal space, *R* rectum

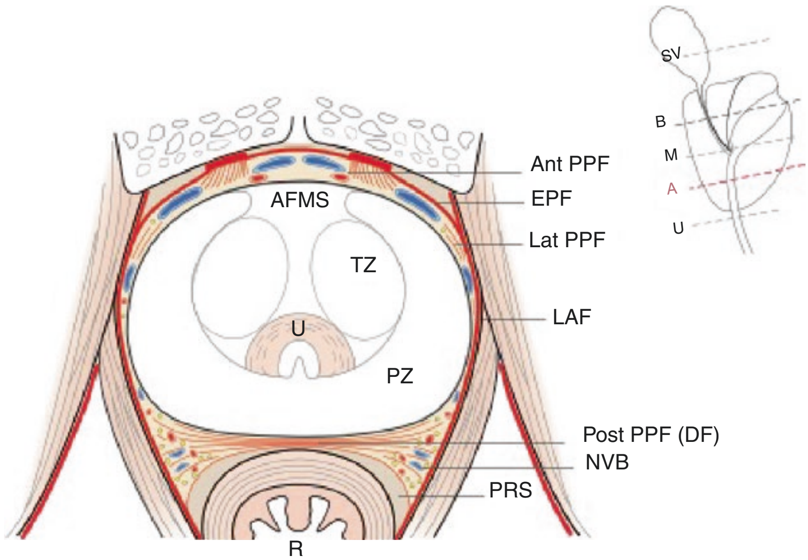


Fig. 13.6 Transverse section of prostate and periprostatic fasciae at the level of the apex. *AFMS* anterior fibromuscular stroma, *PZ* peripheral zone, *TZ* transition zone, *U* urethra, *EF* endopelvic fascia, *LA* levator ani, *LAF* levatorfascia, *NVB* neurovascular bundle, *latPPF* lateral prostatic fascia, post *PPF/DF* posterior prostatic fascia/seminal vesicle fascia (Denonvilliers' fascia), *R* rectum, *PRS* prerectal space

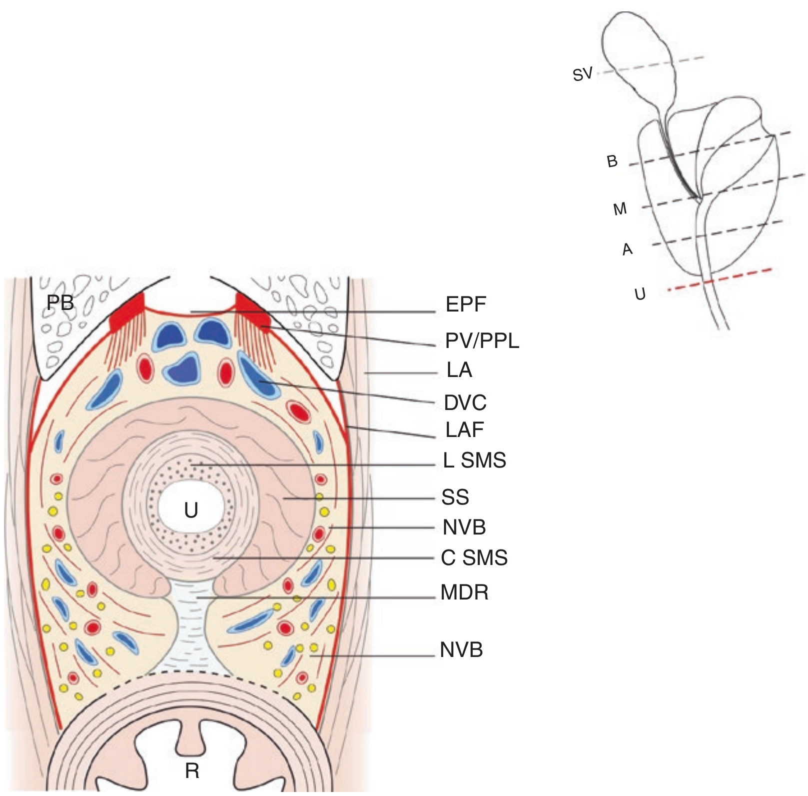


Fig. 13.7 Transverse section of urethra at the level striated urethra. *PV/PPL* pubovesicle/puboprostatic ligaments, *EPF* endopelvic fascia, *LA* levator ani, *LAF* levatorfascia, *DVC* dorsal vein plexus, l *SMS* longitudinal smooth muscle sphincter, *SS* rhabdosphincter, *LatUF* lateral urethral fascia, c *SMS* circular smooth muscle sphincter, *MDR(RU)* median dorsal raphe (recto urethralis), *NVB* neurovascular bundle, *R* rectum

sphincter surface area are laterally overlapped by the dorsal vein plexus at the prostate apex and 5 mm distal to the apex, respectively. The dorsal vein plexus covers the urethral sphincter tissue laterally and dorsally [15].

Lateral prostatic fascia. Medial to the levator-fascia the lateral glandular surface of the prostate is covered by a multilayered fascia. Its layers extend from the anterolateral prostate, then posteriorly or dorsally to embrace the neurovascular bundle with the outer levatori ani fascia passing lateral to the neuro vascular bundle.

Posterior prostatic fascia and s*eminal vesicular fascia and* known eponymically as Denonvilliers' fascia (septum rectovesicale, TA). The foregoing terminology does not capture the continuous sweep of the fascia from the posterior surface of the prostate superiorly over the posterior surfaces of the seminal vesicles (Fig. 13.1). We propose herein SVF and pPF to describe anatomically this posterior fascia, which is neither rectal nor a septum. The SVF and pPF are separated from the rectal fascia propria by a prerectal cleavage plane, which trails distally from the variable distal end point of the rectovesical pouch. This cleavage plane is a remnant of the two peritoneal layers that fused and disappeared before birth. On the posterior surface of the prostate, the SVF and pPF has no macroscopically discernible layers. Distally, the pPF thickens and is demonstrably multilayered just distal to the prostatourethral junction. The pPF extends posterior to the prostate apex and sphincteric urethra and, as a terminal plate ([7, 16]), has direct continuity with the midline raphe ending in the perineal body or central tendon of the perineum.

A work from Muraoka et al. investigated the intraand interindividual variations of the posterior prostatic fascia (PPF) and seminal vesical fascia [17].

The posterior raphe division is not part of radical retropubic procedure. The final posterior cut at the prostatourethral junction is through the "terminal plate" of Denonvilliers' (prostatorectal) fascia. In contrast to the posterior surface of the prostate, the SVF is frequently multilayered over the seminal vesicles (predominance of smooth muscle fibers which are seen grossly), but is, with only very rare exception, a single layer of fascia over the immediate posterior surface of the prostate [16, 18]. It has been suggested to distinguish a part of SVF anterior to the seminal vesicles and a part of SVF posterior to the seminal vesicles. The anterior part has been referred to as vesicoprostatic muscle [13]. Posterolaterally, the neurovascular bundle (NVB) is embedded in the SVF and pPF, and medial to the levator fascia, which passes lateral to the bundle (Fig. 13.4); thus, in axial or transverse histological section, the NVB is bounded by a triangle of fascia as illustrated by Kourambas and colleagues [19]. The radical prostate specimen should be covered with Denonvilliers' fascia particularly at the prostatoseminal vesicular junction because this is a location for the early extraprostatic extension of cancer.

Fascial Surgical Dissection

Definitions of Fascial Dissection

We propose, from an anatomic standpoint with respect to surgical dissection of the prostate, the following:

1. Extrafascial plane of dissection would define the prostate removed with all layers of visceral and parietal fascia present on the specimen (wide resection).
2. Interfascial dissection would define partial fascial thickness removal laterally and posterolaterally, with thin layers of fasial tissue left on the specimen. Grossly, over all the lateral aspect of the specimen, thin fascial layers can be grasped with a forceps, and microscopically some layers of adypocytes and/or connective tissue are always seen adherent to the glandular prostatic surface which is not at the margin. Usually, anteriorly and posteriorly, at the midline where it is fused with the glandular prostate, visceral and parietal fascia are present on the specimen (extrafascial).
3. Intrafascial plane of dissection would define some portion of the visceral PP fascia being absent on the specimen. Grossly, nothing can be grasped with a forceps, and microscopically no layers of adypocytes can be seen outside the glandular prostatic surface which at the margin. Usually, posteriorly, at the midline, pPF (DF) fascia is present on the specimen (extrafascial). Anteriorly, visceral and parietal fascia can be removed with an intrafascial dissection (DVC is nor divided) to preserve continence or for exemple in the perineal approach. Intrafascial dissection carries with it the greatest risk of inadvertent iatrogenic capsular penetrations.

Options of Dissection at the Lateral Aspect of the Prostate (Fig. 13.8)

Surgical aspects of the neurovascular bundle in prostate surgery are detailed in the chapter by Ash Tewari. After the endopelvic fascia is incised just lateral to the FTAP, the levator muscle fibers are displaced laterally to expose the lateral surfaces of the prostate. This levatorfascia remains adherent to the lateral PF of the prostate and extends in a posterior direction continuously over the neurovascular bundle and the rectum and distally over the prostatourethral junction and its surrounding vessels. Some authors have suggested that avoiding incision of the endopelvic fascia during radical prostatectomy, often combined with an intrafascial nerve sparing procedure, might improve early recovery of urinary continence as well as improve postoperative erectilefunction, but definitive evidence has yet to be established.

During interfascial dissection, scissors may progress within the thickness of this visceral sheath, leaving some layers on the gland and some on the side of the parietal fascia. Small perforating vessels and nerves to the prostate are to be divided at that time. The amount of connective tissue layers preserved depends upon the location on the prostate surface and upon the size of the gland. For example, at the anterolateral aspect of the gland the LPP is 2 mm in normal glands and 1 mm in enlarged glands, and once a layer of 0.5–1 mm of areolar fatty and fibrous tissue has been left on the gland surface, the remaining thickness left on the lateral side adherent to the parietal fascia is almost absent or less than 0.5 mm. This safety zone PP fascia covering the specimen reduces the risk of positive surgical margins. This is important because perineural tumor extension has been shown to involve microscopic posterolateral nerves to the prostate in the area of the NVB. This is the main mechanism of extraprostatic extension, and an important factor for positive margins [16, 20, 21].

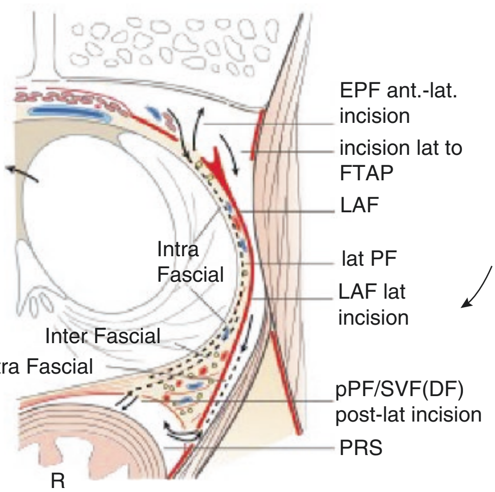


Fig. 13.8 Three different surgical dissection planes are demonstrated intrafascial, interfascial and extrafascial. Transverse section of prostate and periprostatic fascias at the level of the mid prostate. *EPF* endopelvic fascia, *FTAP* fascial tendinous arch of the pelvis, *LAF* levatorfascia, *latPF* lateral prostatic fascia, *pPF/SVF* posterior prostatic fascia/seminal vesicle fascia (Denonvilliers' fascia), *R* rectum, *PRS* prerectal space

Options of Dissection at the Base of the Prostate and Seminal Vesicles

Laparocopic/robotic retrobupic approach may perform an extrafascial (Fig. 13.9) or intrafascial (Fig. 13.10) dissection of the seminal vesicles/vas deferents and of the prostatic base. These options should be part of the surgeon experience and be used according to the risk of positive margins in case of cancer the base with extraprostatic extension to the pPF/SVF (DF) or to the seminal vesicles. Same options of vesical sphincter excision/preservation can also be used.

Options of Dissection at the Apical Aspect of the Prostate

Laparocopic/robotic retrobupic approach may divide the prostate apex, urethra and terminal plate of *pPF/SVF (DF)* from a anterior or posterior approach (Fig. 13.11) [22].

Proximal Vesical Sphincter and Detrusor Apron

The bladder neck is the anatomic area of the urinary bladder outlet and is in continuity with prostatic urethra sphinteric part. It is formed by several structures, including detrusor muscle, the vesical sphincter and is adjacent to proximal prostatic tissue.Loss of anatomic integrity and compromised neural innervation must then contribute to the observation that the vesical sphincter never regains normal sphincteric function in the postoperative period. Attempts to preserve the vesical sphincter during RP may expose cancer if located at the anterior margin [21]. From the vesical sphincter to approximately the mid-anterior commissure of the prostate, the anterior surface of the prostate is cov-

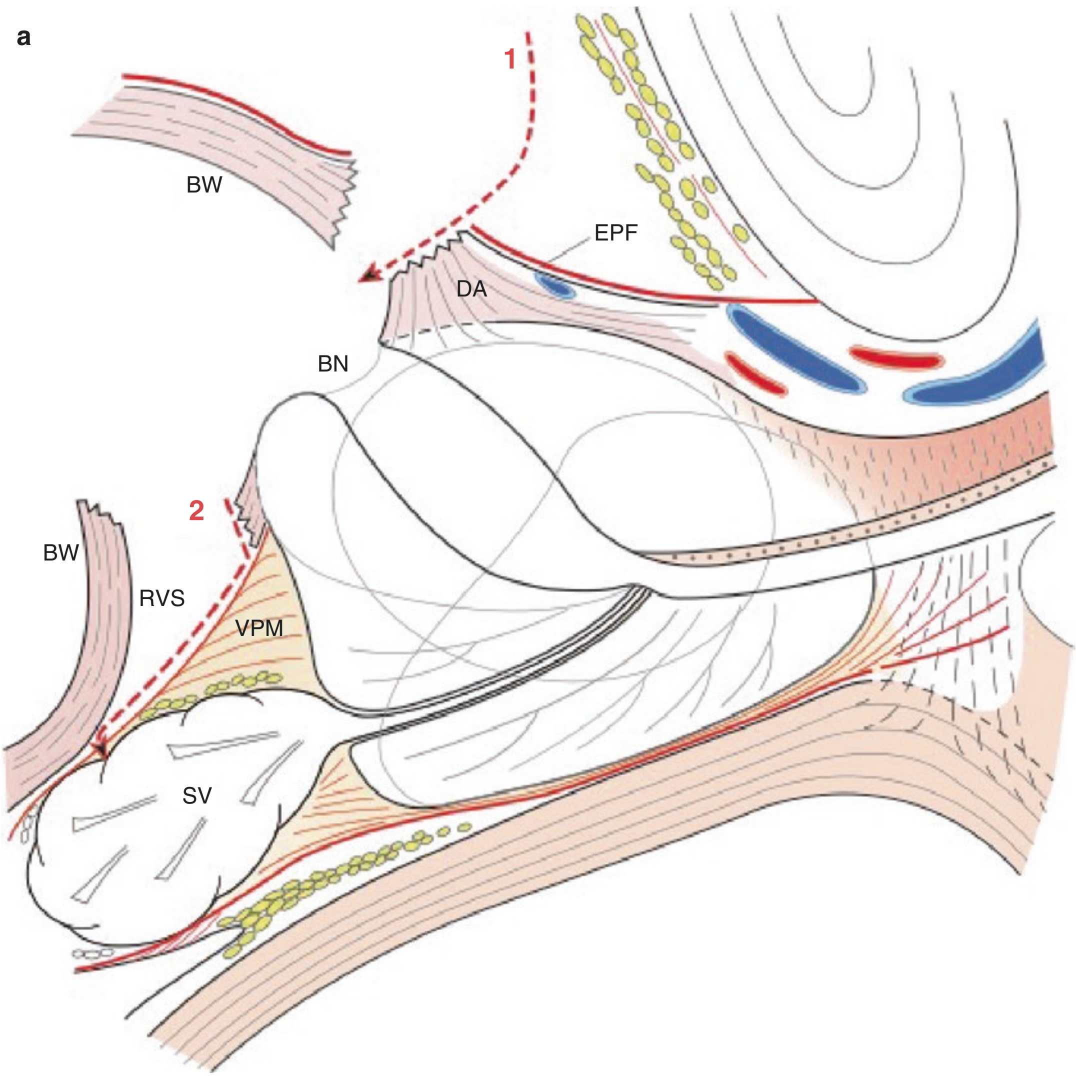
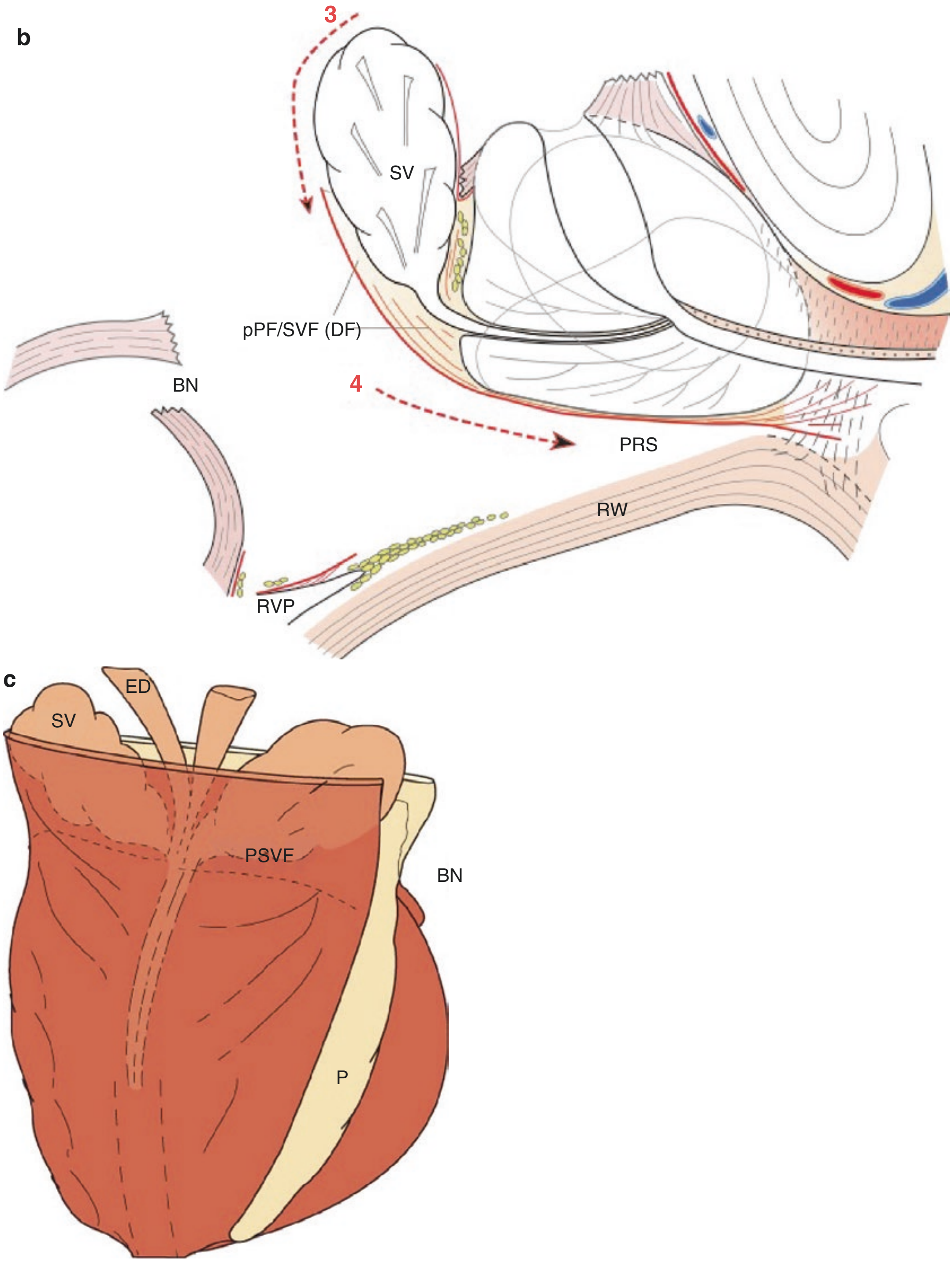


Fig. 13.9 Laparocopic/robotic retrobupic approach showing extrafascial dissection of seminal vesicles/vas deferents and prostatic base. (**a**) Sagittal section. Anterior BN division (1) without sphincteric preservation, extrafascial development of RVS (2) between BW and VPM or anterior SVF. (**b**) Sagittal section. SV tips are exposed and VD are divided (3). Extrafascial development of PRS anterior to RVP and posterior to SVF (DF), at distance from prostatic base (4). (**c**) Posterolaterla 3D view of specimen showing PSVF covering prostatic base and proximal part of SV and VD. *BW* bladder wall, *BN* vesical sphincter, *EPF* endopelvic fascia, *DA* detrusor apron, *PRS* prerectal space, *RW* rectum wall, *RVS* retrovesical space, *RVP* rectovesical pouch, *SV* seminal vesicles, *U* urethra, *VPM* vescio prostatic muscle. *pPF/SVF (DF)* posterior prostatic fascia/seminal vescicle fascia (Denonvilliers' fascia), *P* prostae glandular surface



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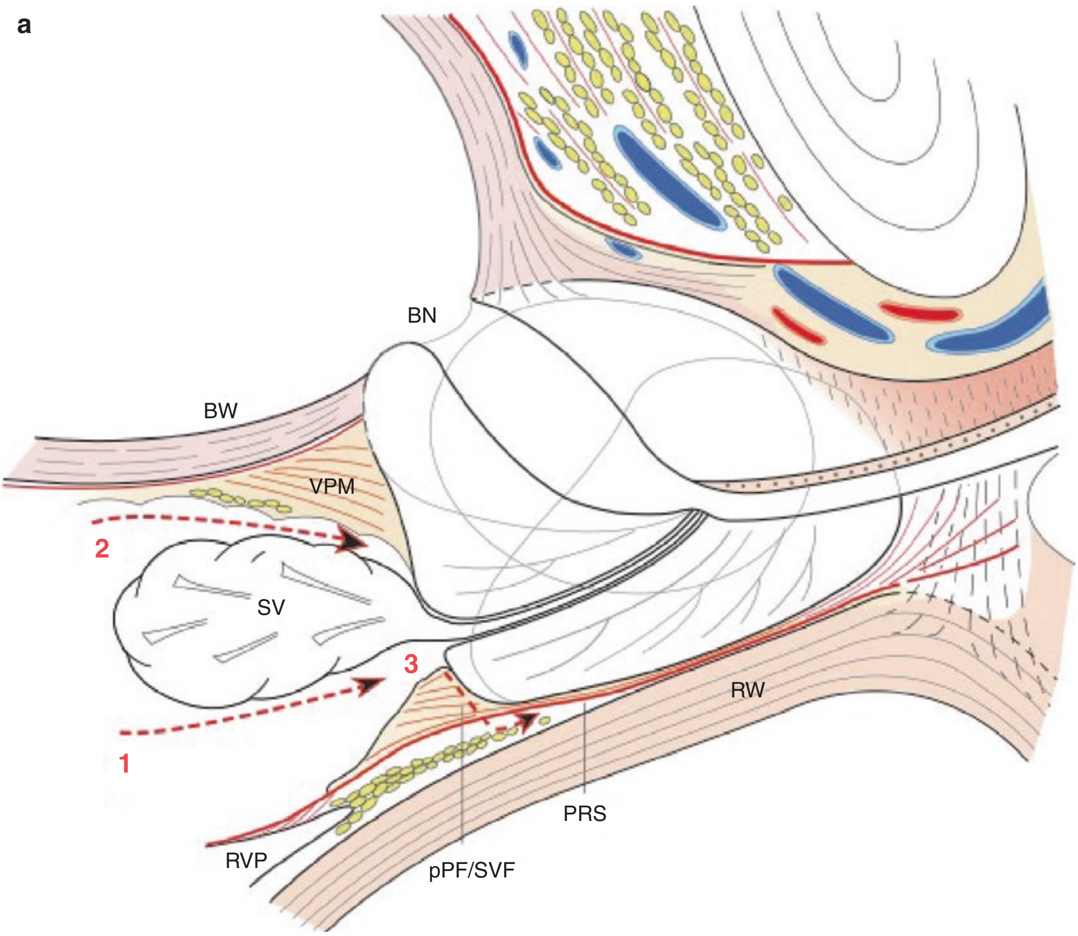
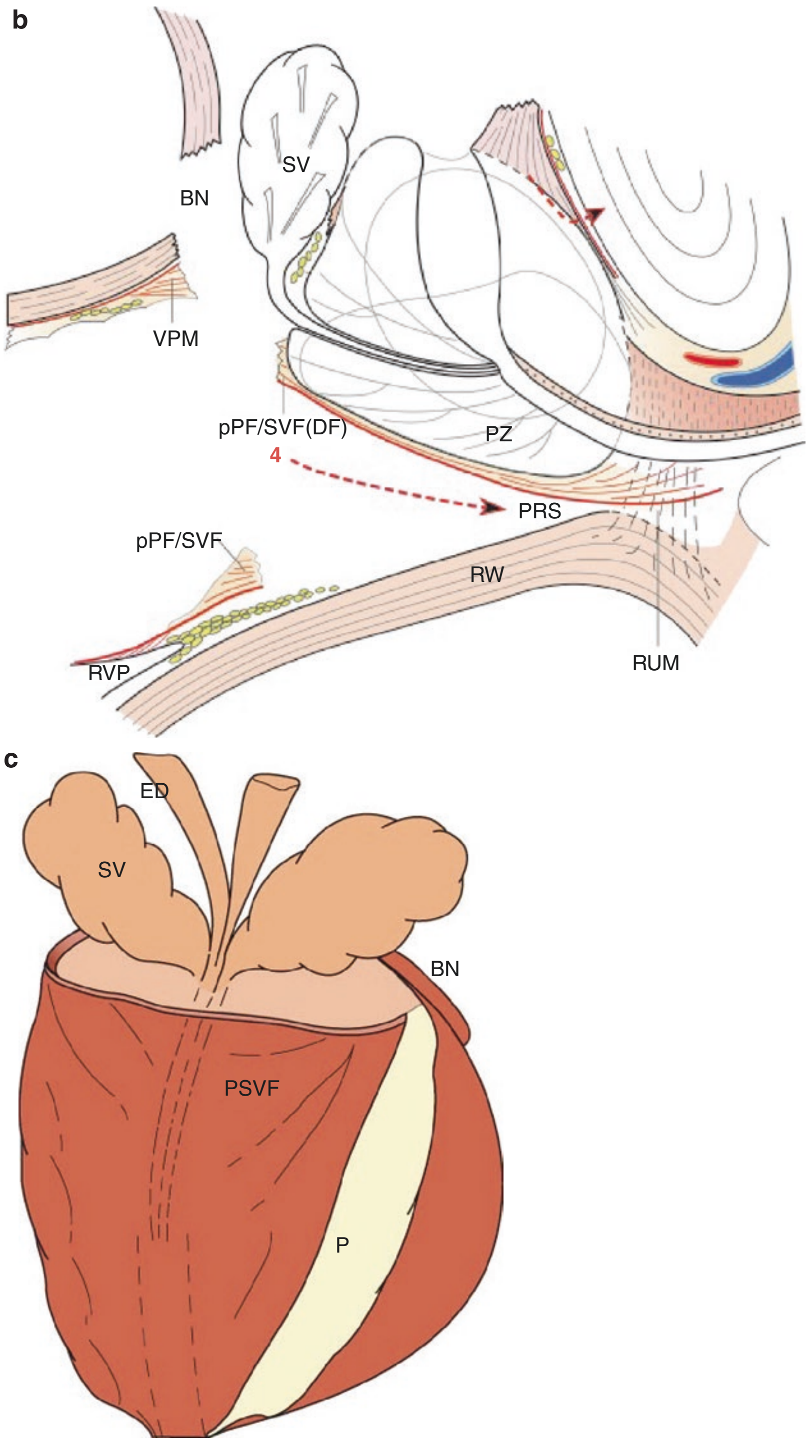


Fig. 13.10 Laparocopic/robotic transperitoneal approach showing intrafascial dissection of seminal vesicles/vas deferents and prostatic base. (**a**) Sagittal section. Peritoneum division, exposition of SV tips VD division. Intrafascial development of SV and VD, posterior to VPM/anterior SVF(DF) (1), and anterior to RVP and posterior SVF(DF) up to the prostatic base (2). (**b**) Sagittal section. After division of BN and SV anterior retraction, division of posterior SVF (DF), at is junction with pPF(DF) (3) to get into the PRS posterior to SVF (DF), and extrafascial develpopment of PRS (4). (**c**) Posterolaterla 3D view of specimen showing PSVF covering prostatic posterior surface but not prostatic base and not proximal part of SV and VD. *BW* bladder wall, *BN* vesical sphincter, *EPF* endopelvic fascia, *DA* detrusor apron, *PRS* prerectal space, *RW* rectum wall, *RVS* retrovesical space, *RVP* rectovesical pouch, *SV* seminal vesicles, *U* urethra, *VPM* vescio prostatic muscle. *pPF/SVF (DF)* posterior prostatic fascia/seminal vescicle fascia (Denonvilliers' fascia), *P* prostae glandular surface

ered by outer longitudinal smooth muscle of the bladder in a layer, a detrusor apron, that extends distally to end as two pubovesical ligaments on either side of the pubic symphysis (Fig. 13.1) [23]. The bunching maneuver over the anterior commissure of the prostate allows hemostasis of the anterolateral pudendal plexus as well as significantly increasing visibility of the adjacent anterolateral surfaces of the prostate for the purpose of subsequent NVB preservation. Furthermore, the bunching facilitates control of any anastomotic veins (and there is pronounced variability) traversing the lateral surface of the prostate from NVBs to the anterolateral plexus [23].



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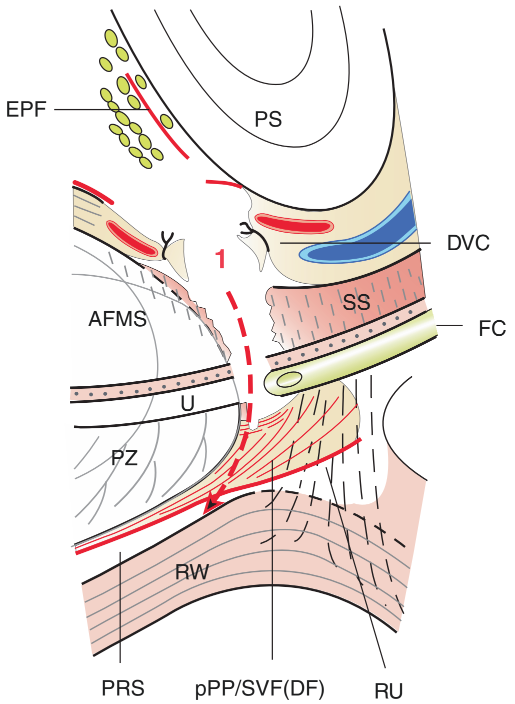

Fig. 13.11 Laparocopic/robotic retrobupic approach showing division of prostate apex, urethra and terminal plate of *pPF/SVF (DF)*(1). *AFMS* anterior fibromuscular stroma, *DVC* dorsal vein plexus, *EF* endopelvic fascia, *DA* detrusor apron, *RU* recto-urethralis, *PS* pubic symphisis, *pPF/SVF (DF)* posterior prostatic fascia/seminal vescicle fascia (Denonvilliers' fascia), *PRS* prerectal space, *PZ* peripheral zone, *RW* rectum wall, *SS* rhabdosphincter, *U* urethra, *FC* foley catheter

Urethral Stump (Sphincteric Urethra) Preservation

Variations in apical configuration of the prostate affect the exit of the sphincteric.

(membranous) urethra from the prostate [23]. Laterally, thickened fascial band components of the DVC called Walsh's pillars or Müller's ischioprostatic ligaments provide insertion for the anterior layer of the rhabdosphincter. Posteriorly, there is a variably thick fibrous tissue raphe rhabdosphincter into which is inserted into the circular component fibers of the horseshoe-shaped rhabdosphincter [24].

Prostatic Surface (Pseudocapsule)

There is no prostatic capsule. The structure that we call the "capsule" is a transversely arranged fibromuscular layer that is recognized at the outermost region of the prostate surface, but [25] at the posterolateral apex or base and at the vesical sphincter. Vessels and nerves, coursing within this adipose tissue, enter into the prostate at these areas; thus, the capsule does not exist due to merging with the visceral fascia, which is adherent to the prostatic stroma which should be called pseudocapsule. These transversely arranged fibromuscular layers contain the spread of cancer [16]. Consequently, there is always peril at the apex. In the absence of BPH it is sometimes difficult to define the prostatourethral junction.

Posterior Raphe (Rectourethralis)

The Posterior raphe is a fibromuscular complex that produces anterior angulation of the anorectal junction as noted above. It consists primarily of a dominant (more substantial) midline component of smooth muscle from the anterior wall of the anal canal coming from below (anoperinealis, TA) and a less dominant midline component of smooth muscle from the anterior wall of the rectum coming from above (rectoperinealis, TA). These two components then converge from below and above, respectively, and insert into the perineal body (central tendon of the perineum; Fig. 13.1). There is no direct urethral attachment. Importantly, the attachment anteriorly is distal to the posterior apex of the prostate and therefore the Posterior raphe is not part of the retropubic operation as it is in the perineal operation. Descriptions of the retropubic operation often mistakenly describe transection of the Posterior raphe after urethral transection when what is being described is actually transection of the termination of the PSVF as it joins the midline fibrous tissue raphe of the perineal body. The Posterior raphe attachment varies considerably in bulk from thick to thin [16].

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14

Anatomical Aspects of the Neurovascular Bundle in Prostate Surgery

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Introduction

Over recent years, widespread prostate-specific antigen screening has resulted in a downwards stage migration of prostate cancer in developed nations, with most patients being diagnosed nowadays at a younger age with early organ-confined disease [1–3]. Radical prostatectomy has a proven survival benefit over conservative treatment [4, 5], and thus is the gold standard for the management of clinically localized prostate cancer. Hence, with more patients undergoing surgery, minimizing functional loss is of utmost importance. However, despite recent advances in surgical technique and technologies, return of erectile function sufficient for sexual intercourse at 1 year after surgery varies from 15 to 87%, respectively, in contemporary series of radical prostatectomy [6–8]. For younger men, postprostatectomy erectile dysfunction (PPED) significantly affects their sense of masculinity and their daily interactions with women [9, 10]. Patient age, clinical and pathological stage of cancer, preoperative potency status, and aggressiveness of nerve-sparing are the most significant factors for recovery of potency after surgery [11–13]. Surgeon experience and surgical volume, penile ischemia and subsequent fibrosis, and veno-occlusive disease are also important for successful return of sexual function following surgery [14, 15].

Much of the progress achieved in the past two decades in improving potency outcomes after radical prostatectomy has resulted from an improved appreciation of the anatomical basis of the nerves responsible for erection. Diminished innervation of the corpora cavernosal tissue prevents the release of nitrous oxide from non-adrenergic non-cholinergic nerves, decreases the production of cyclic nucleotides within the vascular smooth muscle, and causes impairment of

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_14

vascular engorgement. Vascular injury, namely, arterial insufficiency and veno-occlusive leakage, is becoming increasingly implicated as a cause of erectile dysfunction after radical prostatectomy [16–18]. Recent advances in the anatomical course of these cavernosal nerves have led to various innovative techniques for improving nerve-sparing radical prostatectomy (nsRP). In addition, developments in fibre-optic imaging technologies have led urologists to explore their potential for improved visualization of the erectogenic neural scaffold during nsRP.

Anatomical Basis of Erectogenic Nerve Preservation

Neurovascular Bundles and Cavernosal Nerves

The autonomic neural system is directly responsible for penile erection. The inferior hypogastric plexus (IHP), also termed the pelvic plexus, is responsible for the mechanisms of erection, ejaculation, and urinary continence. The IHP contains sympathetic and parasympathetic components. The sympathetic fibres arise from T11 to L2 ganglia, while the parasympathetic fibres originate from the ventral rami of S3 and S4. The IHP is a dense network of neural fibres located within a fibro-fatty, sub-peritoneal plate between the urinary bladder and rectum [19].

Walsh and Donker [20] first detailed the anatomy of the nerves supplying the corpora cavernosal in male stillborns. Subsequent cadaveric and intraoperative studies by Walsh [21, 22] demonstrated that the neurovascular bundles (NVB) run posterolateral to the prostate between two layers of lateral pelvic fascia—the prostatic fascia medially and levator fascia laterally (Fig. 14.1). These neurovascular bundles consist of (1) the cavernosal nerves (CN) directly responsible for erectile function, which originate from the most inferior portion of the IHP; (2) the arterial branches from the inferior vesical artery; and (3) venous vessels. The majority of these cavernous nerve fibres, approximately 6 mm wide, then run caudally at the 3 and 9 o'clock positions of the membranous urethra beneath the striated sphincter at the prostatic apex (Fig. 14.2).

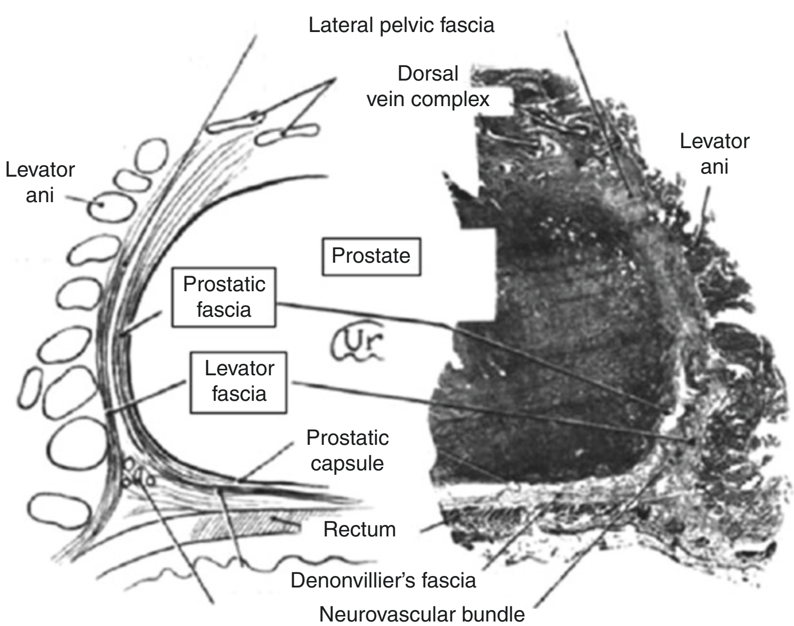

Fig. 14.1 Cross section of adult prostate demonstrating the posterolaterally situated neurovascular bundle running between the layers of the lateral pelvic fascia—the levator fascia lies lateral, and the prostatic fascia lies medial to the bundle (© Copyright 1996 Brady Urological Institute)

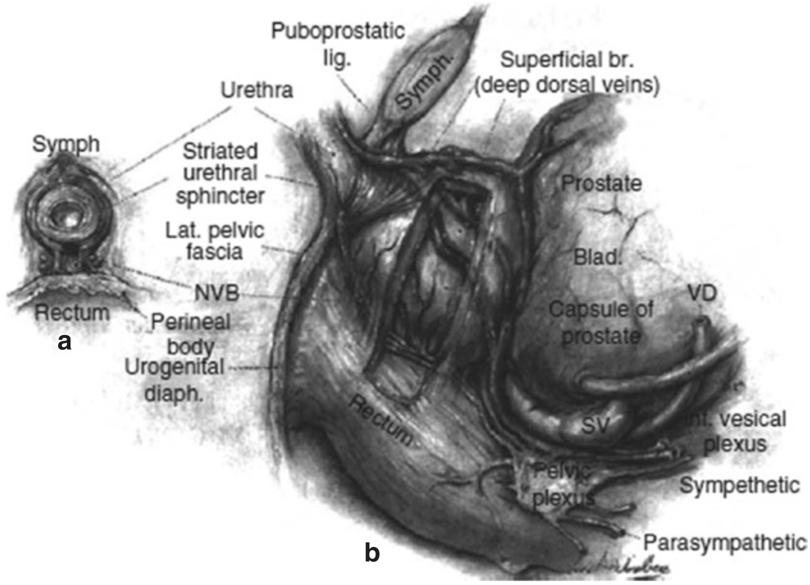

Fig. 14.2 (**a**) Cross section of membranous urethra just distal to the prostatic apex, demonstrating the relationship of the neurovascular bundle to the striated urethral sphincter and the perineal body. (**b**) Lateral view of the neurovascular bundle, tracing its course from the pelvic plexus through the layers of the lateral pelvic fascia distally to lie lateral to the membranous urethra (© Copyright 1996 Brady Urological Institute)

Anatomical Variants of Cavernosal Nerves

Recent studies have reported variants to the 'train track' course of cavernosal nerves described above. Costello et al. [23] demonstrated that the NVBs in male cadavers descend posteriorly to the seminal vesicles, converging at the mid-prostatic level and then diverging on approaching the prostatic apex into indistinguishable fibres. Takenaka et al. [24] highlighted the lattice-like distribution of the NVB on the lateral surface of the prostate, demonstrating that the NVB is more a network of multiple fine dispersed nerves than a distinct structure. Kiyoshima et al. [25] further reported that these dispersed nerve fibres are located between the prostate capsule and the levator fascia. Eichelberg et al. [26] also found that only 46–66% of all nerves were found in the classical posterolateral location as described by Walsh, while 21–29% were found on the anterolateral surface of the prostate.

Trizonal Hammock Concept

Tewari and colleagues [27, 28] proposed that the periprostatic nerves consistently fell into three

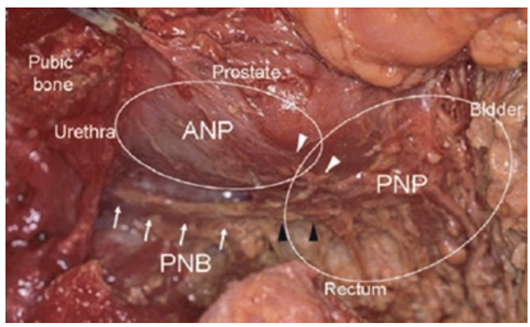

Fig. 14.3 Gross anatomy photograph (*right*) showing the proximal neurovascular plate (*PNP*), predominant neurovascular bundle (*PNB*), and accessory neural pathways (*ANP*)

broad surgically identifiable zones: the proximal neurovascular plate (PNP), the predominant neurovascular bundle (PNB), and the accessory neural pathways (ANP) (Fig. 14.3). The predominant neurovascular bundles are usually located in a posterolateral groove on the side of the prostate. Significant variations in the location, shape, course, and composition of this bundle occur. They can be widespread on the rectum, Denonvilliers' fascia, and lateral pelvic fascia, or they can be circumscribed on the posterolateral groove enclosed in the triangular space. The PNB is closely related to the prostatic pedicle and

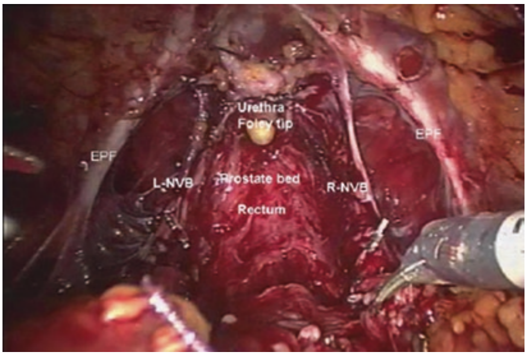

Fig. 14.4 View of the left and right neurovascular bundles (*L-NVB* and *R-NVB*) in the prostatic fossa after removal of the prostate gland. Note that the NVBs are closely related to the prostatic pedicle and prostatic fascia, and its branches can sometimes be intermingled with the lateral pedicles of the prostate (*EPF* endopelvic fascia)

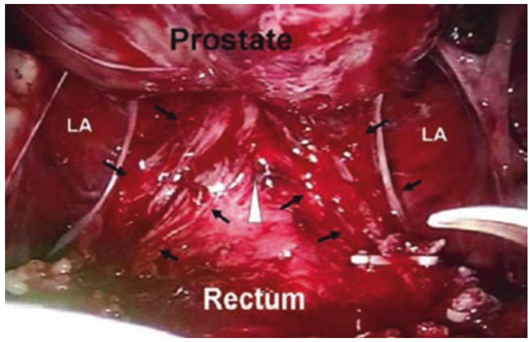

Fig. 14.5 Retro-apical region of the prostate has a rich plexus of nerves formed by cross-communicating (*White arrow head*) fibres between the left and right neurovascular bundles and fibres (*LA* levator ani, *Black arrows* neural tissue)

prostatic fascia, and its branches can sometimes be intermingled with the lateral pedicles of the prostate (Fig. 14.4). Correlating their anatomic findings from cadaveric dissections to intraoperative video footage and final histology slides, Tewari's group observed accessory neural pathways in several locations around the prostate: specifically, between the prostatic and levator fascia, posterior to the prostate and in the layers of Denonvilliers' fascia, in several planes between the layers of lateral pelvic fascia, and even in the outer layers of the prostatic capsule. The superficial layer of Denonvilliers' fascia has cross-communicating fibres between the left and right neurovascular bundles. Distally, these bundles coalesce to form a retro-apical plexus. In up to 35% of cases, this distal plexus penetrates the rectourethralis muscle (Fig. 14.5). Being the final exit pathway for the cavernous and retro-apical nerves, these delicate structures may easily be damaged during urethral transection and anastomosis. Tewari observed that the overall architecture of these delicate erectogenic nerves coursing around the prostatic capsule is similar to suspension of a weight in a hammock (Fig. 14.6), and that nerve preservation should not be considered a discrete technical manoeuvre, but rather an overarching surgical priority to be

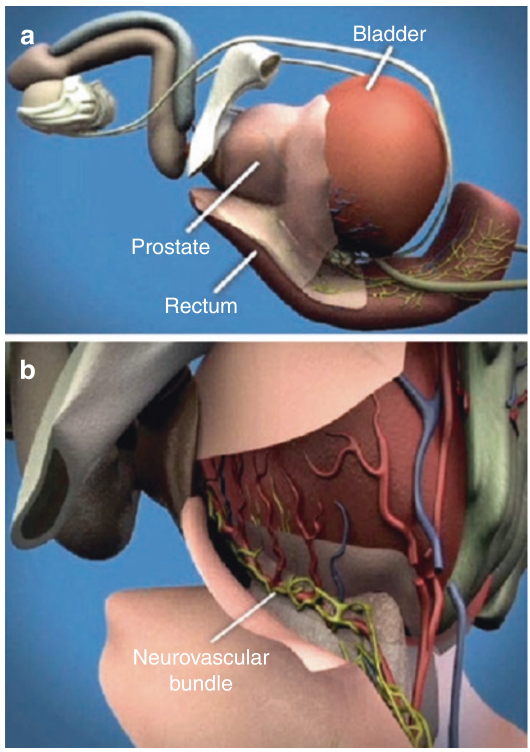

Fig. 14.6 (**a**) Graphical representation of the pelvic anatomy encountered by surgeons during robotic-assisted radical prostatectomy. (**b**) Close-up pictorial representation of the delicate scaffold of erectogenic nerves that run in the fascial planes around the prostatic capsule

pursued at all stages of this complex procedure for achieving optimal outcomes [28].

Fascial Planes Surrounding the Prostate Capsule

Correlating their intraoperative observations during robotic-assisted radical prostatectomy with histological specimens, Tewari and Menon recognized that numerous nerve bundles are present in the different layers of fascia enveloping the prostate [29] (Figs. 14.7 and 14.8). The lateral pelvic fascia (LPF)—a multilayered fascial covering—surrounds the prostatic capsule. The medial, well-defined component of the LPF is known as the prostatic fascia, and directly wraps around the prostate capsule. The laterally defined part of LPF is the levator fascia, which lies on the levator muscles. Interposed between the prostatic fascia and the levator fascia are the periprostatic venous plexus and the neurovascular tissue that travel distally to supply the sphincter, urethra, and cavernous tissue. These neural fibres can travel close to the vessels, or occasionally, independently, on the surface of the prostate or laterally on the rectum.

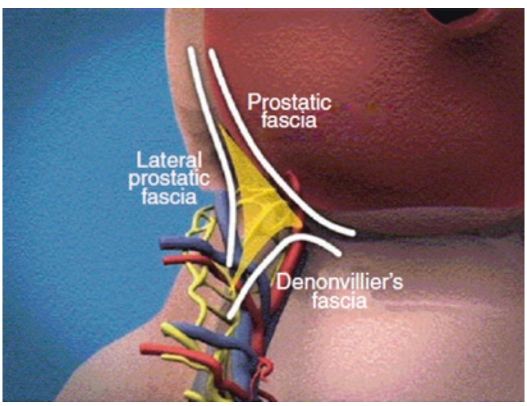

Fig. 14.7 Graphical representation of the neurovascular triangle, which is a potential avascular space bounded posteriorly by the Denonvilliers' fascia, laterally by the levator fascia, and medially by prostatic fascia covering the prostate capsule

Advances in Cavernosal Neural Imaging

With the above-described plethora of nerves outside the conventional posterolateral NVB, it can be difficult for surgeons to identify these accessory pathways. In recent years, significant efforts have been made to improve real-time identification and preservation of these cavernosal nerves during radical prostatectomy. Optical magnification of the operative field with surgical loupes has been demonstrated to improve earlier return of potency and lower rate of positive surgical margins following retropubic radical prostatectomy [30, 31]. Intraoperative nerve stimulation and tumescence monitoring using the CaverMap™ has also been reported to help improve potency outcomes, although its specificity for accurate NVB identification has remained weak with considerable background variables contributing to penile tumescence [32–34]. Ukimura and Gill reported that real-time TRUS using power Doppler during laparoscopic radical prostatectomy helped the surgeon identify the anatomical course of the NVB, measure the number of visible vessels and quantify arterial blood flow resistive index in the NVB [35]. However, the variability of NVB imaging with positioning of the ultrasound probe, insufficient resolution for defining microscopic structures, and operator dependency of this approach has not resulted in this technique being adopted by other centres.

Recent advances have been made in fibre-optic-based imaging technologies for visualizing biological structures at a cellular and microscopic level, such as optical coherence tomography (OCT) [36], spectroscopy (elastic scattering [37], Raman [38]), and fluorescent imaging (confocal microscopy [39], multiphoton nonlinear microscopy [40]). These technologies may become integrated in the future onto the robotic platform for use in real-time identification of nerves during radical prostatectomy and may provide yet more

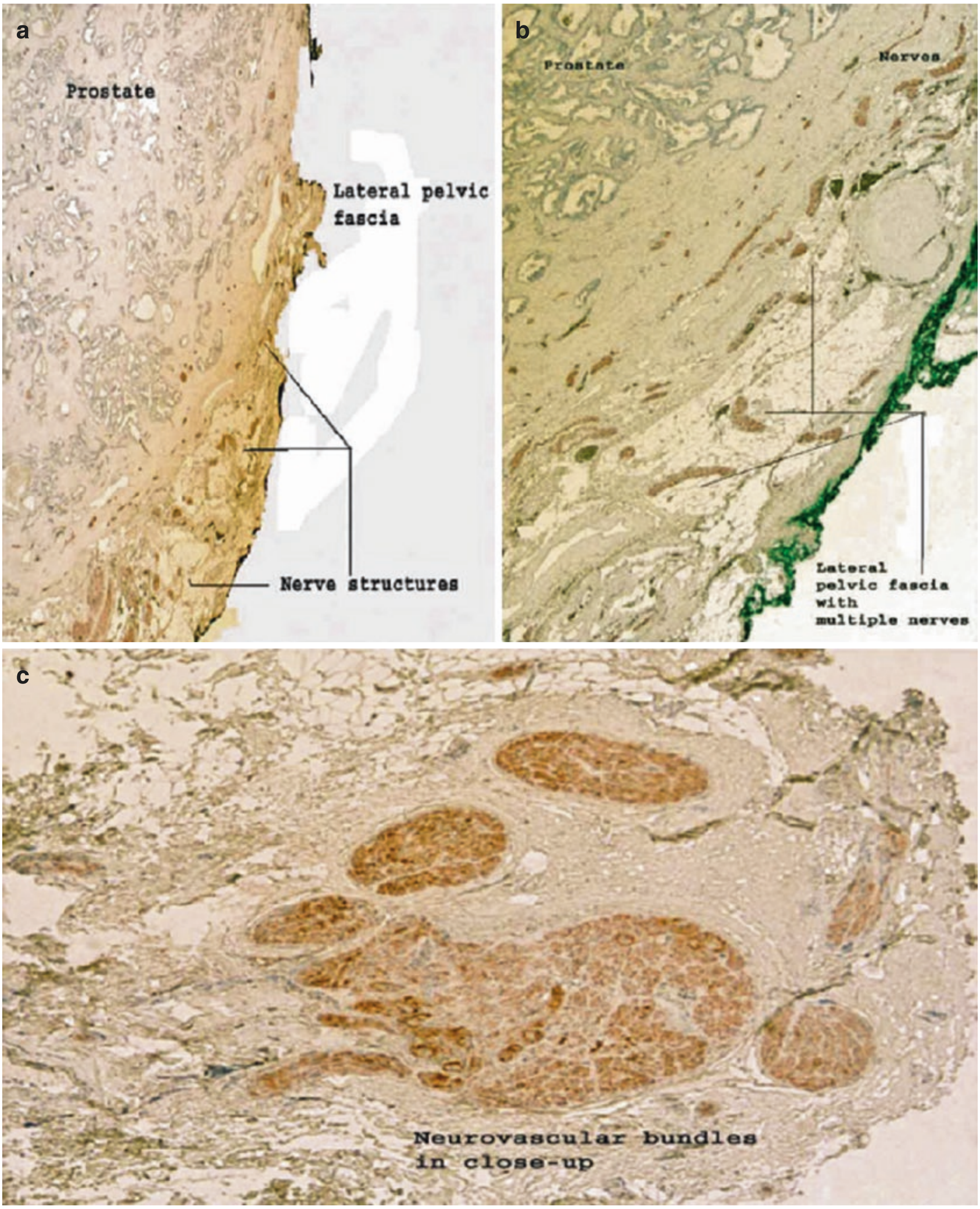

Fig. 14.8 Microscopic images of the nerves in the lateral pelvic fascia (*brown* structures) (note the small nerves posterior and anterolateral to the prostate): (**a**) low magnification; (**b**) medium magnification; (**c**) high magnification (© Elsevier Inc. [29])

anatomical information about the cavernosal neural architecture during prostate surgery.

Conclusions

The cavernosal nerves that are vital for erectile function are not simply distributed as train tracks on the posterolateral aspect of the prostate, but rather can be divided into three zones: the proximal neurovascular plate, the predominant neurovascular bundle, and the accessory neural pathways. Better appreciation of this anatomy is key to the optimization of sexual outcome after radical prostatectomy and is currently facilitated by the magnification allowed in the robotic platform. Future advances in fibre-optic imaging technologies may bring about further knowledge of this important anatomy.

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Part V

Bladder

15 Female Robot Assisted Radical Cystectomy - Anterior Exenteration

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Introduction

Radical cystectomy (RC) with pelvic lymph node dissection (pLND) represents the cornerstone for treatment of muscle invasive bladder cancer, and refractory non-muscle invasive disease. However, RC remains a major procedure that poses considerable risks and perioperative morbidity [1–3]. In this context, much interest has been spurred in robot-assisted radical cystectomy (RARC) aiming at improving perioperative outcomes and enhancing patient recovery while providing superior visualization, magnification and ergonomics for the surgeons. Recently, RARC has been shown to provide equivalent long term oncologic outcomes to its open counterpart, and to be superior in terms of blood loss, transfusion rates and hospital stay [4].

Although anterior pelvic exenteration remains the standard of care for female patients with bladder cancer, recent data suggest that involvement of female reproductive organs is relatively uncommon (<8%) [5]. Removal of female reproductive organs adversely impact sexual function and quality of life. Sparing the female reproductive organs helps in maintaining the support of the pelvic floor, which may improve urinary function. Additionally, preservation of the anterior vaginal wall may decrease the incidence of fistula formation between the vagina and bowel or neobladder [6].

In this chapter we will discuss and demonstrate a step-by-step anatomic approach to RARC in females, both anterior pelvic exenteration and female organ-Sparing cystectomy.

Preoperative Preparation

Informed consent should be obtained from all patients undergoing RARC after thorough counseling about the risks, benefits and possible complications and consequences, including stoma management and the possibility of self-catheterization if a catheterizable reservoir is created. A comprehensive preoperative anesthesiology assessment that includes cardiac, renal and hepatic testing and correction of modifiable medical disease should be performed. Careful evaluation of the patient's pulmonary function is vital considering the steep Trendelenburg position.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_15

"Fast track" or enhanced recovery protocols (ERAS) have been incorporated in the preoperative, intraoperative and postoperative management to promote patient recovery and minimize the associated morbidity [7]. Screening patients revealed that a significant number of patients are malnourished. Improving the preoperative nutritional status of patients has been shown to reduce complications and enhance recovery in gastrointestinal surgery [8–11]. Smoking cessation prior to major surgery reduces perioperative complications and readmission rates [12, 13]. Despite the well-known benefits of physical exercise, the current evidence supporting the benefits of physical exercise prior to RC remains inconclusive to provide any recommendations.

Patients are safely allowed intake of solids up to 6 h and liquids up to 2 h before surgery [14]. Preoperative oral intake of a clear fluid rich in carbohydrates 2–3 h prior anesthesia reduces thirst, anxiety, catabolism and may promote postoperative muscle strength, and earlier return of bowel function [15, 16]. Omitting mechanical bowel preparation is largely supported by the colorectal surgery literature. However, non-digestible vegetables can be seeded into the peritoneum during construction of the urinary diversion, and vegetables should be avoided for 1 day before RARC [14].

Thrombo-embolic complications are not uncommon after RC [17]. Mechanical methods (as compression stockings and intermittent pneumatic compression devices) and low molecular weight heparin are important for measures for thrombo-embolic prophylaxis [18]. Broad-spectrum intravenous antibiotics are preferably administered 1 h before the start of the procedure.

Positioning and Port Placement

The patient is positioned in the Trendelenburg position (with feet at least 10–15° higher than the head) to displace the intestinal loops upwards, providing more working space. The abdomen is insufflated using the Veress needle or Hasson technique. After placing the camera port, all ports are placed under direct vision. Ports should be placed more cephalad to facilitate bowel maneuvering and performing extended pelvic lymph node dissection. A standard 6-port transperitoneal approach is used with an additional 12 mm short suprapubic port placed later to facilitate bowel anastomosis (Fig. 15.1).

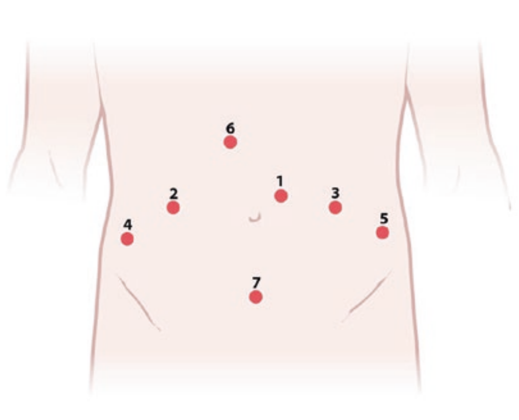

Fig. 15.1 Standard 6-port transperitoneal approach

"Technique of Spaces"

'Technique of spaces' deconstructs the procedure into smaller measurable portions that keeps the surgeon focused and facilitates training. The spaces of dissection are the periureteral spaces, lateral pelvic spaces, retrouterine space, and retropubic space [19].

Peri-Ureteral and Lateral Pelvic Spaces

The ureter is identified by incising the posterior peritoneum above the iliac vessels, where the uterine artery is encountered crossing the ureter. Both structures are left intact until all other landmarks are identified. Ureteral identification may be more difficult on the left because of the possible inflammatory adhesions from previous diverticular disease. The fourth arm can be used to retract the sigmoid colon on the left side to improve exposure and facilitate dissection. The ureter is dissected distally toward the uretero-vesical junction (UVJ) maintaining adequate peri-ureteral tissue to prevent ischemia to the distal ureter.

Lateral pelvic space is identified by incising the anterior peritoneum lateral to the medial umbilical ligament, and the incision is extended towards the ipsilateral ureter. This space contains the round ligament (which extends from the deep inguinal ring to the uterus) and the infundibulopelvic ligament (which contains the ovarian pedicle, lies anterior and lateral to the ipsilateral ureter) (Fig. 15.2). Control of the ovarian pedicle is achieved by dissecting the peritoneum connecting the infundibulopelvic ligament with the internal iliac vessels. Then, any areolar tissue is swept from lateral to medial to maintain adequate soft tissue margin and avoid injury to the iliac vessels. The endopelvic fascia is identified and incised.

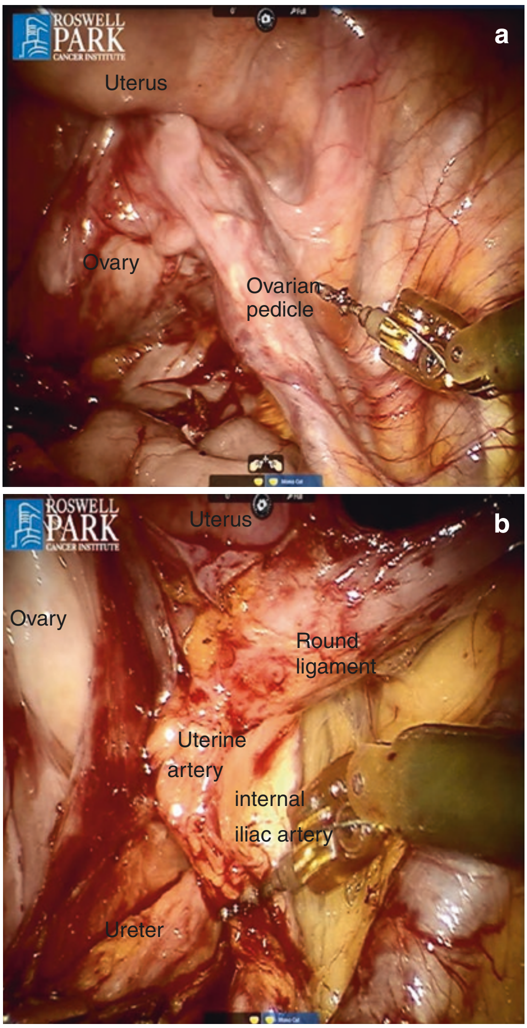

Fig. 15.2 (**a**) The round and infundibulopelvic ligaments. (**b**) Ureter, uterus, ovary, internal iliac and uterine arteries

After identification of all the landmarks, the ureter is clipped, and the distal margin is cut using scissors and sent for frozen section. The uterine and vesical blood vessels are divided.

Retro-Uterine Space

Once both lateral pelvic spaces are developed on either side, the posterior peritoneum remaining between the two ureters is incised across the midline, including the recto-uterine pouch (Fig. 15.3). Manipulation of an intravaginal dilator helps identifying the junction of posterior fornix with the cervical os. This is followed by blunt dissection in a sweeping manner of the posterior vaginal fornix from the Denonvillier's fascia overlying the rectum. Care must be taken to preserve the pelvic plexus that descends on the lateral vaginal wall (which supplies the

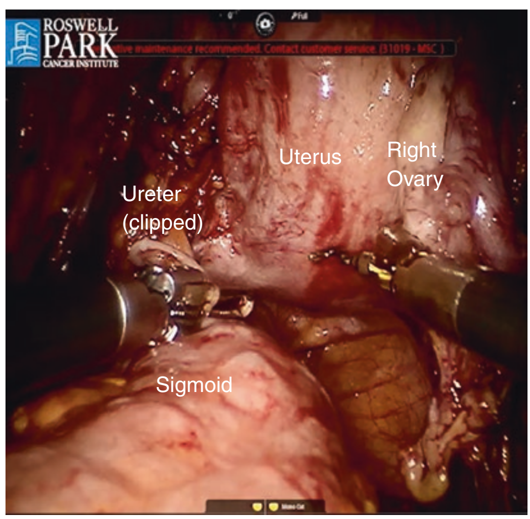

Fig. 15.3 Recto-uterine pouch

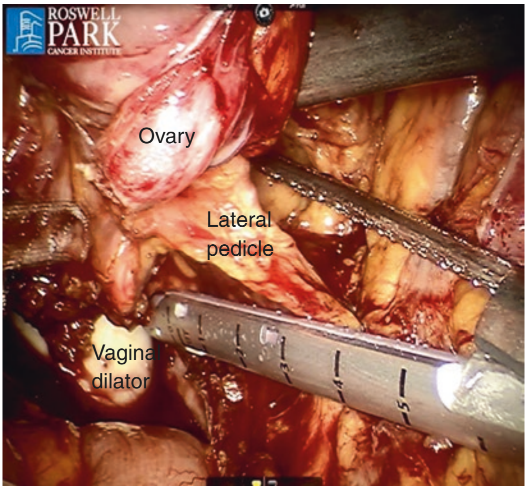

Fig. 15.4 Endo GIA stapler is used to divide the vascular pedicles

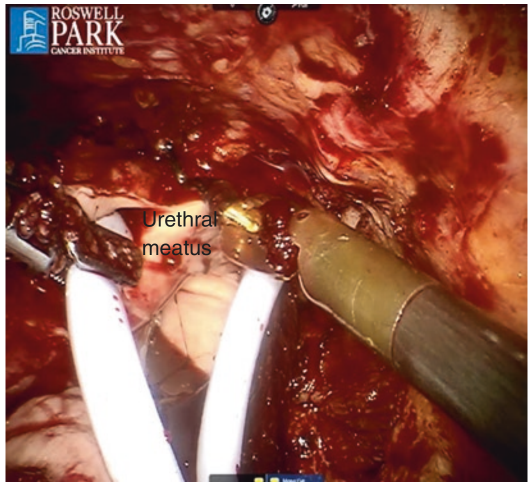

Fig. 15.5 The whole length of the urethra is excised if an ileal conduit was preoperatively planned

vagina and urethra, and therefore important for adequate sexual function).

Ligation of the Vascular Pedicles

After developing the aforementioned spaces, the fourth robotic arm is used to apply anterior retraction to the uterus. The right and left arms are used to manipulate the perivesical tissue to clearly define the vascular pedicles. An endo GIA stapler is used to divide the vascular pedicles (Fig. 15.4).

Retropubic Space (Cave of Retzius)

The bladder and the uterus are dissected from the anterior abdominal wall by incising the urachus and medial umbilical ligaments as cranial as possible in order to ensure an adequate soft tissue margin. The urethra is exposed and the indwelling Foley catheter is drawn out. The whole length of the urethra is excised if an ileal conduit was preoperatively planned (Fig. 15.5). Alternatively, if a neobladder was planned, a large clip is placed across the urethra to prevent antegrade urine spillage, and the distal urethral margin is sent for frozen section.

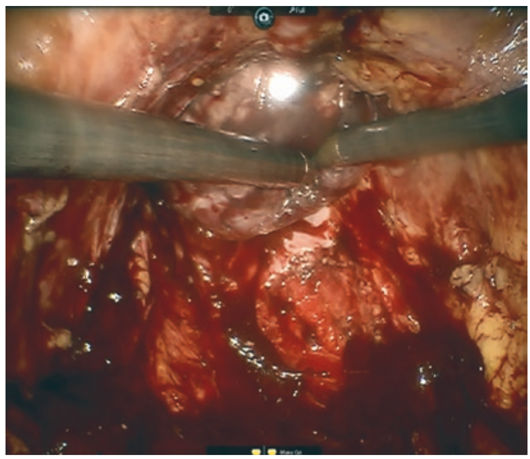

Fig. 15.6 The specimen is put in an endo bag and can be extracted transvaginally

Development of Anterior Vaginal Space

Preservation of the anterior vaginal wall is important for sexual function and largely depends on preoperative oncologic planning. In order to preserve adequate length of anterior

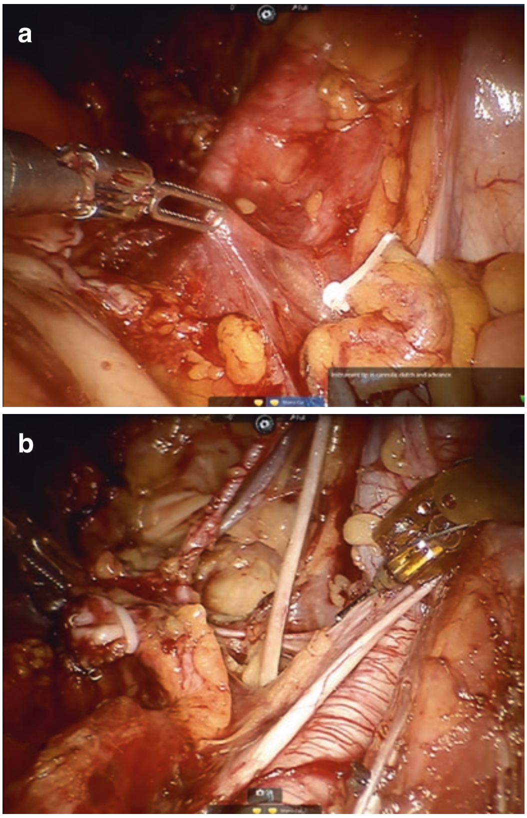

Fig. 15.7 (**a**) Before Pelvic lymph node dissection. (**b**) After Pelvic lymph node dissection

vaginal wall, traction is applied on the uterus using the fourth arm followed by careful dissection between the anterior vaginal and posterior bladder walls.

The specimen is put in an endo bag and can be extracted transvaginally (Fig. 15.6). The vagina is closed in a transverse fashion to avoid a narrow dysfunctional vagina.

Pelvic Lymph Node Dissection

Pelvic lymph node dissection is an integral part of the procedure. It is crucial for adequate staging, removal of any possible micrometastatic disease, and identifying patients who may require adjuvant treatment. It has been shown that thorough lymph node dissection improves survival even in node negative patients. There is a growing body of evidence suggesting that extended lymph node dissection template, and lymph node count of more than 20 lymph nodes are associated with the highest benefit [20–22]. Adequacy of lymphadenectomy has been used as a surrogate for the quality of surgical performance [23].

One advantage of performing the lymphadenectomy after RARC is that it allows more freedom of movement within the pelvis. The fourth arm is used to retract the sigmoid medially away from the dissection area allowing access to the more proximal nodal tissue. All lymphatic tissue overlying he common, external and internal iliac vessels is removed. Dissection is extended to the genitofemoral nerve laterally, internal iliac artery medially, lymph node of Cloquet distally and proximally to the aortic bifurcation (Fig. 15.7). Judicious use of cautery is exercised control and seal the lymphatic channels while avoiding vascular injury.

The dissected nodal tissue is placed in an endo bag and can be extracted through the vagina incision or through extension of one of the ports incision. Care must be undertaken to avoid spillage of the endo bag contents.

Postoperative Care

Although gastric decompression may be beneficial in reducing postoperative nausea and vomiting, it has been shown that early removal of nasogastric tube in the recovery room after extubation is associated with reduced complications [24]. Alvimopan and chewing gums allow early return of bowel function and shorter hospital stay [25, 26]. Adequate pain control is crucial. Baseline treatment should include regular administration of acetaminophen. Epidural analgesia is very effective, but may hinder early mobilization [7].

Early mobilization has been associated with better cardiac and respiratory functions and psychological well-being, in addition to prevention of thrombo-embolic complications [27]. Early institution of an oral diet seems to enhance bowel function and decrease the time to first bowel motion and shorten hospital stay without increasing complications [28]. It has been also associated with improved cognitive function in the postoperative period [29].

There is no consensus on the optimal timing for stent or catheter removal [7]. It is our preference to remove the stents after 8–10 days in patients who had ileal conduits, and to remove the urethral catheter with the stents after 3 weeks in patients who had neobladders following a normal pouchgram.

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16 Male Robot-Assisted Radical Cystectomy

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Introduction

Radical cystectomy and lymphadenectomy remains the recommended treatment for muscle invasive bladder cancer (MIBC) and selected high grade non-muscle invasive bladder cancer (NMIBC) [1, 2]. The cohort of patients requiring this procedure are often elderly with multiple co-morbidities secondary to long standing tobacco smoking and exposure to environmental carcinogens. In addition, the technical challenging nature of radical cystectomy can result in significant morbidity and mortality [3].

Efforts to minimise perioperative complications have led to the development of minimal invasive cystectomy [4]. Parra et al. described the first laparoscopic cystectomy operation in 1992 however, it was not widely adopted due to technical challenges of intracoproreal urinary diversion reconstruction [5]. The advent of the daVinci surgical system (Intuitive Surgical, Sunnyvale, CA) has led to the rapid uptake of robot-assisted radical cystectomy (RARC) which is now the default option in many institutions.

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In this chapter, we will describe preoperative assessment, detailed description of the surgical technique of RARC, postoperative care and outcomes.

Patient Selection

Patient selection for RARC is similar to open radical cystectomy (ORC) and there are no absolute contraindications. The Pasadena consensus recommend that surgeons early in their learning curve should avoid operating on morbid obese patients, those with a history of pelvic radiotherapy and/or patients with large bulky tumour suggesting advanced disease [6]. Patients with previous pelvic surgery such as radical prostatectomy or low anterior resection should be avoided in the learning curve due to the risk of significant adhesions as well as those positive for pelvic lymphadenopathy on cross sectional imaging [6].

As experience develops, we find that a robotic approach may be advantageous to some of the contraindications described above. A RARC approach allows access to the deep pelvis and is well adapted for high BMI patients and consistent with this, others have reported that RARC for high BMI cases is not associated with increased postoperative complications [7, 8]. We have shown that poor performance patients may infact benefit from a robotic approach. Patients treated with preoeprative anaemia and poor cardio-pulmonary reserved assessed by cardio-pulmonary exercise

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_16

testing (CPET) undergoing RARC with intracorporeal urinary diversion in fact were not associated with adverse perioperative outcomes in contrast to open surgery [9–12]. In salvage cystectomy cases, the desmoplastic reaction following radiotherapy may make the dissection betweeen the rectum and bladder more challenging but the robotic approach arguably allows better visualisation to promote a more precise dissection compared to open surgery.

A potential disadvantage of the robotic approach is the prolonged operation in steep Trendelenburg position which may affect respiratory ventilation function although data from physiological studies suggest that haemodynamic and pulmonary variables are within safe limits and well tolerated by patients [13]. In obese patients, patients with raised intraocular pressures or those with osteoarthritis of the hip or fixed lower limb deformities we minimise head down by breaking the operating table at the mid-abdominal point and side-docking the robot to allow the lower limbs to be positioned in a near horizontal position (Fig. 16.1).

It is the authors experience that many of the stated relative contraindications are not so, and other than failure to access the pelvis because of adhesions relating to previous surgery, the advantage of enhanced visualisation, dexterity and a bloodless field mean that the roboic approach is preferable to open radical cystectomy in poor perfromance patients.

Preoperative Care

At our institution, all patients attend a specialist multi-disciplinary cystectomy clinic where they are evaluated by a surgeon, anaesthetist, urinary diversion nurse, oncology specialist nurse and a dietician. Patients also undergo cardiopulmonary exercise tollerence (CPET) test which measures cardio-respiratory physiology function and assigns risk of a significant perioperative event to inform the need for preoperative optimisation.

Patients are advised to consume a low residue diet for 2 days prior to surgery but can continue eating up to 6 h prior to surgery and can have clear fluids up to 2 h before. A low residue diet enables the contents of the ileal segment to be cleared by endoscopic suction which may prove difficult when a high fiber diet has been injested. Bowel preparation is not necessary even for slavage cystectomy. Patients are provided high calorie carbohydrate energy drinks to injest the day prior to surgery to help prevent a catabolic state and the development of insulin resistance secondary to surgery [14].

In our experience, a spinal neuroaxial block with 2 mL 0.5% heavy bupivacaine +1 mg dia-

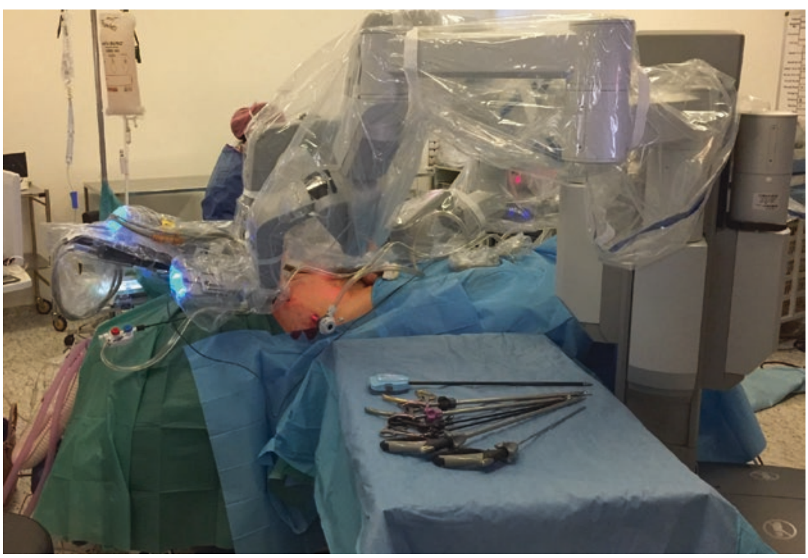

Fig. 16.1 Side docking of the robotic system to allow a near horizontal position of the patient.

morphine is advantageous compared to epidural because it promotes early mobalisation by reducing postoperative fall in blood pressure, reduced incidence of motor block and frees patients from being connected to an infusion pump. An arterial line allows continuous blood pressure monitoring and arterial vascular access for intraoperative and perioperative anterial blood gas analysis. Indirect cardiac output monitoring is measured using transoesophageal doppler to allow goal directed fluid therapy. Level one evidence suggest that goal-directed fluid therapy can reduce the risk of postoperative ileus following surgery which represents the main cause of prolonged hospital stay [15].

Patients are given broad spectrum antibiotics which covers gram negative organisms and anaerobes within 60 minutes of skin incision to reduce the risk of wound infection. Intravenous ondansterone and dexamethasone is prescribed as anti-ematics and a combination of diclofenac and paracetamol are used for intraoperative analgesia. Patients are also given intravenous lidnocaine (2 mg/kg/h for the first 2 h) based on randomised control trial data from laproscopic colectomy which have reported a reduced need for postoperative analgesia, opioid use, shorter hospital stay and faster return to normal bowel function [16]. Compression stockings and calf pneumatic compression reduce the risk of deep vein thrombosis. A nasogastric tube in inserted to deflate the stomach and a urethral catheter is inserted to drain the bladder after general anaesthetic induction. A Bair Hugger (3M, St Paul, MN, USA) is used to prevent hypothermia.

Surgical Technique

Patient Positioning and Port Placement

The conventional patient position is in 20° lithotomy Trendelenburg with arms adducted and tucked to the sides. All pressure points should be padded and the hips in a neutral position with slight flexion to prevent pressure sores and neuropraxia of the femoral nerve.

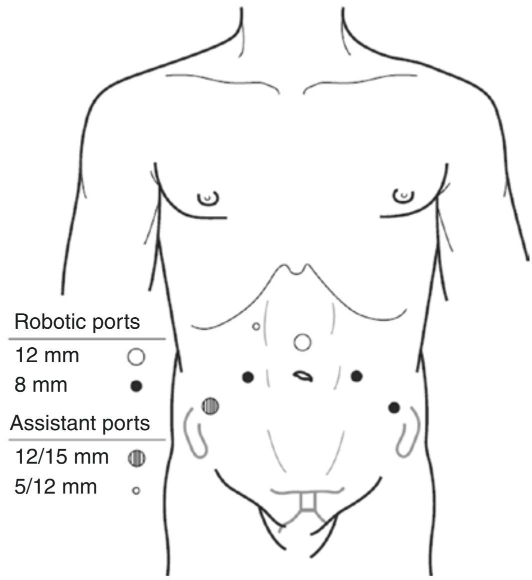

Fig. 16.2 Port placement for robotic assisted radical cystectomy

As an alternative and for high BMI patients, we utalise a side docking of the robot with a mid-abdominal break just cranial to the iliac crest which avoids steep Trendelenburg and also allows synchronous urethrectomy where necessary. A six port transperitoneal approach is used to gain access to the peritoneal cavity (Fig. 16.2). The Hassan technique is used to introduce a 12-mm camera port at least 4 cm cranial to the umbilicus. Pneumoperitoneum is set at 12 cm H_2O and followed by the insertion of two 8-mm robotic ports either at the level of or just above the umbilicus just lateral to the rectus abdominis muscle (minimum 9 cm away from the camera port). We favour a 15-mm AirSeal port (ConMed, New York, USA) which is placed 5 cm above and 1 cm anterior to the right iliac crest to maintain a constant uniform CO_2 pressure. A 12-mm port is positioned 5 cm above and 1 cm anterior to the left iliac crest where the third 8-mm robotic port is inserted as a port in port. The last 5-mm port is inserted approximately 5 cm cranial to a line joining the camera and first robotic arm, along a longitudinal line perpendicular to midpoint of this line. A 0° lens is used and diathermy set at 30W for both coagulation and cutting setting throughout the operation unless stated otherwise.

Step 1: Identification of the ureters

Instruments used:
Robotic arm 1: Monopolar curved scissors
Robotic arm 2: Maryland bipolar forceps
Robotic arm 3: ProGrasp forceps

The pelvic anatomy is evaluated and the peritoneum lateral to the left colon is incised to release the decending and sigmoid colon to access the left ureter. The ureters are identified at the crossing of the common illiac arteries, medial to the junction of the medial umbilical ligament and the internal iliac artery (Fig. 16.3). The lower third of the ureter transits posterio-medial to the lateral vesical pedical and can be mobilised from the lateral pedical mass by cauterising and dividing small vessels between ureter and pedical vessels. The distal ureter gains its blood supply from its lateral surface and therefore the medial dissection of the ureter is relatively avascular. The ureters are dissected towards the bladder. Periureteric tissue is preserved to maintain vascular supply and care is taken not to grasp the ureters above the common iliac arteries to minimise traction trauma. The distal third ureter below the common iliac artery is divided between Hem-o-lock clips. A 15 cm 2-0 polyglactin 910 suture (Ethicon Inc., Somerville, NJ, USA) is preloaded to the proximal Hem-o-lock clip (Teleflex, Morrisville, NC, USA) to allow easy identification of the ureter later.

Step 2: Posterior plane dissection

The peritoneal reflection at the pouch of Douglas is incised identifying fat deposits anterior to the rectum and posterior to the bladder

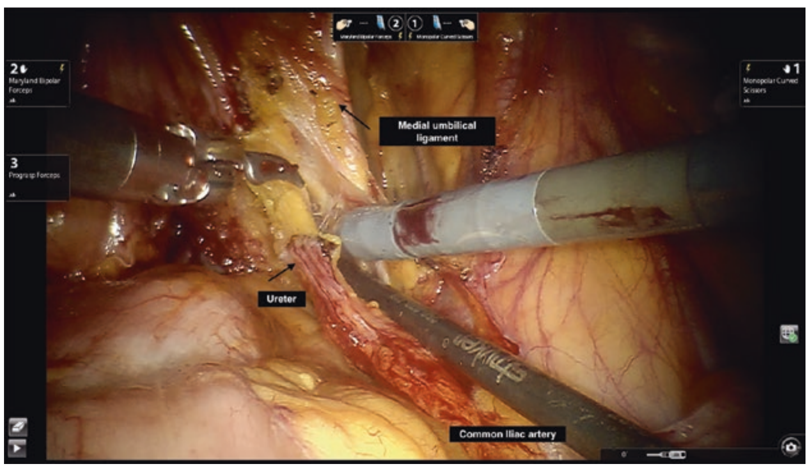

Fig. 16.3 Identification of the right ureter. This can be made either at the level of the Common Iliac artery or medial to the Medial Umbilical ligament

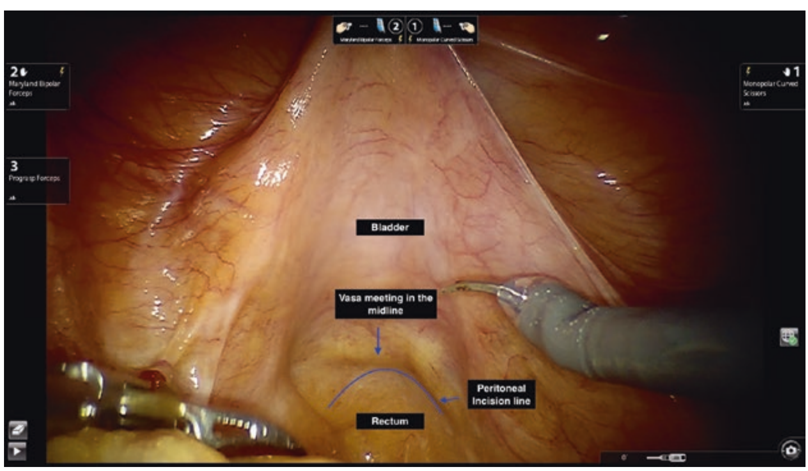

Fig. 16.4 Anatomy during the approach for posterior dissection. The Robotic 4th arm with the ProGrasp is on the peritoneum retracting the bladder anteriorly. The impressions of the Vasa through the peritoneum are visible. The incision is made in the peritoneum caudal to the Vasa, cranial to the peritoneal reflection over the rectum

(Fig. 16.4). In thin male patients, the incision is made distal to the prominence of the vasa as they course medially to open into the prostate. The reterovesical plane is developed using a combination of blunt dissection and diathermy staying within the fatty layer (Fig. 16.5). To facilitate dissection, the bladder is retracted anteriorly using the third arm and the prerectal fat is swept towards the rectum. Key landmarks include the rectum with perirectal fat posterior and the seminal vesicals and bladder anterior. At the insertion of the seminal vesicals, it is necessary to incise Denonvillier's fascia and from there, care is taken when dissecting towards the level of the rectourethralis. Dissection should be perfromed anterior to the Denonvillier's fascia along the intrafascial plane where a nerve sparing procedure is preffered as the neurovascular bundles are positioned posterior lateraly. When performing a salvage cystectomy, the plane between bladder/ prostate and rectum is frequently not clearly demarcated due to a desmoplastic layer of fat and care should be taken to disect anterior to this plane staying close to prostate to avoid rectal injury.

Step 3: Lateral perivesical dissection

The vas deferens is identified and the covering peritoneum, is incised and the vas clipped using Hem-o-locks and divided. The distal vas deferens and the medial umbilical ligaments can be retracted medially to provide traction and facilitate the opening of the lateral perivesical space. The lateral perivesical space is developed using a combination of blunt dissection and diathermy towards the endopelvic fasica (Fig. 16.6).

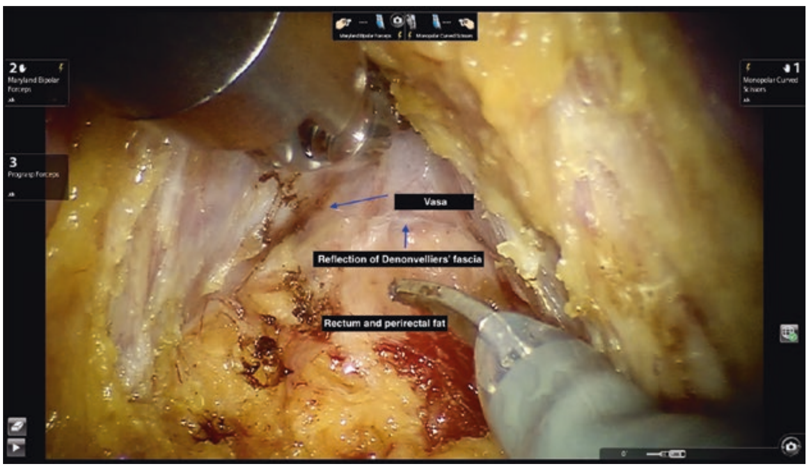

Fig. 16.5 The Denonvilliers fascia, Vasa and Seminal vesicles are visible after the peritoneal incision during the posterior dissection

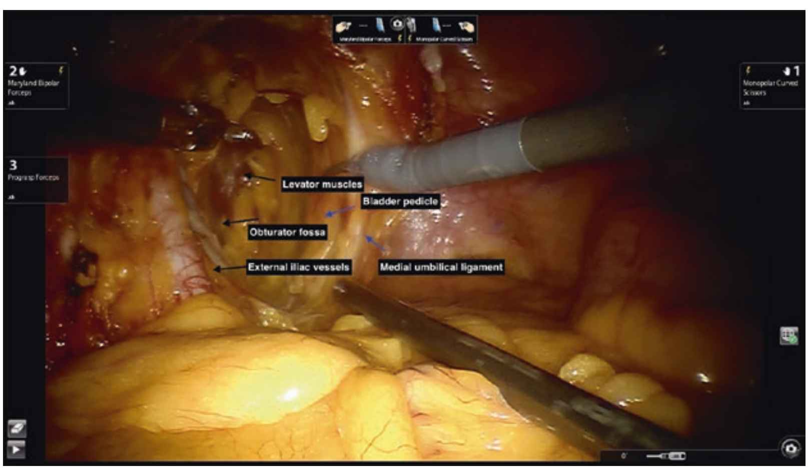

Fig. 16.6 Anatomy during the Lateral dissection of the bladder. The left Medial umbilical ligament has been retracted medially. The external Iliac vessels are visible laterally. The dissection is continued in the fat around the bladder, sticking as close to the bladder as possible to avoid entering the Obturator fossa. The dissection is complete when the Endopelvic fascia is reached

Dissection is kept within the fat, in the plane between the bladder and the obturator fossa. The limit of the dissection is the endopelvic fascia. This can either be opened at this point, or spared to preserve the Arcus tendineus and the enclosed perineal neurovscular structures that supply the sphincter which are essential for patients with planned orthotopic neobladders or nerve sparing cystectomy.

Step 4: Division of lateral pedicle

The bladder is retracted medially using the third arm to mantain the lateral pedical almost perpendicular to the pelvic side wall to facilitate identification of the following structures which are divided between hemolocks from above down: obliterated umbilical ligament, one or several superior vesical arteries and one or several vesical veins. For a nerve sparing approach, an athermal dissection of the inferior neurovascular pedicals is favoured and haemostasis is achieved using a combination of surgical clips and Hem-o-lock clips.

Step 5: Division of the posterior pedicle

The posterior pedicle comprises of the remnants of the inferior vesical artery and the prostatic vascular pedicle which extends to the neurovascular bundle towards the apex of prostate. The pedicles are placed under traction using the third arm to grasp the tip of the seminal vesicles and retracting the bladder towards the anterior abdominal wall. The vessels described above are divided between Hem-o-lock clips (Fig. 16.7). Variations to the standard technique include the intrafascial nerve sparing approache and the use of energy sources such as Harmonic (Ethicon, New Jersey, USA), LigaSure (Covidien, Dublin, Ireland) or the EndoWrist Stapler (Intuitive Surgical, Sunnyvale, CA) to divide vascular structures.

Prostate or seminal vesicle sparing cystectomy can be performed in patients with planned orthotopic neobladder reconstruction with the aim to improve early return to urinary continence and erectile function. A prostate sparing procedure refers to subtotal resection in younger patients or a resection of prostatic adenoma while sparing the prostatic capsule in older men with large prostates (Fig. 16.8). These procedures should only be attempted in patients where prostate cancer has been excluded [17].

Prostate capsule sparing is achieved by incising the prostatic capsule anteriorly akin to performing a retrograde nerve spare, removing the prostatic adenoma and leaving the surgical capsule and seminal vesicles intact. Another method described by Spitz et al., involves performing a transverse prostatic excision through the proximal prostate, leaving the distal prostate, including the distal adenoma and seminal vesicles and utricle intact (Fig. 16.9) [18]. In both cases, the neurovascular bundle, distal sphincter complex and the continuity of the seminal vesicles and ejaculatory duct are preserved (avoiding the hypogastric plexus). In both scenarios the prostatic urethra must be clipped proximally and prior to division in order to prevent spillage of bladder contents. Distal frozen section analysis can be performed to determine the need for complete prostatic excision, however this is not routinely necessary in our experience.

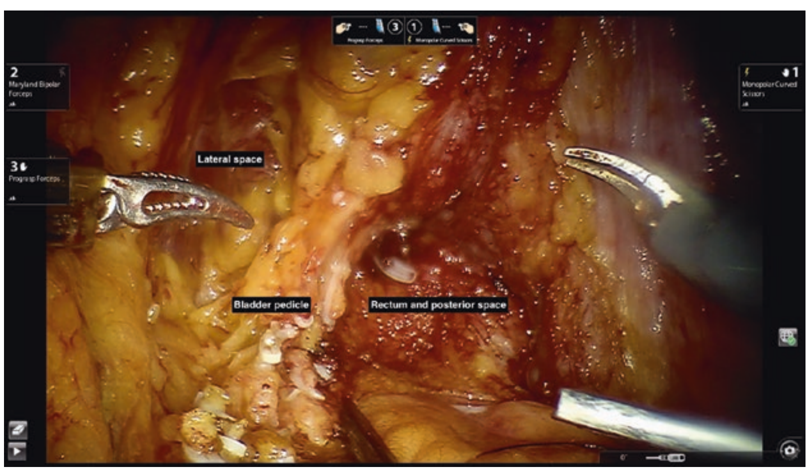

Fig. 16.7 Bladder pedicel dissection. Once the posterior and anterolateral dissections are completed, the pedicle structures can be divided safely

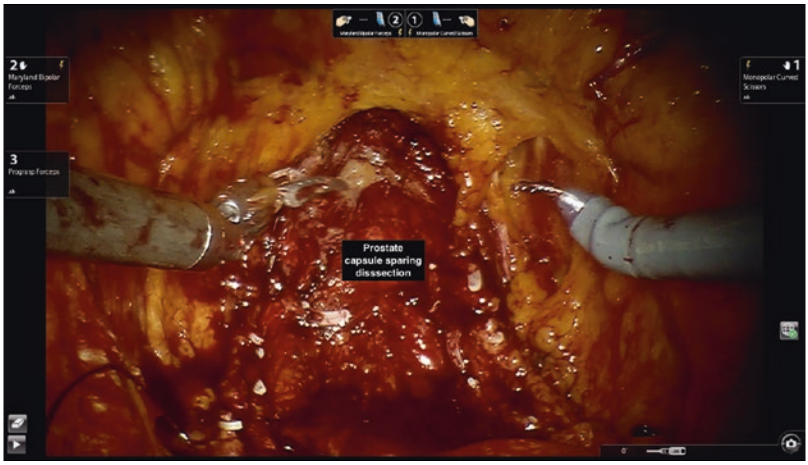

Fig. 16.8 Prostate capsule sparing dissection

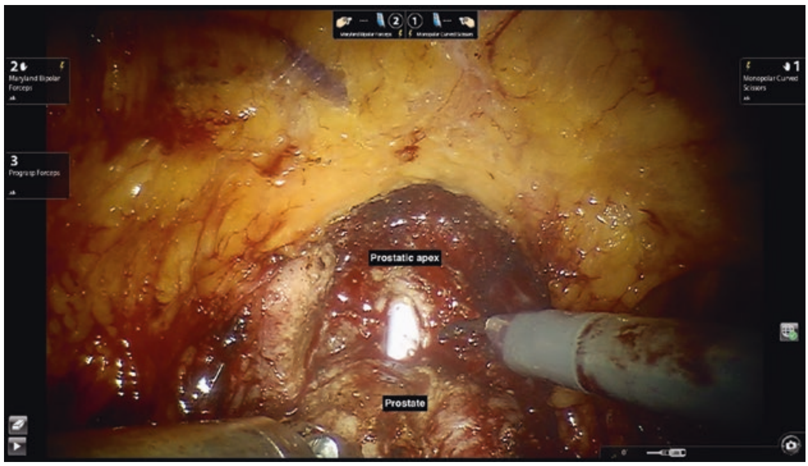

Fig. 16.9 Prostate apex sparing dissection during creation of an orthotopic neobladder

Step 6: Anterior and apical dissection

The bladder disection is completed to the apex posteriorly with incision of the endopelvic fascia. The approach is then to mobilise the anterior aspect by incising and dividing the median umbilical ligament through the space of Retzius. The fat over the dorsal venous complex is excised and the dorsal complex is divided using electrocautery for ileal conduit or cold cutting for neobladder cases. Additionally, where neobladder reconstruction is desired it is important to preserve maximum urethra length as well as apical sphincter to improve continence outcomes [19]. If oncologically necessary, a long segment of urethra can be excised and removed *en bloc* with the cystoprostatectomy specimen by mobilising the urethral posteriorly to the dorsal complex down towards the bulbar urethra. For standard cases, the proximal membranous urethra is incised and the urethral catheter is clipped using Hem-o-locks following traction to form a seal which prevent spillage of bladder contents. The bladder is now free from all surrounding attachments and placed in an Endo Catch bag (Covidien, Dublin, Ireland) and temporarily placed away from the pelvis.

Step 7: Controlling the dorsal venous complex

Instruments used:
Robotic arm 1: Large needle driver
Robotic arm 2: Large needle driver
Robotic arm 3: ProGrasp forceps

The bladder is now free from all surrounding attachments and placed in an Endo Catch bag (Covidien, Dublin, Ireland). The bag can be sta-

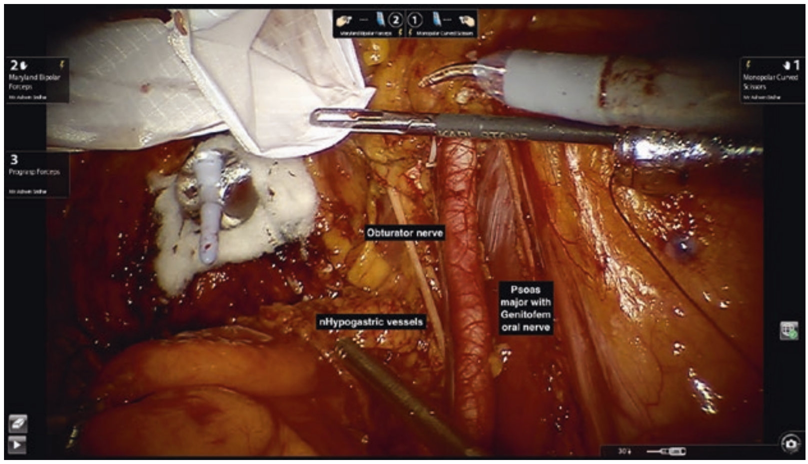

Fig. 16.10 Limits of a standard lymph node dissection. The metal sucker represents the location of the ureter (which has been reflected)

bilise by grasping the rim with the third arm to avoid bag rotation. The bag with the specimen is temporarily placed away from the pelvis.

The dorsal venous complex is controlled with 2-0 polyglactin 910 suture on a ½ circle needle with horizontal continuous sutures. The urethra opening is closed in ileal conduit cases and left open for urethro-ileal anastomosis for neobladder cases.

Step 8: Lymph node dissection

For lymph node dissection, the authors perform a standard lymph node dissection comprising of obturator lymph nodes as well as external, internal and common iliac lymph nodes. Data from randomised controlled trials have failed to show a survival advantage in extended lymph node dissection for radical cystectomy and a template beyond that described above is tailored to individual patients [20]. The boundaries for node dissection include the genitofemoral nerve on psoas laterally, the ureteric crossing at the common iliac artery proximally, the circumflex iliac vein and node of Cloquet anteriorly and the hypogastic vessels posterior medially (Fig. 16.10). Care should be taken to avoid the obturator and genitofemoral nerve, as well as the pelvic communicating vessels that are encountered lateral to the lymph node packet, entering the psoas muscle. Traction can lead to significant bleeding, which will need to be control by pressure using surgical swabs and haemostatic agents. A 'split-and-roll- technique is used if aberrant vasculature is encountered. Haemostasis is performed using surgical clips and diathermy. For surgeons preferring to perform extended lymph node dissection the boundaries are similar to the standard description above except the medial boundary would be the midline and the proximal boundary would be the bifurcation of the aorta. It is essential that all lymph node packets are placed in an Endo Catch prior to removal due to the risk of port site recurrence [21]. Following urinary diversion reconstruction, the bladder and lymph node specimen can be removed through a Pfannenstiel incision.

Step 9: Transferring of the left ureter under the sigmoid mesentery

Prior to urinary diversion reconstruction, the left ureter is transposed posterior to the sigmoid mesentery under the pelvic splanchnic nerves. The plane is similar to that of total mesorectal excision used in low anterior resection and can be identified by dissecting on the common iliac vessels from right to left. This is an avascular plane and care must be taken when mobilising veins in the mesentery as any shearing force will cause rupture and small vessel bleeding.

Step 10: Placement of drain and ureteric stents

We use 6 Fr infant feeding tubes as ureteric stents. Ureter-ileal anastomosis is performed with a continuous 4-0 PDS suture. Stents are externalised through an opening in the ileal conduit or neobladder through to the anterior abdominal wall. A passive 20 Fr drain is placed in the pelvis through the left lateral port.

Postoperative Care and Enhanced Recovery

Enhanced recovery is becoming the standard of care following RARC. The European Association of Urology Robotic Section Scientific Working Group recently published enhanced recovery consensus for RARC in efforts to guide the standardisation of postoperative care [22]. Evidence for enhanced recovery largely draws from experience from colorectal surgery where enhanced recovery reduced perioperative complications and length of stay without compromising patient safety [23].

Full details of the enhanced recovery protocol used at our institution has been described previously [24]. The nasogastric tube is removed postoperatively in the operating theatre. Intravenous antibiotics are continued for a minimum of 24 hours and then switched to oral antibiotics for 72 h. However, if significant spillage of bowel contents occurs, antibiotics should be continued for 5 days. The use of systemic opiates and epidural is avoided and non-steroidal analgesia and paracetamol is preferred in conjunction with regional block analgesia which reduces the incidence of postoperative ileus. Oral morphine is prescribed for breakthrough analgesia.

Patients are encouraged to sit out on the chair for a minimum of 2 h, 4 h following surgery. From postoperative day one, patients are provided targets for breathing and limb exercises and walking for a minimum of 20 m three times a day. Patients are commenced on free fluids immediately following surgery as tolerated. Oral feeding can be started the day after surgery if there is minimal nausea or vomiting and free fluids is tolerated.

To minimise nausea and vomiting, prokinetic agents such as regular metoclopramide is prescribed. Alvimopan, a μ receptor opioid antagonist, has been shown to significantly reduce time to bowel movement in a randomised controlled trial [25]. Ranitidine is used for gastroprotection and magnesium hydroxide and senna are prescribed as laxatives. Subcutaneous low molecular weight heparin can be started 6 h following surgery in the absence of bleeding and should be continued for a minimum of 4 weeks postoperatively to reduce the incidence of deep vein thrombosis [26]. Neobladder patients are required to perform daily aspiration and flushing of neobladder to prevent mucous build up which can lead to bowel perforation.

The pelvic drain can be removed if output is <50 mL/24 h and drain fluid creatinine suggest serum levels. Stents from ileal conduit patients can be removed at 14 days. In neobladder patients, the urethral catheter together with the ureteric stents are removed 21 days postoperatively following a cystosgram.

Perioperative Outcomes

Meta-analysis of randomised controlled trials (RCT) comparing ORC and RARC report that RARC treated patients had significantly lower blood loss but longer operating times compared to ORC [27]. However, there were no significant difference in perioperative morbidity and length of stay between the two surgical techniques. All RCTs to date performed extracorporeal urinary diversion and such results cannot be generalised to intracorporeal urinary diversion which avoids the need for mini laparotomy incision. The Pasadena Consensus report a 90-day overall and major complication rate of between 59–77% and 15–32% respectively and a 3–5% mortality at 90 days for RARC with extracorporeal urinary diversion [28]. In cases of intracorporeal urinary diversion, 90-day overall and major complication rate of between 30–67% and 24–28% respectively with a 90-day mortality rate of 1.7–2.7% [28]. Mean length of stay was around 8.7 days (range: 3.3–20.7). However, it is likely that these cases were performed by surgeons still on their learning curve and before the wide spread use of enhanced recovery. This is consistent with published reports where technical complications are responsible for majority of major complications following RARC [29]. It is the authors opinion that RARC performed by a high volume surgeon can augment the ability of enhanced recovery pathway and allow early return to normal activity and reduce length of stay.

Oncological Outcomes

In any curative cancer surgery, oncological outcomes are of paramount importance. While there is limited data on long term oncological outcomes for RARC, early report comparing ORC with RARC with intracorporeal or extracorporeal urinary diversion are comparable [30, 31]. A systematic review conclude that 5-year oncological outcomes were comparable between the two techniques [32]. This is reassuring given that <5% of all bladder cancer recurrence occur after 5 years [33]. Five year oncological outcome rates following RARC are between 53–74%, 66–80% and 39–66% for DFS, RFS and OS respectively [32].

The two histopathological surrogates for oncological outcomes namely positive surgical margins and lymph node yield are comparable between RARC and ORC. A RCT of 41 reported that there was no difference between lymph node yield or positive surgical margins [34]. These results are consistent with the Pasadena Consensus. Lymph node yield is highly dependent on extent and template of lymph node dissection and there is reported inter-observer variability between pathologists. Results of the recently reported German Association of Urologic Oncology randomised controlled trial comparing standard vs extended lymph node dissection did not show a survival advantage for extended lymph node dissection [20]. Overall reported positive surgical margin rates are approximately 5.6% (range: 0–26%) with pT2 positive margin rate of approximately 1% [32].

Conclusions

Male RARC is a safe and feasible operation which is increasingly considered the default surgical technique for radical cystectomy in high volume centres. With the advent of any new surgical technique, the learning curve effect and confound early reports of perioperative outcomes. This minimal invasive approach is ideally suited for patients who are physiologically unfit and may offer better postoperative return to normal activity and outcomes as well as potentiate the effects of enhanced recovery [9, 10]. In addition, oncological outcomes following RARC are equivocal to ORC. We believe that RARC represents an ideal radical treatment option for bladder cancer.

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17 Intracorporeal Urinary Diversion: Ileal Conduit

Isabelle S. Keller and Hubert John

Introduction

The intracorporeal urinary diversion after robotic-assisted radical cystectomy (RARC) is a major challenge to the surgeon and the assisting team especially due to the limited field of vision and the long operative time during the learning curve. Therefore most RARC surgeons perform an extra-corporeal technique for the urinary diversion using the incision to deliver the cystectomy specimen.

Several experienced robotic centres with high-volume of RARC published their techniques and outcomes of intracorporeal urinary diversion [1–9]. Here we describe the adopted technique of the intracorporeal ileal conduit with a Wallace plate at our institution step-by-step.

Patient Selection and Preoperative Preparation

Patient selection is similar to the open technique, inclusion criteria for the robotic-assisted laparoscopic technique itself need to be followed.

Bowel preparation prior to intracorporeal ileal conduit is not necessary [10]. Stoma site should be marked preoperatively regarding the same aspects as in open surgery.

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Operative Setup and Patient Positioning

Because of the long laparoscopic operative time in Trendelenburg position great care must be taken in patient positioning and padding to avoid decubitus and neuromuscular damage. Regularly controls of the blood circulation in both legs are mandatory during surgery. We use a pulse oximeter at the toe and regular leg repositioning with control of tenderness of the calf to prevent post-operative compartment syndrome.

At the beginning of urinary diversion, positioning of the patient remains the same as in RARC. The same trocars are used, whereby we place a 15-mm trocar in the lower left abdomen for the laparoscopic stapling by the assistant and for the third robotic arm placing the 8-mm trocar through the 15-mm trocar (piggyback, Fig. 17.1).

After RARC and lymph node dissection, the specimens remain plastic-wrapped in the upper abdomen to proceed to the urinary diversion. We stay with the 30° down lens during the whole surgery.

Ileal Conduit

After adhesiolysis the left ureter is tension-free transposed to the right side under the sigmoid colon. After the extended lymphadenectomy up to the aortic bifurcation, the passage is already created. With the fourth arm the two ureters

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_17

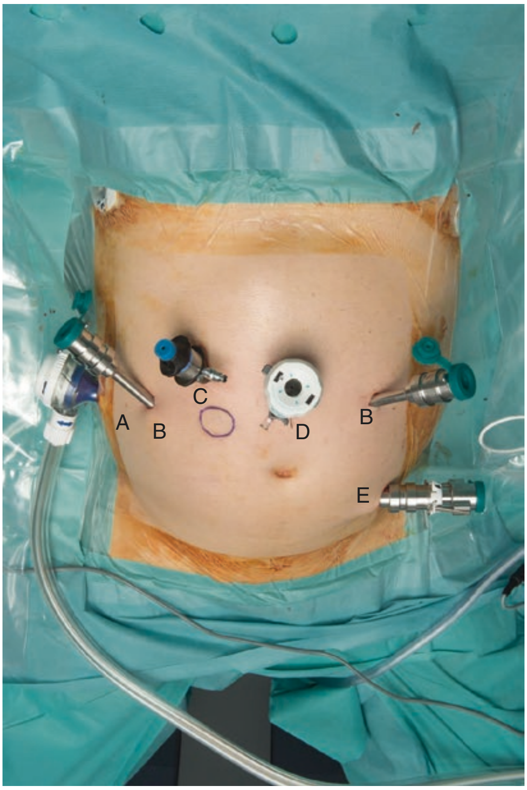

Fig. 17.1 Trocar placement for RARC and urinary diversion. The robotic trocars (*B*) should be placed slightly above the level of the aortic bifurcation in order to be able to perform the extended lymph node dissection and the urinary diversion. (*A*) 12 mm trocar, (*B*) 8 mm trocar, (*C*) 5 mm trocar, (*D*) camera trocar, (*E*) 15 mm trocar piggy-backed with a 8 mm trocar

are hold in front of the iliac vessels and spatulated at the same level over 15–20 mm. The dorsal wall of the Wallace plate is created with an absorbable 4-0 or 5-0 PDS® running suture (Fig. 17.2).

At this time, we disconnect the robotic arms and decrease the Trendelenburg position from 25° head down to 10–15° head down and reconnect the robotic stative to the ports, leaving the third arm still sterile off.

With two bowel graspers the terminal ileum is located and over 20 cm spared. For the ileal conduit, 20 cm of ileum are isolated with an Endo-GIA™ 60-mm stapler (Fig. 17.3) and placed in the pelvis. The continuity of the small bowel is restored side-by-side with an Endo-GIA™ 60 mm stapler carefully not to affect the mesentery (Figs. 17.4 and 17.5). To enlarge the passage a second Endo-GIA™ 45 mm stapler is again used in the same direction. The ends of the two sides are closed with a 60 mm stapler transverse positioned (Fig. 17.6). With large bowels, a second 45 mm stapler is sometimes needed to fully close the small bowel properly.

The isolated ileal sling is opened on both sides. Irrigation of the conduit is not necessary

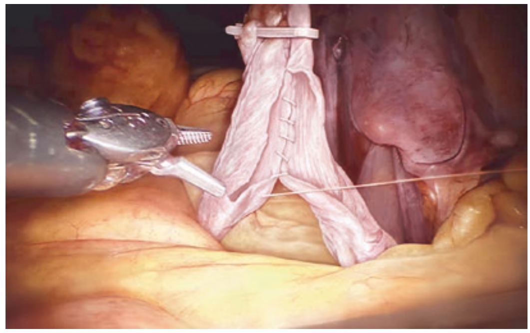

Fig. 17.2 Running suture of the dorsal Wallace plate after spatulation of the two ureters

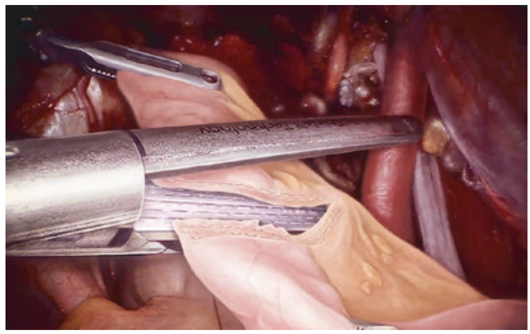

Fig. 17.3 Stapling of the ileum, using a Endo GIA™ 60 mm stapler, to isolate a 20 cm sling of the ileum

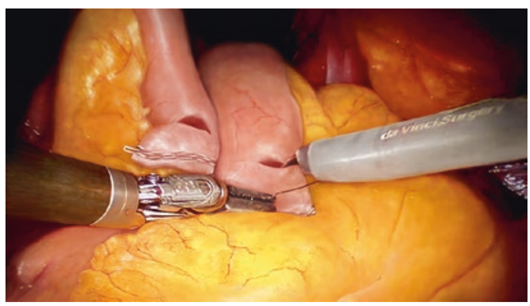

Fig. 17.4 Incision of the two ileum ends to prepare for the restoring of the bowel continuity

Fig. 17.5 Site-to-site anastomosis of the small bowel with an EndoGIA™ 60 mm stapler. Normally the stapler is introduced through the 15 mm trocar from the left side. Due to anatomical reason in this case, the stapler was used trough the 12 mm trocar on the right side

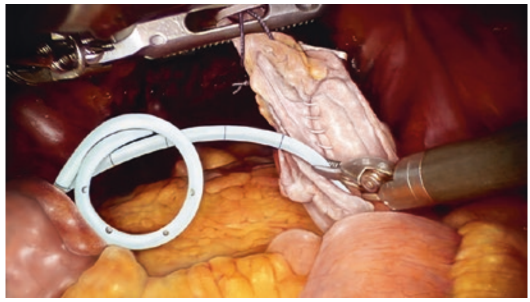

Fig. 17.7 Introducing the Single-J in the ureters. The guide-wire is advanced and withdrawn by the table-side assistant through the 12 mm trocar

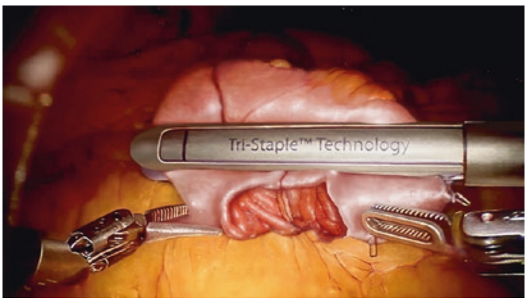

Fig. 17.6 Closing of the ileo-ileostomy with a transverse 60 mm stapler

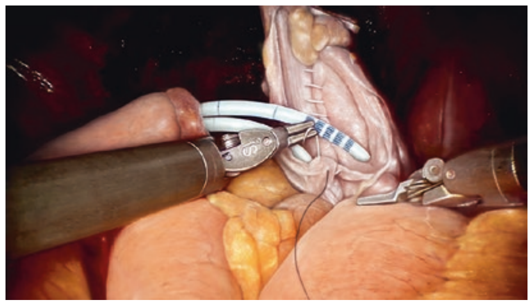

Fig. 17.8 The uretero-ileal anastomosis is done with a Quill™ or a Stratafix™

[6]. Two single-J 8 French ureteric stents are introduced after each other from the right 12 mm trocar through the ileal conduit (from the aboral to the oral side) and into the two ureters (Fig. 17.7) with Seldinger technique [11]. The Single-Js are shortened and the ends placed in the abdomen.

The uretero-enteric anastomosis is closed with a running technique using a double-armed bidirectional barbed suture as Stratafix™ or Quill™ (Fig. 17.8).

Before skin-incision at the stoma site, the endobags need to be located and secured extracorporeal at the site of delivering. A potential draining system should also be placed before losing the pneumoperitoneum. The aboral end of the ileal conduit is hold by one arm close to the incision side for the stoma (Fig. 17.9), the other instruments are removed. The skin- and fascial incision are made in the same way as in open surgery. The two single-Js and the aboral end of the

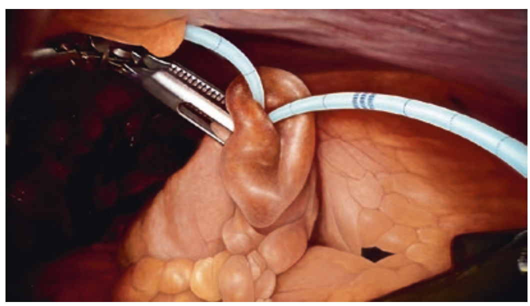

Fig. 17.9 Holding of the completed ileal conduit before skin incision for the stoma and retrieval of the aboral end

ileal conduit are hold with the fingers or an atraumatic clamping forceps. After removal of the last robotic instrument and termination of the pneumoperitoneum, the aboral end of the ileal conduit can carefully be pulled over skin level and fixed as usual. The cystectomy specimen is retrieved by enlarging the supraumbilical incision of the camera throkar (Fig. 17.10). In women, we

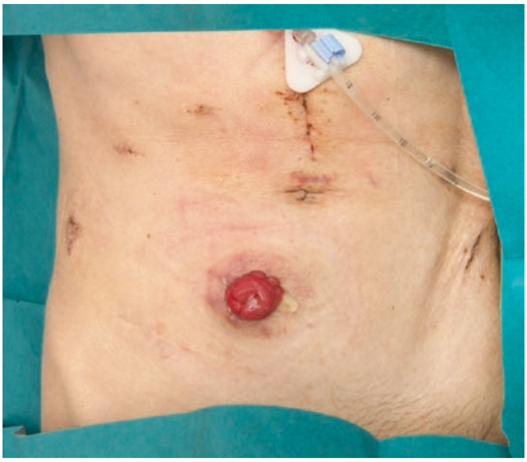

Fig. 17.10 Postoperative situs in a neurologic patient with a PEG tube after cystectomy and intracorporeal ileal conduit. The specimen was retrieved through the enlarged supraumbilical incision of the camera throkar

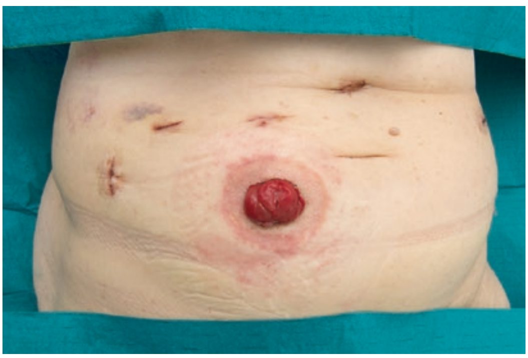

Fig. 17.11 Postoperative situs of a woman, the cystectomy specimen was retrieved through the vagina

deliver the specimen through the vagina right after the cystectomy and before beginning with the urinary diversion (Fig. 17.11).

Discussion

Intracorporeal ileal conduit is a safe and time-efficient urinary diversion in trained robotic teams with a standardized technique. Experienced teams report an operative time of about 125 min for the intracorporeal conduit [6]. Data show a lower 30-day readmission rate (5% vs. 15%, p <0.0001) and a lower 90-day mortality rate (1.6% vs. 4.9%, P = 0.043) with an intracorporeal technique compared to an extracorporeal approach [12]. In a large series of 100 consecutive intracorporeal ileal conduits [6], 50% of patients had a postoperative infection, thereof 9% sepsis. Only 1% needed a transfusion due to anemia, 9% developed a hydronephrosis, thereof 4% needed a percutaneous nephrostomy. Due to bowel obstruction or fascial dehiscence 3% needed a surgical exploration.

Further experience and long term follow-ups are needed to strengthen the intracorporeal technique.

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18 Intracorporeal Urinary Diversion: Orthotopic Neobladder

Abolfazl Hosseini, Achilles Ploumidis, Prasanna Sooriakumaran, Martin N. Jonsson, Christofer Adding, and Peter Wiklund

Introduction

The creation of the urinary diversion is a challenging surgical part after radical cystectomy and holds a special place in the development of urological practice. Following cystectomy, urine can either be diverted into an incontinent stoma, into a continent urinary reservoir catheterised by the patient or controlled by the anal sphincter, or into an orthotopic bladder substitute so that the patient voids per urethra.

During the last decade, urologists worldwide have witnessed a tremendous development of laparoscopic surgical treatment due to the development of robot-assisted surgery in many urological diseases. In parallel, the interest in expanding the role of robot-assisted radical cystectomy (RARC) for the management of urinary bladder cancer has risen during the last years and continues to grow. Robotic-assisted laparoscopic techniques have emerged allowing surgeons to more readily overcome the difficult learning curve and shorten operative times in minimally invasive abdominal and pelvic operations [1].

RARC has been grown steadily during the last years and has replaced LRC in centres where the robot is available. The neobladder can be formed intracorporeally [2–5], but operative time may be reduced if this is done extracorporeally through the same incision used to deliver the cystectomy specimen.

Most RARC surgeons advocate a combination of robotic-assisted laparoscopy and open surgery, performing the cystectomy and extended PLND with the robot, but due to technical difficulties and longer operative time [6–10] using an extracorporeal approach for the construction of the conduit or neobladder [6]. However, some centres including our own institution have developed techniques for RARC with a complete intracorporeal urinary diversion [2, 3].

Herein, we describe step by step the method used at the Karolinska Institutet for robot-assisted urinary diversion with ileal conduit and orthotopic neobladder by intracorporeal technique.

Patient Selection

The inclusion criteria for robotic-assisted continent or non-continent urinary diversion are the same as for open surgery. The selection process includes preoperative investigation to ensure fitness for surgery as well as specific counselling about robotic technology. Patients with decreased pulmonary compliance who cannot tolerate the Trendelenburg position are not candidates for the robot-assisted technique. Furthermore, if the patient has a history of previous extensive abdominal surgery, RARC may be contraindicated. Patients with bulky disease should be avoided.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_18

Preoperative Preparation

In patients scheduled for receiving an intracorporeal orthotopic neobladder, mechanical bowel preparation (osmotic laxative) may be used the day before surgery. A stoma site is also marked the day before surgery. Broad-spectrum intravenous antibiotics are administered at the start of the procedure.

Operative Setup

Patient Position

After induction of general endotracheal anaesthesia, a nasogastric tube and an 18-Ch Foley urinary catheter are inserted. The patient is placed in lithotomy position with arms adducted and padded. The legs are also abducted and slightly lowered on spreader bars. The table is placed in 25° Trendelenburg position during the RC and PLND. For the urinary diversion, the Trendelenburg position is decreased to 10–15°.

Equipment

The technique is challenging, requiring conventional laparoscopic infrastructure as well as an assistant skilled in conventional laparoscopy. Standard laparoscopic surgical equipment must be supplemented by some extra instruments (Ligasure® Covidien, surgical endoscopy clip applicators, laparoscopic Endo-Catch bags and laparoscopic stapler for intestinal stapling).

Trocar Configuration

Port placement is critical for successful robotic surgery. A six-port technique is used with the camera port placed 5 cm above the umbilicus in the midline. The camera port is placed by a small mini laparotomy as described by Hasson [11], and the other ports are placed in view of the camera. Pneumoperitoneum between 10 and 12 mmHg is desirable during the procedure, but during the port placement, a pressure of 18 mmHg can be helpful in creating additional tension on the abdominal wall. Two robotic ports are placed symmetrically and level with the umbilicus on the left and right side, lateral to the rectus sheath. A third robotic instrument port is placed just above and medial to the left anterior superior iliac spine through a 15-mm port, thereby enabling laparoscopic stapling by the assistant when the third robotic port is temporarily disconnected. Two assistant ports are placed, one on either side of the right robotic instrument port (Fig. 13.1).

Urinary Diversion

Orthotopic Neobladder

Anastomosis Between the Urethra and Ileum

After the cystectomy and the lymph node dissection are finished, the urinary diversion is performed. The first step is to perform an anastomosis between the ileum and the urethra. The 0° lens is used for this initial step. The ileum is sufficiently mobilised in order to reach down to the urethra. This is important for two reasons, first the anastomosis between the neobladder and urethra can be performed without tension, and second the neobladder will be placed correctly in the small pelvis during the whole procedure. This will help

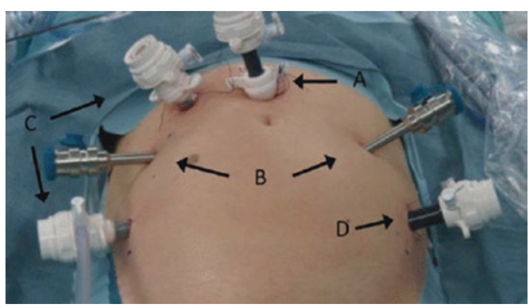

Fig. 13.1 Trocar placement for standard da Vinci system. (*A*) Camera trocar. (*B*) 8-mm trocar, right and left robot instrument. (*C*) 12-mm trocar, suction, bowel grasping, Ligasure. (*D*) 15-mm four robotic arm, specimen retrieval and stapling

during construction of the neobladder by running suture. A 20-Ch opening (Fig. 13.2) is made in the antimesenteric site of ileum, using robotic scissors. The anastomosis is performed according to the Van Velthoven technique with a 16 cm 4–0 Quill™ suture, allowing for 10–12 stitches (Fig. 13.3). A needle driver and a Cadiere are used to establish the anastomosis.

Isolation of 50-cm Ileum

The orthotopic neobladder is fashioned from a 50-cm segment of terminal ileum. The intestine is isolated using laparoscopic Endo-GIA with a 60-mm intestinal stapler (Fig. 13.4). The stapler is inserted by the assisting surgeon, using the 15-mm port on the left side. The ileum is stapled 40 cm proximal to the urethral-ileal anastomosis. The continuity of the small bowel is restored by using Endo-GIA with a 60-mm intestinal stapler, positioning the distal and proximal end of the ileum side to side with the antimesenterial parts facing each other (Fig. 13.5). An additional transverse firing of the Endo-GIA stapler is used to close the open ends of the ileal limbs (Fig. 13.6).

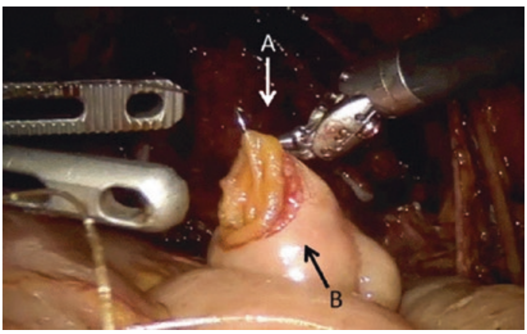

Fig. 13.2 An opening (*A*) in the ileum (*B*) is performed to allow the passing of a 20-Ch catheter

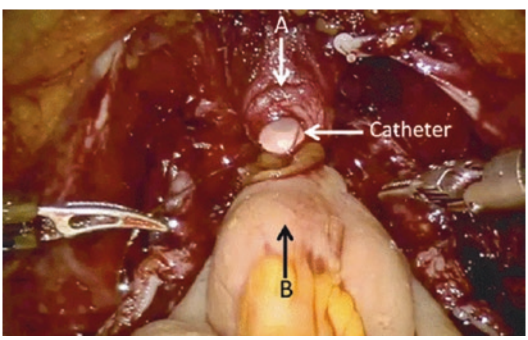

Fig. 13.3 Anastomosis between urethra (*A*) and ileum (*B*) using a 16-cm 4–0 Quill™ suture

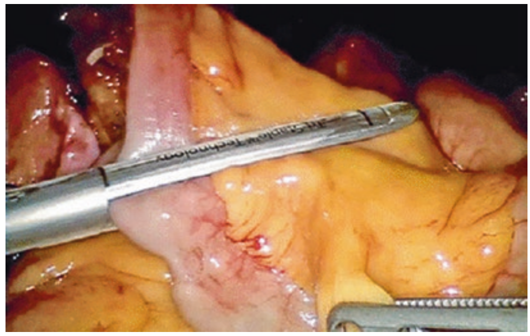

Fig. 13.4 Stapling of the ileum, using Endo GIA 60 mm

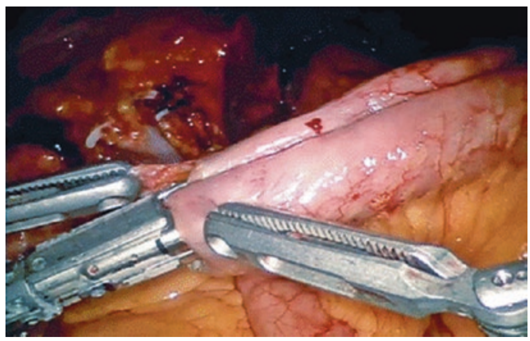

Fig. 13.5 Side to side anastomosis of the ileum by Endo GIA 60 mm

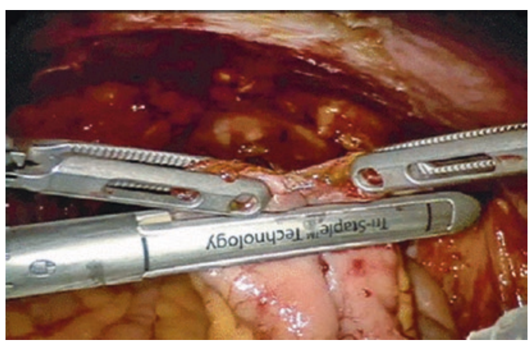

Fig. 13.6 Closing of the open end of the ileal limbs, using the Endo GIA stapler

Detubularisation

The distal 40 cm of the isolated ileal segment is detubularised along its antimesenteric border with cold scissors (Fig. 13.7), leaving a 10-cm intact proximal isoperistaltic afferent limb. Care is taken not to interfere with the sutures used for the anastomosis to the urethra (Fig. 13.8).

Formation of Studer Neobladder

After detubularisation, the posterior part of the Studer reservoir is closed using multiple running sutures (15-cm 3–0 V-Loc™) in a seromuscular fashion, avoiding suturing the mucosa. After the posterior part is sutured, the distal half of the anterior part of the reservoir is sutured, using the same suture. The 0° or 30° lens can be used for this part of procedure. The proximal half of the anterior part of the reservoir is left open and is closed in the last part of the procedure.

Ureteric Entero-Anastomosis

The anastomosis between the ureters and the afferent limb is performed using the Wallace technique [11] using a 0° lens. A 3–0 Biosyn® stitch is placed at the distal end of each ureter. The left ureter is tunnelled under the sigmoid mesentery to the right side. The ureters are then incised and spatulated 2 cm (Fig. 13.9). The posterior walls of the ureters are sutured side to side, using a 15-cm 4–0 V-Loc™ suture. Before the anastomosis between the ureters and the intestinal loop is performed, two Single-J 40-cm ureteric stents are introduced with Seldinger technique [12] through two separate 4-mm incisions at the lower part of the abdominal wall. The stents are pulled through the afferent limb (Fig. 13.10) and pushed up into the ureters on each side (Fig. 13.11). The ureters are then sutured to the afferent limb of the Studer pouch, using a 16-cm 4–0 Quill™ suture

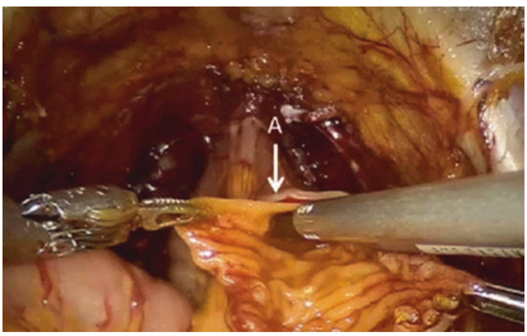

Fig. 13.7 Detubularisation of the ileum, antimesenterically (*A*) in order to create the neobladder

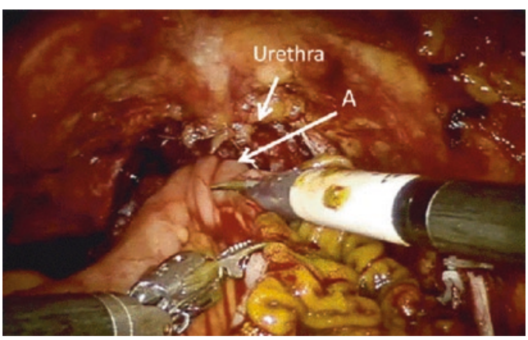

Fig. 13.8 Detubularisation, close to the ileourethral anastomosis (*A*), special care is taken not to interfere with the anastomotic suture

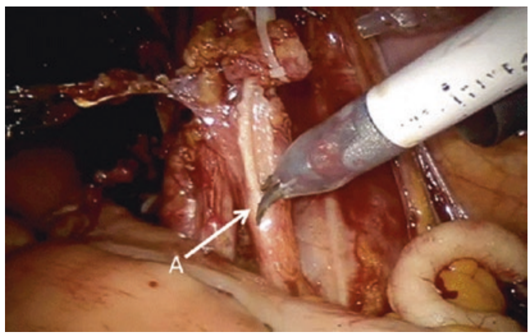

Fig. 13.9 Spatulation of the right ureter (*A*)

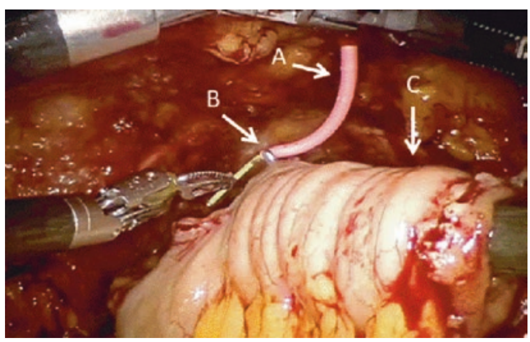

Fig. 13.10 Placement of a ureter stent (*A*) through a 3-mm port. The right robotic instrument (*B*) grasps the tip of the stent and inserts it upwards through the afferent limb (*C*) of Studer reservoir

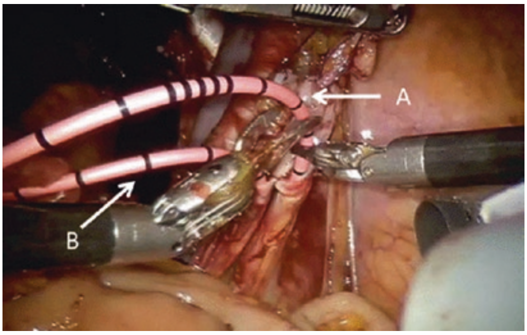

Fig. 13.11 Placement of a stent into the right ureter (*A*). The left ureter stent is already in place (*B*)

(Fig. 13.12). After the ureteric entero-anastomosis is completed, the stents are sutured and fixed to the skin.

Closure of the Studer Reservoir

The remaining part of the reservoir is then closed with a running 3–0 V-Loc™ suture, using a 0° lens. The balloon of the indwelling catheter is filled with 10 cc. The neobladder is then filled with 50 cc of saline to check for leakage (Fig. 13.13). If leakage is observed, extra sutures will have to be considered. A 21-Ch passive drainage is introduced and placed in the small pelvis.

Ileal Conduit, Intracorporeal Technique

Twenty centimetre of intestine is isolated from the terminal ileum, using an Endo-GIA with 60-mm intestinal staples. The continuity of the small bowel is restored as described above. The distal end of the conduit is fashioned as a stoma by the surgical assistant at the previously marked site on the abdominal wall. The left ureter is tunnelled under the sigmoid mesentery to the right side. The ureters are then incised and spatulated 2 cm. The Wallace technique is used here as described above. Single-J 40-cm ureteric stents are then introduced through the isolated ileal segment (ileal conduit). The stents are then pushed up into the ureters on each side and the ureteroenteric anastomosis is completed, using a two times 16-cm 4–0 Quill™ suture.

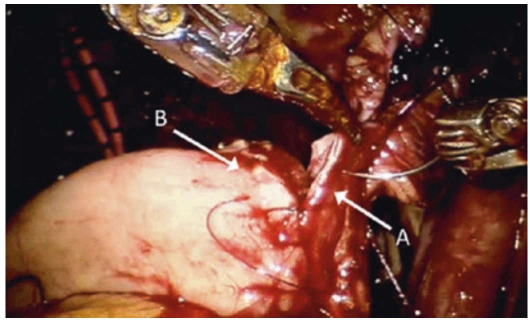

Fig. 13.12 Anastomosis between Wallace plate (*A*) and afferent limb (*B*) of the Studer reservoir, using a seromucosal suturing technique

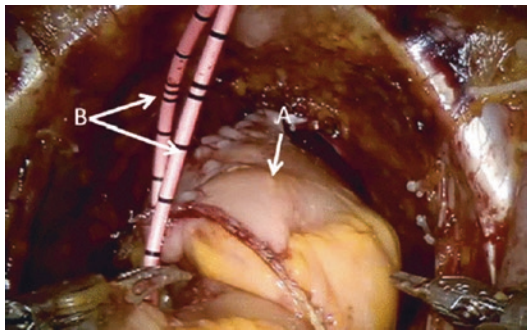

Fig. 13.13 After the neobladder (*A*) is completed, it is filled with 50-cc saline to check for leakage. The ureteric stents (*B*) are placed separately in the Studer reservoir

Special Considerations

Patient Position

Care should be taken to use a pneumatic leg compression system due to risk of decreased vascular perfusion during the procedure. To avoid cardiovascular complications for the patient, anticoagulant treatment is started with low-molecular-weight heparin according to the patient's body weight, the evening before surgery and until the patient is fully mobilised. It is feasible to perform the urinary diversion with a 10–15° Trendelenburg, as a higher Trendelenburg inclination is to be avoided to minimise the risk for cardiopulmonary complications.

Port Position

It is always important to make sure the fourth arm port and the left robotic arm port are not in the same alignment to avoid clashing of the robotic arms.

Urethral-Neobladder Anastomosis

Making the anastomosis between the urethra and the ileum should be the first step in the formation of an intracorporeal orthotopic neobladder. This is a critical step because the anastomosis can be made without tension, and the neobladder will be placed correctly in the small pelvis during the whole procedure.

Steps to Avoid Complication

Shoulder pads should be avoided due to high risk for plexus damages. Care should be taken during the tunnelling of the left ureter behind the colon sigmoid to avoid damaging any vascular structures. It is important to check for leakage after the neobladder has been created. Extra suturing to secure a water-tight reservoir and anastomosis is fundamental to decreasing postoperative complications.

Discussion

With the introduction of the da Vinci® robotic system (Intuitive Surgical) in urological clinical practice, a large number of robot-assisted surgical procedures have been performed. Compared with the traditional laparoscopic technique, the hand-eye alignment and depth perception provided by the robotic system are advantageous and may eventually be superior to using open procedures, resulting in less surgical morbidity and a shorter learning curve. However, RARC with totally intracorporeal urinary diversion is still considered a technically challenging procedure [2, 3, 9]. Since the first report by Beecken et al. [2] in 2003 RARC, PLND and urinary diversion have been adopted by several institutions worldwide, and today >1500 procedures have been reported to the IRCC.

It has been debated whether the intracorporeal technique for urinary reconstruction has any advantages over the extracorporeal technique. The intracorporeal technique allows the restoration of small bowel continuity and the construction of the neobladder performed without incision of the abdominal wall. In the female, the specimen may be taken out through an incision in the vaginal wall, and in the male, the specimen is extracted through a small incision at the end of the procedure. It has been argued that the intracorporeal approach should only be used if specimen retrieval may be performed without an additional incision. The intracorporeal reconstruction is less traumatic for the patient, but on the other hand, more technically demanding for the surgeon. Robotics makes an intracorporeal technique a more feasible procedure even though most centres prefer an extracorporeal approach for urinary diversion [6–8, 10]. One major advantage of performing the urinary diversion intracorporally is that performing the running suture of the anastomosis between the urethra and the ileum minimises the risk of urinary leakage. There is also less traction to the anastomosis between the reservoir and the urethra using an intracorporeal approach, as an appropriate ileal segment long enough to reach down to the urethra can be used [1].

The robotic system may positively influence functional results at RARC, especially if a nerve-sparing procedure is attempted. Furthermore, this system might facilitate suturing the anastomosis between the urethra and the reservoir, which in turn may improve urinary continence.

Conclusion

RARC with totally intracorporeal urinary diversion for patients with TCC of the bladder is technically feasible and reproducible with results comparable with those from ORC series and with acceptable complication rates, adequate lymph node yield and good functional results.

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19 Technique of Extracorporeal Urinary Diversion

Avinash Chennamsetty and Kevin G. Chan

Introduction

The purpose of this chapter is to provide a step-by-step approach to the different extracorporeal urinary diversions that may be performed in the setting of robot-assisted laparoscopic radical cystectomy (RARC). Recent reports indicate comparable results to open surgery with regard to intermediate- and long-term oncological outcomes and extent of pelvic lymph node dissection [1–3]. However, operative times are one of the main obstacles that hinder widespread acceptance of RARC [4]. Extracorporeal urinary diversion with RARC provides a method of reconstruction that mirrors that of open surgery with regard to operative times [5]. Complication rates and functional outcomes with extracorporeal urinary diversion also appear at least comparable to open series.

We will discuss in detail the extracorporeal techniques of a Studer orthotopic neobladder, Indiana pouch continent cutaneous urinary diversion, and ileal conduit urinary diversion. At our institution, we have performed more than 550 RARCs. Urinary diversions were primarily performed extracorporeally and the majority were continent urinary diversions. We describe our technique that follows a common template, which can be applied to all types of urinary diversion.

We first describe the technique of the Studer orthotopic neobladder. This is the most technically difficult of the three diversions because there are more maneuvers required to adapt it to robotic surgery, and because the robot needs to be re-docked. The Indiana pouch and ileal conduit techniques are simpler variations of the same basic template. The port site placement used for the cystectomy portion and referenced later in this chapter has been previously described [6].

Studer Orthotopic Neobladder

The extracorporeal Studer neobladder technique is best described in three stages: steps performed prior to undocking the robot, steps performed while the robot is undocked, and steps performed when the robot is re-docked.

Steps Performed Prior to Undocking the Robot

During the course of the radical cystectomy, there are a number of maneuvers that facilitate the creation of the neobladder. We maintain maximal periureteral tissue on the mobilized ureters. We typically divide our ureters early in the operation. The ureters are divided between extra large Weck Hem-o-lok® clips. The clips have a pre-tied 8-cm

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_19

dyed or un-dyed suture to denote left and right. The clips are placed on the ureter through the right iliac 12-mm bedside assistant's port in a right to left orientation. This allows us to identify any twists in the ureter at the time of the uretero-ileal anastomosis. The ureteral sutures are placed aside, out of the operative field, during the completion of the cystectomy.

As the urethra is divided, we place a 9-in. 2–0 Vicryl™ (Ethicon, New Brunswick, NJ) suture at the 6 o'clock position of the urethra that will be used for the first stitch in the urethral anastomosis. The needle is set aside in the retropubic fat so that it can be easily found when the robot is re-docked for the anastomosis.

Once the cystectomy and lymph node dissection are complete, there are a small number of final steps performed prior to undocking the robot. The left ureter is brought under the sigmoid mesentery by guiding the attached suture with a laparoscopic grasper. An 8-cm silk stitch is placed in the terminal ileum to allow for quick identification through the small midline incision. A 16-Fr red Robinson catheter with an 8-cm silk suture pre-tied to the end is placed in the urethra. The catheter will later be sutured to the neobladder to serve as a handle for the assistant to bring the assembled neobladder down into the pelvis. The two ureteral sutures, the ileal suture, and the red Robinson suture are then placed into the assistant's laparoscopic grasper by the console surgeon. This allows for all four of the components to be readily available for the urinary diversion when the robot is undocked and the infra umbilical midline incision is opened.

Steps Performed After Undocking the Robot

The robot is undocked but kept sterile as it will be used for the urethral anastomosis. The insufflation is turned off and all port sites are kept in place. We keep the patient in Trendelenburg position to keep the small bowel out of the way during the neobladder construction. The midline incision is extended inferiorly 6–8 cm, and the specimen is extracted using an Endo Catch™ II 15-mm specimen pouch (Covidien, Mansfield, MA). The use of the specimen bag serves to preserve the intact specimen and to also facilitate using a smaller incision.

Several sites have been used for the extraction of specimen and subsequent extracorporeal urinary tract reconstruction including periumbilical midline (incorporating the camera port), infraumbilical midline (separate from the camera port), Pfannestiel, and McBurney (incorporating right-sided port site for ileal conduits) [7]. We routinely use an infraumbilical midline incision that provides the best access to the ureters and afferent limb of the diversion regardless of body habitus. While the specimen can be removed through a generally smaller incision, an incision between 6 and 7 cm is approximately the smallest incision that allows us to place the constructed neobladder back into the abdomen. The use of an Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA) provides optimal exposure through the incision (Fig. 19.1).

The laparoscopic grasper holding the sutures on the ureters, ileum, and urethral catheter is brought out through the midline incision. The ureters are placed in their correct anatomic orientation, using both visual and manual evaluation to check for twisting or crisscrossing of the ureters.

The ileum is then brought out through the incision to create the ileal neobladder. For orthotopic diversions, we prefer a low-pressure ileal reservoir as described by Studer; however, this

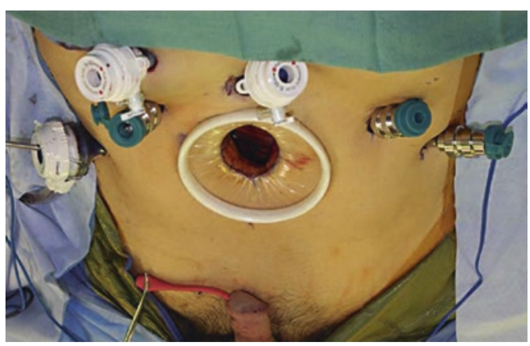

Fig. 19.1 The 6-cm incision with Alexis wound retractor provides excellent exposure of small bowel for neobladder reconstruction

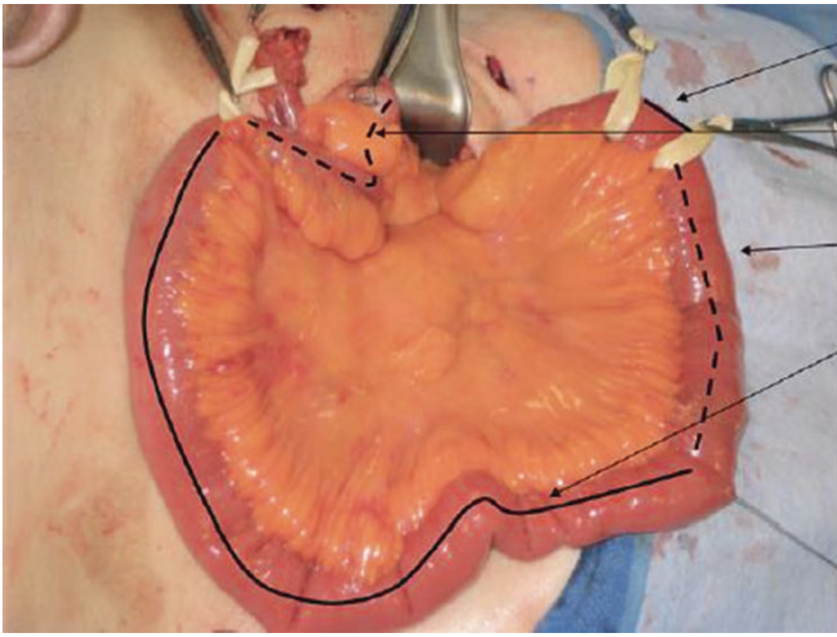

Fig. 19.2 Isolated small bowel used to construct the neobladder

technique will also accommodate most other types of orthotopic diversion [8].

Prior to the construction of the reservoir, bowel continuity is restored by means of a stapled anastomosis and the mesenteric trap is closed.

We isolate a 60-cm segment of distal ileum beginning 15 cm proximal to the ileocecal valve. We prefer to discard a 5-cm segment of ileum proximally to afford us better mobility of the neobladder down to the urethra and farther from the bowel anastomosis (Fig. 19.2). The neobladder is constructed in the exact manner as would be done open.

Once the neobladder is complete, we estimate the most dependent portion where we think the urethra will be anastomosed. We place a dyed 0 Vicryl™ figure-of-eight suture at the estimated 6 o'clock portion of the neourethra that will be used as a handle by the console surgeon's fourth arm using a ProGrasp™ forceps (Fig. 19.3). An additional suture is placed in the same position and sutured to the red Robinson catheter that is in the urethra. This acts as an additional handle for the bedside assistant to help bring the neobladder down into the pelvis. An un-dyed Vicryl™ is placed at the 12 o'clock portion of the neourethra to give the console surgeon better orientation of the pouch and to provide an additional handle with which to manipulate the pouch.

The neobladder is then placed into the pelvis with only the afferent limb and bilateral ureters exposed at the infraumbilical midline incision (Fig. 19.4).

One of the most common concerns regarding extracorporeal urinary diversion is the degree of ureteral mobilization necessary to perform the ureteroenteric anastomosis at the level of the skin incision. Guiding principles include minimizing tension and performing the ureteral anastomosis as proximally on the ureter as possible [7]. In patients in whom the ureter needs to be resected more proximally or in obese patients, the surgeon should not hesitate to extend the incision to optimize conditions for the ureteral anastomosis.

The ureters are once again inspected to ensure they are oriented in their correct anatomic positions. Each ureter is then spatulated and individually sewn in an end-to-side fashion with interrupted 4–0 Vicryl™ sutures. Each uretero-ileal anastomosis is stented with an 7 Fr urinary diversion stent that is brought out through an

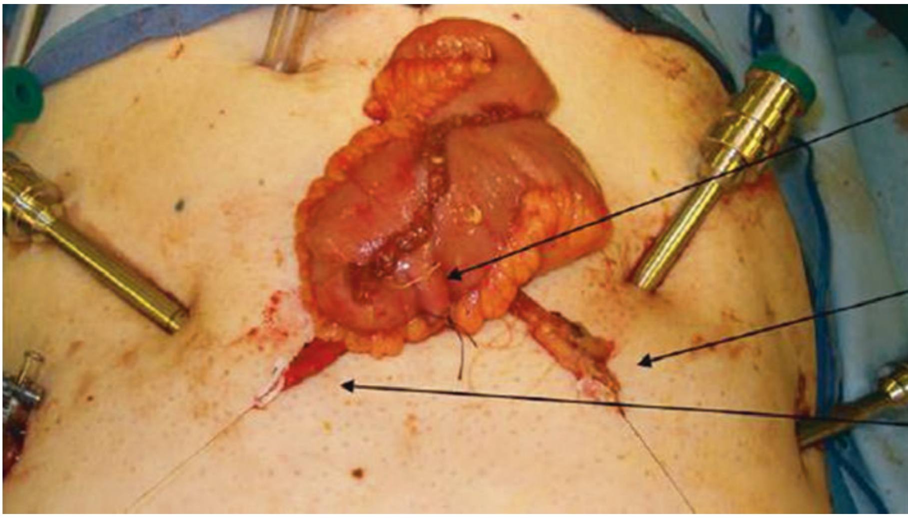

Fig. 19.3 The neobladder is completed with the 6 and 12 o'clock sutures placed at the site of the anticipated neourethra

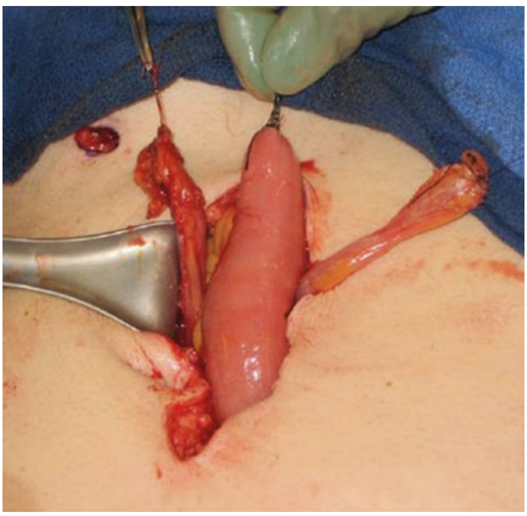

Fig. 19.4 The completed neobladder is placed back into the abdomen, leaving only the ureters and afferent limb exposed for the uretero-ileal anastomoses

opening in the afferent limb and beside the right paramedian robotic port. The feeding tubes are secured at the afferent limb with a 3–0 plain gut purse-string suture.

The infra-umbilical midline incision is then closed to ensure an airtight seal for re-insufflation. The robot is then re-docked.

Steps Performed After Re-docking the Robot

The urethral anastomosis is performed robotically using either a 0° or 30° down lens. We first inspect the uretero-ileal anastomoses to ensure they are lying in their correct orientation.

The redundant sigmoid colon is moved out of the pelvis. The neobladder is then brought down into the pelvis by the console surgeon using the pre-placed 6 o'clock Vicryl™ handle and the fourth arm. The assistant can aid in the maneuver by placing gentle traction on the red Robinson catheter that is also attached to the 6 o'clock position of the neobladder.

The posterior urethral plate reconstruction is then performed in similar fashion to a Rocco reconstruction [9]. The musculofascial plate of the rectourethralis is approximated to the cut edge of Denonvilliers' fascia in figure-of-eight fashion using 3–0 polyglactin suture. The neobladder is then brought down to the pelvis by applying gentle pressure on the red Robinson catheter and the 6 o'clock suture in the neobladder. Once in the pelvis, the neobladder is held in place using the robotic fourth arm on the 0 polyglactin 6 o'clock suture. Care should be taken to ensure that the fourth arm of the robot is not compressing the external iliac vessels while it is holding the neobladder down in the pelvis for the urethral anastomosis. Next, the musculofascial plate of the rectourethralis is approximated to the posterior neobladder, approximately 2 cm posterior to the planned urethral aperture, using 3–0 polyglactin suture. The suture on the red Robinson catheter is the cut.

Occasionally, the neobladder does not completely reach the urethra, creating tension at the anastomosis. Two maneuvers can be employed to decrease this tension. The first is simply perineal pressure. The second is to undock the robot, minimize the Trendelenburg, and re-dock the robot.

The site of the urethral anastomosis on the neobladder is opened using a robotic shears. This site is determined by choosing an area where the opening is well visualized and easy to work with.

Using the 2–0 Vicryl™ suture that was pre-placed at the 6 o'clock position of the urethra at the time of the urethral division, we begin the urethral anastomosis by re-approximating the urethral plate with 3–4 interrupted sutures. Additional 3–0 Vicryl™ sutures are placed at the 5 and 7 o'clock positions and run anteriorly to be tied at 12 o'clock. We typically use CT-3 needles for the urethral anastomosis, but RB-1 needles are sometimes used in very narrow pelvises. Alternatively, two 3–0 absorbable barbed sutures that are interlocked at the ends are run on each side of the urethral anastomosis from the 6 o'clock position, where the posterior urethral plate has been reapproximated, and tied at the 12 o'clock position.

The completed anastomosis is tested by irrigating the neobladder with 60–120 mL of normal saline. Any visible area of extravasation from either the neobladder or the anastomosis is reinforced with an additional 3–0 Vicryl™ suture. A new two-way 18-Fr hematuria catheter is placed into the neobladder to gravity drainage with 15 mL of sterile water in the balloon.

A closed suction drain is placed through the left pararectus robotic port and placed over the urethral anastomosis and adjacent to our uretero-ileal anastomoses. The drain and stents are secured with sutures. The robot is then undocked, and the closure of all robotic incisions are completed. The stents are cut 5 cm from the skin and placed to gravity drainage using a urostomy drainage bag, and the skin incisions are closed.

Numerous centers are now approaching the ureteroenteric anastomosis for neobladders in a hybrid fashion. The bowel anastomosis and pouch construction are performed extra corporeally, and then the robot is redocked to perform the urethral anastomosis, and, subsequently, the ureteral anastomoses. By performing the ureteral anastomoses after the urethral anastomosis, the fixed position of the afferent limb allows the surgeon to use a more proximal, less mobilized and presumably better perfused ureter [7]. The ureters are spatulated and individually sewn in an end-to-side fashion with interrupted 4–0 Vicryl™ sutures. Each uretero-ileal anastomosis is stented with an 7 Fr urinary diversion stent that is brought in by the bedside assistant and placed over a wire. The stent is brought out through an opening in the afferent limb and is externalized through one of the port sites. The aperture in the afferent limb is closed around the stent using a purse string suture.

Indiana Pouch Continent Cutaneous Catheterizable Reservoir

Continent cutaneous urinary diversion remains an important option for those patients who are not candidates for orthotopic urinary diversion. With the Indiana pouch, minimal steps are required prior to undocking the robot. As with the neobladder, the ureteral sutures are secured with a laparoscopic grasper through the right iliac port.

We undock the robot but keep the abdomen insufflated with all ports in place. The Trendelenburg is decreased and the table tilted left as far as possible. Using our existing port placements, a conventional laparoscopic technique can be utilized to mobilize the right colon and hepatic flexure. However, since we will already be using an Alexis wound retractor for exposure through an infraumbilical midline incision, we prefer to use its associated GelPort®

(Applied Medical, Rancho Santa Margarita, CA) to facilitate a simple and expeditious hand-assisted mobilization of the right colon and hepatic flexure. The table is then leveled, the ports are removed, and the specimen is removed using the existing 8 cm midline incision. This incision is larger than the incision made for the neobladder because the Indiana pouch tends to be bigger and this also allows us better exposure for the uretero-colonic anastomoses. In obese patients, the size of this incision may need to be further increased to optimize exposure.

We isolate the 15 cm of proximal ileum along with 31 cm of right colon. The avascular plane of Treves is divided to allow mobility to our stomal segment. Bowel continuity is then reestablished using a side-to-side ileal-colic-stapled bowel anastomosis. The mesenteric trap is then closed.

We perform a modified Indiana pouch as described by Ahlering et al., but this technique can be adapted to most continent catheterizable pouches [10].

The colonic portion of the isolated bowel segment is open along its antimesenteric border, excising the staple line and the appendix. The staple line at the end of the ileal segment is also excised. At the point, we taper the ileal segment over a 14 Fr red robinson catheter using multiple loads of a GIA stapler down to the distal 1 cm of terminal ileum as it enters the cecum (Fig. 19.5a, b).

The base of the ileocecal valve at the is 1 cm space in imbricated over the catheter with three interrupted 3–0 silk lembert sutures at the superior, anterior, and inferior aspects. This reinforces the ileocecal valve and should facilitate a smooth passage of the catheter into the colonic pouch. If there is any difficulty passing the catheter after placing these stitches, the three silk sutures are removed and the imbrication performed once more. The colonic segment is then closed in a Heineke-Mikulicz fashion with a running 3–0 Vicryl™ suture.

The colonic pouch is then rotated counterclockwise 90°, bringing the right-sided corner of the colonic closure pointing down towards the pelvis. This is the natural lay of the pouch as influenced by its mesentery. This also allows the tapered ileal segment to lay medial in its final position that facilitates the stoma positioning on the abdomen. This pouch position then dictates the location of the ureterocolonic anastomoses, with the left ureter anastomosed to the left side of the colonic corner in the pelvis, and the right ureter anastomosed to the right side of the colonic corner. The ureteral anastomoses are performed in a spatulated, end-to-side fashion with interrupt 4–0 Vicryl™ sutures on a cutting PS-2 needle. These anastomoses are stented with 7 Fr urinary diversion stents that exit out the right side of the pouch and out the right iliac port site. The stents

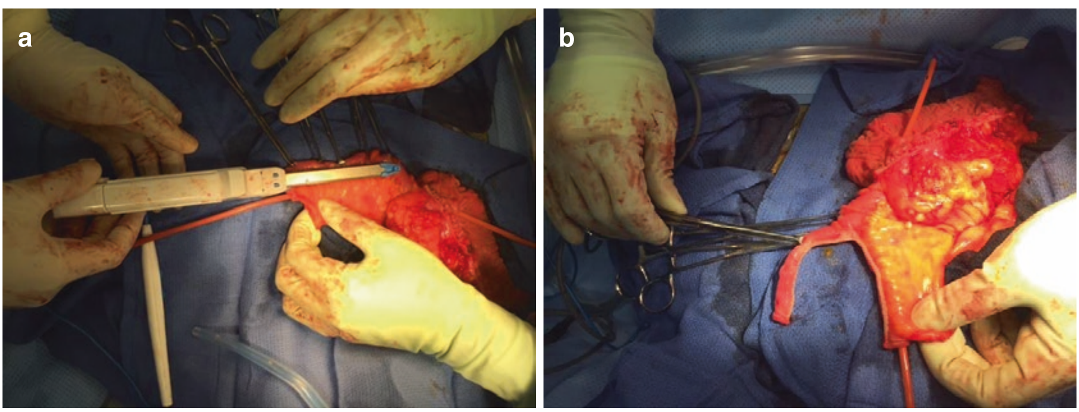

Fig. 19.5 (**a**) Staple loads are used to taper the 15 cm segment of ileum as narrow as possible (image courtesy of Jonathan Warner M.D.). (**b**) Care must be take to ensure he stapler stays completely antimesenteric so as not to include the mesentery in the staple line. The final 1 cm near the ileocecal valve is imbricated over the catheter (image courtesy of Jonathan Warner M.D.)

are secured with silk sutures at the skin and cut short to drain into an ostomy bag.

We use a 24-Fr Malecot or Foley catheter as a “suprapubic” catheter that exits out the most superior aspect of the Indiana pouch and is brought out through a 1 cm incision approximately 5–6 cm superior to the stoma location. The distance between the stomal segment and the suprapubic tube should match the distance between the stoma and suprapubic tube at the level of the skin. The suprapubic tube is secured to the anterior abdominal wall in a Stamm fashion. The right pararectus robotic port site is commonly used as the stoma location, provided it is traversing the rectus abdominus. Care is taken not to place the suprapubic tube site is too high as it can distract and place tension on the ureteral anastomoses. In this situation, we use the right pararectus robotic port site for the suprapubic tube, and create a separate more inferior opening for the stoma.

The ileal segment is brought out through the designated stoma site, and amputated in a fashion that creates a short and direct channel to the Indiana pouch. The stoma is matured to the skin with interrupted 3–0 Vicryl™.

A closed suction drain is placed along the pouch and adjacent to our uretero-colonic anastomoses and brought out through the left pararectus robotic port site. The stoma is dressed with a petroleum dressing and not cannulated until the time of pouch training. The midline incision is then closed.

Ileal Conduit Urinary Diversion

Prior to undocking the robot, as with the neobladder, the ureteral and ileal sutures are secured on a laparoscopic grasper through the right iliac port. The ports are then removed and a 5 cm infra umbilical midline is made. This incision can be smaller since it does not have to accommodate a pouch. The specimen is removed and the ureters and ileum are brought out through the incision and oriented.

We isolate our distal ileal segment in the conventional open fashion, discarding an additional 5-cm segment of ileum proximally to give us additional mobility of the afferent aspect of our conduit. Bowel continuity is reestablished with an ileal-ileal side-to-side stapled anastomosis.

Our uretero-ileal anastomoses are performed using a Bricker end-to-side spatulated anastomosis bilaterally as describe above. We mature the stoma as described by Brooke and place our closed suction drain into the pelvis and adjacent to our uretero-ileal anastomoses [11]. Our stents are brought out through the stoma and secured with a suture. The infra umbilical midline incision is then closed.

The ureteroenteric anastomosis for an ileal conduit may also be approached in a hybrid fashion [7]. The bowel segment is isolated, bowel continuity is reestablished, the incision is closed, and the robot is redocked to performed the ureteral anastomosis.

Perioperative Care

Recently, a shift has occurred in the perioperative management of patients undergoing RARC and urinary diversion. Referred to as enhanced recovery after surgery (ERAS) pathways, these steps have shown to accelerate posteropative convalescence, decrease costs, and maintain quality [12]. Patients are placed on Alvimopan, an μ-opioid antagonist, prior to the induction of anesthesia and continued on this postoperatively until first bowel movement. Nasogastric tubes and bowel preparation are avoided. Clear liquid diets are started on postoperative day 1, and patients are discharged home when tolerating a regular diet. Multimodal postoperative analgesia to minimize opioids and early ambulation are also cornerstones to ERAS protocols. The closed suction drain is typically removed at the time of discharge if outputs stay at or below 200 mL/8 h. In addition to the above mentioned ERAS protocols, our institution has created a care coordination pathway focusing on preoperative patient and family goals of care and treatment expectation, daily post-operative multidisciplinary rounds, and close outpatient monitoring on discharge via scheduled phone calls as well as clinic visits. Implementation of these steps in the perioperative management of RARC and urinary diversion patients has led to a decreased length of stay and post-operative complication rates [13].

For the continent diversions, a pouchogram is obtained at 3 weeks after surgery, and the urinary or suprapubic catheter and stents are removed if no extravasation is identified. A renal ultrasound is obtained 6 weeks after stent removal as a baseline evaluation of the upper tracts.

Advantages and Disadvantages of Extracorporeal Urinary Diversion

Compared to the intracorporeal technique, the key advantage of extracorporeal urinary diversion is the utilization of open suturing. This results in a shorter learning curve, operative times comparable to open procedures, less time under general anesthesia for the patient, and ultimately less cost. A prolonged learning curve would be justified if prospective, randomized trials show an obvious advantage to the intracorporeal technique [14]. However, retrospectively reviewed data that exist comparing intracorporeal to extracorporeal urinary diversions is neither robust nor mature enough to draw definite conclusions and justify change in surgical technique [15]. Using our hybrid extracorporeal technique that re-docks the robot to perform the neobladder-urethral anastomoses allows efficient and purposeful use of the robot, accessing the deep pelvis and enabling placement of sutures under direct vision [14]. Other advantages of extracorporeal diversion include minimizing fecal contamination of the peritoneal cavity and minimizing surgeon fatigue.

The main disadvantage of the extracorporeal urinary diversion is the need for a larger incision (typically ranging from 5 to 8 cm) which can lead to poorer cosmesis and theoretically a higher pain medication requirement. Another potential problem cited with the extracorporeal technique is impaired tissue orientation/positional distortion and the need for considerable mobilization of the ureters, both of which may contribute to ischemia and possible ureteral stricture. Other disadvantages include increased evaporative fluid loss and external bowel manipulation, both of which may contribute to ileus.

Complications and Outcomes

As the technique of RARC matures, we are seeing complication rates at least comparable to open surgery [1, 2, 4, 16–19]. Wang and colleagues described no significant difference in complication rates between RARC with extracorporeal urinary diversions and open radical cystectomy (21% compared with 24%; $p = 0.3$) [18]. Similarly, Nix and colleagues reported similar results with no significant difference between complication rates of the same two cohorts (33% complication rate for RARC with extracorporeal urinary diversion compared with 50% complication rate for open radical cystectomy; $p = 0.28$) [19]. Similarly, in a comparison of readmission rates between patients who received RARC and open radical cystectomy, several studies have reported no significant difference [4, 20].

However, there is a paucity of data looking at functional outcomes with extracorporeal orthotopic and cutaneous continent urinary diversion in the RARC setting. To date, several large series of open radical cystectomy have shown day and nighttime continence ranges from 87% to 100%, and 70% to 95%, respectively [21]. A RARC series mostly including patients who underwent an extracorporeal studer urinary diversion reported 12 month continence rates ranged from 83 to 100% in men and 67% in women; the nighttime rates were 66–76% [22]. With regard to continent cutaneous urinary diversion, Torrey and colleagues reported 97% daytime and nighttime continence rate at 20 months for patients undergoing RARC with extracorporeal Indiana Pouch diversion, which is comparable to open cystectomy rates of 96–100% daytime, and 73–100% nighttime continence rates [23]. While the data is still limited, it appears that both complications and functional outcomes with extracorporeal urinary diversion are comparable to open techniques.

Conclusion

The extracorporeal urinary diversion technique provides an effective and smooth transition from open radical cystectomy to the labor-intensive technique of RARC. We expect that with refinements in technology and surgical technique, complication rates and functional outcomes will continue to improve upon existing open surgical standards.

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20 Robot-Assisted Treatment of Bladder Diverticula

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Definition of Bladder Diverticula

A bladder diverticulum is an outpouching caused by protrusion of the bladder mucosa through the bladder wall. Raised bladder voiding pressure forces bladder mucosa through gaps in the muscle meshwork, leading to formation of narrow or wide neck diverticula. The result is a thin-walled structure connected with the bladder lumen and filled with urine. Histologically, the diverticulum wall is composed of mucosa, subepithelial connective tissue or lamina propria, scattered thin muscle fibres, and an adventitial layer [1, 2].

Classification, Pathophysiology, and Aetiology

In the following text, we will consider only big symptomatic congenital bladder diverticula. These have a narrow neck and are mostly located laterally and posteriorly to the ureteral orifice and usually solitary (Fig. 20.1). Rarely, they are located at the bladder base with a wide supratrigonal diverticulum neck (Fig. 20.2). Sometimes the diverticula are bilateral (Fig. 20.3). Typically, these congenital perihiatal bladder diverticula have a narrow neck, are found in smooth-walled bladders and are not associated with significant trabeculation [3]. Though in the past such diverticula were considered to be secondary to bladder neck obstruction many occur in the absence of obstruction. A primary weakness of the bladder wall at the level of the ureterovesical junction obstruction is accepted as a cause of congenital bladder diverticulum [3–5].

However, in many men with a bladder diverticulum there is a concomitant bladder neck obstruction characterised by a steep bladder neck and small prostate with a predominant muscular component (authors' personal experience). Congenital bladder diverticula are seldom seen in women and quite rare in the absence of obstruction [5–7].

Big bladder diverticula empty poorly during micturition, leaving a large post void residual urine volume (Fig. 20.4a–c).

Symptoms

Adult patients often complain of urinary tract infection or of double voiding i.e. the need to urinate again immediately after voiding. Clinically

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_20

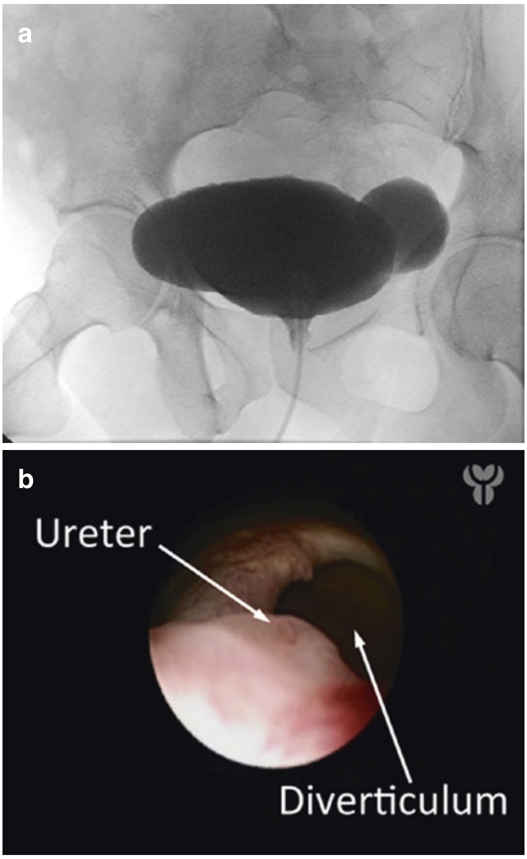

Fig. 20.1 Left-sided solitary congenital bladder diverticulum; (**a**) cystographic and (**b**) endoscopic view

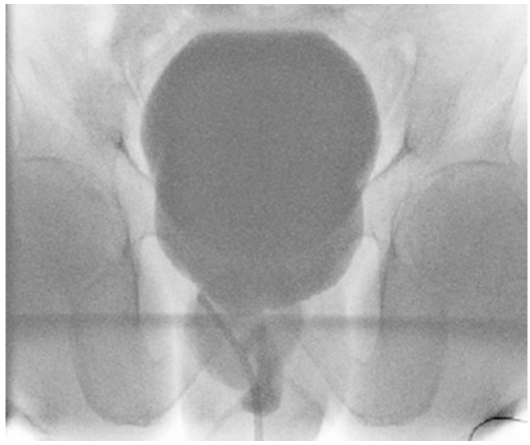

Fig. 20.2 Supratrigonal congenital bladder diverticulum

Fig. 20.3 Bilateral congenital bladder diverticula

sometimes a soft tumour in the lower abdomen is palpable. Most bladder diverticula are found during the radiographic or endoscopic investigation of these symptoms. Occasionally a diagnosis of bladder diverticulum is made incidentally during CT, ultrasound or MRI of the abdomen. In countries where urologists and other specialities use ultrasound examination routinely in their daily work they will mostly, after discovering a huge liquid mass in the pelvis, refer the patient for CT scan or MRI where the diagnosis will be made, followed by endoscopy. Sonographically or fluoroscopically monitored voiding is an excellent method to study anomalous voiding into the diverticulum during detrusor contraction which may result in paradoxical enlargement of the bladder diverticulum during micturition. Figure 20.4 shows us an increasing volume of the diverticulum during urination ending with a volume of the diverticulum equal to the bladder volume at beginning of micturition. A voiding urethrocystogram provides information regarding anatomy, location and size, as well as associated vesicoureteric reflux and, importantly, emptying of the bladder. Figure 20.2 shows a big medially located wide neck diverticulum with poor emptying during the urodynamic examination under fluoroscopic control.

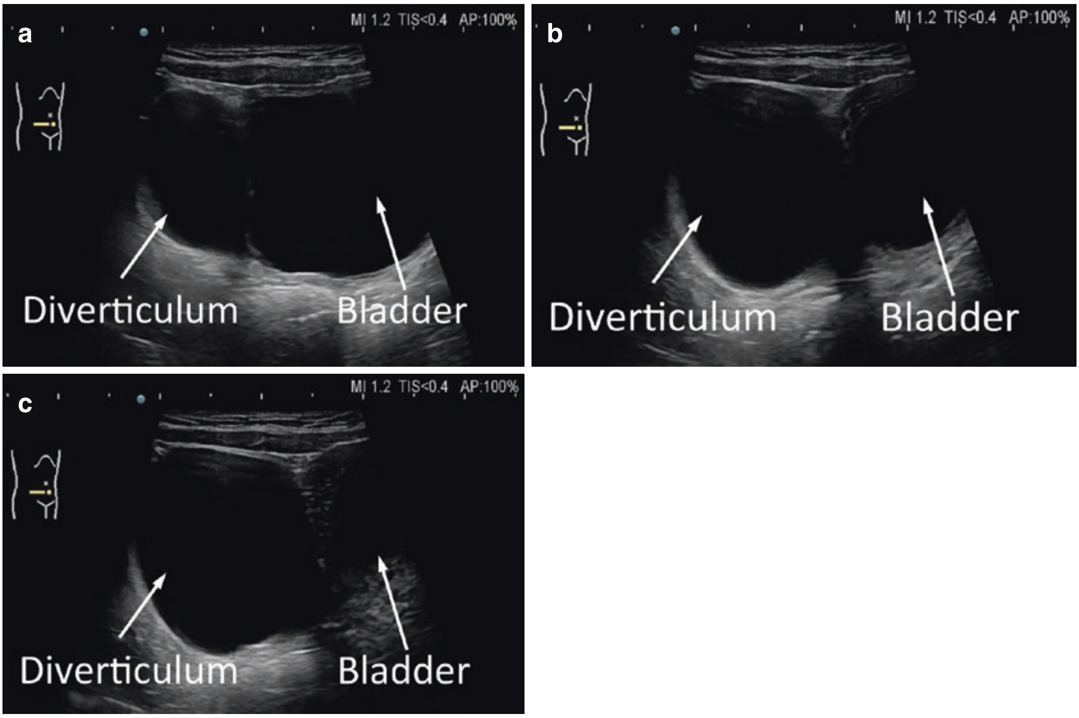

Fig. 20.4 Giant congenital right-sided bladder diverticulum with increasing volume during micturition; sonographic view (**a**) at the beginning, (**b**) during, and (**c**) at the end of micturition

Work-up

Endoscopy

Flexible cystoscopy is performed to localise a bladder neck diverticulum, to detect a tumour in the diverticulum, to determine the relationship of the ipsilateral ureteric orifice and the bladder diverticulum neck and to detect a sub vesical obstruction as far as possible. The look inside the diverticulum will inform us about additional pathology such as bladder stones or bladder tumour. The latter present sometimes as a papillary tumour or as red, velvet like carcinoma in situ. In such a case, the urine is sent for cytological examination and the patient admitted for transurethral tumour resection or cold cup biopsy in the case of flat lesions to prevent perforation, because due to the lack of a muscularis propria layer the wall of the diverticulum is very thin. In such a situation we have found use of hexaminolevulinic acid very helpful to identify a carcinoma in situ in other regions of the bladder or in the diverticulum itself. If a malignancy in the diverticulum is suspected, multiple cold up biopsies around the diverticulum neck are taken to be sure that the edge of the diverticulum neck is tumour free which should allow safe resection of a tumour bearing diverticulum. If not done before, urine cytology should be obtained from the diverticulum during endoscopic examination. Data from two series with a substantial number of patients and long follow up support a conservative approach for tumours confined to the bladder diverticulum, or diverticulum resection with the bladder preserved provided complete removal is feasible [8, 9].

Furthermore the Cancer Committee of the French Association of Urology (CCAFU) conducted a review of the epidemiology, diagnosis and treatment of intradiverticular bladder tumours and came to the conclusion that such high-grade tumors, unifocal and without associated carcinoma in situ, can be treated by diverticulectomy combined with pelvic lymphadenectomy [10].

Treatment

In symptomatic bladder diverticula, the treatment is always surgical. In rare cases a transurethral incision or resection of the diverticulum neck can be sufficient to allow proper voiding without residual urine [11, 12].

In patients with an asymptomatic diverticulum but substantial residual urine and especially in younger patients diverticulum resection should also be considered because the natural history of untreated bladder diverticula is unknown, and the possibility of malignant transformation over time due to urinary stasis within the diverticulum should be taken into account. Should the results of preoperative diagnostics show a sub vesical obstruction this should be relieved. The authors of this text prefer to first perform the diverticulum resection followed by transurethral bladder neck or prostate resection 3 months later believing that such an approach will prevent continued unbalanced micturition with residual urine and difficult to treat urinary tract infection.

Operations for bladder diverticula were first described in 1884 by Alexander and in 1897 by Czerny [13]. Today bladder diverticula can be treated with open (mostly retroperitoneal) surgery combining an intravesical and an extravesical approach, or by a standard intra- and extraperitoneal, mostly extravesical laparoscopic approach, or by intravesical laparoscopic and robot assisted surgery [14]. Simultaneous resection of all existing bladder diverticula should be performed to optimize postoperative bladder emptying [2].

The first reported robotic assisted bladder diverticulectomy was described by Berger and Stifelman in 2006 [14–16]. There is no doubt that today the standard and robot-assisted laparoscopic techniques for surgery of bladder diverticula are minimally invasive procedures that achieve equal results and are not second compared with open surgery [17, 18]. Small, nonrandomized case series suggest that outcomes are similar to those of established open techniques [14, 19].

Myer et al. write: "Proximity of the diverticulum neck to the ureteral orifice sometimes necessitates reimplantation, so in their initial report of laparoscopic diverticulectomy Parra et al. listed close proximity of a diverticulum to the ureter as a contraindication to the laparoscopic approach. As especially suturing techniques have evolved, ureteral reimplantation has become for a skilled laparoscopic surgeon a standard but still time consuming procedure. In one of the first robotic assisted bladder diverticulectomy series the reimplantation added approximately 1 h to total operative time [14]." We feel that in most cases using the robot reimplantation can be avoided, but where necessary it can be done in less than 20 min. In our practice we never use sequential transurethral resection, photo selective vaporization of the prostate or transvesical prostatectomy in open cases [19, 20].

We prefer to first resect the bladder diverticulum and in the case of later clinically or urodynamically suspected or proven subvesical obstruction to perform a bladder neck incision or transurethral prostate resection several months later. We justify this approach with our opinion that inappropriate voiding in patients with big congenital bladder diverticula is caused mostly by anomalous voiding into the diverticulum during detrusor contraction which results in paradoxical enlargement of the bladder diverticulum during micturition and would not be substantially improved by lowering the bladder outlet resistance.

Robotic Surgery

After performing flexible cystoscopy to determine the relationship of the ipsilateral ureteric orifice (Fig. 20.1) and the bladder diverticulum neck, the patient is placed in a steep

Trendelenburg position (35 Grad) lying on a vacuum mattress. Trocars are positioned as for radical prostatectomy (Fig. 20.5). In our institution we routinely use four arms, one camera trocar, three robot trocars, one 12-mm assistant trocar and one 5-mm port for suction. The fourth arm is positioned on the left-hand side. We use 0° and 30° optics and as instruments we use a ProGrasp forceps, a bipolar fenestrated forceps, one short needle holder and hot scissors. Since 2015 use of the Xi robot with side docking has become routine. In the years 2009–2014 when we used the Standard and Si robots these were positioned between the patient's legs. For creating the pneumoperitoneum we use the Hasson technique and we work during the whole procedure with an intraabdominal pressure of 12 mmHg. We never place ureteric stents cystoscopically but we use them temporarily during the surgery if necessary.

Instruments and other material used:

15 French flexible cystoscope (Olympus, Norderstedt, Germany).
Da Vinci S Robot (Intuitive Surgical, Sunnyvale, CA).
Da Vinci Si Robot (Intuitive Surgical, Sunnyvale, CA).
Da Vinci Xi Robot (Intuitive Surgical, Sunnyvale, CA).
ProGraspTM Forceps (Intuitive Surgical, Sunnyvale, CA).

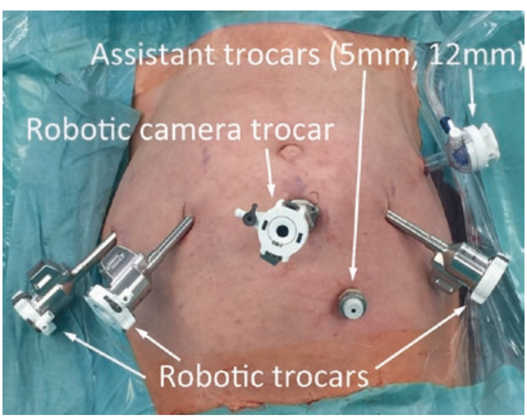

Fig. 20.5 Trocar positioning for bladder diverticulectomy

Hot Shears (Monopolar Curved Scissors) (Intuitive Surgical, Sunnyvale, CA).
Large needle holder (Intuitive Surgical, Sunnyvale, CA).
Bipolar fenestrated forceps (Intuitive Surgical, Sunnyvale, CA).
5 F ureteric Catheter (Urovision, Bad Aibling, Germany)
4-0 Monocryl with RB-1 needle (Ethicon, Norderstedt, Germany).
3-0 Monocryl with RB-1 needle (Ethicon, Norderstedt, Germany).
3.0 V-Loc Sutures with V-20 Needle (Medtronic, Dublin, Ireland)
3.0 V-Loc sutures with GU-46 needle (Medtronic, Dublin, Ireland).

Anatomical Considerations of the Position of Bladder Diverticula and Their Relationship to Ureteric Orifices

Most diverticulum necks are located between the pelvic side wall laterally and the bladder medially (Fig. 20.6). The ureter runs between the medial diverticulum wall and the lateral bladder wall (Fig. 20.7). Some of the diverticula are located in the middle of the bladder base but close to the trigonum. In most cases the necks of big bladder diverticula that need treatment are located medi-

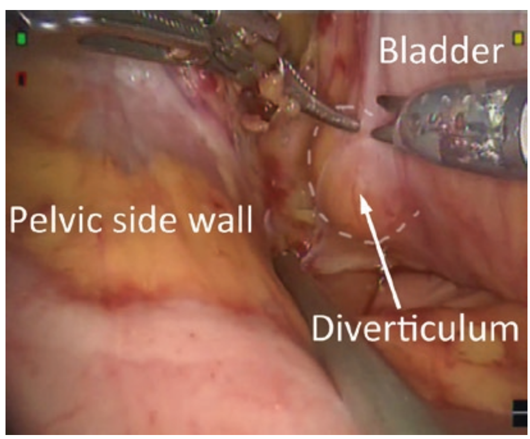

Fig. 20.6 Bladder diverticulum positioned between left-sided pelvic side wall and bladder

ally to the ureteric orifices which are positioned on the lateral edge of the diverticulum neck or in some cases more laterally (Fig. 20.8). Laterally to the diverticulum is the pelvic plexus which should be meticulously handled to avoid impaired emptying of the bladder, especially in bilateral cases. The use of electrical current should be avoided as far as possible. Furthermore, the vesical pedicles with vesical arteries should be preserved if possible.

The operation starts with intraoperative cystoscopy to determine the relation of diverticulum neck and ureteric orifice. Exact knowledge of the position of the ureteric orifice is important for the surgical approach. If the ureteric orifice is exactly on the edge of the diverticulum neck or even in the diverticulum itself a combined extravesical and transvesical approach will facilitate the dissection of the ureteric orifice, thus in most cases avoiding the necessity of ureteric reimplantation. The bladder is accessed via a transperitoneal route. The bladder is then filled with air or saline. The bulging of the diverticulum filled with air or saline is easy identified. The recently described technique of simultaneous individual catheterization of the diverticulum and bladder facilitates identification of the diverticulum even in the presence of multiple diverticula [20].

The dissection begins with a peritoneal incision medial to the obliterated hypogastric artery, i.e. medial umbilical ligament (Fig. 20.9) and dissection of the diverticulum from the surrounding structures until the diverticulum neck is circumferentially exposed (Fig. 20.10). In cases where the preoperative cystoscopy shows close proximity of bladder neck and ureteric orifice we combine an extra- and intravesical approach. Thus we open the bladder on the contralateral side of the diverticulum neck close to the midline with an incision big enough to allow the insertion of a camera and two instruments in the bladder. During this time the fourth arm stocked with a ProGrasp forceps serves to keep the bladder

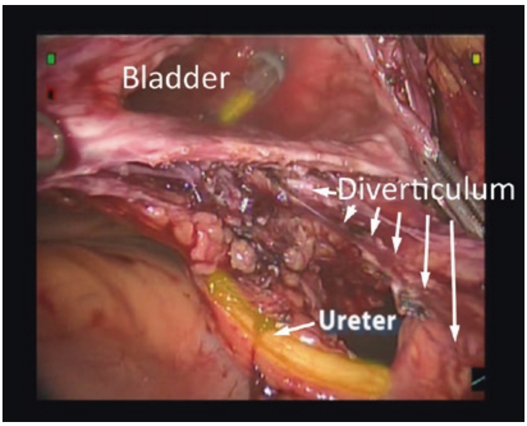

Fig. 20.7 Ureter running between lateral bladder wall and medial diverticulum wall

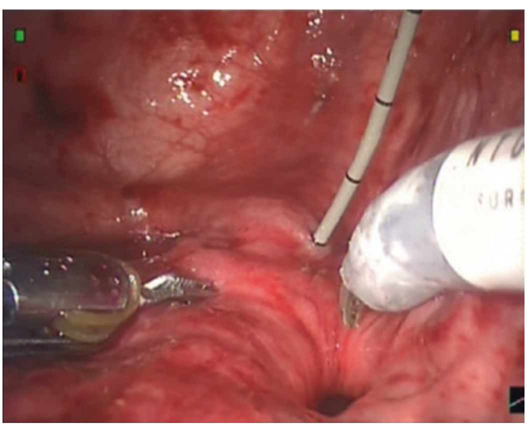

Fig. 20.8 Bladder diverticulum neck positioned laterally to the right-sided ureteric orifice

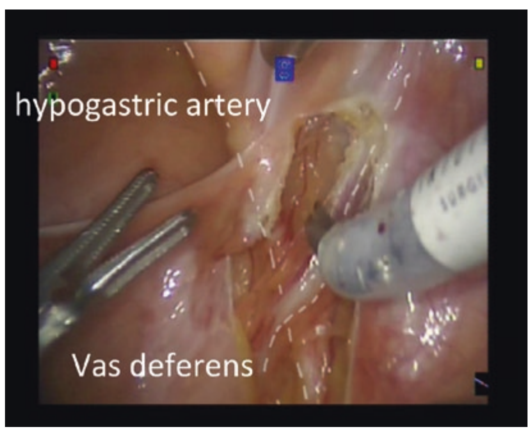

Fig. 20.9 Peritoneal incision medial to the hypogastric artery (medial umbilical ligament)

wall incision open. The ureteric orifices are identified and the ipsilateral ureter temporarily splinted with a shortened ureteric catheter, which allows easier handling of the ureter during its definitive separation from the diverticulum wall (Fig. 20.11). Then the diverticulum wall at the edge of the bladder mucosa is circumferentially incised while attempting not to completely separate the ureter from the bladder. Then the dissection of the diverticulum is continued outside the bladder. In cases where the ureteric orifice has been completely separated from the surrounding tissue the ureter with preserved bladder mucosa around the ureteric orifice is then anastomosed with the bladder wall in an orthotopic position (Fig. 20.12). Figure 20.13 shows a similar approach with a bladder neck located on the right-hand side relatively far from the ureteric orifice thus making the need for reimplantation unlikely. In this case temporary ureteric stenting helped as well. After resecting the diverticulum the bladder wall is closed from the inside of the bladder under continuous view of the ureteric orifice.

In cases where the ureteric orifice is far enough from the edge of the diverticulum

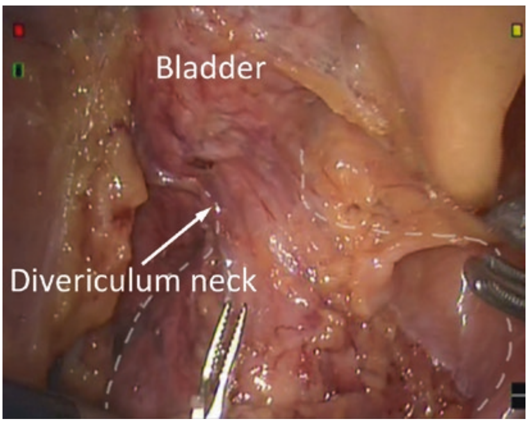

Fig. 20.10 Dissection and exposure of diverticulum neck

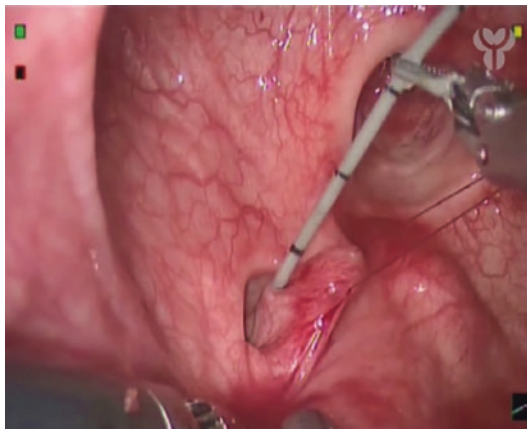

Fig. 20.11 Temporary splinting of the ureteric orifice with a shortened ureteric catheter

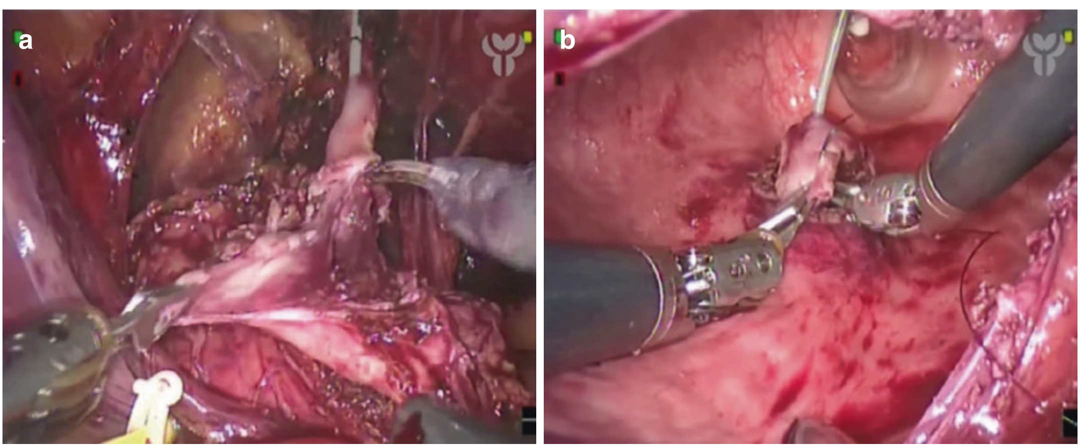

Fig. 20.12 (**a**) Ureter with preserved bladder mucosa flap around the ureteric orifice, which is used for (**b**) orthotopic re-implantation of the ureter into the bladder

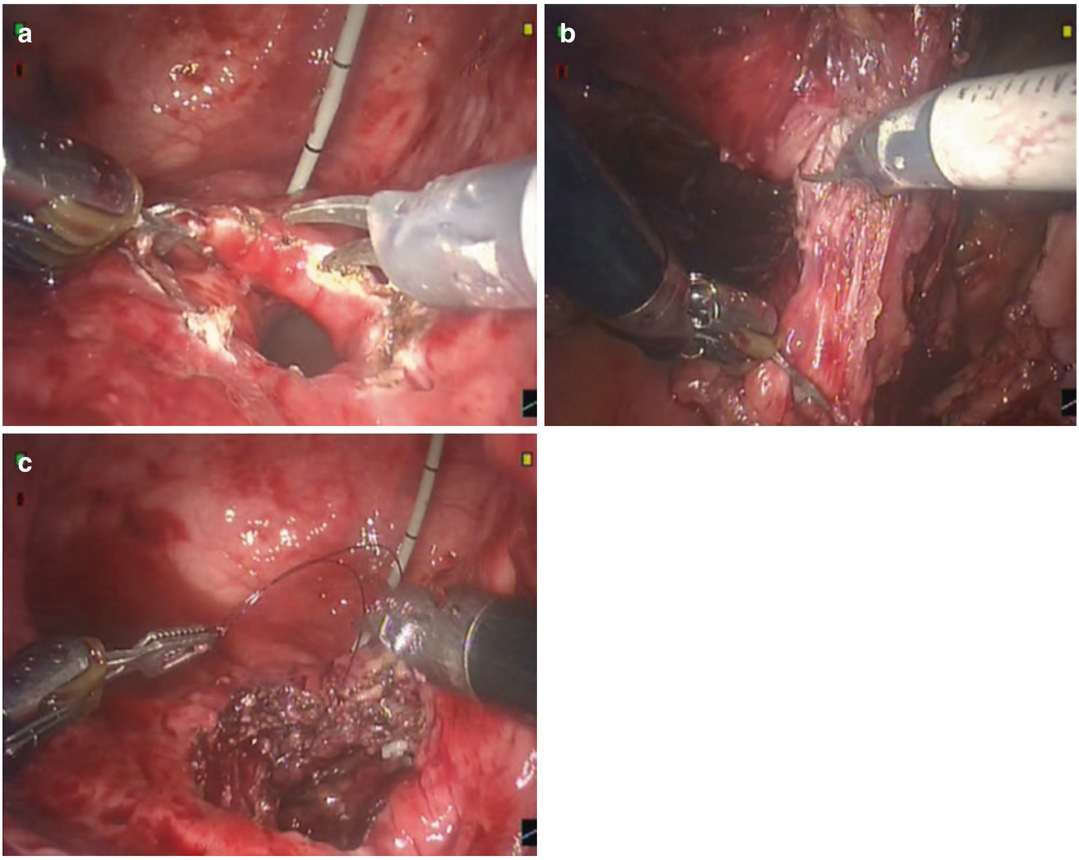

Fig. 20.13 After (**a**) circumcision of the diverticulum neck from inside of the bladder, and (**b**) resecting the diverticulum from outside the bladder, (**c**) the bladder wall is closed from the inside of the bladder under continuous view of the ureteric orifice

neck, thus with a low risk of being harmed during the circumferential incision of the bladder neck wall a completely extravesical approach can be chosen (Fig. 20.14a). The diverticulum is exposed as described above and the bladder neck incised at the margin with the bladder wall. After ensuring that the ureteric orifice will not be harmed the bladder is closed as described below (Fig. 20.14b).

The bladder is usually closed in one or two layers with 3-0 Monocryl suture with an RB1 needle or 3-0 barbed sutures with a UR-5 needle and filled with 200 mL saline to prove the water tightness. A suprapubic tube is placed and the peritoneum is closed with a barbed suture leaving a small opening to allow selective drainage. The transurethral catheter is removed the next day and the suprapubic tube on the fifth postoperative day after cystography has shown no extravasation (Fig. 20.15).

In the case of suspected or proven tumour in the diverticulum the bladder is not filled with saline but with air to avoid spillage of the tumour cells. In such cases we always approach the diverticulum intra- and extravesically. The diverticulum neck at the margin with the bladder wall is intravesically incised circumferentially with a safety margin of approximately 5 mm and completely separated from the bladder wall and the distal ureter. Then the diverticulum neck is closed meticulously with a running suture and placed in a retrieval bag. In such a case, after the diverticu-

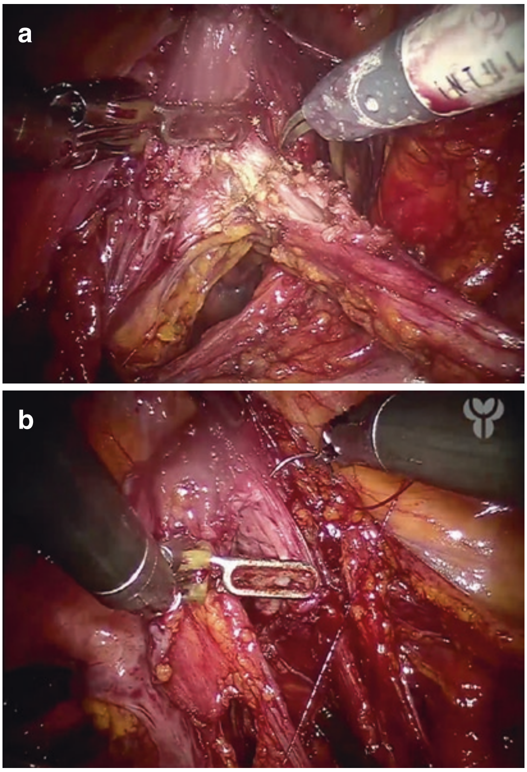

Fig. 20.14 Completely extravesical approach to diverticulectomy; (**a**) resection, and (**b**) closure

Fig. 20.15 Cystography on the fifth postoperative day, showing no contrast media extravasation

lum has been resected, we would perform a pelvic lymphadenectomy on the ipsilateral side.

Conclusion

Robotic assisted laparoscopic pelvic surgery has meanwhile become a well-established operative technique for benign and malignant disease [21].

The advantage of robotic surgery, beside its obvious minimal invasiveness, is its ability for gentle tissue handling and performing of complex reconstructive procedures with outcomes not second to established open surgical procedures.

Robotic assisted laparoscopic bladder diverticulectomy is safe and effective with a low risk of intraoperative or postoperative complications. Perioperative surgical outcomes rival those of previously reported open and laparoscopic diverticulectomies. Recently reported modifications of technique from an external dissection approach to an internal dissection approach have led to a dramatic reduction in operative time and may prove to become the standard approach [22].

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21 Neoadjuvant Chemotherapy in Muscle Invasive Urothelial Bladder Cancer

Günter Niegisch and Peter Albers

Introduction

With about 300,000 newly diagnosed cases every year, bladder cancer (BC) is the seventh most common cancer worldwide. One-third of patients initially present with muscle invasive bladder cancer. In the industrial countries, more than 90% of patients have a typical urothelial BC.

Even with radical cystectomy (RC), patients with ≥pT3 pN0 tumors experience a 10-years cancer specific survival of only 30–50%, with lymphonodal disease it decreases to 20–30%. Only patients with favorable organ confined lymph node negative disease (≤pT2 pN0) experience a disease-free survival of about 70% [1–3]. Also patients in which a negative margin status (either due to tumor burden or due to surgical problems) is not achieved during surgery have a poor prognosis (10-years cancer specific survival R0: 61%, R+: 21%). Once distant metastases or local recurrence are present, patients' outcomes are significantly impaired and long-term survival is rare.

To improve the outcome of surgical treatment, neoadjuvant (NC) and adjuvant chemotherapy (AC) strategies have been extensively studied within the last three decades. However, results are conflicting and a translation of a perioperative strategy including chemotherapy to clinical practice is difficult. The main question is who will respond and thereby benefit from perioperative chemotherapy. Response prediction is crucial since patients not responding to neoadjuvant chemotherapy have to be identified early to prevent disease progression before cystectomy. This may be the reason that despite level 1 evidence supporting the use of NC this treatment concept is hardly accepted in the urological community [4, 5].

In this chapter, we will summarize and discuss current evidence on the impact of neoadjuvant chemotherapy on outcome of urothelial BC patients. Further, we will detail key points for identifying patients eligible for and to exclude patients who may not benefit from NC.

Evidence on the Impact of Neoadjuvant Chemotherapy on Outcome of Urothelial Bladder Cancer Patients

Historical Randomized Controlled Trials and Meta-analyses

The impact of neoadjuvant chemotherapy on patients´ outcome undergoing local treatment (cystectomy or radiotherapy) has been analyzed within three large metaanalyses [6–8]. In these, overall as well as disease-free survival was

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_21

Table 21.1 Overview of metaanalysis on neoadjuvant chemotherapy of bladder cancer patients

	Improvement in 5-year OS (%)	Improvement in 5-year DFS
ABC I, Lancet 2003	5.0	7.0%
Winquist et al., J Urol 2004	6.5	Not reported
ABC II, Eur Urol 2005	5.0	9.0%

improved by neoadjuvant cisplatin based combination-chemotherapy (Table 21.1). Subgroup analyses to identify patients which might preferably benefit were performed without conclusive results [7, 8]. However, these subgroup analyses included only a small proportion of patients and were statistically underpowered.

Of the RCTs included in the three metaanalysis, the main drivers were the Intergroup-0800-trial (n = 317), the Scandinavian NORDIC-I- and -II-trials (n = 325 and n = 316, respectively), and the MRC/EORTC-trial (n = 976) [9–13]. These trials account for about 2/3 of patients analyzed in the metaanalysis (Table 21.2).

The largest RCT was an international collaboration initiated by the MRC and the EORTC **(International Collaboration of Trialists, BA06 30894 trial)** and deserves a closer look, as the longest and most conclusive follow-up data are reported for this trial. First results were published in 1999 and recently updated [12, 13]. Patients with a cT2G3-, cT3-, or cT4a- urothelial bladder cancer including mixed histology subtypes were randomly assigned to three cycles CMV or no chemotherapy before undergoing local radical treatment (cystectomy, radiotherapy, neoadjuvant irradiation followed by cystectomy). Patients with known lymphonodal disease were excluded. Pretreatment imaging by CT, MRI, or sonography was not mandatory.

Of 976 recruited patients, 491 were allocated to receive NC and 485 to immediate local treatment. 15% did not undergo scheduled cystectomy, radiotherapy was incomplete in 24% of planned patients. After 3 years, a 5.5% difference in survival in favor of the NC patients was not statistically significant. The absence of residual cancer in the cystectomy specimen for the NC and control group was observed in 33 and 12%, respectively. In subgroup analyses, only worse grading (G3) and a favorable renal function (GFR >69 mL/min) were predictive for a significant effect of NC. In the trial update recently published (follow-up 8.0 years), a survival advantage for patients who received neoadjuvant chemotherapy was evident both for 10-year OS (NC: 36%, control: 30%, $P = 0.037$) and DFS (NC: 27%, control: 20%, $P = 0.008$). Results on the impact of tumor grading and renal function on the outcome of NC patients were confirmed, but according data were not reported. An update of this trial with a median follow-up of 8.0 years has been published in 2011 [13]. In this analysis, the survival advantage of NC patients was statistical significant. A 16% reduction in the risk of death (hazard ratio, 0.84; 95% CI, 0.72–0.99; P = .037) which corresponded to an increase in 10-year survival from 30 to 36% after CMV.

The MRC/EORTC trial shares common critical points with the other RCTs. These are, in summary, heterogeneity of the respected trial population and difficulties to assess pretherapeutic tumor stage. Local treatment was rather variable and treatment regimens, except for the Intergroup trial, were not representative for current cisplatin-based combinations, e.g. MVAC and GC. Likewise, comparing and interpreting the results of these trials is critical. In addition, all trials were underpowered to detect a survival advantage as an effect of NC was throughout overestimated. Furthermore, it is not reported in how many patients not down- but upstaging was observed due to delay of definite local treatment. A survival advantage in T3/T4a patients indicated by the Intergroup and the NORDIC-I trial was not confirmed by the meta-analyses, probably due to the heterogeneity of included trials.

The most recent meta-analysis of clinical trials on neoadjuvant chemotherapy has been performed for the German Guideline Program in Oncology for the new Guideline on Bladder Cancer [14]. Twelve studies with 3135 patients were included in this analysis. Regarding mortality, a significant benefit from neoadjuvant treatment was observed (Hazard ratio (HR) 0.86; 95%

Table 21.2 Details on the "main driver trials" on neoadjuvant chemotherapy of bladder cancer patients [9–12]

Trial	N	Regimen	No. cycles	Definitive treatment	PFS (+CTx) (months)	PFS (−CTx) (months)	OS (+CTx) (months)	OS (−CTx) (months)	5 year OS (+CT) (%)	5 year OS (−CT) (%)
Inter group 0080 (Grossman et al.)	317	MVAC	3	Zx	n.r.	n.r.	77	46	57	43
Nordic I (Rintala et al.)	325	CisDoxo	2	RTx + Zx	n.r.	n.r.	n.r.	n.r.	58	51
NORDIC II (Sherif et al.)	316	CM	3	Zx	n.r.	n.r.	n.r.	n.r.	53	46
Int. Coll. Trialists	976	CMV	3	Zx, RTx, RTx + Zx	20.0	16.5	44.0	37.5	49	43

Impact of cisplatin-based neoadjuvant chemotherapy on overall survival

ABC I, Lancet (2003)	HR 0.87 [95% CI 0.78 - 0.98]
Winquist et al., J Urol (2004)	HR 0.87 [95% CI 0.78 - 0.96]
ABC II, Eur Urol (2005)	HR 0.86 [95% CI 0.77 - 0.95]
German Guideline on Bladder Cancer (2016)	HR 0.86 [95% CI 0.75 - 0.98]

Fig. 21.1 Hazard ratios (HR) regarding the benefit of neoadjuvant chemotherapy on overall survival of bladder cancer patients following local treatment [6–8, 14]

confidence interval (CI) 0.75–0.98). This translates into an absolute survival benefit of 5% (95% CI 2–9%) after 5 years of follow-up.

Based on the metaanalyses as well as the long-term data of the MRC/EORTC trial and the NORDIC I/II trial, a survival advantage for patients undergoing NC before local treatment of bladder cancer is evident (Fig. 21.1). Consequently, NC is recommended for patients suffering from muscle-invasive, clinically lymph-node negative urothelial bladder cancer by most of the recent guidelines [14–17].

But one should keep in mind that rigorous adoption of NC into clinical practice will result in (1) a significant number of patients treated unnecessarily (probably ≤pT2 patients) and (II) in a number of patients who will even undergo disease progression as they are refractory to NC. Identifying both patients profiting and not profiting from neoadjuvant chemotherapy is an unmet need that requires further evaluation.

Neoadjuvant Chemotherapy with Gemcitabine and Cisplatin

Due to the superior toxicity profile of combination therapy with gemcitabine and cisplatin (GC) compared to MVAC shown by van der Maase and colleagues, GC has been widely adopted as standard of care upfront treatment in metastatic urothelial carcinoma patients. Though prospective studies are missing, this combination regimen has also been adopted in the neoadjuvant setting based on evidence from retrospective studies suggesting non-inferiority of neoadjuvant GC compared to MVAC and other historical treatment regimens. For example, in a retrospective analysis comparing 42 patients undergoing neoadjuvant chemotherapy with GC to a historical cohort of patients treated with MVAC before radical cystectomy, more than 90% of patients completed scheduled treatment with 4 cycle of GC (as compared to 80% in the MRC/EORTC trial). Impact on tumor down-staging following either GC (pT0 rate 26%) or MVAC treatment (pT0 rate 28%) was comparable [18]. These data have been supported only recently by two retrospective multicenter analysis including 935 patients (GC 602 pts., MVAC 183 pts., other 144 pts.) and 212 patients (GC 146 pts., MVAC 66 pts.) [19, 20]. In both studies, comparable response rates (GC: 24–31%, MVAC: 25–29%) were achieved. Regarding survival data, a recent meta-analysis likewise did not find a significant difference comparing patients treated with either MVAC or GC in the neoadjuvant setting [21].

Impact of Neoadjuvant Chemotherapy on Perioperative Complications

A major concern regarding the use of NAC is a potential impact on perioperative outcome of patients undergoing subsequent radical cystectomy.

Data on this issue is controversial. Regarding the large phase III trials, perioperative complication rate was reported only by Grossman et al. for the Intergroup-0800 (see above). In this study, no differences comparing the neoadjuvant cohort and the cystectomy only cohort were observed. Neither the MRC/EORTC trial nor the NORDIC-I and Nordic-II trial reported on perioperative complication rates [9–13].

In a recent analysis of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database comparing 800 patients undergoing immediate cystectomy and 78 patients with prior neoadjuvant chemotherapy, NAC was neither a predictor of complications (p = 0.87), reoperation (p = 0.16), wound infection (p = 0.32), or wound dehiscence (p = 0.32) [22]. Further, operative time (p = 0.24) was comparable in both cohorts and length of stay hospital was decreased in NAC patients (p = 0.02).

In line with these findings, an analysis of the SEER data did neither reveal any differences regarding perioperative outcomes in patients undergoing radical cystectomy with (n = 416 patients) or without (1664 patients) prior NAC [23]. Neither 30- and 90-day complication rate, transfusion rate, length of stay, nor mortality was related to the use of NAC.

Regarding robotic cystectomy, the impact of NAC on perioperative complications has been investigated by the International Robotic Cystectomy Consortium (IRCC) [24, 25]. While Johar et al. reported the use of NAC as an independent predictor of both complications of any grade and major complications (grade 1–5: HR 1.71 (1.16–2.53), grade 3–5: HR 1.88 (1.20–2.94)), these results were not confirmed in the analysis of Al-Daghmin et al.

Thus, whether NAC really impacts perioperative outcomes, especially in robotic cystectomies, is currently unclear.

Identifying Patients Who May Benefit from Neoadjuvant Chemotherapy

Factors Not Related to the Primary Tumor

A benefit for NAC was only evident when cisplatin-containing combinatorial regimens were used (Fig. 21.2) [6–8]. The use of carboplatin is

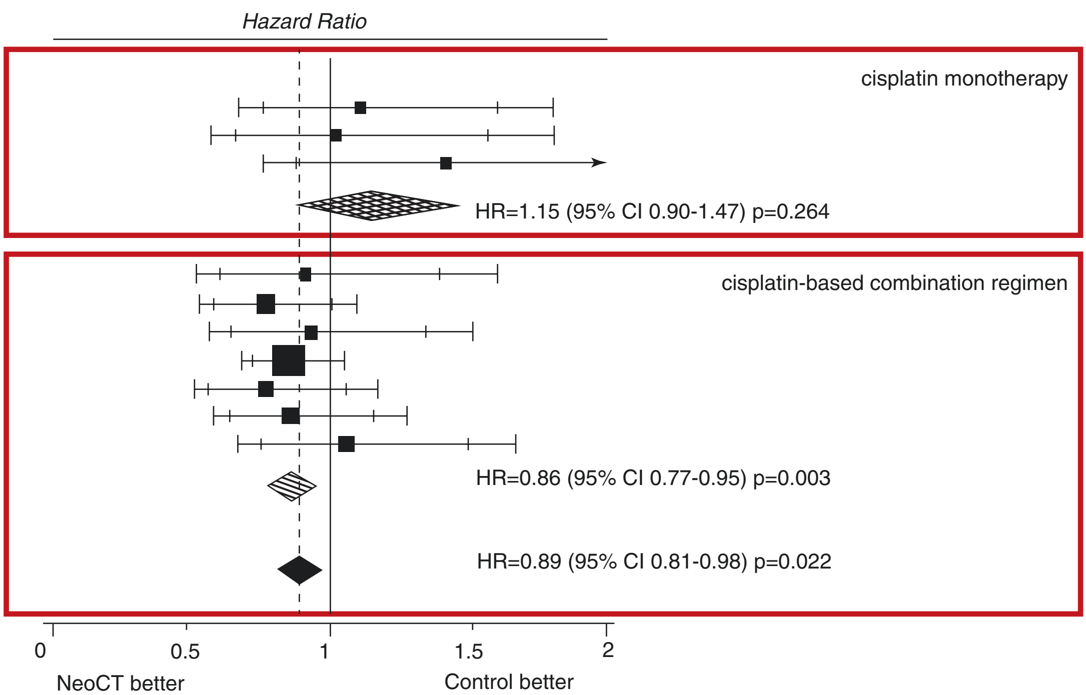

Fig. 21.2 Benefit of neoadjuvant chemotherapy on overall survival of bladder cancer patients following local treatment depending on treatment regimen (adapted from [8])

not an adequate alternative. This is in line with findings in metastatic urothelial carcinoma [26]. Accordingly, based on the MSKCC criteria defining "fitness for cisplatin", a patient eligible for neoadjuvant chemotherapy should present with an adequate performance status (ECOG 0–1) and an adequate renal function (creatinine clearance >60 mL/min). Neither a grade ≥ 2 hearing loss, a grade ≥ 2 neuropathy, nor a New York Heart Association Class III heart failure should be present [27].

These factors indicating "unfitness" for cisplatin may not be regarded as absolute criteria. For example, whether a GFR below <60 mL/min/1.73 m^2 is adequate as a factor precluding cisplatin administration is under debate [16]. In the largest RCT on NC in bladder cancer also patients with a lower GFR (50–59 mL/min/m^2) were included [12, 13]. As in a significant portion of bladder cancer patients (30–40%), impairment of renal function (GFR <60 mL/min/1.73 m^2) is present, one should keep in mind that either alternative dosing schemes (e.g. "split-dose) or dose reductions may be an option to administer cisplatin-based therapy also in these patients [28, 29]. Further in patients with impaired renal function due to hydronephrosis, preoperative urinary diversion by percutaneous nephrostomy or ureteric stents might render these patients eligible for NC.

Tumor-Related Factors

Though the meta-analyses did not confirm outcome differences depending on tumor stage, there is evidence that preferably ≥T3a N0 patients may benefit from NC [6–8, 30]. For example, in the Intergroup 0800 trial as well as in a study on patients undergoing neoadjuvant chemoradiation, patients with locally advanced urothelial cancer (≥T3a) were those who profit most from NC [10, 31]. Nevertheless, patient selection based on clinical tumor stage is critical and differences between initial clinical and pathohistological stage are observed frequently [32].

Further, response of bladder cancer to chemotherapy might depend on histological subtype. Regarding urothelial carcinomas with either squamous or glandular components, evidence from the intergroup 0800 trial as well as data from a retrospective analysis on first-line treatment of advanced or metastatic mixed-urothelial bladder carcinoma suggest comparable response to NC as compared to "pure" urothelial carcinoma [33, 34]. An exception might be urothelial carcinomas with neuroendocrine/small cell components, being one of the most aggressive subtypes. Survival of these patients is generally poor and retrospective analyses suggest that even aggressive surgical treatment will not alter the natural disease course [35]. In these patients, systemic treatment before considering any surgical approach is highly recommended. Alternative treatment regimens, e.g. cisplatin/etoposide or carboplatin/etoposid should be used [36].

Lastly, as a significant number of patients which may not respond to NC is expected early identification of non-responders may be crucial for their postoperative prognosis. In the majority of RCTs 3 cycles of neoadjuvant chemotherapy were administered [6–8]. This is equivalent to a delay in definitive treatment of 9–12 weeks if a chemo-resistant UBC is present. A reasonable approach to this problem would be an early restaging after two cycles of NC. "Non-responders" could be allocated to immediate radical cystectomy with a lower risk of disease progression. Vice-versa, "responders" could receive two additional cycles of NC decreasing their tumor burden.

Summary and Conclusion

Current evidence supports the use of NC to improve the oncological outcome of patients suffering from muscle-invasive UBC. NC should be cisplatin-based combinatorial treatment. Nowadays, the combination of gemcitabine and cisplatin is used despite prospective data comparing this regimen to historical cisplatin-based combinations is missing. The use of carboplatin in patients "unfit" for cisplatin is not a valid option. Accordingly, if the use of cisplatin is not possible, immediate treatment including cystectomy should not be delayed by NC with an inadequate regimen. Patients most likely to benefit from NC are those suffering from ≥T3a N0 tumors. However, patient selection based on clinical tumor stage is critical as pre-cystectomy staging is often inappropriate and upstaging is observed frequently. Except for UBC with small cell carcinoma, efficacy of NC in urothelial carcinomas with mixed features is likely to be comparable to efficacy in pure urothelial carcinomas. Given that advances in surgical treatment did not improve oncological outcome of UBC patients significantly during the last decades, every patient diagnosed with muscle-invasive urothelial cancer should be evaluated regarding neoadjuvant treatment before being scheduled for radical cystectomy.

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22 Consensus Views on Perioperative Management of Robotic-Assisted Radical Cystectomy

J.W. Collins, A. Hosseini, and N.P. Wiklund

Introduction

Radical cystectomy is associated with significant morbidity and prolonged length of stay irrespective of surgical approach [1, 2]. Enhanced recovery programs (ERPs) aim to improve surgical outcomes by reducing variation in perioperative best practices. A recent meta-analysis evaluating the impact of ERPs on patients undergoing radical cystectomy concluded that they reduce the length of stay in hospital, time-to-bowel function, and rate of complications after cystectomy [3]. Whilst ERPs are now recognized to be an important part of surgical management for radical cystectomy, there is comparatively little evidence for ERPs after Robotic assisted radical cystectomy (RARC).

The goal of a modern enhanced recovery program (ERP) is to positively impact patient care from diagnosis, through treatment, to return to normal function. An ERP describes a standardized multimodal perioperative care pathway that aims to minimize the physiological and psychological stress effects of elective surgery. ERPs are also known as enhanced recovery after surgery (ERAS) or fast-track surgery programmes. The concept of enhanced recovery after surgery was first introduced in the 1990s in elective colorectal surgery, as a means to improve postoperative recovery and shorten length of stay [4]. However, there remains a lack of high-level evidence for ERPs following radical cystectomy with much of the evidence coming from the management of patients in colorectal care [5].

There is increasing evidence from open colorectal surgery series that implemented ERPs can successfully reduce complication rates, length of stay in hospital and the time taken to get back to normal activities, following major pelvic surgery [6]. It is also recognised that minimally invasive surgery (MIS) reduces the surgical stress response compared to open surgery [7]. Robotic assisted radical cystectomy (RARC) aligns itself with the original stated principles of enhanced recovery, that minimally invasive surgery is advantageous to aid quicker patient recovery [8]. Several meta-analyses have highlighted that RARC compared to open radical cystectomy decreases blood loss and reduces overall complication rates, resulting in reduced transfusion rates, shorter time to normal diet and reduced length of stay (LOS) [1, 9, 10]. RARC has also been found to be advantageous in susceptible patient groups such as the elderly [11]. However, due to their multimodal nature and inability to blind against, it is recognized that ERPs are difficult to study in a randomized controlled trail (RCT) setting [12]. An approach to radical cystectomy that combines a robotic approach with an ERP optimised for RARC patients, has the potential to further improve patient outcomes (see Fig. 22.1). Therefore, to address the gaps in knowledge on how best to combine current evidence for

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_22

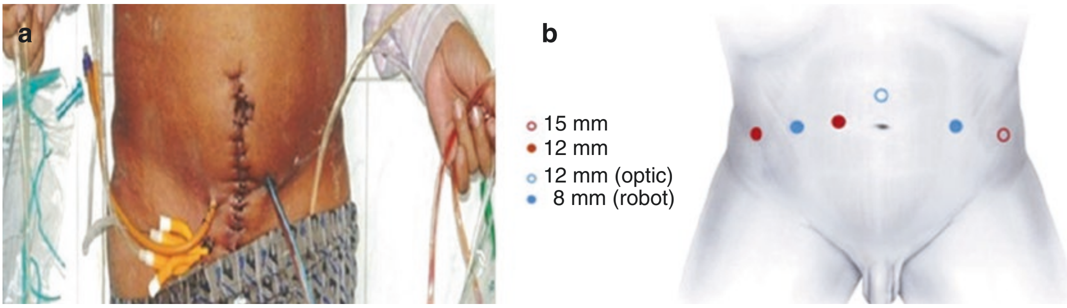

Fig. 22.1 (**a**) Large operative incision related to open radical cystectomy. (**b**) Small incisions for port placement in Robotic-assisted radical cystectomy

ERPs with the evidence for patient management that is specific to robotic surgery, the ERUS scientific working group formed an ad hoc panel of experts to formulate guidelines for an ERP specifically designed for patients undergoing RARC.

The purpose of this work included assessment of the depth and breadth of implementation of the current ERAS® society guidelines for radical cystectomy [5]. We also sought an expert panel consensus view on whether an optimised ERP for robotic surgery may differ from current ERAS guidelines for open radical cystectomy. Additionally, comparison and interpretation of outcome reports from different centres is not currently straightforward, due to the lack of a standardized ERP approach and standardized reporting systems. There is therefore a potential need for both the adaptation of current ERPs that are tailored to the specifics of robotic surgery and standardized reporting templates. Such a reporting template would enable comparison of outcomes between centres, assess implementation of the ERP to new institutions and provide a structure for quality assessment of future interventions.. Our consensus statement aims to guide healthcare providers on the important elements of a standardised ERP that is specific to RARC, and provide a suitable reporting template.

Materials and Methods

In April 2015 the ERUS Scientific Working Group established a working panel with the aim of formulating a consensus view on an ERP optimised for patients undergoing RARC. The panel was chaired by Professor Peter Wiklund, the chair of the ERUS scientific working group and the panel was comprised of ERUS members with a specialist interest in robotic cystectomy surgery and/or enhanced recovery protocols.

The project was carried out in four phases: (1) A systematic literature review of current evidence for ERPs in robotic, laparoscopic and open radical cystectomy. (2) A survey was then generated and sent to panel members. (3) Internet- and panel-based consensus findings were concluded using the Delphi process to agree on and formulate guidance. (4) A standardised reporting template to measure compliance and outcome was designed and approved by the committee.

Review of the Literature

In April 2015 we undertook a comprehensive computerized search using PubMed, Medline and Cochrane databases. We systematically searched using medical subject headings including 'radical cystectomy' and all 22 elements of an ERP, as defined by the ERAS® society guidelines for peri-operative management of radical cystectomy [5]. The literature review was updated in December 2016 for this chapter.

Articles of interest included single centre series reporting an ERP for radical cystectomy, meta-analyses, randomized controlled trials (RCTs) and systematic reviews published between January 1997-first landmark review on ERP published [4]—and December 2016. Other significant studies cited in the reference list of selected papers were evaluated, as well as studies of interest published after the systematic search. Two reviewers independently selected papers for detailed review, evaluating the abstract and, if necessary, the full-text manuscript. Potential discrepancies were resolved by open discussion.

Data Extraction and Quality Assessment

Overall the quality of studies available was low (level of evidence 3b). Considering multimodal interventions, we identified 16 articles reporting results of their ERAS protocols for radical cystectomy, four of which incorporated RARC (see Table 22.1). Consistency throughout these protocols was variable. Commonly employed elements of an ERP included: avoidance of mechanical bowel preparation and carbohydrate loading pre-operatively. Intra-operatively: epidural anaesthesia, opioid sparing analgesia, avoiding hypothermia and careful fluid management. Post-operatively: avoidance or early removal of NG tube in recovery with early mobilization and early oral feeding. Since the publication of the ERAS society guidelines [5], six systematic reviews of ERPs specific to radical cystectomy have been published. Considering single interventions, we identified two meta-analyses, six RCTs and 23 single-intervention studies.

Internet Survey and Delphi Process

An advisory committee was formed which included experts in the fields of RARC and/or ERPs from 23 Institutions in Europe. An Internet survey (Google forms) was generated and sent to all ERP panel members. Each panel member responded to the survey with their representative answers to the questions. The survey included six items concerning principles and definitions and four items on the relevance to RARC. There were 21 items on pre-operative care, 15 items for peri-operative care, 22 for post-operative care and six items on discharge criteria. There were also five items on future development, six items on clinician and organisational roles and discussion on regulation through audit and reporting outcomes [29]. An e-consensus–finding exercise using the Delphi methodology was then applied. The Delphi method structures group communications so that the process is effective in allowing a group of individuals to deal with a complex problem. Questions in which there was 100% consensus were removed from the next round of the survey. For the remaining questions a panel consensus view was ether reached or not after three rounds of voting. Repeated iterations of anonymous voting continue over the three rounds, where an individual's vote in the next round is informed by knowledge of the entire group's results in the previous round. Using SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA) outcomes of the e-consensus at each round were displayed as histograms so that the result could be reflected on before selecting a response in the next round. After three rounds the consensus views included in the final guidance needed to reach a consensus view representing at least 80% of the panel (Tables 22.2 and 22.3).

Pre-Operative Considerations

Preoperative Counseling and Patient Education

Preoperative verbal and written information for the patient and their carers is important for both patient's knowledge and to ensure compliance. Information should include details on the operation, plan of hospital stay, description of the ERP, discharge criteria and stoma care information for conduit patients and catheter care information for neobladder patients. Comprehensive patient information has been shown to empower patients, improve recovery and can reduce the incidence of complications after surgery [30]. Information about the type of urinary diversion is also critical to preventing misunderstandings that may negatively impact quality of life [31]. Future developments are likely to include educational videos to improve understanding. The committee reached 75% consensus view that videos with patient information are beneficial to understanding, however only 7% currently have patient information videos available at their institution.

Table 22.1 Published series on ERAS protocols for radical cystectomy

Study	Year published	No. patients (No. receiving ERP)	Comparative control group included	Number of ERAS recommendations included	RARC included	Additional elements to ERAS recommendations	Level of evidence
Arumainayagam et al. [13]	2008	112 (56)	Y	6	N		3b
Pruthi et al. [14]	2010	362 (362)	N (evolved ERP)	7	N		3b
Shah et al. [15]	2011	30 (30)	N	10	Y		3b
Maffezzini et al. [16]	2012	68 (68)	N	6	N		3b
Mukhtar et al. [17]	2013	77 (51)	Y	12	N		3b
Saar et al. [18]	2013	63 (31)	Y	9	Y		3b
Karl et al. [19]	2014	101(62)	RCT (2:1)	5	N		3b
Dutton et al. [20]	2014	165 (165)	N (evolved ERP)	19	N	Rectus sheath analgesia catheter; intra-operative cell salvage; telephone contact given	3b
Daneshmand et al. [21]	2014	110 (110)	Y (historical)	7	N	Para-incisional subfascial catheter	3b
Smith et al. [22]	2014	133 (64)	Y		N	Rectus sheath catheter; intra-operative cell salvage 24 h ERP telephone helpline	3b
Guan et al. [23]	2014	115 (60)	Y	7	N	Laparoscopic approach	3b
Curreto et al. [24]	2014	31 (31)	N	17	N		3b
Persson et al. [25]	2015	70 (31)	Y	13	N		3b
Kouparis et al. [26]	2015	270 (102)	Y	10	Y	Intracorporeal urinary diversion	3b
Xu et al. [27]	2015	205 (124)	Y	17	N		3b
Collins et al. [28]	2016	221 (135)	Y	20	Y	Intracorporeal urinary diversion	3b

Table 22.2 ERP elements that reached 80–100% agreement on the Google form survey using the Delphi processLevel of agreement

	ERP consideration
100%	• Enhanced Recovery Programmes (ERP's) are relevant to RARC patients
	• There are differences in recovery after surgery between open radical cystectomy patients (ORC) and colorectal surgery patients
	• There are differences in recovery after surgery between ORC and RARC patients
	• Important principles to an optimised ERP for RARC include: reduced bowel preparation, early mobilization, standardised analgesic regimens with sparing use of opiates
	• Minimum discharge criteria to be met prior to discharge include: adequate pain control and patient being mobile (if normally mobile)
	• Preoperative counselling and education should include oral and written information on: surgical method, plan of hospital stay, discharge criteria, stoma nurse information (for stoma patients)
	• Preoperative medical optimisation should include: optimising co-morbidities and pre-operative nutrition
	• Mechanical bowel preparation can be safely avoided
	• Guidance on Preoperative fasting: Solids and clear fluids until 6 and 2 h, respectively before anaesthesia. Encourage low residue food in the 24 h before surgery
	• Pre-anaesthesia medication is appropriate in selected patients if short-acting sedatives used. May be beneficial in anxious patients
	• Thromboembolic prophylaxis should include: LMW Heparin for 4 weeks
	• Antibiotic prophylaxis should consist of limited broad spectrum antibiotics. Principle is to avoid several days of unnecessary antibiotic administration
	• A standardised anaesthetic protocol is important to outcome
	• Current anaesthetic protocols are variable in RARC and this is an area that would benefit from further study
	• To prevent hypothermia an intraoperative device to maintain normal body temperature is important
	• Patients should be mobilised within 24 h of surgery
	• Audit is an important part of an ERP for RARC. Patients should be audited for compliance and outcomes
95%	• There are differences in recovery after surgery between RARC with extracorporeal urinary diversion and intracorporeal urinary diversion
	• Preoperative counselling and education should include oral and written information on catheter care information (for neobladder patients)
	• Oral diet should be started as soon as possible after surgery, as tolerated by the patient
90%	• Important principles to an optimised ERP for RARC include patient education and counselling
	• Minimum discharge criteria to be met prior to discharge includes: patient on regular diet and normal bowel function (bowels opened)
	• Aim is to optimize fluid balance peri-operatively and avoid overhydration
	• Restricted administration of opioids, use only when required
	• Patients may benefit from future/additional elements to an ERP for RARC such as: Patient information videos
85%	• Important principles to an optimised ERP for RARC include early feeding
	• Preoperative carbohydrate loading should be given in suitable patients
	• Thromboembolic prophylaxis should include compression stockings
	• Epidural analgesia can be routinely omitted during RARC with intracorporeal urinary diversion
	• Peri-operative fluid management is an important area that can impact patients outcome and would benefit from further future studies
	• Postoperative analgesia should include standard oral analgesia regimens and additional PRN medication: Regular oral analgesics to include paracetamol (Acetaminophen)
	• Prevention of postoperative ileus, nausea and vomiting requires multimodal approach including: prokinetic agents and chewing gum
	• A core theatre team is crucial to achieving good outcomes

(continued)

Table 22.2 (continued)

	ERP consideration
80%	• Minimum discharge criteria to be met prior to discharge includes: stoma competence (for conduit patients) and catheter competence (for neobladder patients)
	• Pelvic site drain can be removed day 1 if serum creatinine levels in drain fluid indicate only serous fluid. Drain fluid can be sent for creatinine level day 1 post RARC
	• Early removal of NG tube can be safely performed in recovery

Table 22.3 Consensus statement on structured ERP for RARC patients (pre-op, peri-op and post-op care)

Consensus view on an ERP for patients undergoing RARC	
Out-patient assessment	*Day 2–4*
1. Preoperative counseling and education. Verbal and written information supplied on operation and urinary diversion options and planned ERP	1. Prevention of post-operative nausea and vomiting—regular antiemetics may be of benefit (metoclopramide)
Preparation for surgery	2. Chewing gum [76]
1. Preoperative medical optimization	3. Unrestricted diet
2. Preoperative nutritional optimization	4. Drain fluid routinely sent for creatinine day 2 and drain removed mane day 2 if drain fluid indicates serum creatinine levels
3. Seen by stoma nurse specialist. Advice on stoma and neobladder care	5. Thrombosis prophylaxis. Compression stockings and low molecular weight heparin
4. Cardiopulmonary exercise testing if indicated	
5. Advice and support for cessation of smoking	6. Regular analgesia: standardised poly-pharmacological opioid-sparing analgesia to include paracetamol
6. Social issues addressed and discharge planning	
Day before radical cystectomy	
1. No bowel preparation	7. Early mobilisation
2. Carbohydrate loading [31, 49]	8. Daily nutritional supplements with nutrition goal 900 Kcal/day
Day of radical cystectomy: Day 1	
1. Solids up to 6 h and clear fluids up to 2 h pre-op, including carbohydrate loading [31, 49]	9. Fluid/electrolyte (30 mL/kg/day)
	10. Encourage self-care (catheter care/flushing if neobladder and stoma bag care if ileal conduit)
2. Avoidance of long acting sedatives	
3. Thrombosis prophylaxis. Compression stockings and low molecular weight heparin	*Day 4 onwards*
4. Limited antimicrobial prophylaxis and skin preparation with chlorhexidine-alcohol (or equivalent solution)	1. Continue as previous. Increase daily nutritional goal to 1500 Kcal/day
5. Standard anaesthetic protocol to attenuate surgical stress response - intraoperative maintenance of haemodynamic control, central and peripheral oxygenation, muscle relaxation, optmised depth of anaesthesia with spinal and appropriate analgesia avoiding opiates with peripheral action	2. Discharge home when criteria met: *Pain adequately controlled* *Independently mobile* *Regular diet/normal bowel function,*
6. RARC approach	*Competent with neobladder or stoma care*
7. Goal directed fluid management with judicious use of fluid restriction [62]	*Post discharge*
8. Prevention of hypothermia (Bair Hugger®)	
9. Removal of nasogastric tube in recovery	1 .Stents out day 10 (no stentogram)
	2. Removal of clips at day 10
	3. Contact with specialist nurse via telephone
	4. Audit cycle of compliance and outcomes

Preoperative Medical Optimization and Nutrition

Cystectomy patients have multiple risk factors for malnutrition (increased age, loss of appetite, nausea, pain, chemotherapy, co-morbidities including renal, cardiac and pulmonary failure etc.) and studies estimate between 23 and 87% of patients are likely to be malnourished [32, 33]. Malnourished patients are at higher risk for postoperative complications and mortality following cystectomy [34, 35] and perioperative enteral nutritional support has been shown to significantly reduces complications and aid recovery in gastrointestinal surgery [36–38]. Recent studies have shown similar effects in cystectomy patients [39]. Total parenteral nutrition following radical cystectomy is not recommended [32, 40].

Bladder cancer patients are often smokers or ex-smokers. There is overwhelming evidence that cessation of smoking prior to major surgery reduces perioperative complications and readmission rates [41, 42]. Cessation of smoking has also been shown to reduce the incidence of tumor recurrence and progression in bladder cancer patients [43].

Currently the evidence for increased physical exercise prior to cystectomy to improve postoperative mobilization and recovery is inconclusive. A recent RCT found no reduction in LOS with a preoperative and postoperative rehabilitation programme, although enhanced mobilization was achieved [44].

Oral Mechanical Bowel Prep

There is level 1 evidence to advise omitting mechanical bowel preparation in colorectal surgery. Two prospective and one large retrospective study support this strategy in cystectomy with ileal urinary diversion [45–47]. In RARC with intracorporeal urinary reconstruction irrigation, cleaning of the bowel segment can be problematic and non-digestable vegetables can be potentially seeded into the peritoneum due to spillage from the opened ileum. Therefore vegetables should not be part of the diet the day before surgery [7].

Preoperative Carbohydrate Loading

Preoperative oral intake of a clear fluid rich in complex carbohydrates 2–3 h before anaesthesia reduces thirst, anxiety, postoperative insulin resistance, loss of protein and inflammatory responses [30]. Carbohydrate loading does not negatively affect gastric emptying times or gastric acidity and may improve postoperative muscle strength, promote earlier return of gut function and reduce length of hospital stay [48].

Preoperative Fasting

There is no evidence indicating increased anaesthetic risk to patients allowed oral food or drinks after midnight the night before surgery. It has been shown to be safe to allow solids up to 6 h and and liquids up to 2 h before surgery [7, 49].

Pre-Anaesthesia Medications

Currently no studies have assessed the value of anaesthetic premedication in either open or robotic cystectomy patients. A Cochrane review on premedication with anxiolytics before surgery concluded anxiolytics can impair patients ability to mobilize and eat and drink in the early postoperative period [50]. Long-acting sedatives should be avoided. The committee reached 100% consensus that pre-anaesthesia medication is appropriate in selected anxious patients if short-acting sedatives used.

Thrombo-embolic Prophylaxis

Venous thromboembolism (venous thrombosis and pulmonary embolism) is a major complication after cystectomy with an incidence of 4–8% irrespective of open or robotic approach [51–53]. Thromboembolism signifies the most common cause of death within 30 days of oncologic surgery [53]. Patients treated with neoadjuvant chemotherapy seem to be at higher risk for postoperative thromboembolism [54]. The committee reached 85% concensus on recommending compression stockings peri-operatively and 100% consensus on recommending prolonged (4 weeks post-operative) low molecular weight heparin [5].

Intraoperative Considerations

Epidural Analgesia (EDA)

The use of thoracic epidurals is strongly recommended for patients undergoing open radical cystectomy [5]. However, epidurals can result in adverse peripheral vasodilatation and postural hypotension hampering patient mobilization and prolonging hospitalization. Patients undergoing RARC can safely avoid epidurals, patient controlled morphine-pumps and rectus sheath catheters [29]. Although urinary diversion approach may impact this decision. The committee reached 89% consensus that epidural analgesia can be routinely omitted during RARC with an intracorporeal urinary diversion and 75% agreeing it could routinely be omitted with an extracorporeal urinary diversion.

Minimally Invasive Approach

The current ERAS guidelines for cystectomy do not recommend robotic cystectomy outside a trial setting due to the lack of long term oncological results [5]. However, we are now starting to see the first multi-institutional papers reporting long-term outcomes which show equivalent outcomes to open series [55]. The committee reached 100% consensus that there were differences in recovery between ORC and RARC. There was 96% consensus that there are differences in recovery between RARC with an extracorporeal urinary diversion and a completely minimally invasive surgery approach incorporating an intracorporeal urinary diversion.

Resection Site Drainage

Currently no randomized studies have assessed the value of resection site drainage following cystectomy. It is recognised that with urinary reconstruction there is risk of intra-abdominal urinary leakage, potentially advocating the need for drainage. However the drain has potential to impact bowel recovery and some centres have shown that it can be omitted [21]. The committee reached only 61% consensus that a pelvic drain can be avoided in select patients. Current consensus (82%) guidance is that a 21Ch passive silicon drainage tube is placed through one of the port-site holes at the end of surgery and is removed the first postoperative day, if there is no evidence of urinary leakage. This can be confirmed by sending drain fluid for serum creatinine levels on the morning after surgery.

Antimicrobial Prophylaxis and Skin Preparation

There is a high level of evidence for prophylactic intravenous antibiotics and chlorhexidine-alcohol skin preparation to reduce surgical-site infections in colorectal surgery [56]. American Urological Association as well as the European Association of Urology recommends a single course of a cephalosporin given less than 60 min before skin incision [57]. Antibiotic prophylaxis should consist of limited broad spectrum antibiotics and avoid several days of unnecessary antibiotic administration (100% consensus). Skin preparation with a suitable antispetic solution such as chlorhexideine helps prevent wound infections (96% consensus).

Anaesthetic Technique and Analgesia Planning

A standardised anaesthetic protocol is important to outcome (100% consensus). Current protocols are variable in RARC and this is an area that would benefit from further study. Requirements for RARC including lithotomy position with steep Trendelenburg, pneumoperitoneum and limited anaesthetist access to the patient, all present management challenges to the aneasthetist. Patient positioning requirements can cause significant physiologic effects and may result in complications including subcutaneous CO_2 emphysema, pressure sores and compartment syndromes [58]. Attention should also be paid to maintaining normoglycemia and adequate lung ventilation taking into account the Trendelenburg position in RARC [59]. The key aims of anaesthesia are therefore to prevent hypothermia (100% consensus), hypoxaemia and hypovolemia, whilst avoiding overhydration (93% consensus) and to avoid opioid based analgesics and their effects on bowel recovery (100% consensus), whenever possible [16]. Although high levels of evidence for a stanadardised approach to general anaesthesia in RARC patients is currently limited [60], careful monitoring and good communication between all team members is critical to reducing surgical and anesthetic complications.

Perioperative Fluid Management

General anesthesia agents cause vasodilatation and hypotension and these effects can be compounded in RARC by long operation times and significant blood loss [2]. Both overhydration with excess fluid replacement and hypovolemia can provoke splanchnic hypoperfusion, resulting in post-operative ileus, increased morbidity and increased length of inpatient stay. Goal directed fluid management is therefore key to achieve optimum fluid balance and avoid these complications [61]. A recent RCT assessing goal directed fluid therapy with Doppler monitoring in radical cystectomy patients concluded it resulted in a reduced incidences of post-operative ileus and nausea and vomiting at 24 and 48 h [62]. In another recently published double-blind, randomized trial norepinephrine with deferred rehydration, was shown to counteract the detrimental hypotensive effects of general anaesthesia and result in decreased need for intraoperative fluid rehydration. Resulting in significantly reduced postoperative complication rates and also decreased length of stay in hospital [63, 64]. The same group also concluded that this approach was associated with reduced intra-operative blood loss and the need for blood transfusions [65]. A subsequent 1 year follow-up study showing significantly better daytime continence and erectile function 1 year postoperatively in these patients [66]. This finding may be explained by improved surgical views achieved due to the reduced blood in the operative field. Whilst fitter patients (ASA 1 or 2) may be more tolerant of hypovolaemia, all patients should benefit from individualized goal directed fluid management delivered by an experienced anesthetist to ensure adequate tissue perfusion.

Preventing Intraoperative Hypothermia

There was 100% consensus that maintaining body temperature during surgery with a warming device is advantageous. Normothermia during surgery has been shown to help prevent wound infection, morbid cardiac events, bleeding, pain and oxygen consumption [67].

Postoperative Care

Nasogastric Intubation

A Cochrane analysis found that patients undergoing abdominal surgery had more postoperative complications when a prophylactic nasogastric tube was maintained after surgery [68]. Early removal of the prophylactic nasogastric tube did not show any disadvantages in cystectomized patients studied in a randomized controlled fashion [69, 70]. There was 82% consensus that the nasogastric tube can be removed soon after extubation in the recovery unit.

Urinary Drainage

There is currently no study evaluating the optimal timing of removal of the transurethral catheter following cystectomy and orthotopic neobladder. Neither has the optimal duration of ureteral stenting been investigated. Early removal of a transurethral urinary catheter following abdominal and thoracic surgery significantly reduces the incidence of UTI [71], but timing of catheter removal following orthotopic neobladder should not compromise patient safety. No consensus was reached regarding optimum timing of the catheter removal for orthotopic neobladder patients with 71% of the committee stating that they currently leave the catheter for a minimum of 14 days. There was also no consensus on the timing of the removal of stents in ileal conduit patients with 36% removing the stents at 5–7 days and 64% at 8–14 days. For orthtopic neobladder patients, 32% removed the stents at 5–7 days, 36% at 8–14 days and 32%

after a minimum of 14 days. Clean intermittent self catheterization is applied as necessary.

Prevention of Postoperative Ileus (POI)

POI is a major issue following cystectomy and urinary diversion. The majority of patients encounter some degree of POI in the first post-operative days, potentially resulting in delays to early discharge. Pro-motility drugs such as metoclopramide, serotonin receptor antagonists, erythromycin, NSAID or naloxone have not been shown to be effective in studies. However, the opioid receptor antagonist alvimopan appears promising showing reduced time to return of bowel function and impacting both length of stay and hospital costs in a recent RCT [72] It has also been shown to be of benefit in robotic cystectomy [73], although there are some recent concerns for cardiovascular events [74]. Several other specific treatments have been tried to prevent POI and enhance bowel recovery including chewing gum, which may act like early 'sham' feeding, promoting intestinal functioning [75]. RARC itself has also been shown to lead to faster return of bowel function when compared to open cystectomy [76].

Prevention of Postoperative Nausea and Vomiting (PONV)

Multi-modal anti-emetic prohylaxis in selected patients with high risk of PONV is advised [5]. Goal directed fluid monitoring [62] and stenting of uretero-ileal anastomosis [77] have also shown significant reductions in PONV.

Postoperative Analgesia

Aims to enhance recovery without negatively impacting postoperative ileus, nausea and vomiting. The committee reached 100% consensus on recommending standardised poly-pharmacological opioid-sparing analgesia. Baseline treatment should include regular paracetamol (acetaminophen). Epidural analgesia can be omitted for robotic cystectomy patients since RARC patients experience less pain compared to open cystectomy [15, 28, 76]. Omitting the epidural promotes early mobilization.

Early Mobilization

It is recognised that early mobilization in intensive care unit patients is associated with improvements in functional independence, cardiovascular and respiratory function, level of consciousness and psychological well-being [78]. A recent RCT studying the impact of pre- and postoperative rehabilitation compared to regular ERP mobilization did not find any significant difference on length of stay, complications, readmissions and mortality in patients undergoing cystectomy. However, patients in the exercise program were significantly more mobile in the first 7 days and showed improved ability to perform personal activities of daily living [44]. RARC also aids early mobilization due to reduced post-operative pain and because the epidural anaesthesia can be omitted [15].

Early Oral Diet

There is no evidence to support prolonged fasting post cystectomy. Early oral food intake stimulates gastrointestinal pathways and has been shown to decrease the time to first bowel motion and reduce length of stay without increasing complication rates [79]. It also effects the brain-gut axis to positively impact higher cognitive function such as feelings and decision-making [80]. The panel reached 96% consensus that oral diet should be started as soon as possible after surgery, as tolerated by patients, avoiding parenteral nutrition.

Discharge Criteria

Discharge criteria do not currently form part of ERAS guidelines, yet it is known that readmission rates are significant following RARC and ORC [2]. The committee reached consensus that key criteria for safe discharge of patients include adequate pain control, regular diet, normal bowel function, mobilisation, and competence in stoma care for ileal conduit patients and catheter care for neobladder patients.

Audit

Audit and reporting of results are essential measures to asssess quality and guide improvements in healthcare. However, comparison and interpretation of outcome reports from different centres is not currently straightforward, due to the lack of a standardized approach and standardized reporting systems. A standardized reporting template to key to evaluating ERPs and achieving quality improvement [81]. In Table 22.4 we describe a standardized approach to reporting audited outcomes.

Table 22.4 Auditing outcome data—a standardised template

Recommended reporting elements for enhanced recovery protocol
Patient specific details:
Admission date
Co-morbidities (ASA grade)
BMI
Pre-operative staging (TNM)
Administration of neoadjuvant chemotherapy Y/N
Operation details: RARC + diversion type (Ileal conduit or orthotopic neobladder, extracorporeal or intracorporeal)
Pathological staging (TNM)
Length of stay (LOS) in days (Date of admission to date of actual discharge)
Readmission Y/N (date of readmission)
30 day and 90 day Complications (Clavien Dindo classification(ref))
ERP specific details:
Tabular reporting of all elements included from guidelines and any additional elements
Clearly explain all ERP elements including specific algorithms and pathways used in care pathway where applicable e.g.
Medications/concentrations used
Antibiotic prophylaxis
Analgesia escalation strategies
Intravenous infusion rates and criteria for goal-directed therapy
Drain placement algorithms
Epidural (if used)/regional level, single injection vs. infusion/catheter placement
Report compliance for all elements named in ERP
When failure of an ERP element occurs it should be reported and reason for failure explained, including adverse events related to an ERP element
Discharge criteria should be reported. If a substitute for LOS such as ‘readiness for discharge’ is used, there should be a report of actual length of stay and a listing of reasons for non-medical extension of hospitilisation

Future Additional Elements to an ERP for RARC

An ERP is a standardised approach and the importance of a consistent core theatre team was raised by the panel with 86% stating that a core team is crucial to achieving good outcomes. Although this is an area of patient management which has been poorly studied, it is recognised that RARC is complex surgery requiring a co-ordinated team approach [82]. However, the survey revealed that only 50% of surgeons on the panel had the same core team the majority of the time, with 11% having the same core team less than half the time and 21% stating that their surgical team members changed regularly, mostly due to management issues outside of their control. Further elements discussed included open access clinics, home monitoring via telemedicine and video information for patients, none of which achieved an over 80% consensus view.

Discussion

Although there is a growing body of evidence to support the use of ERPs in cystectomy patients, the uptake of enhanced recovery protocols for radical cystectomy patients has been slow. A recent survey of surgeons with a specialist interest in radical cystectomy found that 64% of respondents classified themselves as proponents of ERPs but that only 20% were practicing all interventions as proposed in ERAS society guidelines [83]. ERPs are also not easily studied in RCT settings because they are highly complex and impossible to blind against. Given the current levels of understanding of the benefits of ERPs, there are also ethical issues with performing RCTs [12].

The effect of the surgical insult following radical cystectomy is dependent on the stress response, which is impacted by multiple aspects including pre-operative care, surgical technique, length of operation, patient age, co-morbidities and tumour biology [5]. An ERP can impact all stages of care from diagnosis, through treatment, to return to normal function, whilst minimizing the physiological and psychological effects of elective surgery. The principle findings of a recent meta-analysis were that implementation of standardised, peri-operative pathways for cystectomy patients reduces the length of hospital stay, lowers the rate of low-grade complications and improves the time to bowel function [3]. A recent UK audit of enhanced recovery protocols, found that good compliance with an ERP was associated with a 3 day reduction in median length of stay in urological patients. However, the audit revealed that there were large variations in ERPs between individual hospitals, leading the authors to conclude that changes in process, resulting from protocol driven pathways, may be as important in reducing length of stay as any individual element of the ERPs in isolation [84].

There are currently significant variations in published ERPs for radical cystectomy (Table 22.1). Yet, it is recognized that certain elements of an ERP such as the surgical approach employed, have a significant impact on recovery [1, 85]. It therefore seems logical that a minimally invasive approach, such as RARC, is a key element to a standardized ERP. The Delphi committee were in agreement with this thinking and there was 100% agreement that an ERP is both relevant to RARC surgery and that there are differences in recovery after surgery between open radical cystectomy and RARC.

A RARC approach aligns itself with the original stated principles of ERP that minimally invasive surgery is advantageous to aid quicker patient recovery [4]. It is recognised that minimally invasive surgery (MIS) reduces the surgical stress response compared to open surgery and is therefore likely to have a key role to play in enhanced recovery after surgery [5]. Several metanalyses have highlighted that RARC compared to open radical cystectomy decreases blood loss and reduces overall complication rates, resulting in reduced transfusion rates, shorter time to normal diet and reduced length of stay (LOS) [9, 10]. RARC has also been found to be advantageous in susceptible patient groups such as the elderly [11]. A totally intracorporeal approach has been shown to be associated with a further reduction in overall complication rates [86]. There is also evidence from open colorectal surgery series that implemented ERPs can successfully reduce complication rates and length of stay in hospital [87]. An approach to radical cystectomy that combines robotic surgery with an ERP specifically designed for RARC patients has potential to further improve outcomes.

The evolution of high-volume centres for radical cystectomy has created an environment capable of supporting the dedicated infrastructure and experience required to deliver more consistent, high quality standardised services within a multidisciplinary workforce [88]. Robotic surgery has itself contributed to the centralisation of oncological surgery services [89].

There are important theoretical reasons why ERPs should improve perioperative outcomes. As described, many of the principles of an ERP have a physiological basis. Secondly ERPs are the application of evidence based practice and finally standardised protocols reduce variation in care, even if the protocols differ. ERPs are integrated management strategies that set goals for certain outcomes and provide the sequence and timing of actions necessary to attain such goals with optimal efficiency [3]. Previous research has concluded that implementation of standardised protocols not only improves compliance with recommended guidelines for care, but also improves patient outcomes [3, 84].

This consensus statement aims to give robotic surgeons guidance on a standardised ERP designed specifically for robotic surgery. We have also described a standardised template for reporting audit outcomes that will enable comparative measurement of quality improvements as new evidence becomes available.

Conclusions

This consensus view was formulated by an expert panel assembled by the ERUS scientific working group specifically for this task. There was consensus that an optimized ERP for RARC differs from an ERP designed for either colorectal patients or open radical cystectomy patients. A standardised enhanced recovery protocol for RARC is an important part of optimising patient care for elective RARC surgery. The ERUS scientific working group recognises the role of ERPs and endorses this guidance on standardised peri-operative care for patients undergoing RARC. The key principles include pre-operative patient education, optimization of nutrition, totally intracorporeal RARC, standardised anaesthetic, analgesic and antiemetic regimens and early mobilization.

ERPs in robotic surgery will continue to evolve with technological and pharmaceutical advances and standardised reporting is therefore crucial to enable assessment of improvements.

Acknowledgements This chapter has been based on an updated version of the paper previously published by the authors in European Urology. Elsevier have given permission to re-use this work for this chapter. Reference below:

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Part VI

Prostate

23 Robot-Assisted Simple Prostatectomy

Christian Padevit and Hubert John

Introduction

The surgical management for severely enlarged prostate glands (generally >80 g) in men with symptomatic BPH remains a challenge. Simple prostatectomy is considered the standard of care, if laser enucleation or vaporisation is not available. Although open simple prostatectomy is an effective and durable treatment option, it is associated with the risk of severe bleeding, transfusion and prolonged hospital length of stay. The retropubic transvesical technique [1] and the suprapubic transcapsular operation [2] are still widely accepted as the gold standard. However, the blunt dissection of the adenoma from the capsule, especially in the apical and sphincteral areas makes this procedure very invasive. Therefore minimal invasive approaches have been introduced as laser techniques, conventional laparoscopy and robotic assisted technology.

Open Simple Prostatectomy

Open transvesical [1] or transcapsular [2] prostatectomies still present significant morbidity and complication rates. In a contemporary series from 2002 with 1800 patients and an overall complication rate of 29%, severe bleeding was found in 12%, as well as a transfusion rate of 8% and sepsis occurred in 9% [3]. Another recent multi-centre study of 902 patients with an overall complication rate of 17% describes an 8% transfusion rate, urinary infections in 5% and surgical revisions due to severe bleeding in 4% [4] (Table 23.1). Open prostatectomy is still a common treatment for benign prostate enlargement especially in technically developed areas with a range of up to 40% of all cases performed [3, 5, 6].

Laser Technology

A variety of minimally invasive treatment techniques have been proposed, primarily using laser technology. Holmium laser ablation and enucleation, KTP-laser prostatectomy and photosensitive vaporisation of the prostate have been proposed [7]. Significantly shorter operative, catheterisation and hospitalisation times were found in patients undergoing Holmium laser enucleation (HoLEP) of the prostate compared to open prostatectomy in a comparative study [8]. The improvements in micturition obtained with HoLEP and compared to open prostatectomy were found to be equally good 5 years postoperatively, and reoperation rates were similarly low [9].

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_23

Table 23.1 Open simple prostatectomy series

Author	Year	*N*	Op. time (min)	Blood loss (mL)	Transfusion rate (%)	Specimen weight (g)	Catheter (day)	Reoperations (%)	Hospital (day)
Open (Freyer, Millin)									
Seretta et al. [3]	2002	1800	NA	NA	8	NA	5	5	7
Gratzke et al. [4]	2007	902	81	NA	8	84	NA	4	12

Table 23.2 Simple prostatectomy: published laparoscopic series

Author	Year	*N*	Op. time (min)	Blood loss (ml)	Transfusion rate (%)	Specimen weight (g)	Catheter (day)	Reoperations (%)	Hospital (day)
Laparoscopic transperitoneal									
Mariano et al. [11]	2006	60	138	330	0	131	5	NA	3
Sotelo et al. [14]	2005	17	156	516	29	72	6	0	2
Rey et al. [13]	2005	5	95	NA	NA	120	3	0	4
Baumert et al. [16]	2006	30	115	367	3	77	4	0	5
Laparoscopic pre-peritoneal									
Van Velthoven et al. [15]	2004	18	145	192	0	48	3[b]	6	6
Rehman et al. [12]	2005	2	180	125	0	120	NA	0	NA

Conventional Laparoscopy

Conventional laparoscopic adenomectomy in transperitoneal and extraperitoneal technique has been repeatedly evaluated since 2002 [10–15]. The large Italian and Bavarian multi-institutional studies in open prostatectomy [3, 4] observed similar functional outcomes and complication rates when compared to laparoscopy [11–16], however with significantly longer hospital stays than in the laparoscopic series (Table 23.2). So far, over 800 conventional laparoscopic simple prostatectomies have been reported in the literature [17]. However, laser and conventional laparoscopic techniques are still not wide-spread due to long learning curves, absent long-term outcomes and lack of endourological expertise and equipment.

Robot-Assisted Simple Prostatectomy

The feasibility of robot-assisted simple prostatectomy was first demonstrated transperitoneally by Sotelo et al. [17] in 2008 and in extraperitoneal technique by John et al. [28] in 2009. They showed encouraging results combining the benefits of open simple prostatectomy with the potential advantages of a minimal invasive approach, shorter hospital stay, decreased blood loss, lower transfusion rates and lesser postoperative pain. In general, the transperitoneal access is the most common used access to the prostate gland [17–27]. John et al. [28] and Stolzenburg et al. [29] described similar results performing an extraperitoneal approach.

However, in most cases the so called, Freyer'-technique is used: After urinary bladder mobilisation, a transverse transvesical incision cranial of the bladder neck performed to gain access to the adenoma. Furthermore, Pokorny et al. [27] described a longitudinal incision including the vesicoprostatic junction. Thuroff et al. [30] perform a robot-assisted transperitoneal-transvesical enucleation of the prostate adenoma. After establishing the pneumoperitoneum, the bladder is filled with saline and without any mobilisation the bladder is incised longitudinally at its roof. After identifying the ureteral orifices, the bladder mucosa on top of the adenoma is incised and the whole operation is done in the bladder cavity (Figs. 23.1, 23.2, 23.3 and 23.4).

For all the transperitoneal surgical techniques described above, the port placement is exactly the same as for radical prostatectomy: The camera port (12 mm) is placed in a midline supra-umbilical position. A 12-mm assistant port is placed about 3 cm medial the right lliacal crest. On the left hand side, a 8-mm robotic post for the fourth arm is inserted exactly in the corresponding position to the 12-mm assistant port on the right side. Two robotic 8-mm trocars are placed pararectally on the left and right hand side slightly more caudal in a distance of about 10 cm to the camera port. Last but not least a 5-mm assistant port is placed midway between the camera port and the right robotic port. Robot-assisted single port prostate adenoma enucleation has also been reported [31–33]. Unfortunately, prospective randomised studies to compare open, robot-assisted and laser enucleation are missing until now. Hoy et al. [26] published on a short series comparing open vs. robot-assisted transcapsular simple prostatectomy ('Millin'-technique). They confirmed the advantage of the robot-assisted technique in view of blood loss (218 mL vs. 835 mL), transfusion rate (0% vs. 46%), hospital stay (2.2 day vs. 5.5 day) and 90-day-comlication rate (0% vs. 57%). The duration of the operation meanwhile was longer than in the open group (161 min vs. 79 min) (Table 23.3).

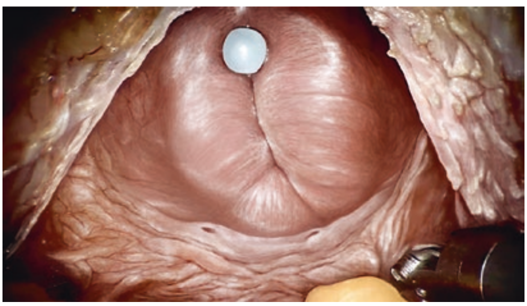

Fig. 23.1 Laparoscopic view into the longitudinally opened urinary bladder to the bladder neck and both ureteric orifices. The tip Fogarty catheter markes the beginning of the prostatic urethra

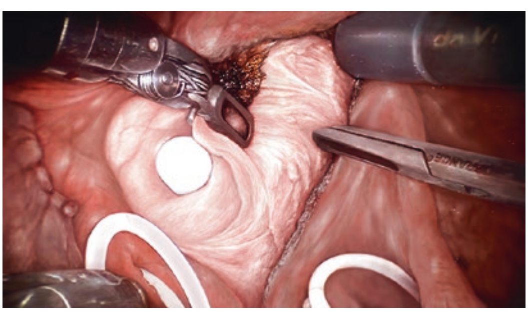

Fig. 23.2 Both ureteric orifices are stent with JJ-catheters. The bladder mucosa is incised with monopolar scissors and the prostatic adenoma is elevated with the ProGrasp forceps

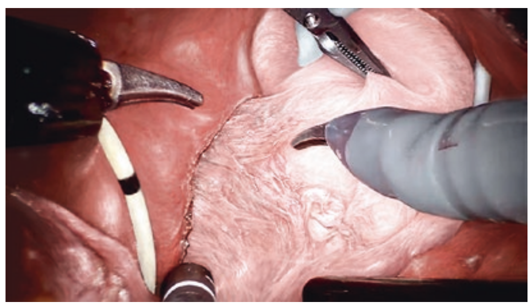

Fig. 23.3 The ProGrasp forceps pulls the adenoma to the right side. With blunt and sharp dissection, the prostatic adenoma is circumferentially freed from the prostatic capsule

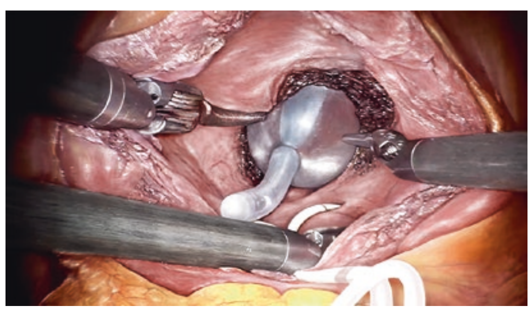

Fig. 23.4 After completed enucleation, the prostatic fossa is irrigated and a careful coagulation is performed. The indwelling catheter balloon is finally placed in the prostatic fossa and blocked. The bladder wall is then closed with a 2–0 V-loc running suture

Table 23.3 Robot-assisted prostatectomy-overview

Author	Year	N	Access path (T:transperitoneal, E: extraperitoneal)	OP Time (min)	Blood loss (ml)	Transfusion rate (%)	Specimen weight (g)	Catheter (day)	Complication (%)	Hospital (day)
Sotelo et al. [17]	2008	7	T	195	382	14	50	8	0	1
Yuh et al. [18]	2008	3	T	211	558	33	301	NA	33 (bladder neck stenosis)	1
John et al. [28]	2009	13	E	210	500	0	82	6	8 (bladder neck stenosis)	6
Uffort et al. [19]	2010	15	T	129	140	0	46	5	0	3
Sutherland et al. [20]	2011	9	T	183	206	0	112	13	0	1
Vora et al. [21]	2012	13	T	179	219	0	127	3	8 (urinom)	9
Matei et al. [22]	2012	35	T	186	121	0	87	7	0	3
Coelho et al. [23]	2012	6	T	90	208	0	145	5	0	1
Clavijo et al. [24]	2013	10	T	106	375	10	81	9	0	1
Banapour et al. [34]	2014	16	T + E	228	197	0	94	8	13 (prolonged hematuria, congestive heart failure)	1
Leslie et al. [25]	2014	25	T	214	143	4	88	9	20 (clot retention, recurrent hematuria, urinary tract infection)	4
Stolzenburg et al. [29]	2014	10	E	122	229	0	102	7	10 (prolonged fever postoperatively)	8
Hoy et al. [26]	2015	4	T	161	219	0	124	NA	0	2
Pokorny et al. [27]	2015	69	T	97	200	2	84	3	33 (wound bleeding, urinary tract infections, cystoscopy for gross hematuria)	4
Autorino et al. [35]	2015	487	T + E	155	200	4	75	7	17	2

Conclusions

The present findings confirm, that simple prostatectomy can safely and efficient be performed as a minimally invasive procedure using the robot-assisted or the conventional laparoscopic technique. Intraoperative blood loss, transfusion rate, hospital stay and the complication rate is reduced compared to open simple prostatectomy. Long-term follow-up data are missing until now as well prospective randomised studies to compare open, robot-assisted and laser enucleation.

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24 Trans- and Extraperitoneal Approach for Robotic-Assisted Radical Prostatectomy

Marcus Horstmann, Stephanos Papadoukakis, and Hubert John

Introduction

The technique of robotic-assisted radical prostatectomy was first described in 2001 using a transperitoneal access [1]. This approach has remained the most common and the most favoured. The feasibility of an extraperitoneal access was first reported by Gettman and Abbou in 2003 [2]. Since then the extraperitoneal approach has been routinely described [3, 4] and compared to the transperitoneal approach [5–12]. It mimics the open retropubic technique and offers some distinct advantages over the transperitoneal approach. This chapter describes both techniques step by step and discusses their advantages and disadvantages with the recent literature.

Patient Positioning

For both approaches either a front or side docking technique of the patient cart can be chosen (Fig. 24.1). Whereas in the front docking the patient cart is positioned between the abducted legs, the patient can remain in a supine position in the sidedocking technique [13]. For all techniques in radical prostatectomy the patient has to be put in a Trendelenburg position ranging from 20 to 35°. To achieve secure patient positioning the patient is either hold by padded receptacles or by a vaccum mattress (Fig. 24.2). The arms of the patient are placed alongside the body in arm padding. No matter what technique is chosen, meticulous care has to be taken to avoid compression of the shoulders, arms and lower extremities.

Transperitoneal (TP) Approach: Step by Step

Trocar Placement

Prior to trocar placement after abdominal desinfection and draping a 20 Fr silicon catheter is inserted to fully drain the bladder. A supraumbilical midline incision of 2–3 cm is performed, and the anterior rectus fascia is exposed from fatty tissue by two Langenbeck retractors. Using the Hasson technique, the anterior and posterior sheet of the rectus fascia and the peritoneum are opened stepwise (Fig. 24.3). The camera trocar (Ethicon®) is inserted into the abdominal cavity, and a pneumoperitoneum with high flow CO_2 insufflation is installed. Alternatively the pneumoperitoneum can be created by a Veress needle. To avoid CO_2 leakage camera trocars with ballons can be used or more

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_24

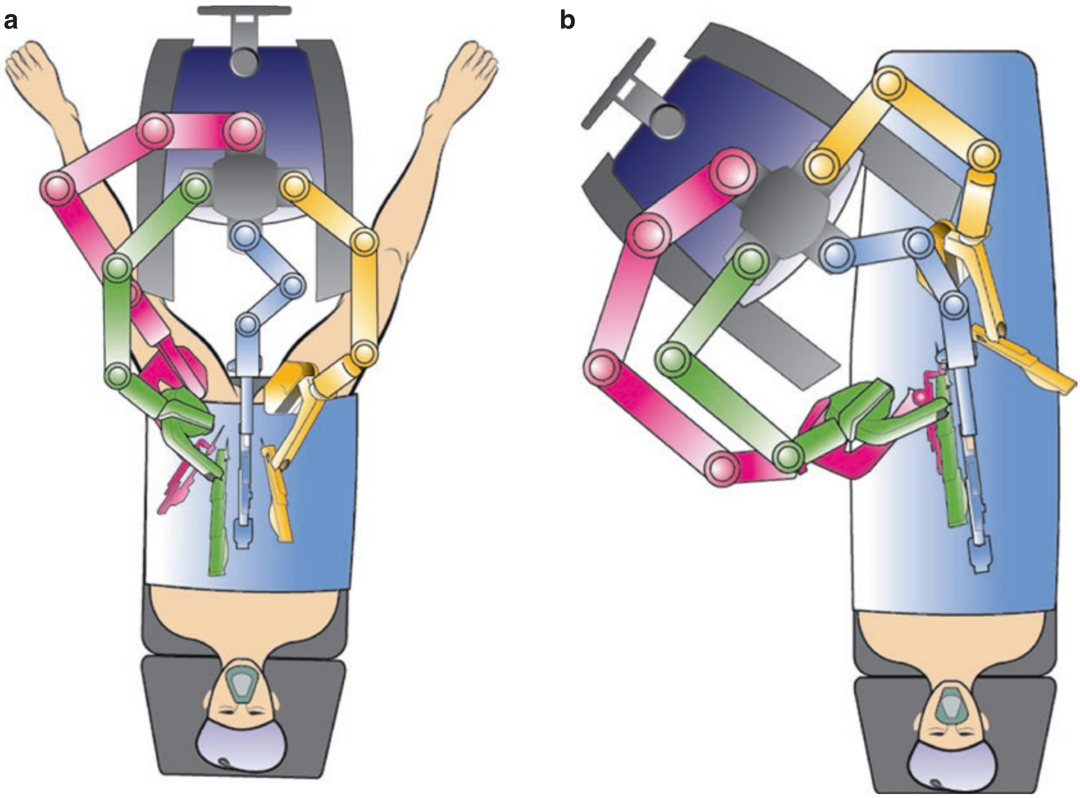

Fig 24.1 Front docking (**a**) and sidedocking (**b**) of the patient cart for radical prostatectomy

Fig. 24.2 Patient positioning and monitoring. The patient is placed in a supine position with the legs slightly abducted. Special care has to be taken in positioning and protecting the arms and the head. Central venous monitoring is not routinely necessary

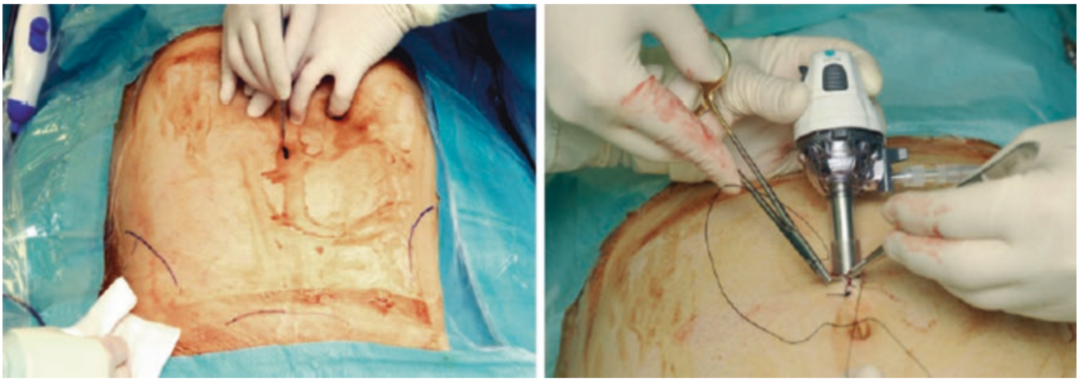

Fig. 24.3 Median supra-umbilical incision and transperitoneal positioning of the optic trocar. Skin closure after creation of the pneumoperitoneum to avoid leakage

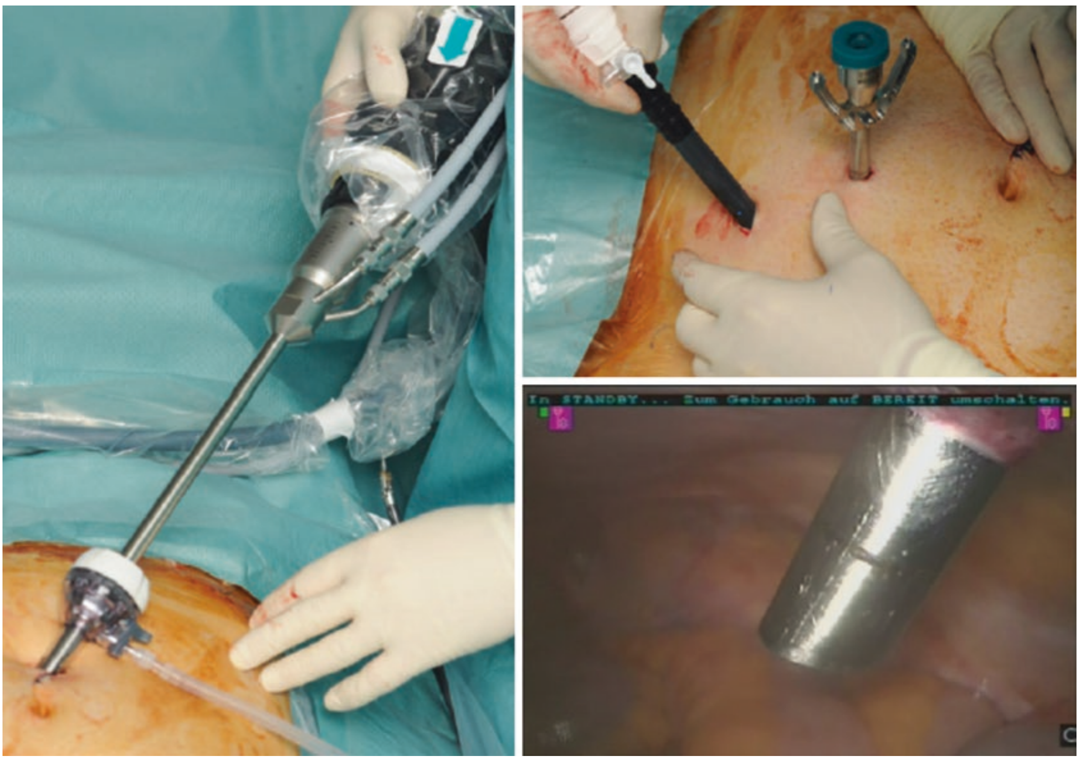

Fig. 24.4 Insertion of the right robotic trocar and the 12 mm assistant trocar under visual control

simply the skin incision can be closed by a continuous suture. The da Vinci® camera (Intuitive Surgical®) with a 0° optic is inserted and the abdominal cavity is explored. In case of clear vision and no adhesions, the right 8-mm robotic trocar (Intuitive Surgical®) is placed under endoscopic control about 9 cm laterally to the umbilicus with a maximal distance of 18 cm to the pubic bone (Fig. 24.4). Translumination is used to avoid vessels of the abdominal wall (epigastric vessels).

Three to four fingers laterally to the right robotic port and preferably 2–3 cm more cranially, a 12-mm assistant trocar (Versaport®,

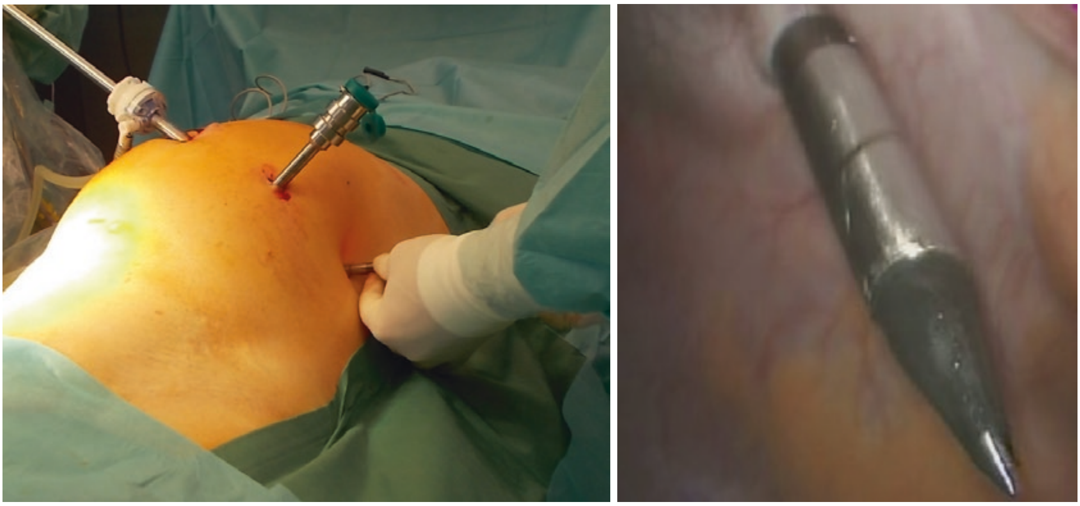

Fig. 24.5 Insertion of the left robotic trocars under visual control through the camera trocar

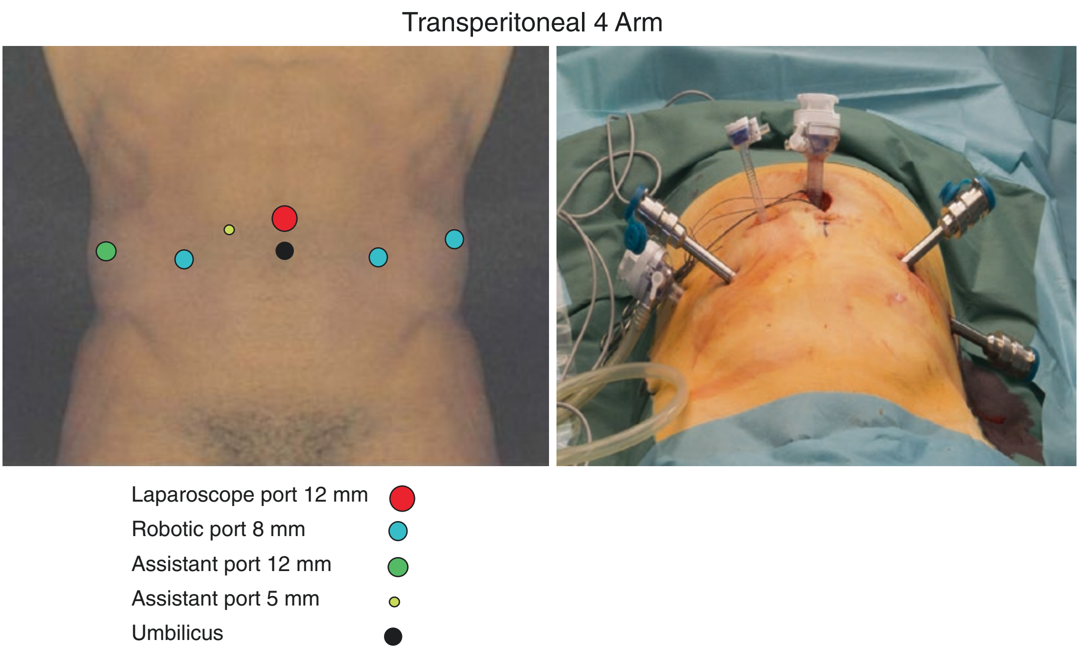

Fig. 24.6 Final port placement in transperitoneal robotic prostatectomy

Covidien) is placed with a minimal distance of 3 cm to the iliac crest. CO_2 insufflation is connected to this assistant port. Then the left 8-mm robotic trocar is placed about 8–9 cm laterally to the umbilicus under endoscopic vision through the Versaport (right assistant trocar). In the four arm technique another trocar is placed 8–9 cm laterally and slightly cranially to the left robotic trocar (Fig. 24.5). Finally a 5-mm assistant trocar is placed cranilly between the camera port and the 12 mm right robotic port. The final position of all trocars is shown in Fig. 24.6.

The patient is then put into a Trendelenburg position of about 25°, and the surgical arm cart is pushed into position (Fig. 24.7). The column is positioned next to the patient and the camera arm

Fig. 24.7 Approximation of the patient cart in the side docking technique. The patient is a Trendeleburg position of 25°

is connected. The 0° 3D endocamera is introduced under vision into the abdominal cavity and gently elevated with the camera arm lifting the abdominal wall ('laparo-lift'). All robotic arms are connected to the robotic trocars, and the position of the surgical arm cart is checked. Compression of the lower extremities by the robotic arms is excluded, and the most optimal working angles for each robotic arm are established. The bipolar and monopolar cables are connected onto the bipolar forceps and the monopolar scissors, respectively. The robotic instruments are attached to the robotic arms and inserted under endoscopic control into the abdominal cavity. Usually right-handed surgeons use a pair of monopolar scissors on the right and a bipolar forceps on the left side. Finally, the assistant's instruments: a suction device and a Johann forceps are introduced under optical control. The transperitoneal access is then accomplished, and the radical prostatectomy can be started.

In case of adhesions, modifications to the sequence and the localisation of the ports have to be considered. Minor adhesions can be removed by the console surgeon using the robotic system after installation of the surgical arm cart. In case of severe adhesions which do not allow regular port placement, standard laparoscopic adhesiolysis has to be performed prior to the connection of the surgical arm cart.

Extraperitoneal (EP) Approach: Step by Step

Installation of the Patient

The patient is prepared and positioned analogous to the above-described transperitoneal approach, although the Trendelenburg can be considerably reduced to around 20°.

Trocar Placement

The skin is incised over 2 cm transversely just below the umbilicus. With two Langenbeck retractors, the anterior rectus fascia is freed. The anterior rectus sheet is incised vertically over 1 cm (Fig. 24.8). The two Langenbecks divide the rectus muscle and expose the posterior layer of the rectus sheet. The preperitoneal space is freed by blunt finger dissection and further developed with an inflatable balloon trocar (Tyco®). The balloon is filled by 10–15 pumping actions, until the extraperitoneal space is appropriately created (Fig. 24.9). Balloon dilation must be carefully performed to avoid bladder ruptures that have occurred in cases of over-dilatation. The first 8-mm robot trocar (Intuitive Surgical®) at the left side is bluntly introduced between the subumbilical incision and the left anterior iliac crest, about 1 cm lower than the optical trocar incision (Fig. 24.10). Then, the 12-mm optic trocar (Ethicon®) is introduced and the insufflation is started (high flow, maximal intra-abdominal pressure 12 mmHg). After closing the incision around the trocar with a silk suture to prevent gas loss, an inspection of the extraperitoneal space is performed with the 0° 3D endocamera. Under direct vision, the camera can be used to increase the size of the extraperitoneal space by gently sweeping the peritoneal borders latero-cranially (Fig. 24.11). The extraperitoneal exposure is expanded by circular movements of the tip of the camera and the optical trocar—until the second 8-mm robot trocar can be placed under visual control. Performing an extraperitoneal approach, the robotic trocars are placed about 1–2 cm caudal to the camera port. The 12-mm disposable assistant trocar (Versaport®, Covidien) at the right side is placed

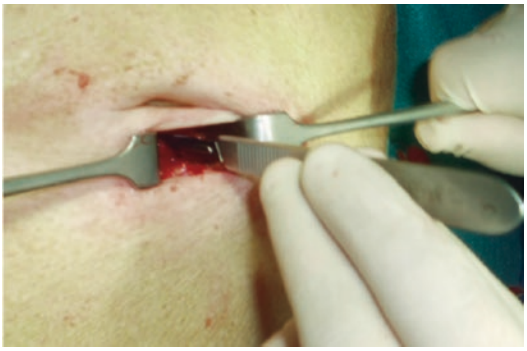

Fig. 24.8 Incision of the anterior rectus fascia. After the infra-umbilical incision is performed and the fascia exposed by the Langenbeck retractors, the anterior rectus fascia is incised vertically over 1 cm

Fig. 24.9 First robotic trocar placement. The tip of the right index finger guides the blunt obturator tip of the 8 mm robotic trocar down into the extraperitoneal space that has been created by prior balloon dilatation

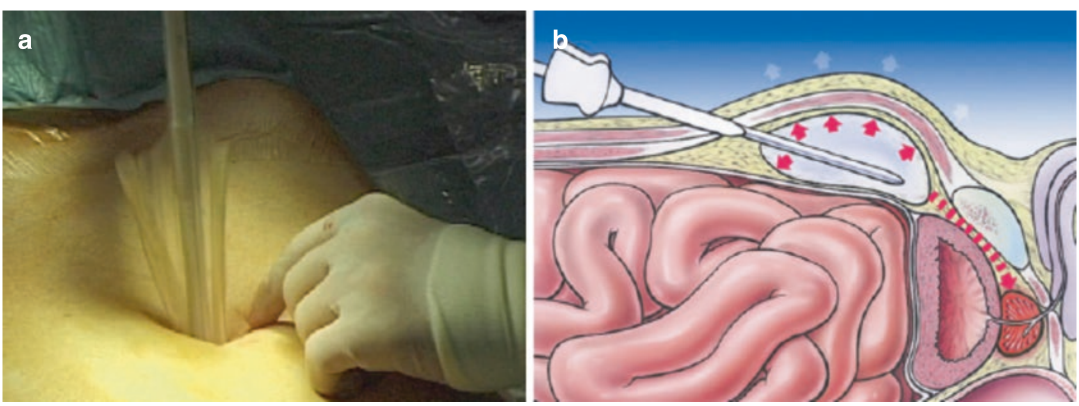

Fig. 24.10 Balloon dilation of the extraperitoneal space

Fig. 24.11 Expanding the extraperitoneal working space under trans-illumination, the camera can be used to enlarge the extraperitoneal space by gently sweeping the peritoneal borders to the side and upwards (*pt* peritoneum, *aw* abdominal wall)

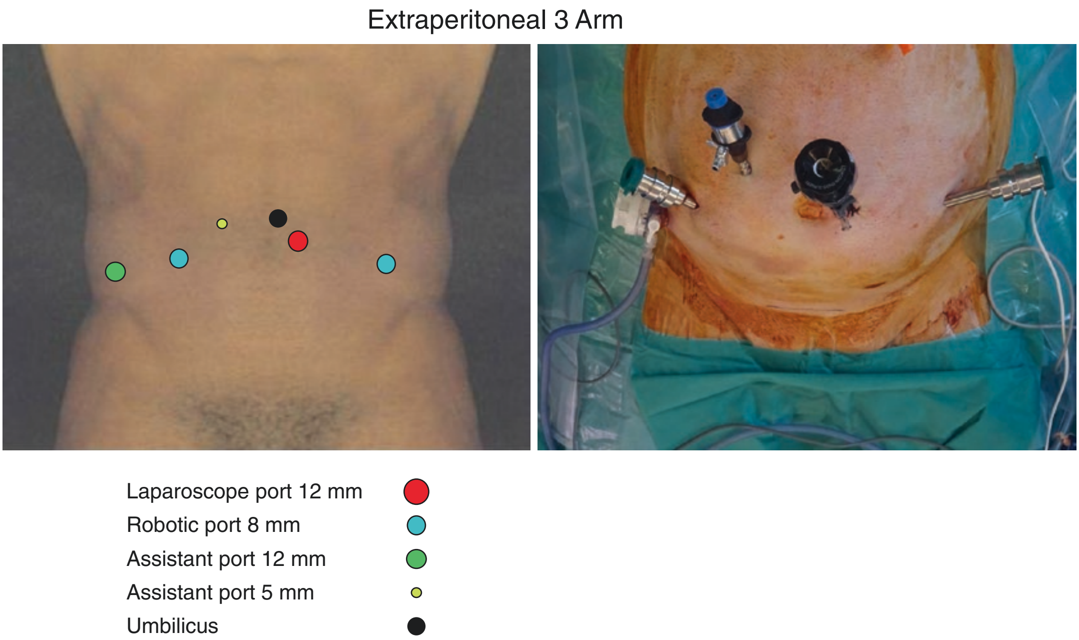

Fig. 24.12 Final port placement in an extraperitoneal robotic prostatectomy using a three arm technique

just cranio-medial of the right anterior iliac crest. Finally, the 5-mm assistant trocar is placed in between, but preferably if possible about 2 cm cranial to the right robotic and the optic trocar (Fig. 24.12). The abdominal wall is slightly lifted by the camera arm trocar ('laparo-lift'). If a four arm technique is chosen the fourth arm is positioned 8–9 cm laterally to the left robotic arm and if possible cranially to it.

Alternatively to the right sided 5-mm trocar, a 10-mm trocar can be introduced medial of the left iliac crest in the two-assistant situation. Minimal Trendelenburg position is required (20–25°). The column of the patient cart is positioned and the robot arms are attached to the trocars. All arms are connected and the EndoWrist® instruments (bipolar forceps on the left side and curved scissors on the right side) are inserted under visual control. The bipolar and monopolar cables are attached to their respective instruments. Before starting with the operation, it is insured that the lower extremities are not compressed by the robotic arms. The console surgeon leaves the operating table after port placement and is not sterile scrubbed during the remaining procedure. Usually, the console surgeon works with the pyramid tip (PreCise™) Maryland forceps or PK™ dissecting forceps at the left side and cold or hot scissors at the right side. An aspirator serves the operating field through the 10-mm trocar from the right side. The intra-abdominal CO_2-pressure is regulated at 12 mmHg but may be increased during the dissection of the Santorini plexus to 20 mmHg to avoid bleeding and reduced to 8 mmHg at the end of the procedure to check haemostasis.

Discussion

The debate which approach in which patient is more appropriate for radical prostatectomy first started in standard laparoscopy. Some authors described the advantages of the transperitoneal procedure with an easier approach and a bigger operating space whereas others stressed the advantages of an extraperitoneal procedure due to its reduced risk of intra-abdominal complications [14–16]. Since the introduction of robotic-assisted radical prostatectomy, this discussion continued. Currently, the transperitoneal approach especially in the four arm technique is the most favoured and most often performed. Similar to standard

Table 24.1 Synopsis of three prospective studies evaluating the trans- vs. the extraperitoneal approach

	Chung et al. [9]			Akand et al. [5]			Capello et al. [8]		
Approach	EP	TP	*p*	EP	TP	*p*	EP	TP	*p*
Study design	Prospective, non-randomised			Prospective-randomized			Prospective, randomized		
Patients (n)	155	105		60	60		31	31	
Mean operative time (min)	150	162	0.078	193	200	0.225	181	191	0.2
Access time (min)	n.e.	n.e.		26	16	<0.001	25	18	<0.001
Console time (min)	89	107	0.030	160	177	0.005	n.e.	n.e.	
Mean age (years)	66	66	0.612	60	60	0.791	56	59	0.06
BMI (kg/m^2)	24	24	0.386	26	27	0.350	30	27	0.004
PSA (ng/mL)	16	15	0.138	9.0	8.6	0.720	7.8	6.1	0.014
pT2	61	66	0.080	38	40	0.815	90	78	
pT3-T4	39	34		22	20		10	22	
Positive margins (*n*)	35	26	>0.1	18	20	0.741	1	0	
Lymph nodes removed (*n*)	10	11	0.091	n.e.	n.e.		n.e.	n.e.	
Overall (%)	7	19		13	13		0	3	
Blood loss (mL)	351	362	0.060	181	254	0.001	199	163	0.019
Ileus (*n*)	0	7		0	1		0	0	
Hernia (*n*)	1	8		0	0		0	0	
Lymphocele (*n*)	10	4		0	0		0	0	
Conversion (*n*)	0	0		0	0		0	0	
Pain (10-cm visual analog scale)				n.e.	n.e.		n.e.	n.e.	
POD 1	3	6	<0.001						
POD 2	2	5	<0.001						
POD 3	1	2	0.089						
Functional outcome				n.e.	n.e.		n.e.	n.e.	
Nervesparing (uni/bilateral (*n*))	28/98	19/65		58 14/44	55 19/36	0.241			
Potency rates (uni−/bi-%)	46/55	43/52		23	25	0.827			
Continence rates (%)	99	97		56	55	0.927			

n.e. not evaluated, *EP* extraperitoneal, *TP* transperitoneal, *POD* postoperative day, *m* month

laparoscopy, it is widely perceived to offer a larger working space, an easier port placement and connection to the robotic arm cart. However, also in robotic surgery the extraperitoneal approach offers some distinct advantages over the transperitoneal approach [17]. Recent studies among them two randomized studies have compared the transperitoneal to the extraperitoneal approach for radical prostatectomy [5, 6, 8–10, 12] (Table 24.1).

Trocar Placement

In the transperitoneal approach, the camera is placed in a midline position just above the umbilicus, and the robotic trocars are ideally placed laterally to the umbilicus. In case of large patients, the distance of about 18 cm to the symphysis should not be exceeded. In extraperitoneal robotic-assisted radical prostatectomy, the trocars

Table 24.2 Benefits of the extraperitoneal approach

Shorter operative time [2, 11, 19]
Better pulmonal ventilation due to reduced Trendelenburg position
Open dissection planes after previous intraperitoneal surgery [20]
Better working space in obese patients [20]
Less subileus, return to full diet earlier [2, 21]
Less abdominal pain [2, 22]

Table 24.3 Pitfalls and tricks in the extraperitoneal approach

Problem	Solution
Peritoneal leak	Drain with solution cannula
Extraperitoneal dilatation impossible	Change to transperitoneal access
Very small pelvis	Bilateral assistant trocar position
Interferences robotic/ conventional Instruments	Transpose robotic trocar 1–2 cm
Tension on anastomosis	Reduce CO_2 pressure (aspirator), use forceps for bladder wall

are placed more caudally with the robot trocars 1–2 cm below the infra-umbilical camera access. This is necessary not to injure the peritoneum which generally can be mobilised up to that level. In case of an accidental pneumoperitoneum, it should be corrected by a drainage cannula placed in the upper left quadrant of the abdomen (Table 24.3).

Especially in the extraperitoneal approach the close vicinity of the robotic and assistant instruments can create some conflict. In our experience most often it can be overcome by minimal lateral displacement of the camera and/or robotic trocars. In general the extraperitoneal space is large enough, even to work with a fourth arm [18]. In patients with a very narrow pelvis, the use of bilateral assistant trocars can be recommended (Tables 24.2 and 24.3).

Intraoperative Ventilation

In the transperitoneal access, a Trendelenburg position of about 25–35° has to be established in comparison to about 20–25° in the extraperitoneal approach. This improves intraoperative ventilation and prevents conjunctival oedema. Also the fact that no pneumoperitoneum is created in the extraperitoneal procedure facilitates intraoperative pulmonary ventilation. However in a recent randomized prospective study by Dal Moro et al., a higher $PaCO_2$ was observed in 30 patients with an extraperitonel in comparison to 32 patients with a transperitoneal approach suggesting a higher CO_2 absorption in the extraperitoneal approach [23].

Avoiding the Intraperitoneal Cavity

The extraperitoneal approach strictly avoids the intraperitoneal cavity by using the peritoneum as a natural barrier and bowel retractor. This makes it the access of choice in patients after extensive pelvic surgery or inflammations with adhesions and fixed intestinal slings. In case of a pelvic kidney and patients after renal transplantation, a high trocar placement is required, and therefore a transperitoneal approach is recommended. Generally, using the extraperitoneal approach, the risk of bowel injury is very low, and post-operative ileus and peritonitis are rare. With the extraperitoneal approach, less subileus and earlier return to full diet [16, 21] have been described [22]. This was recently confirmed in a randomized trial by Akand et al. showing a significant shorter time ot oral diet in patients with an extra- in comparison to a transperitoneal approach. (32.3 vs. 20.1 h, $p = 0.031$) [5]. Also trocar hernias are reported less frequently in the extraperitoneal approach. Next, the extraperitoneal approach proved to be superior in patients with gross obesity [21]. This is because less bowel interference is observed, and the working space generally is created easily through the fatty tissue. Even though the extraperitoneal approach is feasible [8] in patients in whom this space is closed due to prior laparoscopic hernia repair, we generally recommend a transperitoneal approach in these patients (Table 24.4).

Table 24.4 Recommendations which approach to choose

Transperitoneal AP	Extraperitoneal AP
Extended lymphadenectomy	No extended lymphadenectomy
Pelvic or transplanted kidney	Severe adhesions
Uni- or bilateral mesh implant	Severe obesity
	Patient cannot endure steep
	Trendelenburg

AP approach

Operative Time

In three recent prospective trials total operative time is shorter for extraperitoneal than for transperitoneal robotic-assisted radical prostatectomy (Table 24.1). Chung et al. reported a shorter overall operative time in extraperitoneal (150.3 ± 47.7 min) in comparison to transperitoneal procedures (162.1 ± 31.5 min) [9]. Also Akand et al. and Capello et al. described a shorter mean operative time in extraperitoneal than in transperitoneal prostatectomies (EP 193 min vs. TP 200 min, $p = 0.225$ and EP 181 min vs. TP 191 min, $p = 0.2$) [5, 8]. The reduced or equal overall operative time was mostly due to a reduced console time, because peritoneal dissection and bladder mobilisation were not necessary in the extraperitoneal approach. Chung et al. reported a significant shorter console time of 89.1 ± 19.8 in the extra- vs. 107.8 ± 19.7 in the transperitoneal approach ($p = 0.030$). Similar results were presented by Akand et al. and Capello et al.. However, the extraperitoneal approach itself took longer in most series. This was mainly attributed to the fact that additionally to the port placement the retrovesical space had to be established by balloon dilatation. In our experience of 170 prostatectomies, mean time for an extraperitoneal approach was 21 min. The transperitoneal approach took in average 19 min [10]. All other surgical steps (from opening of the endopelvic fascia) such as removal of the prostate, preparation of the neurovascular bundle and time for anastomosis were reported to be equal in the literature as well as in our experience.

Anastomosis

Some authors argue that urethrovesical anastomosis is easier to perform using a transperitoneal approach. Reasons are mainly a larger working space and less tension on the anastomosis due to the mobilised bladder. As possible solutions in the extraperitoneal approach perineal pressure, reduction of the CO_2 pressure and bladder mobilisation were proposed (Table 24.3) [6]. Even though described as more difficult, objective outcome measurements such as time for anastomosis, the number of patients with non-watertight anastomosis and the days of catheterisation showed no differences regarding the approach in the current literature. The extraperitoneal approach was described as advantageous in case of urinary leakage as urine could not enter the abdominal cavity avoiding peritoneal irritation [12].

Lymph Node Dissection

Standard lymph node dissection is described as feasible using both approaches. However, Atug et al. reported in their series of 80 patients a reduced space especially in the region of the bifurcation of the iliac vessels using the extraperitoneal approach. This is considered necessary for an extended lymph node dissection [6, 7]. Consequently, Atug et al. reported a reduced mean number of lymph nodes in patients after extraperitoneal prostatectomy when compared to patients after transperitoneal prostatectomy (EP: 8.7 nodes vs. TP: 13.2). Similar problems were discussed by Capello et al. who nevertheless concluded that a standard template lymphadenectomy can be carried out using both approaches [8]. Chung et al. reported in their series no differences in the number of removed lymph nodes (EP 10.8 ± 6.2 vs. TP 9.7 ± 5.7) [9].

They concluded that even though slightly more challenging similar lymph node dissection was feasible using both techniques. In our experience an extended lymph node dissection covering the template of the iliac bifurcation including clear visualisation of the ureter is only possible using the transperitoneal approach [10]. In this setting the more cranial trocar placement allows an easier access to the cranial lymph node dissection planes including the iliac bifurcation. Such an extended lymph node dissection should usually result in 18 or more lymph nodes. In that situation the transperitoneal approval additionally offers the advantage of less lymphocele formation. With regard to the easier approval and the reduced risk of lymphoceles, we therefore recommend the transperitoneal approval in patients in whom an extended pelvic lymph node dissection is necessary (Table 24.3).

Nerve Sparing

Technically nerve sparing can be performed equally using both approaches. In the most recently published series, the decision if nerve sparing was performed or not was independent of the chosen access. In the series of Chung et al. and Akand et al., this resulted in an equal number of patients with uni- or bilateral nerve sparing [5, 9]. In these groups none of the authors described any advantages or disadvantages for nerve sparing using one approach or the other.

Complications

Several studies investigated post-operative complications after robotic-assisted radical prostatectomies using both approaches (Table 24.1). In the series of Chung et al., overall complication rates were higher after transperitoneal prostatectomies (TP: 20 (19%) vs. EP 11 (7.1%), $p = 0.73$) [9]. Post-operative ileus was observed in 7/105 (6.7%) patients after trans- and in 0/155 (0%) patients after extraperitoneal prostatectomy. Also a higher incidence of inguinal and ventral hernias in the transperitoneal group (eight after TP (five inguinal/three ventral) vs. one inguinal after EP) was observed. Only lymphoceles were more frequent in the extraperitoneal group (TP: 4 (3.8%) vs. EP: 10 (6.5%)). No differences were found in blood loss using both techniques. Studies of Madi et al., Atug et al. and Capello et al. reported no differences of complication rates [5, 6, 8, 12]. Also in the prospective randomized trial of Akand et al. no differences in minor and major complications according to the Clavien Dindo Classification were observed [5]. Still Madi et al. reported in one out of two patients with post-operative complications a prolonged ileus due to urinary extravasation after transperitoneal prostatectomy. Another patient who also had urinary extravasation was successfully treated at home after an extraperitoneal procedure. Also Atug et al. reported one case of post-operative ileus due to urinary extravasation after a transperitoneal prostatectomy which was not observed in patients after an extraperitoneal intervention; however, overall complication rates were equal and mainly vascular complications (deep vein thrombosis, pulmonary embolism, epigastric vessel injury). In the extraperitoneal approach, some authors discuss a higher risk of epigastric vessel injury due to a more caudal trocar placement. Still, no differences were found in any recent study regarding this complication. Conversion was described in none of the series underlining the safety and feasibility of both approaches.

Post-Operative Pain

Only Chung et al. investigated differences in post-operative pain in patients operated using either the trans- or extraperitoneal approach [9]. In their study patients with an extraperitoneal procedure reported less pain after radical prostatectomy. Post-operative pain was reported using a 10-cm VA (Visual Analog) scale and the amount of analgetics as outcome parameters. Although there were no significant differences between both groups in the quantity of opioides used, pain scores on post-operative day 1 and 2 were significantly lower in the extraperitoneal than in the transperitoneal group (2.7 vs. 6.3 and 2.1 vs. 4.8, respectively, $p < 0.001$). This resulted in the conclusion that post-operative pain was lower after an extraperitoneal prostatectomy. Similar results were also described in a study by Remzi et al. who compared extraperitoneal to transperitoneal laparoscopic radical prostatectomy [22].

Oncological Outcome

According to the studies cited above, oncological outcome seems to be equal using both approaches [5, 8, 9, 11, 12]. In the series of Chung et al. with similar preoperative tumour and prostate characteristics of both groups oncological outcome such as positive surgical margins and post-operative tumour stage were equal [9]. Interestingly in their study, the number of resected lymph nodes was also reported to be equal using both techniques. Also Atuq et al., Capello et al. and Akand et al. reported in their series similar results regarding positive surgical margins and post-operative tumour stage [5, 6, 8]. In these studies preoperative tumour and prostate characteristics were equal in both groups, as well. In all cited studies, the decision which approach was chosen was irrespective of preoperative oncological parameters.

Functional Outcome

Chung et al. and Akand et al. compared post-operative functional outcome after robotic-assisted radical prostatectomy using both approaches [5, 9]. Principal limitations of such comparisons include evolving surgical techniques and growing individual surgical experience during the learning curves. This might have a bigger impact on functional and oncological results than the approach itself. Chung et al. reported similar or even slightly better functional results in patients after an extraperitoneal approach. Functional outcome was considered possible for evaluation as pre- and post-operative functional and oncological parameters as well as the number of patients who had uni- or bilateral nerve sparing were the same. Continence and potency rates were evaluated using the IIEF-5-score, pad use per day and the incontinence questionnaire: ICIQ-UI SF. For patients with preserved bilateral bundles, potency rates were 51.8% in the trans- and 54.8% in the extraperitoneal group, and continence rates were 96.6% in the trans- and 98.6% in the extraperitoneal group 12 months after surgery. Interestingly even though final results were similar, early continence rates at 2 weeks, 1 month and 3 months were significantly better after an extraperitoneal approach. In the prospective randomized trial of Akand et al. no differences were found regarding continence and erectile function after 6 months. Continence rates with no pads were 91.7 and 93.3% B for the trans- and extraperitoneal group respectively. Erectile function was evaluate by standardized questions. Reported spontaneous erections allowing vaginal penetration were 41.7% in the trans- and 38.3% in the extraperitoneal group ($p = 0.873$).

Conclusions

Although the transperitoneal approach is favoured by the majority of the robotic teams, the extraperitoneal approach can be beneficial option for some patients. Figure 24.12 and Table 24.4 give an overview of how we proceed in decision-making which access to choose in robotic-assisted radical prostatectomies. In low risk cancers, we routinely use an extraperitoneal approach combined with a limited pelvic lymphadenectomy. Only if hernia mesh implants or pelvic kidney is present or if the extraperitoneal approach is simply not feasible then a transperitoneal approach is chosen. In case of intermediate or high-risk prostate cancer, we prefer a transperitoneal approach that allows an extended lymphadenectomy. In intermediate and high-risk cancers, we only switch to an extraperitoneal approach in case of severe adhesions or morbid obesity. While oncological and functional outcome seem to be similar in both techniques, the extraperitoneal approach offers in our opinion some distinct benefits in avoiding the intraperitoneal cavity (Table 24.2). However, special circumstances as described above ask either for a transperitoneal or extraperitoneal technique.

Therefore, centres of robotic expertise should train the parallel use of both approaches.

Outlook and Future Perspectives

Recently technical and surgical advances have added new aspects to the debate of which approach to chose for robotic radical prostatectomy. Kaouck et al. reported that transperitoneal single port robotic prostatectomy has become feasible with the introduction of the da Vinci SP Surgical System (Model SP999; Intuitive Surgical Inc., Sunnyvale, CA, USA) [24]. Even though this technique is experimental in robotic prostectomy and has only been performed in few patients it potentially allows an even less invasive surgery and therefore is a logic step ahead in minimal invasive surgery. Next, the development of perineal robotic single port radical prostatectomy has added a new option in radical robotic prostatectomy [25]. It was performed in smaller series of patients and seems to be especially attractive in patients with previous extended abdominal surgery by completely avoiding the abdominal cavity. Another new option it the Retzius sparing radical prostatectomy [26]. In this technique the prostate is completely developed by a posterior transperitoneal approach without dropping the bladder. In future these techniques have to be carefully evaluated and compared to the current standard approach for robotic prostatectomy namely the trans- and extraperitoneal approach using a three or four arm technique.

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25 Radical Prostatectomy: Anterior Approach

Charles-Henry Rochat

Removal of the prostate due to cancer can be done in many ways but it is useless to open this debate because it is now well established that experience and preference of the surgeon trump the choice of technique.

The anterior approach best permits immediate recognition and approach of the bladder and prostate from above as in retro-pubic prostatectomies. This approach suits both conventional and robotic laparoscopy, whether intra or extra peritoneal, anterior or retrograde.

The key is to lower the bladder, to clean the anterior face of the prostate and then, after opening or not of the endo-pelvic fascia, to incise the bladder neck and to descend into the intra prostato-vesical plane.

In this case the ampulla are approached after sectioning the bladder neck, or in the case of retrograde prostatectomies, after sectioning the ureter and reclining the prostate. The prostate can now be raised which straightens and perfectly exposes the seminal vesicles, and allows preservation of their tips should the surgeon decide to preserve them in order not to damage the neurovascular bundles which lie along their extremities.

The posterior approach on the other hand concerns only robotic trans-peritoneal laparoscopy and starts with directly approaching the seminal vesicles and ampulla bloc with a transverse incision of the Douglas. The inter prostate-rectal dissection is then accomplished, followed by the anterior approach described below.

The posterior approach is gaining in interest because of the increasing popularity of the Retzius sparing prostatectomy. In this technique the whole approach is accomplished from below and the incision of the anterior peritoneum is done along vascular axes when lymphadenectomy is indicated. These different incisions of the peritoneum present the theoretical risk of having an intestinal limb slide. And by the way, the incision of the Douglas is closed in the original description of the Retzius-sparing prostatectomy by Bocciardi (see next chapter).

The sigmoid is rarely a hindrance in the anterior technique, whereas it may require suspending with traction sutures to approach the seminal vesicles in the Douglas technique (posterior approach).

Most teams today prefer the trans-peritoneal approach: this creates greater space for the Da Vinci and allows with a single incision, to complete the prostatectomy and lymphadenectomy.

Finally the choice of the approach whether anterior or posterior has no influence on the position of the trocars nor on the length of the surgical procedure. Indeed, there has been no

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_25

randomized prospective study to show a difference in functional results between the two approaches.

The anterior approach has several distinct stages, of increasing difficulty, very compatible with teaching robotic laparoscopy and easily apprehended by those who wish to learn this technology.

This step by step approach is documented in the curriculum offered by ERUS and called modular training.

EAU/ERUS Robotic Training Curriculum Program:

1. Bladder detachment (at least 20 cases)
2. Endo-pelvic fascia incision (at least 20 cases)
3. Bladder neck incision (at least 15 cases)
4. Section of vasa and preparation of seminal vesicles (at least 15 cases)
5. Dissection of the posterior plane (at least 10 cases)
6. Dissection of prostatic pedicles (at least 10 cases)
7. Dissection of neurovascular bundles (at least 5 cases)
8. Ligation of the Santorini plexus (at least 10 cases)
9. Apical dissection (at least 10 cases)
10. Urethro-vesical anastomosis (at least 15 cases)

Steps 1, 2 and 4 will be treated in this chapter.

In my opinion the following are my favourite's approaches after more than 15 years of laparoscopic and robotic prostatectomy experience:

1. Trans-peritoneal da Vinci prostatectomy (dVP) with anterior approach (large working space for the prostatectomy as the lymphadenectomy)
2. Trans-peritoneal dVP with posterior approach for large T3 tumours, after radiotherapy or HIFU or history of rectal surgery (in order to be sure of the feasibility of the prostato-rectal cleavage)
3. Trans-peritoneal dVP with posterior approach and retzius sparing procedure for low risk tumours (no lymphadenectomy necessary, early continence established)
4. Extra-peritoneal dVP if heavy story of abdominal surgery (no risk of intestinal lesion during adhesiolysis and time saving).

Docking and Access (Fig. 25.1)

No difference in the trocar's position between anterior and posterior approach, but the camera trocar should be high enough to have a good view of the anterior peritoneum. The incision starts at the junction of the umbilical arteries to prevent the risk of a flap of fatty tissue disturbing the camera. If the patient measures less than 175 cm the incision is made above the umbilicus, transverse as recommended in the Passadena consensus meeting (Figs. 25.2 and 25.3).

Some surgeons leave the uracus attached in order for the bladder to stay in the anatomical

Fig. 25.1 Position of the trocars

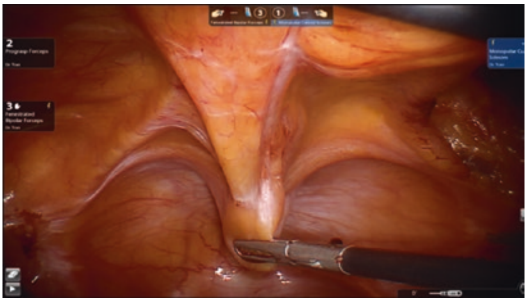

Fig. 25.2 Incision of the anterior peritoneum, the assistant pulls down the uracus with the Johann forceps

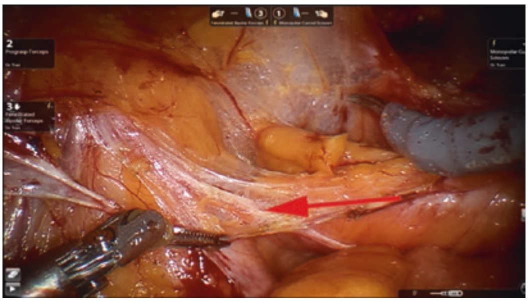

Fig. 25.3 Incision of the anterior peritoneum, the lateral dissection goes down to the vas deferens (*arrow*)

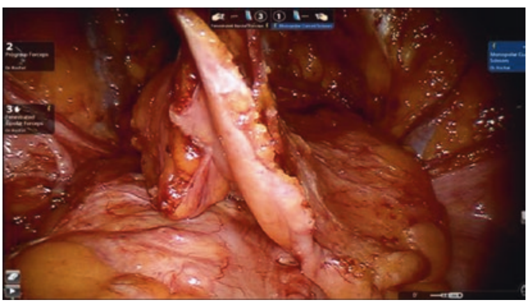

Fig. 25.4 The uracus can be left intact

position during the whole the procedure. The incisions of the anterior peritoneum follow the line of the umbilical ligaments (arteries) (Fig. 25.4).

Instrumentation

A 0° lens allows the whole anterior approach and gives the best luminosity. An extra 30° lens should be nevertheless available in case the plane between the bladder and the prostate (median lobe, inflammatory tissues) is more difficult to dissect than expected.

The choice of instruments is made according to the operator's preferences, but we personally use four robotic tools:

Monopolar scissors
Bipolar fenestrated forceps
Prograsp forceps
One needle holder

For the Assistant

Johann Forceps (One Extra-Long)

Suction device.

Material

Air seal insufflator
Clips (Hem-O-lock and 5 mm Aesulap Challenger clip applicator)
Barbed suture (posterior reconstruction and urethro-vesical anastomosis)

Setting

Pneumoperitoneum 10–12 mmHg.
Cautery 25 W.

Step 1

Bladder Detachment

The procedure starts with the 0° lens, monopolar scissors in the right arm, Prograsp forceps on third arm ready to be used but not yet in the field (to avoid any conflict with the arms as the assistant will help with a Johann in the 5 mm trocar and the suction device is in the 12 mm Airseal trocar) and the bipolar forceps in the fourth arm.

The aim is to reach the avascular plane between the abdominal wall and the bladder by incising the anterior peritoneum following the inverted V created by the umbilical arteries. One must stay

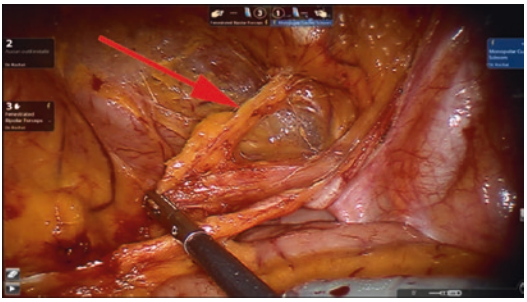

Fig. 25.5 Incision of the anterior peritoneum down to the right vas deferens. A small obturator hernia is reduced (*arrow*)

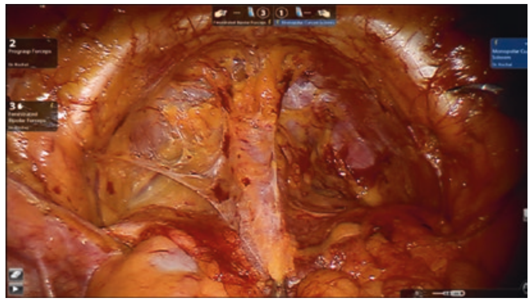

Fig. 25.6 The anterior peritoneum and the bladder are dropped and the pre-prostatic fat is visible

above the umbilical arteries in the direction of the vas deferent where it crosses the iliac vessels and then follows the vas very closely for 4 cm medially.

Care must be taken not to enter in the rectus muscle in skinny patients (Fig. 25.5).

In high BMI patients the fat is thick and care must be taken not to injure the inferior epigastric artery which runs laterally to the umbilical artery.

The alveolar tissue of the avascular plane can be opened by using the scissors and the bipolar in opposition and the pneumoperitoneum will also facilitate the dissection. Small vessels are coagulated with the monopolar scissors.

The lateral plane between the pelvis and the bladder has to be opened from the level of the external iliac vessels down to the endo-pelvic fascia. If necessary the vas can be somewhat released and the peritoneum incised medially to the ureter to give the bladder extra mobility. At this moment the Prograsp forceps can be introduced in the peritoneal cavity and to grasp the bladder just above the bladder neck and lift it backward (Fig. 25.6).

It is mandatory to clean the anterior pre-prostatic fat in order to have a perfect vision on the prostate surface, to identify the pubo-prostatic ligaments, the endo-pelvic fascia and the bladder neck. During this step, accessory pudental arteries can be found and preserved. The fat should be sent to histopathology as lympnodes can be present (Figs. 25.7, 25.8, 25.9).

The superficial Santorini veins should be coagulated as distally as possible using the bipolar forceps with at 90° inclination (Fig. 25.10).

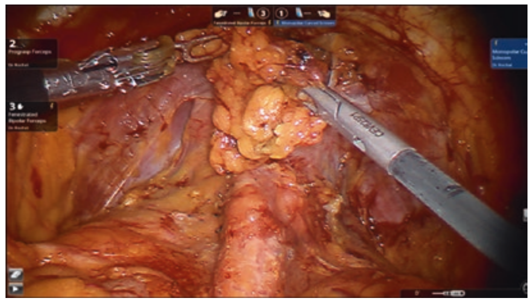

Fig. 25.7 Pre-prostatic fat is removed and sent for histology

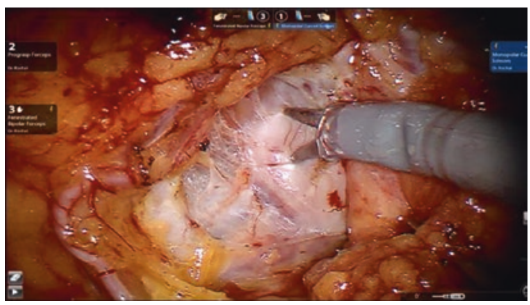

Fig. 25.8 Accessory pudental artery is seen on the left side

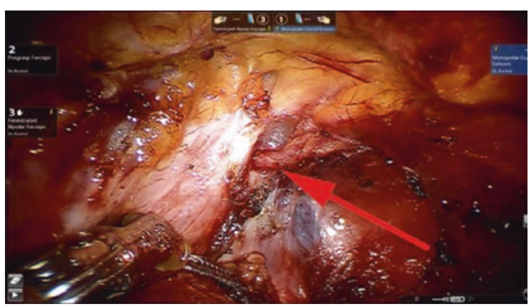

Fig. 25.9 Accessory pudental artery is seen on the right side entering at the level of the apex

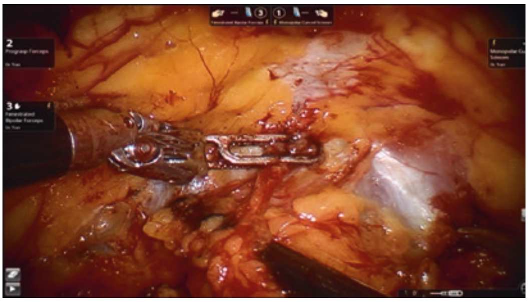

Fig. 25.10 The superficial Santorini veins are coagulated

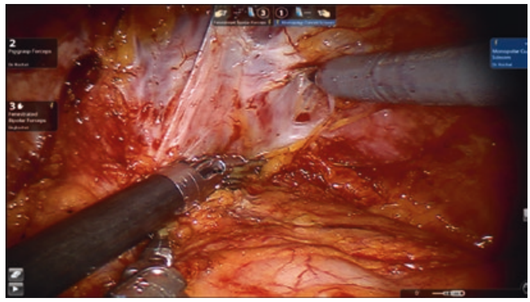

Fig. 25.12 Superficial incision of the endo-pelvic fascia on the right side

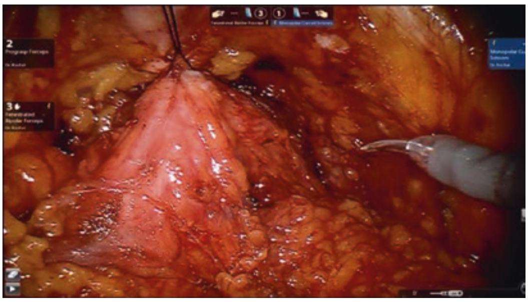

Fig. 25.11 Stich on the anterior part of the prostate

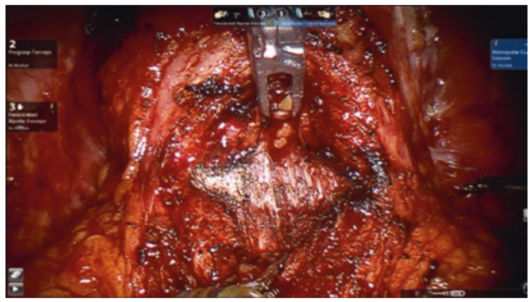

Fig. 25.13 The vesico-prostatic muscle is seen after incision of the bladder neck

Small fatty obturator hernias should be reduced and the remaining pedicle coagulated in order to give better access laterally.

At this step some surgeons place a stich on the anterior surface of the prostate to secure the dorsal veins and to elevate the prostate for a better exposure during the bladder neck incision (Fig. 25.11).

Step 2

Endo-Pelvic Fascia Incision

If a nerve sparing procedure is planned the incision of the prostatic fascia will be high on the upper third of the lateral side of the prostate. We just open the plane by pushing the tissue and leaving some fascia on the levator muscle. That is enough to determine the shape of the prostate before the bladder neck dissection. At this stage some surgeons don't even open the endo-pelvic fascia. If only a partial nerve sparing procedure is planned, the incision of the prostatic fascia will be at the lower third and by the way one should open the plane between the lateral side of the prostate and the levator ani (Fig. 25.12).

At this stage the balloon of the Foley catheter is deflated

Step 3

The bladder neck incision is part of another chapter

Step 4

Section of vasa and preparation of the seminal vesicles:

Once the bladder neck has been separated from the prostate the first structure to identify is the besico-prostatic muscle (named also anterior Denonvilliers). This plane is open transversally with the scissors angulated at 45° downwards and the prostate lifted with the Prograsp forceps maintained on the third arm (Fig. 25.13).

Once this muscle structure is opened you will encounter some fat and further in depth the deferential ampulla.

If the vision with the 0° lens is not satisfactory and you cannot progress safely, a 30° downward trocar can help (Fig. 25.14).

The assistant takes the vas deferens, as distally as possible with the Johann forceps and the vas deferens is sectioned using the monopolar scissors. It is then coagulated. The traction on the Johann forceps enables a good opening angle on the median side of the seminal vesicles (Fig. 25.15).

The seminal vesicle arteries are clipped with two 2–mm clips (Aesculap Challenger) on their distal extremities (Fig. 25.16).

For low-risk cancers the tips of the seminal vesicles can be left in place by cutting through the seminal vesicles with minimum electrogoagulation.

The dissection continues by opening the posterior Denonvilliers fascia in order to initiate the cleavage plane between the prostate and rectum in the middle, and to begin to free neuro-vascular bundles laterally (Fig. 25.17).

Special Cases

Inguinal Hernias

Inguinal hernia is a frequent condition. Some patients are symptomatic or diagnosed in the pre-operative examination, some have already been operated (open or laparoscopicaly) and others will have a direct or indirect hernia (lateral to the epigastric artery) discovered at the time of the initial step of the anterior approach. These different conditions impair the surgical protocol and require an adapted procedure.

Pre Diagnosed Inguinal Hernia

The associated hernia repair procedure should be discussed with the patient and the prophylactic antibiotherapy adapted to the Institutional practice. The choice and the availability of the mesh has to be anticipated.

Per Operative Discovery of an Inguinal Hernia

It may be an indirect hernia with a visible orifice before incising the anterior peritoneum. In this

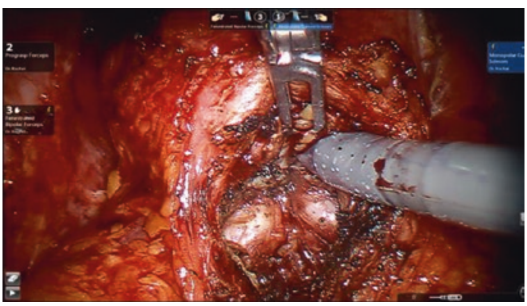

Fig. 25.14 View of the deferential ampulla

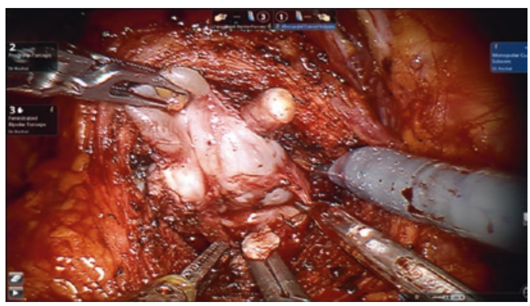

Fig. 25.16 Clipping of the vascular pedicles of the right seminal vesicle

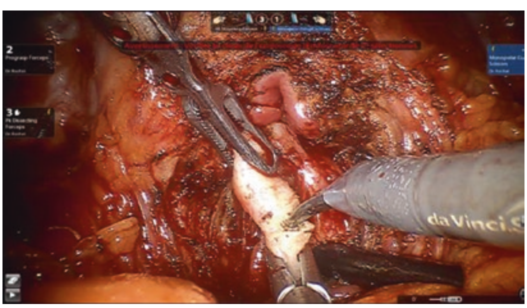

Fig. 25.15 Section of the right vas deferens

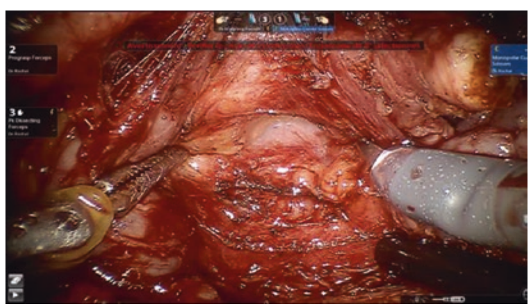

Fig. 25.17 Opening of the posterior Denonvilliers fascia at the begin of the inter prostato-rectal cleavage

case the incision of the peritoneum should be modified on the hernia side and conducted more laterally and above the inguinal ring. The epigastric artery should be identified. The best way to avoid its injury is to open the peritoneum superficially and to keep the vision on the tip of the monopolar scissors.

Beginners often push the scissors too deep while incising tissues which is a risk of vessel injury.

The modified incision of the peritoneum will allow good positioning of the mesh and will help at the end to cover the mesh at least partially with the peritoneum.

The issue of per-operative recognition of an inguinal hernia should be part of the patient information and consent as it not very clever in my point of view to leave an untreated obvious inguinal hernia discovered during a dVP just because this as not be discussed preoperatively with the patient.

The procedure of laparocopic or robotic repair of inguinal hernia requires specific training in term of placement and fixation of the mesh and of course a perfect knowledge of the material used. A good way to learn the technic is to operate with a general surgeon the cases when a inguinal hernia has been diagnosed preoperatively (Fig. 25.18).

State After Hernia Repair

An open hernia repair does not interfere with a laparoscopic prostatectomy as the Retzius has not been dissected.

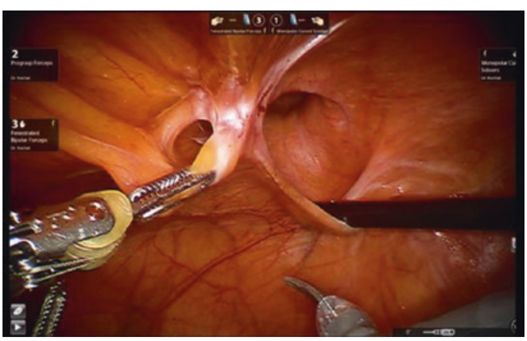

Fig. 25.18 Discovery of an inguinal hernia during the anterior approach

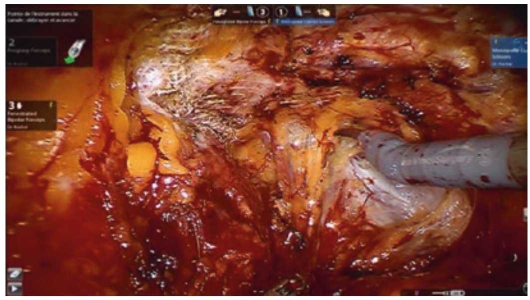

Fig. 25.19 The mesh covers the Cooper's ligament but no adhesions are seen at the level of the endo-pelvic fascia

A contrario the laparoscopic inguinal hernia repair is performed with the use of meshes placed over the deep inguinal ring, covering a large surface of the Retzius and Bogros spaces. Two difficulties are obvious: the release of the bladder and the lymphadenectomy. The trick is to stay close to the mesh and to gently bring the bladder down (filling the bladder with 150–200 cc of saline can help). Once you reach the lower end of the mesh the dissection plane is again free of adhesions and the prostatectomy can be done in a normal way (Fig. 25.19).

The lymph node dissection is only partially feasible in the area where the mesh does not cover the anatomical landmarks.

Lymphadenectomy

The lymphadenectomy can be performed before or after the prostatectomy. If the personal choice of the urologist is to perform the lymphadenectomy first, some will go straight to the peritoneal incision along the external iliac artery from the bifurcation with the hypogastric artery to the epigastric artery, the assistant pulling the umbilical artery medially with the Johann forceps. That is also the way to perform the extended lymphadenectomy as the first step of the radical cystectomy as the bladder has to remain attached anteriorly before the posterior dissection.

This allows a perfect exposure of the iliac vessels and the obturator fossa. Once both sides are done the bladder can be dropped. The other way

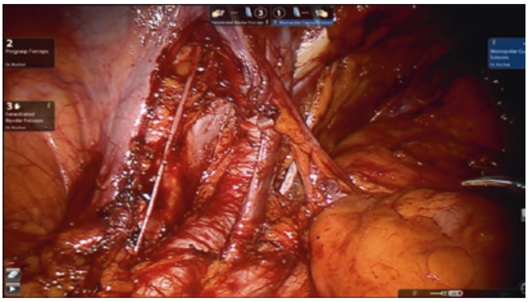

Fig. 25.20 Lymphadenectomy on the left side

is to first drop the bladder completely before performing the lymphadenectomy, which seems to be the most common sequence (Fig. 25.20).

Conclusion

The anterior approach is part of any laparoscopic prostatectomy, except the Retzius sparing procedure. It is the most popular approach worldwide. Nevertheless some teams are more confident with the dissection of the deferential ampulla and seminal vesicles as a first step, because it was the first technique they learned. There is no need to debate this point, but at least every expert surgeon should be familiar with different approaches to the seminal vesicles. The posterior approach, if completed to the apex, offers the guarantee that the prostatectomy can be done safely in cases where we fear that the cleavage plane between the prostate and the rectum may be difficult. It is also the first step approach of the Retzius sparing prostatectomy.

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Web link

http://uroweb.org/section/erus/robotic-curriculum/

Robotic Prostatectomy: The Posterior Approach

26

Randy Fagin

Background

For over 15 years, urologists have described individual techniques for the laparoscopic approach to the seminal vesicles. These approaches have received the greatest attention over the last 10 years as the robotic approach to radical prostatectomy has gained popularity. Despite the differences in technique preferred and professed by individual surgeons, the dissection of the seminal vesicles during robotic prostatectomy can be broken down into two basic approaches: dissection posteriorly where the surgeon performs this portion of the operation below the bladder prior to opening the extraperitoneal space or dissection anteriorly where the surgeon performs this portion of the procedure through the posterior bladder neck after opening the extraperitoneal space and dissecting the prostate off of the bladder. There have been published articles, podium lectures, and editorials, including a point counterpoint written by myself and Dr. David Lee, espousing the personal preferences of experienced surgeons. To date, there is no consensus on a "superior" technique, only opinion as to advantages of each approach in the hands of individuals. Having learned my laparoscopic prostatectomy technique from the time I spent in the operating room with Drs. Guilloneau and Vallancian in 2000, I have always approached the seminal vesicles posteriorly, under the bladder, prior to opening the extraperitoneal space. When I made the transition from laparoscopy to robotics in 2004, I transferred my laparoscopic technique to the robotic platform and have continued to use the posterior approach to the seminal vesicles in over 2100 robotic prostatectomies to date. In listening to the debate over whether the anterior or posterior approach is superior, it is my opinion that the answer is neither. Each technique has its merits in the hands of individual surgeons. However, when looking at the two techniques from the perspective of consistency, efficiency, and complexity one can begin to appreciate the assets of the posterior approach.

Understanding how the posterior approach allows the surgeon to have consistency, efficiency, and simplicity when performing this portion of the operation can be best explained in the context of access and efficiency. After discussing these assets, I will then describe the details of performing the posterior technique, the keys to success with it, and tips to avoid complications.

Access

Because the posterior approach is performed prior to dropping the bladder, the working space can make use of the entire abdominal cavity.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_26

This large working space reduces the potential for instrument collisions, reduces the need for intricate coordination of movements between the surgeon and assistant, and improves the surgeon's orientation by giving him a broad view of the surrounding anatomy. Furthermore, access to the seminal vesicles and vas deferens via the posterior approach is not limited or restricted by variations in patient anatomy like the size and length of the seminal vesicles, the size of the prostate, or the presence of a median lobe or protuberant lateral lobes. This lack of variability in anatomy allows for consistency and predictability in performing this portion of the operation.

Efficiency

The posterior approach also allows this portion of the operation to be performed with great efficiency. When performing the posterior approach, because the access to the vas deferens and seminal vesicles is not limited or affected by patient anatomy (the size and length of the seminal vesicles, the size of the prostate, or the presence of a median lobe or protuberant lateral lobes), the dissection is very consistent which improves reproducibility and reduces the time that it takes to complete this portion of the procedure. The large working space and ease of access to these structures also mean that the surgeon needs only one assistant whose job is to simply retract the anterior reflection of the peritoneal incision anteriorly also lending to the simplicity, efficiency, and reproducibility of this approach. Performing the posterior approach to the vas deferens and seminal vesicles also makes the posterior bladder neck dissection efficient. By approaching the vas deferens and seminal vesicles posteriorly, the posterior bladder neck dissection is simplified in that it becomes a straightforward midline dissection where the surgeon merely follows the contour of the bladder until reaching the previously created "hole" where the freed vas deferens and seminal vesicles reside.

Technique for the Posterior Approach to the Vas Deferens and Seminal Vesicle

Avoiding Injury to the Ureters

Before discussing the "how to" let me spend a moment discussing the "how to avoid" in the context of ureteral injuries. Due to the proximity of the ureters when performing this technique, there has been discussion over the potential for ureteral injury and cases of ureteral cauterization, ligation, and transection have been reported. Because of the ease of access to this location and the ability to gain perspective relative to surrounding structures, ureteral injury can be easily avoided if one familiarizes oneself with three facts about the anatomy in that region and follows three simple rules.

Three Important Anatomy Facts

1. The ureters are located superior and lateral to the location of the vas deferens.
2. The vas deferens meet in the midline and the ureters do not.
3. The seminal vesicles lie behind the vas deferens and not behind the ureters.

Understanding these three simple anatomy facts, however, is not enough. To avoid injury to the ureters, these facts must be applied in the context of following the three important rules below.

Three Important Rules

1. Make your peritoneal incision low and in the midline.
2. After incising the peritoneum, only use blunt dissection.
3. When dissecting out the vas deferens and seminal vesicles, only dissect on these structures, never around them.

Let's explore these three rules in greater detail and discuss how our three anatomy facts should

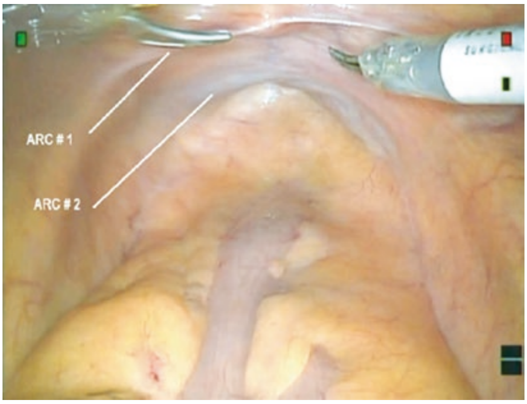

Fig. 26.1 Posterior arcs

Fig. 26.2 Peritoneal reflection

be applied in this context as we describe the technique for the posterior approach to the vas deferens and seminal vesicle.

Step 1: Make Your Peritoneal Incision Low and in the Midline

The initial opening in the peritoneum should be made low and in the midline. Technically, there are supposed to be two arcs (Fig. 26.1) as the peritoneum arises off the rectum. The incision to access the seminal vesicles and vas deferens is traditionally described as being made in the lower of the two arcs (ARC #2 in Fig. 26.1). In real practice, however, these two arcs do not always exist, so I prefer a more predictable anatomic landmark: the junction of the sigmoid/rectum and the peritoneal reflection (Fig. 26.2). Using this

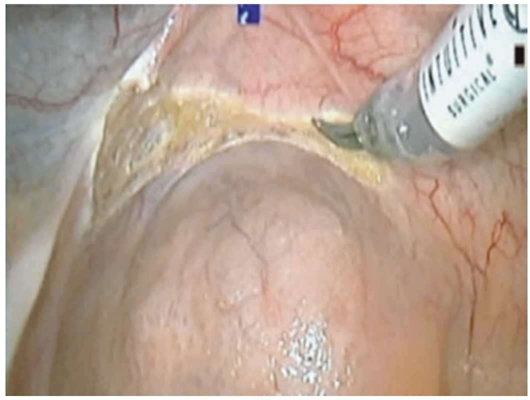

Fig. 26.3 Initial incision in peritoneum

landmark, I simply make my incision in the midline, ½ cm above the transition point where the peritoneum arises off the distal sigmoid colon/rectum. Figure 26.2 demonstrates this point at the tip of the scissors, and Fig. 26.3 shows this location after making the initial incision in the peritoneum. Staying low and in the midline here will keep you away from the ureters *which are located superior and lateral to the location of the vas deferens.* After making the peritoneal incision, it is important to note that the way in which you dissect becomes important in keeping you from inadvertently injuring surrounding structures.

Step 2: After Incising the Peritoneum, Only Use Blunt Dissection

Once the peritoneal incision is made, there is a real plane between the perivesical fat and the vas deferens and seminal vesicle. After opening the peritoneum, have your assistant retract anteriorly on the anterior leaf of the incision. If the surgeon then uses blunt dissection to simultaneously spread anteriorly and posteriorly with the instruments in the right and left hands, a thin layer of areolar tissue will become apparent. Continued blunt dissection in this manner and in this plane will lead to visualization of the vas deferens with the seminal vesicle directly behind it (Fig. 26.4). This blunt spreading dissection is important because continued sharp dissection and cauterization after making the peritoneal incision increases the potential for dissection in the wrong

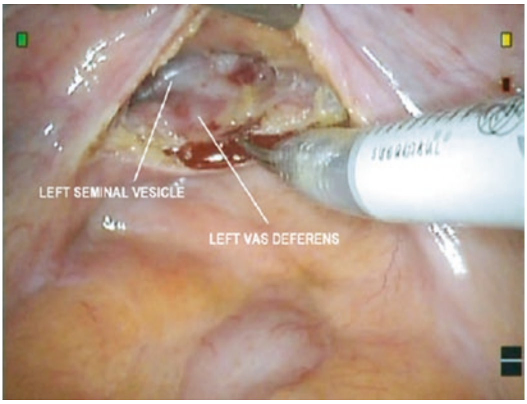

Fig. 26.4 Exposure of left seminal vesicle and vas deferens

plane resulting in injury to the detrusor and/or ureters. Once the structure believed to be the vas deferens comes into view, there are two more steps I would recommend prior to transection or ligation to ensure that the structure you are dissecting is truly vas deferens and not ureter. The first step to ensure the dissected structure is vas deferens is to trace the structure to the midline. If the structure being dissected meets a similar structure in the midline (and that similar structure it meets in the midline is arising from the opposite side), then the structure being dissected is vas deferens. Quite simply, *the two vasa deferentia meet each other in the midline and the ureters simply do not*. The second step is to perform blunt dissection behind the tubular structure believed to be vas deferens. This dissection will reveal the seminal vesicle if the structure being dissected is the vas deferens since *the seminal vesicles lie behind the vas deferens and not behind the ureters*. Once these two confirmations have been made, then transection and/or ligation of the vas deferens can be performed safely.

Step 3: When Dissecting Out the Vas Deferens and Seminal Vesicles, Only Dissect on These Structures, Never Around Them

Despite doing all of the above, there is still the potential to injure the bladder or ureters if one additional rule is not followed. When dissecting out the vas deferens and seminal vesicles, the surgeon should only dissect *on* these structures and *never around* them. Performing dissection and cauterization in the tissues surrounding the vas deferens and seminal vesicles has the potential to injure those structures that lie within proximity (bladder, ureters, and neurovascular bundles). There is a true plane that separates the vas deferens and seminal vesicles from the surrounding structures. The simple task of dissecting and cauterizing *on* the vas deferens and seminal vesicle and then peeling the surrounding structures off bluntly can prevent injury to these nearby structures.

After dissection of the vas deferens and seminal vesicles bilaterally, many surgeons then incise Denonvilliers fascia and dissect the prostate off the rectum. I prefer not to incise Denonvilliers fascia at this time. At this point in the procedure, although you are able to perform this dissection, you do not have knowledge of where the neurovascular bundles are in relation to the viewed anatomy, and inadvertent injury to them can occur especially when you dissect toward the apex of the prostate where the two bundles are known to converge toward the midline. By waiting until after the posterior bladder neck dissection is performed, to incise this fascia and perform the dissection of the prostate off the rectum, the surgeon will have a greater appreciation for the lateral and medial limits of the prostatic pedicle and neurovascular bundles. This perspective allows for a more controlled incision in Denonvilliers fascia and an improved ability to avoid inadvertent injury to the neurovascular bundles. In addition, if one makes the incision in Denonvilliers and attempts to dissect the prostate off the rectum, and bleeding occurs in this deep hole, the surgeon's only solution is cauterization which also has the potential to injure the neurovascular bundles as well as the rectum.

Another asset of the wide access afforded by the posterior approach is related to the importance of staying athermal at the tips of the seminal vesicles. Due to the proximity of the tips of the seminal vesicles and the neurovascular bundles, remaining athermal at this location is important to improving potency outcomes. Because of the large working space afforded by the posterior technique, it is consistently easy to stay athermal at the tips and lateral portions of the seminal vesicles.

In conclusion, as surgeons decide on a method to approach the vas deferens and seminal vesicles for robotic prostatectomy, the posterior approach affords wide access, minimal dependence on one's assistant, consistency, and efficiency. This does not, however, mean that this approach is superior to the anterior approach. It is my belief that surgeons benefit from knowledge of both techniques and that to perform this portion of the operation consistently well, each surgeon should choose the technique that they prefer and perform it consistently.

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27

Bladder Neck Dissection During Robotic Radical Prostatectomy

Thierry Piechaud and Filippo Annino

Introduction

The approach to the bladder neck (BN) is the first critical step of antegrade laparoscopic radical prostatectomy. Its identification can be difficult in some cases, and a mistake at this point of the surgery can compromise the rest of the operation, influencing the next steps of dissection as well as the anastomosis.

Because of the complexity of the continence mechanism, the value of preserving the BN during radical prostatectomy is still debated, even if there is some evidence for an earlier return to continence in the cases where it is preserved [1]. Preservation of the BN does not seem to be correlated with a higher risk of positive margins [2, 3], even if some authors suggest that a wide resection of the BN decreases the positive surgical margin rate [4]. In our opinion, an accurate dissection of the BN and its preservation, especially of the posterior wall, could improve the early return to continence.

The preservation of the BN is not always possible during laparoscopic radical prostatectomy, particularly when a large median lobe is present, and preservation is never possible in case of a previous TURP in which the BN was destroyed. In suspected clinically advanced disease or in the case of positive biopsies at the base of the prostate, we suggest nonpreservation of the BN.

For all the above-mentioned reasons, we describe different approaches to dissection of the BN for each one of these scenarios.

Anatomy of the Bladder Neck

The bladder neck is the junction between the urinary bladder and the prostatic urethra and is placed at the distal corner of the trigone. At this level, the detrusor muscle is clearly separable into the three layers: inner longitudinal, middle circular, and outer longitudinal layers.

In men, radially oriented inner longitudinal fibers pass through the internal meatus to become continuous with the inner longitudinal layer of smooth muscle in the urethra.

The middle layer forms a circular preprostatic sphincter that is responsible for continence at the level of the bladder neck.

The outer longitudinal fibers are thickest posteriorly at the bladder base. In the midline, they insert into the apex of the trigone and interweave

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_27

with the smooth muscle of the prostate to provide a strong trigonal backing. Laterally, the fibers from this posterior sheet pass anteriorly and fuse to form a loop around the BN. This loop is thought to participate in continence at the BN. On the lateral and anterior surfaces of the bladder, the longitudinal fibers are not as well developed. Some anterior fibers course forward to join the puboprostatic ligaments [5].

Anatomical—Surgical Correlations

As explained previously, the BN is composed of three layers of detrusor muscle and has in its luminal part the mucosa which continues together with the inner longitudinal fibers into the prostatic urethra.

On a three-dimensional view, we can identify six regions around the BN, like the faces of a cube.

Anterior to the BN are the Retzius space, the endopelvic fascia with the end of the puboprostatic ligaments, and the superficial branch of the deep dorsal vein of the penis. Proximally, the BN is related to the bladder lumen and the trigone. Laterally and behind the lateral part of the BN, we find the prostatic pedicles and the neurovascular bundles of the prostate as well as the lateral part of the seminal vesicles. Posterior to the BN we find, under the Denonvilliers fascia, the ducts vasa deferentia and the medial part of the seminal vesicles.

Posterior to the BN was always considered to be the anterior layer of the Denonvilliers fascia, which was considered to be a muscular layer of longitudinal fibers. Recently, Secin et al. reported an anatomical study demonstrating that this layer corresponds to the posterior longitudinal fascia of the detrusor muscle which is externally upholstered by the bladder adventitia [6].

Caudally, the BN has a close relation with the prostate, which in this area does not have a really well-defined capsule; however, at this level with the introduction of laparoscopy, and even more with the robotic approach to radical prostatectomy, we are able to find a real anatomical space in which we can clearly separate the muscular fibers of the bladder neck from the prostatic base. We describe this technique but want to highlight the reality of this anatomy, in which it is possible to find the initial part of the urethral tube, in the initial part of the supraprostatic dissection.

Median Lobe

The normal anatomy can be modified in the case of a large median lobe, where usually the posterior relations are changed. In fact, the presence of a voluminous median lobe pushes the BN cranially, reducing its distance from the ureteral orifices and separating the ducts and the seminal vesicles, which in some cases can be placed far away from the BN, with consequent difficult identification of the right plane of dissection.

This specific situation does not modify the anterior relations of the BN, but it can compromise the right identification of his position during the procedure. For this reason, the presence of a median lobe should be well investigated before the surgery with an ultrasound or an MRI.

Previous TURP

In the case of a previous TURP, the BN is usually destroyed and modified in its medial portion. In this case, the BN can be very close to the ureteric orifices. This modified anatomy should be well considered in order to prevent injury in the ureteric orifices during the dissection. It is also important to try and leave sufficient space between the limit of resection and the ureteric orifices to achieve a pristine urethrovesical anastomosis, without risk of injury to one or both ureteric orifices.

Functional and Oncological Principles of Bladder Neck Preservation

Radical prostatectomy should aim to maintain sexual function and achieve early continence after surgery, without hindering the final oncological outcome of the procedure.

In previous years, a great effort has been put into developing technical refinements in order to improve the clinical outcome and minimize the morbidity of radical prostatectomy. Various mechanisms responsible for male urinary continence have been reported in the literature, but no single definitive conclusion has been reached [7]. The factors favoring continence preservation after radical prostatectomy seem to be (a) the preservation of pelvic floor structures, (b) external urethral sphincter muscle and the anterior urethral support, and (c) the preservation of the neurovascular bundles. Another important role seems to be the age of the patient. As the patient ages, the elasticity of the pelvic floor muscles appears to diminish, and there is limited ability for nerve recruitment [8–13].

Puboprostatic ligaments support the external striated urethral sphincter, and their anatomical and morphological stability seems to have an important role in achievement of continence after radical prostatectomy, even if this remains an issue of debate.

Since Young in 1905 first described the role of puboprostatic ligaments in supporting the BN and promoting urinary continence after perineal radical prostatectomy, many authors have quoted the important role of this hypothesis, concluding that the ligaments are part of a larger urethral suspensory mechanism, stabilizing the membranous urethra to the pubic bone, thereby assuring continence [14, 15].

Other authors have reported a positive correlation between the mean urethral length and the continence rate showing a difference in the maximal urethral closure pressure [16, 17].

Poore et al. examined the effects of puboprostatic ligament and/or BN preservation on urinary continence after radical retropubic prostatectomy and observed an early return to continence with BN preservation but the same final outcomes with a puboprostatic ligament preservation technique or a combination of both [1].

Deliveliotis et al. evaluated three groups of patients in which they preserved the BN, the puboprostatic ligaments, or both and reported no difference on the final continence rate but an early return to continence in the patients in whom the BN had been preserved [3].

The puboprostatic ligament-sparing technique, as well as the BN-sparing technique, can be discussed also from the point of view of their oncological outcomes. Some authors suggest that sacrificing the puboprostatic ligaments and the BN decreases the apical positive margins [4]; however, this idea is controversial, since other authors have shown no significant differences in positive margin rates between two groups of patients treated with or without puboprostatic ligament-sparing technique [18].

Even if this point is still debatable, if the preservation of the BN does not clearly demonstrate an improvement in the rate of final continence, some studies suggest an earlier recovery of continence, with an obvious improvement in the quality of life, without an increase in the rate of positive margins [1, 3, 18].

Surgical Technique of Bladder Neck-Sparing Dissection During Robotic-Assisted Prostatectomy

We describe initially the classical approach and dissection of the BN during a transperitoneal laparoscopic radical prostatectomy assisted by the Robotic Intuitive Surgical System, known as the da Vinci robot, which can provide two or three operative arms. The dissection of the BN could be performed with both systems without substantial differences.

In this chapter, we describe the use of the four-arm da Vinci robot, but in the case of the three-arm robot, the third arm can easily be substituted by the assistant grasp. This can be achieved working with one assistant on the right side of the patient or with two assistants, where the second assistant should be placed on the left side of the patient in the same place as the fourth arm of the robot.

Next, we describe port positioning and the use of the fourth arm to illustrate how to use it.

We find it more comfortable using the red arm on the left side to leave enough space for the assistant who is placed on the right side of the patient. The dissection is performed using the yellow arm placed on the right iliac fossa, between the right anterior superior iliac spine (ASIS) and the umbilicus in the middle line or to the proximal third, depending on the position of the assistant ports. With this arm, we use the monopolar scissors or the monopolar hook. We suggest to perform the entire procedure with the monopolar scissors on the right arm, to avoid multiple changes of instruments, and to reduce the costs.

On the left side of the patient, we place the green arm 2 cm laterally to the left rectus muscle and 2 cm cranially to the port for the camera. The red arm is placed as lateral as possible on the anterior left axillary line, three fingers cranially to the left ASIS. The assistant works with two 5-mm ports on the right side (Fig. 27.1).

We always begin with the division of the left colon adhesions in order to better mobilize the bladder once separated from the anterior abdominal wall. This maneuver is performed incising the umbilical arteries as high as possible and continuing the dissection laterally until the vasa deferentia are reached. It is very important to open this space well, incising the peritoneum as cranially as possible to achieve a better mobilization of the bladder (Fig. 27.2).

After the dissection of the Retzius space, the anterior part of the prostate and the endopelvic fascia are liberated from the surrounding fat tissue. During this maneuver which should be continued laterally until the level of the umbilical artery is reached, the superficial branch of the deep dorsal vein of the penis is treated with the bipolar cautery and is divided. The puboprostatic ligaments are also freed from the fat tissue and well identified. At this point, the vesicoprostatic junction is clearly visible, and its

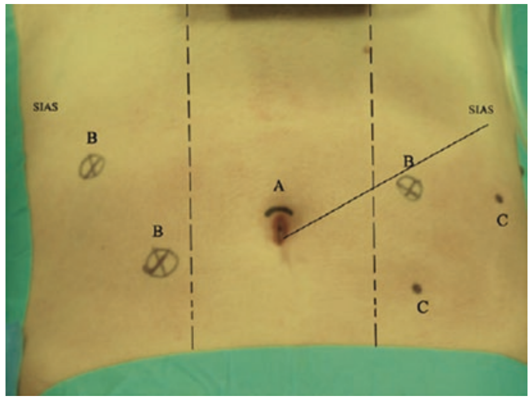

Fig. 27.1 Port positioning. (**a**) The optical 12-mm port is placed under or above the umbilicus. (**b**) The three operative 8-mm robotics ports are placed in the middle line between the right superior anterior iliac spine and the umbilicus for the yellow arm, 2 cm cranially to the optical port laterally to the left rectus muscle and three transverse fingers cranially to the left iliac crest at the anterior axillary line. (**c**) The two ports for the assistant are placed three transverse fingers cranially to the right iliac crest on the anterior axillary line and 3 cm cranially to the camera laterally to the right rectus muscle

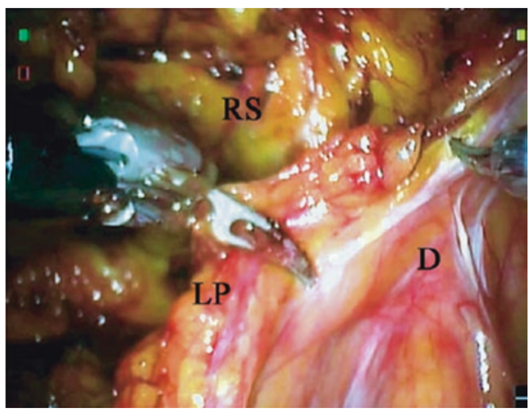

Fig. 27.2 The bladder is separated from the abdominal wall, and the peritoneum is opened until the vas deferens is reached as laterally and cranially as possible, to achieve complete mobilization of the bladder. This image is the detail of the right side where the peritoneum is incised until vas deferens is reached. *D* vas deferens, *RS* retius space, *LP* limit of peritoneum incision

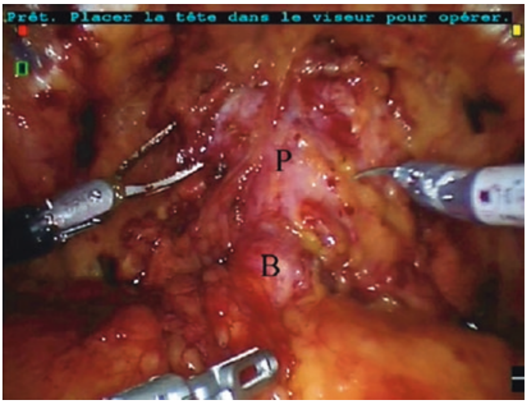

Fig. 27.3 Vision of the prostate (*P*) freed from the fat tissue. The bladder neck and the balloon of the bladder catheter (*B*) are clearly visible

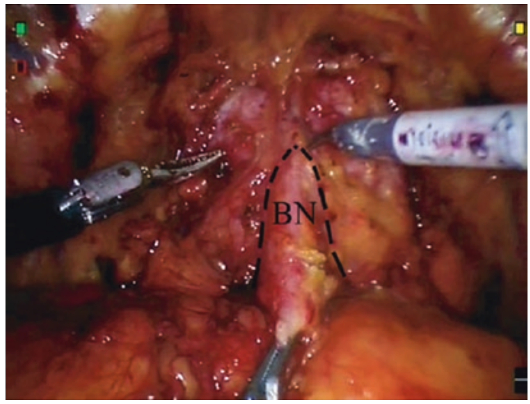

Fig. 27.4 The balloon of the bladder catheter is deflated, and a moderate traction is performed on the bladder, and the right position of the bladder neck is identifiable. If compared with Fig. 27.3, one can see how the real site of the bladder neck (*BN*) is higher on the prostate base and more caudal of the one identified with the balloon of the bladder catheter

lateral margins are free to begin the dissection. If the endopelvic fascia is well prepared, we can identify the prostate, the bladder with the catheter balloon (previously inflated with 4–5 cc of water), and the puboprostatic ligaments reaching the BN (Fig. 27.3).

A little trick to better identify the BN and to begin our dissection in the right place is to follow the puboprostatic ligaments which usually cross at the level of the BN. At this point, the balloon of the bladder catheter can be deflated. Another trick is to follow the deflation of the balloon which can allow better identification of the BN. At this step, the fourth arm is introduced. We use a pro-grasp (Johannes) to gently retract the bladder to create a little tension on the BN, in order to better identify it. This maneuver is very important and allows an easier identification of the vesicoprostatic junction, even in situations where there is an evident median lobe. With this we cannot miss our site of dissection (Fig. 27.4).

The aim of the procedure is to find the vesicoprostatic plane that we mentioned in the paragraph covering anatomy. To achieve this step of the surgery, it is very important to prepare the endopelvic fascia, the BN, and the anterior surface of the prostate and to gently retract the bladder with the robotic grasper. We begin at this point, with a combination of blunt and sharp dissection that can be performed as distal as we see the vesical fibers on the anterior prostatic

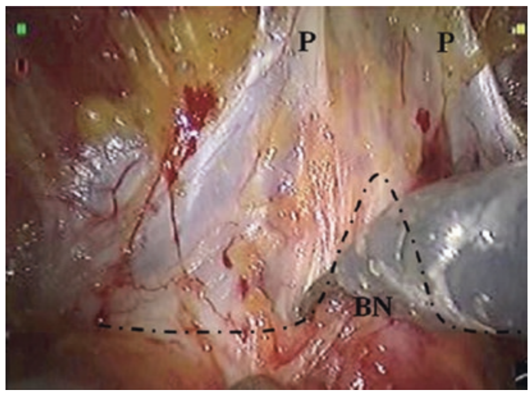

Fig. 27.5 A sharp and blunt dissection of the bladder neck begins at the 10 o'clock position. *P* puboprostatic ligaments, *BN* bladder neck

surface or can begin from one side (Fig. 27.5) of the supposed BN in order to move the fibers medially and discover the anterior surface of the prostate (Fig. 27.6). The hemostasis is achieved at this step using the monopolar or the bipolar cautery.

Once the first layers of muscular fibers are dissected from the prostate base, we must follow the plane at 12 o'clock and laterally to the BN at 2 and 10 o'clock, until we clearly identify the inner longitudinal fibers of the BN coming out from the external layer of the outer longitudinal

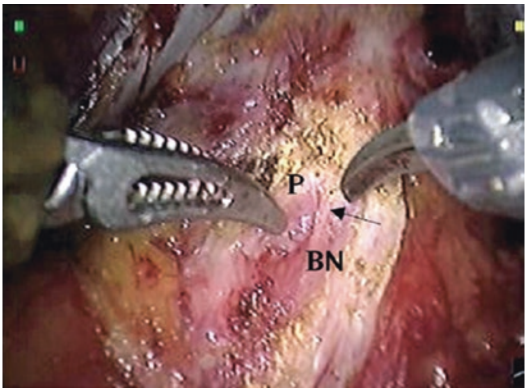

Fig. 27.6 The plane between the prostate base (*P*) and the bladder neck (*B*) is going to be dissected. The muscular fibers are clearly visible (*arrow*)

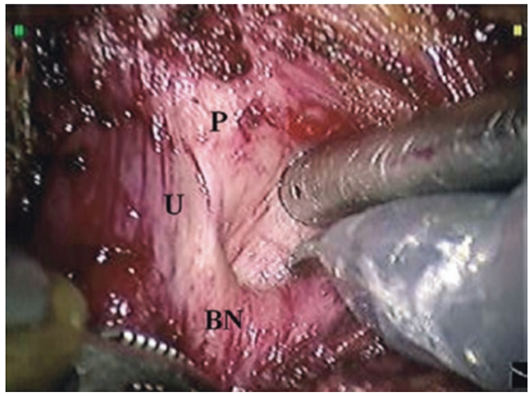

Fig. 27.8 The right lateral margin of the urethra and the bladder neck is dissected from the prostate base. One can clearly identify the prostate (*P*), the bladder neck (*BN*), and the preprostatic urethra (*U*)

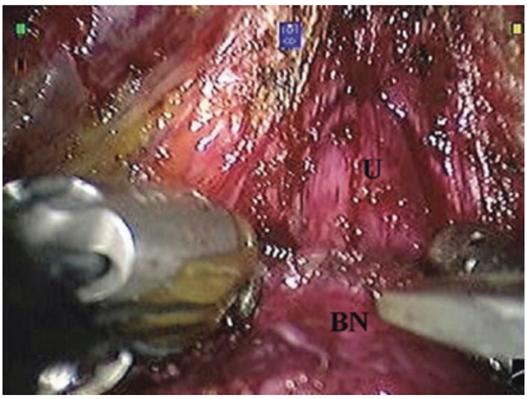

Fig. 27.7 The preprostatic urethra (*U*) and the bladder neck (*BN*) are dissected on their anterior planes. The longitudinal fibers of the urethra are clearly visible

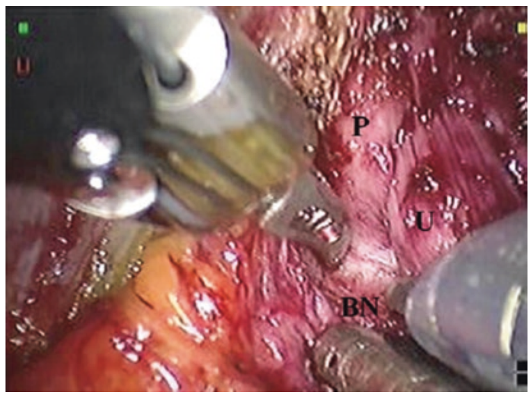

Fig. 27.9 The left lateral margin of the urethra and the bladder neck is dissected from the prostate base. One can clearly identify the prostate base (*P*), the bladder neck (*BN*), and the preprostatic urethra (*U*)

fibers and continuing in what we call "preprostatic urethra" (Fig. 27.7).

When this structure is identified, we continue always with blunt and sharp dissection laterally to the urethra with the aim of passing behind the urethra, preserving the proximal urethral sphincter (Figs. 27.8 and 27.9). To better achieve this step, we can open the space laterally in the direction of the prostatic pedicles as far as necessary to have enough space.

Once the bladder external layer of muscular fibers is completely dissected from the prostatic base all around, the inner longitudinal layer and the preprostatic urethra are clearly visible, coming out from the BN and continuing into the prostate, and we can take out the bladder catheter and transect the urethra (Fig. 27.10).

With this kind of dissection, the posterior plane of the BN is at this point partially freed so that in the next step, we have to continue the dissection of the same plane in order to reach the anterior layer of the Denonvilliers fascia (Fig. 27.11). We begin the dissection behind the BN, and we move laterally until the medial margin of the prostatic pedicles.

Once the Denonvilliers fascia is reached, the bladder should be completely detached from the prostate base apart for the lateral prostatic

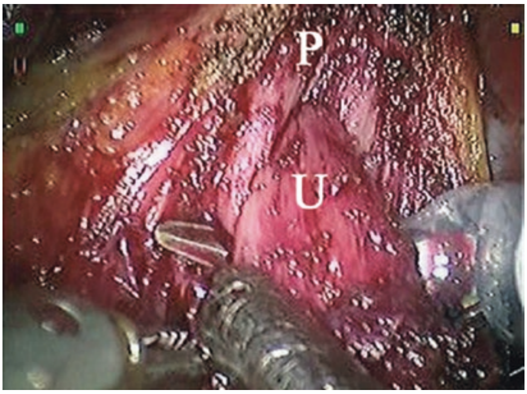

Fig. 27.10 The preprostatic urethra is completely isolated and prepared for transection. *U* preprostatic urethra, *P* prostate base

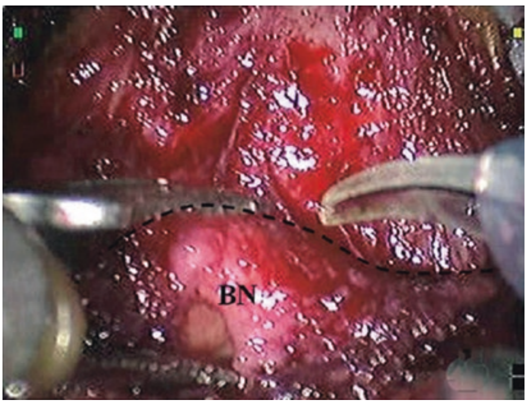

Fig. 27.11 The posterior plane of the bladder neck is going to be dissected from the prostate base. After the division of the "preprostatic urethra," the posterior plane is clearly identifiable (*curve*). The bladder neck (*BN*) is visibly preserved

pedicles, and we are ready for the next step which is the dissection of the seminal vesicles (Fig. 27.12).

Median Lobe

In the previous paragraph, we described how to perform the dissection of the BN in a standard case. Now examine the difference in the procedure when an enlarged median lobe is present.

As explained previously, in the case of an enlarged median lobe, we usually find a some-

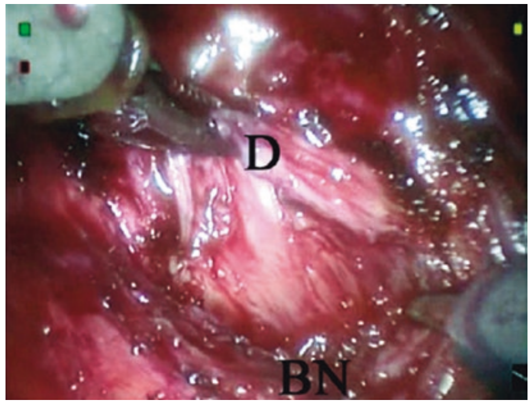

Fig. 27.12 After the posterior plane of the bladder neck is completely dissected, the anterior Denonvilliers fascia (*D*) is identified and incised to dissect the seminal vesicles. In this figure, the transected bladder neck (*BN*) is laying down, and the bipolar grasp is holding the Denonvilliers fascia to expose it, so that it can be incised

what different anatomy, with reference to supports from the surrounding structures, especially with the seminal vesicles. With the presence of a median lobe, the site of the BN appears to be more cranial. This can lead to dissection starting at a point too cranial with the risk of opening the bladder on his anterior surface and thus losing the ability to preserve the BN. For this reason, once the endopelvic fascia is well prepared, we should follow the same steps explained elsewhere in this book, to better expose the BN (balloon of the bladder catheter deflating, traction on the bladder). Once the right site is identified, we perform the same sharp and blunt dissection of the anterior fibers from the prostate base searching the plane of dissection between it and the external fibers of the bladder. If we find the right plane, we will be able to identify the preprostatic urethra as described previously. In this case, it appears larger than usual because of the presence of the underlying median lobe. Our dissection can now continue in two different ways: with a lateral blunt dissection of the urethral mucosa from the median lobe, delaying its transaction, or with the division of the anterior portion of the urethra and a delayed dissection of the median lobe from the urethral mucosa. A third kind of dissection is performed without BN preservation and will be described later.

The first approach is performed using a laterally gentle, blunt separation of the preprostatic urethra from the underlying median lobe. After the identification of the preprostatic urethra, we continue its isolation in its lateral portion in order to pass behind it. In this case, we will progressively identify the median lobe which prevents this maneuver. Once the median lobe and its limit with the urethra are well identified, we can begin to move the urethra from the median lobe. This is possible, of course, especially with the robot-assisted approach; however, in some cases, this will not be possible because of fibrous attachments. Once the urethra is completely freed from the median lobe, we can usually pass behind it with our grasp or with the scissors, transect the urethra, and continue our dissection of the posterior plane. In most cases, we will have the muscular fibers and the mucosa of the BN preserved, and we will be ready to easily perform the subsequent steps of our prostatectomy.

When the urethra is identified but not easily dissected from the median lobe, we can incise it on its anterior surface before dissecting the posterior plane from the median lobe.

Once the urethra is open, we can dislocate the median lobe outside of the urethra and proceed incising the urethral mucosa on the median lobe. Once the mucosal and the urethral muscular layer are incised, we can perform a dissection of them from the underlying median lobe using again a sharp and blunt dissection.

This maneuver needs to be performed with very gentle dissection because the urethra is usually very thin. The robot allows one to achieve this step, a step which is not always possible with the traditional laparoscopic approach.

Once the urethra is completely dissected on its posterior plane, we should continue our dissection following the muscular fibers carefully, cranially, and laterally, in order to not enter into the abdomen, until we are able to find the anterior layer of Denonvilliers fascia and then the vas deferens.

Previous TURP

The dissection of the BN, even in case of previous endoscopic resection, should follow the same initial steps, as previously described, in order to identify the vesicoprostatic junction. Even if we give the same attention in identification of key steps, this can be, in some cases, a real challenge because of the possible presence of fibrous scar tissue. The difference that can be encountered during the dissection will appear when we are getting close to the preprostatic urethra. In its lateral margins, the plane of our dissection will become unclear, and the tissue will be usually very sticky and with no clear plane. When we reach this point and cannot progress with blunt dissection, it is often not possible to clearly isolate the preprostatic urethra as shown previously. For this reason, we usually proceed with sharp dissection and then the incision of the BN at this level initially on its anterior surface. Once the BN is open, we proceed with the identification of the ureteric orifices, and we perform a sharp dissection of the posterior margin of the BN, as far as possible from the ureteral orifices, then continuing with sharp and blunt dissection of the posterior plane as described previously.

In some cases, when the BN is preserved during the endoscopic resection and the inflammatory reaction of the previous surgery did not occur, it is possible to isolate a sort of preprostatic urethra that is usually shorter and not as clear as usual. Once it is identified and isolated, it is transected and the dissection proceeds in the same way as described previously.

Wide Resection of the Bladder Neck

In case of positive biopsies on the prostate base, we do not suggest to preserve the BN as described previously, in order to not risk positive margins at this level. In this case, we proceed always with the preparation of the endopelvic fascia and with the same steps in order to identify the vesicoprostatic junction. Once its identification is achieved, we use a sharp dissection with monopolar cautery of all the muscular layers of the BN, on its anterior surface first and then, once the BN is opened, we proceed with the incision of its posterior surface and in the dissection of the posterior plane. Our dissection is performed with a safety distance from the prostate base which allows us to avoid any risk of positive margins. Of course, with this dissection, we should perform a BN reconstruction before beginning the anastomosis. This is possible without any difficulty using the robot because of its well-known EndoWrist instruments (Intuitive Surgical, Sunnyvale, Calif.). We can perform a posterior BN reconstruction before the anastomosis, or we can complete this step on the anterior surface of the BN at the end of our anastomosis. These steps are clearly discussed elsewhere in this book.

Indications and Choice of Technique

It is clearly possible dissect precisely between prostate and bladder, with full preservation of the BN unit. We think that this kind of preservative dissection is extremely relevant for the formation of the future anastomosis, which becomes a "uretro-urethral anastomosis," and the future postoperative continence; however, as reported by some authors, this technique could lead to an increasing rate of positive margins on the primary part of the prostate [4]. Therefore, we reserve this ultra-BN preservation dissection to the cases of localized prostatic cancers, with negative biopsies on the prostatic base, without MRI tumoral localization on the base and without clinical abnormality on the base in digital examination.

In these last situations, we recommend to enlarge the BN dissection in order to let a little part of it get fixed on the prostatic base.

Bordeaux Series

In our institution (Clinique Saint Augustin, Bordeaux, France), we performed from January 2005 to June 2007, 677 robot-assisted radical prostatectomies. Five different surgeons have performed the same technique of BN preservation, as described in this chapter, in 614 cases (90.6%). In the other, 9.4% of patients the BN were not preserved, and these cases included cases which we considered a contraindication: previous TURP, voluminous median lobe which did not allow preservation, multiple positive biopsies at the base, and cases limited by technical problems of dissection.

In our series, we observed 80% of continence (no pads) at 4 months and 91% at 12 months, with less than 1% of anastomotic leakage in immediate postoperative time and less than 2% of anastomotic stenosis.

Our functional results are suggestive of an earlier return to continence, without significantly better results on final continence, in keeping with other series where a BN-sparing technique was used [3].

Concerning the oncological outcome, we observed a positive margin rate on the base of 3% of cases for pT2 disease and of 5% for pT3 disease. These results are comparable to those reported from some authors in non-sparing BN series [2, 4] as well as series of BN-sparing technique [3].

Conclusion

The use of robotic assistance gives a fantastic quality of vision and precision of gesture for this difficult step of the radical prostatectomy. It allows a very precise choice of the plane of dissection and a high level of preservation of the BN, which can be adapted to the oncological characteristics and the anatomical specifics of the patient.

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28 Techniques of Nerve Sparing in Robot-Assisted Radical Prostatectomy

Travis Rogers, Gabriel Ogaya-Pinies, Hariharan Palayapalayam Ganapathi, Eduardo Hernandez-Cardona, and Vipul R. Patel

Introduction

Cancer prostate is the most commonly diagnosed cancer as well as the second most common cause of death in the United States of America. In 2009, as many 192,280 (25%) men were estimated as new diagnosis with prostate cancer [1]. Of the several treatment options available, surgery is the gold standard and offers potential for long-term cure [2].

Though the approach and techniques of radical prostatectomy have changed over the years the principles remain the same. Oncological cure assumes primary importance followed by preservation of continence and then potency.

Hugh Hampton Young [3] introduced perineal prostatectomy in 1904, and Terrence Millin [4] introduced the retropubic prostatectomy in 1945 [4]. The popularity of these procedures was not high because of major side effects. Most patients were impotent and incontinent, and in 1970s, radiotherapy was considered as a less troublesome alternative for the patient.

Nerve sparing gained importance after the seminal work by Walsh and Donker [5] showed the location and advantages of preservation of cavernous nerves. The rapid dissemination and encouraging results of anatomical radical retropubic prostatectomy (RRP) changed patient's and surgeon's perception of this surgery. With subsequent adoption of laparoscopy and robotics in performing RRP, the magnification (10×) the dexterity (7 degrees of freedom of motion) which has resulted in good outcomes has played a major part in dissemination of RRP so much so that more than 85% of all radical prostatectomies performed in the US are done with robotic assistance [6].

Today's patients are both younger and healthier with a no compromise attitude. They expect the trifecta, i.e., being cancer-free, continent, and potent [7]. Nerve sparing has been shown to improve potency and continence. With the advent of robot-assisted radical prostatectomy (RARP), nerve sparing has become more prevalent. As a result, more surgeons have developed varying methods of preserving the cavernous nerves. This chapter deals with the varying techniques of nerve sparing. Nerve sparing needs a thorough understanding of the neurovascular anatomy of the cavernous nerves as well as the fascial layers surrounding the prostate.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_28

Neurovascular Anatomy

The innervations for erectile function come from the pelvic splanchnic nerves. They originate from anterior sacral roots of S4 with minor contributions from S2 to S3. The parasympathetic nerves converge with the sympathetic fibers from the hypogastric nerves to form the pelvic plexus. The pelvic plexus is rectangular, approximately 4–5 cm in length with its midpoint being at the tip of the seminal vesicles. It is retroperitoneal and fenestrated and lies in the anterior wall of the rectum. Tewari et al. have termed this the proximal neurovascular plate [8]. According to Costello et al. [9], there are three reflections of neural tissue from the pelvic plexus to the bladder, seminal vesicles, and prostate. The anterior reflection travels across the seminal vesicles on the inferolateral aspect of the bladder. The anteroinferior reflection travels across the lateral aspect, and the inferior reflection travels across the inferolateral aspect of the prostate.

The Neurovascular Bundle

The components of anteroinferior and inferior reflections of the pelvic plexus have been construed as the neurovascular bundle (NVB) of Walsh [10]. It has been suggested that they are primarily responsible for erectile function. This has been classically described as a tubular structure that is running along the posterolateral aspect of the prostate enclosed in the fascial sheaths around the prostate and closely associated with capsular vessels. The neurovascular bundle varies in size and shape as well as course from base to apex of the prostate. It is thickest at the base of prostate, converges at the mid part, and then diverges as it moves toward the apex. Tewari et al. [8] have described this neural tissue as predominant neurovascular bundle. In their studies, they found that 65% of the time this bundle had a medial extension, and 30% of the time it converged medially behind the apex of the prostate. They also described accessory neural pathways, which varied in course from anterolateral aspect to the posterior part of the prostate. These supposedly provide additional neural pathways for erections and may come into play if the NVB is damaged.

Fascial Layers Surrounding the Prostate

The prostatic capsule in not considered a true capsule but a fibromuscular band located between the glandular units and the periprostatic connective tissue [11].

The endopelvic fascia is a multilayer fascia that covers the prostate and the bladder and is linked to the prostate capsule by collagen fibers, finally inserting in the form of puboprostatic ligaments to the pubic bone. The part of the endopelvic fascia that covers the prostate is called the prostatic fascia. The outer part of the endopelvic fascia is called the levator fascia or the lateral pelvic fascia. The two layered Denonvilliers fascia is in between the rectum and the prostate. The posterior layer covers the rectum, while the anterior layer covers the dorsal aspect of the prostate. The anterior layer fuses with the lateral pelvic fascia.

There are distinct planes that can be defined in theory but can defeat even the most experienced surgeon during surgery. The intrafascial plane is the plane in between the prostatic capsule and the prostatic fascia [12]. The interfascial plane is the plane in between the prostatic fascia and the levator fascia [12]. Posteriorly the interfascial plane exists as the space between the prostatic fascia and the Denonvilliers fascia and in between the prostatic fascia and the anterior extension of the Denonvilliers fascia. The neurovascular bundle of Walsh is thought to travel in this interfascial plane along the dorsolateral aspect of the prostate, in between the anterior extension of the Denonvilliers fascia and the levator fascia. Extrafascial plane is lateral to the levator fascia. Both intrafascial and interfacial dissection may result in preservation of the neurovascular bundle, and an extrafascial dissection would result in damage to all or part of the NVB.

Approach to Nerve Sparing

Open radical prostatectomy has always been classically a retrograde prostatectomy and a retrograde nerve sparing [13]. The apex of the prostate is dissected first and nerve sparing proceeds from the apex to the base. As minimally invasive surgery was introduced, the approach shifted from a retrograde approach to an antegrade one where the bladder neck is dissected first and the nerve sparing proceeds from the base to the apex [14]. Hence, the approach could be either retrograde or antegrade nerve sparing.

Types of Energy Use in Nerve Sparing

Physical nerve preservation alone may not be sufficient for early return of function. These are tenuous, nonmyelinated nerves that require gentle dissection without traction to avoid any damage. Moreover, thermal energy when used for dissection can cause temporary or permanent damage to these nerves. In a study done by Ong et al. [15], comparing monopolar, bipolar, and harmonic energy with no energy (athermal) nerve sparing in a canine model, the postoperative intracavernous pressures were substantially decreased in the energy groups as opposed to the athermal and control groups. Hence, the type and the amount of energy used have an impact on the return of erectile function.

Ahlering et al. [16] in their case control series demonstrated the effect of thermal energy on the return of sexual function. About 8.3% (3/36) were potent in the cautery group as opposed to 43% (10/23) in the cautery-free group. Moreover, they also studied the effects of hypothermic nerve sparing on 50 patients. Pelvic cooling was achieved with cold saline irrigation as well as endorectal cooling balloon cycled with 4° saline. This method resulted in significant improvement in continence and potency; results have yet to be published [17].

KTP laser has been analyzed as an energy source to aid in nerve sparing [18]. Gianduzzo et al. have recently evaluated cavernous nerve function following KTP laser dissection and compared outcomes to those of ultrasonic shears and scissors [19]. They compared several parameters including intracavernous nerve pressure after cavernous nerve stimulation acutely and 1 month after stimulation as well as histological evidence of thermal spread in harvested peritoneum. They showed that KTP laser had similar outcomes to athermal technique and was superior to ultrasonic shears for preserving cavernous nerve function. Hence, the energy source (cautery, harmonic, ultrasonic shears, or laser) or the lack thereof (athermal) will have an impact on the functional outcome.

Categorization of Nerve Sparing

Nerve sparing has been found to positively influence both potency [10] and continence [20]. Nerve sparing can be categorized according to the fascial planes used, the approach used, i.e., antegrade or retrograde and the type of energy used to dissect these planes and control the pedicles. Hence, we have antegrade and retrograde, unilateral or bilateral, partial or complete, interfascial, intrafascial, and extrafascial as well as the type of energy used.

The Henry Ford: Veil of Aphrodite Technique and Superveil Technique

Antegrade, Intrafascial Athermal Approach

This technique was pioneered by Menon et al. [21] from the Vatikutti Institute of Urology. This technique involves a high intrafascial anterior release of NVB. The rationale of this approach is to preserve the NVB and accessory neural pathways that have been shown to travel in the anterior and posterior aspect of the prostate. In some patients, rather than distinct neurovascular bundles, the cavernosal nerves form lattices or curtains that extend from the posterolateral to the anterolateral surface of the prostate. The veil of Aphrodite (Aphrodite is the Greek goddess of love and ecstasy) is an area of cavernosal nerves that extends from the posterolateral to the anterolateral surface of the prostate like a curtain.

The avascular plane between the posterior prostatic and the anterior layer of Denonvilliers fascia, covering the vasa and the seminal vesicles is exposed. This layer is incised, exposing the vasa and the seminal vesicles. Both the vasa and seminal vesicles are grasped and the posterior prostate is retracted upward, allowing exposure of posterior layer of the Denonvilliers fascia. An incision is made in this fascia and a plane is developed between the posterior layer of the Denonvilliers fascia and perirectal fat. This hypovascular plane can be created easily using blunt dissection. The dissection is carried down to the apex of the prostate. This plane of dissection is extended laterally to expose the lateral pedicles of the prostate, which are controlled by either clipping or individually coagulating the vessels by bipolar cauterization.

A plane between the prostatic capsule and the prostatic fascia is developed cranially, at the base of the seminal vesicles. This plane is deep to the venous sinuses of the Santorini's plexus. Sharp and blunt dissection of the neurovascular bundle and contiguous prostatic fascia is performed using the articulated "cold" scissors until the entire prostatic fascia up to the pubourethral ligament is mobilized in continuity. This plane is mostly avascular except anteriorly where the fascia is fused with the puboprostatic ligament and covers the dorsal venous plexus. The dissection is performed in such a way that curtains of periprostatic tissue hang from the pubourethral ligament, the veil of Aphrodite.

Menon et al. [21] have shown good results with his technique with intercourse rate being 93% in men with no preoperative erectile dysfunction undergoing veil nerve-sparing surgery, although only 51% returned to baseline function.

Superveil Technique

In the veil technique of radical prostatectomy, intrafascial (between the capsule and prostatic fascia) dissection is performed between the 1 o'clock position and the 5 o'clock position and between the 6 o'clock position and the 11 o'clock position, but not between the 11 o'clock position and 1 o'clock position, where the prostatic fascia is adherent to the capsule. In the current modification by Menon et al. [22], dissection was extended anteriorly, preserving this tissue, the pubovesical ligaments, and the dorsal venous plexus. Where the planes did not separate easily with blunt dissection, sharp dissection was used with either the cold round tip da Vinci scissors or the hot monopolar hook. At 6–18 months after surgery, 94% of men who attempted sexual intercourse were successful with a median Sexual Health Inventory for Men (SHIM) score of 18 out of 25.

Athermal Early Release of Neurovascular Bundle

Athermal, Interfascial, Retrograde Nerve-Sparing Approach

The conventional approach to nerve sparing during laparoscopic and robotic prostatectomy has been from the prostate base to apex (antegrade). Since the NVB is closely and complexly related to the base of the prostate which might be at risk during antegrade nerve sparing, Patel et al. [23] have developed a technique, which combines elements of open and laparoscopic prostatectomy. The prostatectomy is performed in an antegrade fashion, and the nerve sparing is performed in a retrograde fashion using an athermal technique. The basic premise is that the NVB can best be identified and released at the apex of the prostate and delineated back to the pedicle avoiding the possibility of inadvertent damage while controlling the pedicle, a possibility that is present during the antegrade laparoscopic approach.

The posterior dissection after the seminal vesicles have been dissected out is carried out in the interfascial plane between the rectum and the prostate in between the two layers of the Denonvilliers fascia. The prostate is then elevated. This dissection should be carried out till the prostate is completely separated from the rectum, so that the prostate can be rotated to either side. This dissection is further extended laterally allowing the pedicles to become prominent where it can be controlled easily. The lateral pelvic fascia is incised at the level of the apex and mid portion of prostate, and an avascular plane is developed. The entire dissection is carried out athermally and in a retrograde manner. The vascular pedicle in ligated with a hemlock clip that is placed above the NVB. Early release of the bundle and delineating its entire path will avoid inadvertent damage to the NVB at this juncture. It is released distally at the apex to the level of the pelvic floor to avoid damaging it during the apical dissection or vesicourethral anastomosis. The NVB is stabilized and the prostate is gently stroked away using scissors. The interfascial plane between the NVB sheath and the prostatic fascia is relatively avascular consisting of only tributary veins, which does not require the use of energy or clipping. As the dissection proceeds in a retrograde fashion, the NVB is clearly seen being released off the prostate. The prostate pedicle can then be thinned out with sharp dissection, and the path of the NVB is delineated at this level. The clear definition of the NVB and pedicle allows placement of clips on the pedicle without compromising the NVB and sharp dissection is used to completely release the prostate. This procedure can be performed unilaterally or bilaterally. Moreover depending upon the volume, grade, and location of the cancer on the biopsy specimen this procedure can be tailored to the individual patient. On the side with more cancer, the nerve sparing can be proportionately reduced by carrying out the dissection more laterally at the level of the pedicles and NVB so as to reduce PSMs and thereby maintain oncological safety.

Patel et al. [24] have recently published data using this technique. Between January 2008 and September 2009, 1100 patients underwent RARP. Of 1100 patients who underwent RARP, 541 were considered preoperatively potent (shim more than 21) and of these 404 underwent bilateral nerve sparing. Potency was defined as the ability to achieve and maintain satisfactory erections for sexual intercourse >50% of times, with or without the use of oral phosphodiesterase type 5 inhibitors. The overall potency rates were 53.5, 68.8, 91.5, 97.4, and 96.6% at 6 weeks, 3, 6, 12, and 18 months after RARP, respectively. Potency data was collected by validated patient administered questionnaires.

Antegrade Clamp and Suture Technique

This technique was pioneered by surgeons at UC Irvine [17].

The evolution of this technique was due to the need to avoid injury to the neurovascular tissue by thermal damage when using electrocautery. Most studies evaluating neural injury have used a myelinated nerve such as the rat's sciatic nerve. However, the cavernosal nerve is an unmyelinated autonomic nerve that might respond even more poorly than thicker myelinated nerves. Donzelli and associates [25] have shown that temperatures as low as 41 °C can injure neural tissue. Alternative energy sources such as ultrasound have been introduced in an attempt to reduce tissue injury. However, the temperature of the blade of ultrasonic shears rises to 63 °C or more with as little as 3 s of application. Initially the authors used a bioadhesive, which they subsequently modified, by using suture ligation.

After the rectum is freed from the prostate, the vascular pedicles and NVB are delineated. The vascular pedicles are thinned to allow placement of laparoscopic bulldog clamps (30 mm) at least 1 cm from the prostate. Using scissors, the vascular pedicles are divided right at the prostate, and the NVB is then gently and completely dissected free of the prostatic capsule. Control of the vessels in the vascular pedicles is achieved using a running 3-0 polyglycolic acid suture ligature. Prior to removing the bulldog clamp, two throws are placed through the vascular pedicle; the bulldog clamp is then removed, and the suture is used to display the remaining vessels such that precise superficial needle placement is facilitated to avoid injury to the NVB. If pulsatile bleeding is seen along the NVB, precise ligature of the bleeding site is performed with a 4-0 suture on an RB needle. This is very much facilitated by the 10–12× magnification and ease of suturing with the robot.

One hundred and twenty-five RALPs were performed between June 2002 and March 2004 by the team at UC Irvine [17]. Preoperatively, 42 met inclusion criteria, which included age younger than 66 years, IIEF-5 of 22–25, and unilateral or bilateral nerve-sparing surgery. Thirty-eight had a follow-up data of 24 or more months. Postoperative sexual outcomes were obtained via self-administered questionnaires At 2 years, the average IIEF-5 score for the 24 potent men was 18.4, the 14 impotent men, 3.6, and overall, 13.3. Further, the mean firmness compared with preoperative baseline was 83% with 80% reporting that the firmness was 75–100% of preoperative firmness. Ten had a unilateral nerve-sparing procedure, and 50% reported return of potency versus 69.7% with bilateral preservation ($P=0.31$). With unilateral preservation, the average IIEF-5 was 20.6; all indicated that the firmness of erections was 75–100% of baseline levels. They demonstrated that the use of mono- or bipolar electrocautery during transection of the prostatic vascular pedicle and dissection of the NVB appears to create a dense but (mostly) reversible neurapraxia to the cavernous nerve, with return of potency being severely retarded for 15–24 months. This data showed the benefit of avoiding thermal energy in nerve-sparing surgery.

Antegrade Thermal Clip Less Approach (Thermal Antegrade Interfascial Technique)

This technique is a modification of the antegrade open technique originally described by Kursh and Bodner [26]. It is similar to the technique described by Guillonneau and Vallancien [14], but, as opposed to the other technique, Chien et al. [27] carry out their dissection from medial to lateral than vice versa. An advantage quoted is that after having initially mobilized the neurovascular bundle, the thermal spread may theoretically diminish.

After division of the bladder neck, the previously dissected seminal vesicles and vasa deferentia are retracted anteriorly, exposing the posterior base of the prostate. The plane between both layers of Denonvilliers fascia is identified and developed, separating the prostate from the rectum. Once this plane has been dissected distally toward the apex of the prostate, the thick lateral pedicles of the prostate are visualized bilaterally. Using blunt dissection, the vascular pedicles are teased off the prostatic capsule, proceeding from the developed posterior plane in a medial to lateral direction and leading to the initial release of the vascular pedicles before the NVBs. The vascular pedicles are further mobilized off the capsule of the prostate in an anterior direction until the most distal ends of the vascular pedicles are identified before penetrating the prostatic capsule. Such small vessels are then cauterized at their most distal ends using only a bipolar device. The vascular pedicles are then swept off the prostate, further mobilizing the NVBs, which are then dissected sharply from the prostatic capsule. The dissection is continued, peeling off the periprostatic fascia, NVB, and prostate pedicle en bloc until the urethra was reached. The dissection is performed starting posteromedially at the base of the prostate, marching laterally and anteriorly, and then advancing distally, hence in an antegrade fashion. During dissection, delicate handling of the tissue minimized trauma and protected the neurovascular bundles from trauma due to traction. Avoiding monopolar cautery, ignoring small venous bleeds, and controlling only pulsatile arterial bleeds with bipolar cautery coagulation are key points of this technique.

The results released from the University of Chicago using this technique from February 2003 to May 2004 are encouraging [27]. Using a validated sexual function questionnaire, they found that, at 1 month, patients had returned to 47% of their baseline preoperative sexual function scores. At 3, 6, and 12 months, this rate had increased to 54, 66, and 69%, respectively. Their data at 12 months are favorable; however, only six patients had reached 1 year of follow-up.

Nerve Sparing in Laparoscopic Radical Prostatectomy

Clamp and Suture Technique with Ultrasound Guidance

Utilization of vascular clamps for controlling the vascular pedicle during conventional laparoscopic radical prostatectomy was reported by the Cleveland Clinic [28]. A 25 mm straight bulldog clamp is placed across the pedicle after dissecting it out. Using cold scissors, the lateral pedicle is divided leaving a 1–2 mm edge beyond the bulldog clamp. The course of the NVB is delineated with USG and flow pattern in it as well as resistive index of NVB is measured, which gives a further measure of confidence while carrying out the dissection. The authors experimented with the use of bioadhesive (FloSeal) but ultimately reverted to suturing the pedicle due to better homeostasis. Moreover, there was concern the bioadhesive had the potential to induce substantial fibrosis which may compromise the NVB. There are still concerns that the bulldog clamp could compromise the NVB. Moreover, identification of the NVB with ultrasound is at best a soft sign and hence not widely reproducible.

Heilbronn Technique

In the Heilbronn technique [29], lateral pelvic fascia is incised prior to the incision of the urethra and positioning the prostate on its side exposes the lateral surface of the prostate. A right angle clamp is inserted under the lateral pelvic fascia beginning at the bladder neck and extending distally toward the apex of the prostate to detach the area of the NVB from the posterolateral border of the prostate and dissect it gently from the apical part of the prostate. All the prostatic branches of the NVB are managed one by one with 5-mm titanium clip application with avoidance of cautery.

New Developments in Minimally Invasive Dissection and Protection of the NVB During RARP [30]

Human Amniotic Membrane Allograft Nerve Wrap Around the Prostatic Neurovascular Bundle

Clinical use of growth factors and anti-inflammatory substances for prostatic NVB regeneration is novel, and human amnion membrane allograft (dHACM) is a source of implantable neurotrophic factors and cytokines [31, 32]. Since 2014, we implemented a local application of this allograft for pre-operatively potent men. The bilateral, retrograde, athermal NS RARP was performed in each patient (Fig. 28.1a), with bladder neck reconstruction, an anterior suspension stitch, and posterior reconstruction (Rocco stitch). There were 58 patients in this series, who were pre-operatively continent (American Urological Association Symptom Score < 10) and potent (Sexual Health Inventory for Men [SHIM] score > 19) and underwent bilateral dHACM placement (AmnioFix; MiMedx Group, Marietta, GA, USA) at a cost of $900 per patient. The dHACM allograft was cut into two longitudinal pieces and placed over each NVB as a nerve wrap. The wrap was placed circumferentially around the NVB after extirpative RARP, post anastomosis (Fig. 28.1b).

This group was computer-matched with a similar group of patients who did not receive allograft placement. Post-operative outcomes were analyzed between both groups, including time to return to continence, biochemical recurrence and potency. Potency at eight weeks returned in 65.5% of the patients in the dHACM group and 51.7% of the patients in the no-dHACM group. The mean time to potency was significantly shorter in the graft group (1.34 months) than in the non-graft group (3.39 months; $p = 0.007$) (Fig. 28.2). SHIM

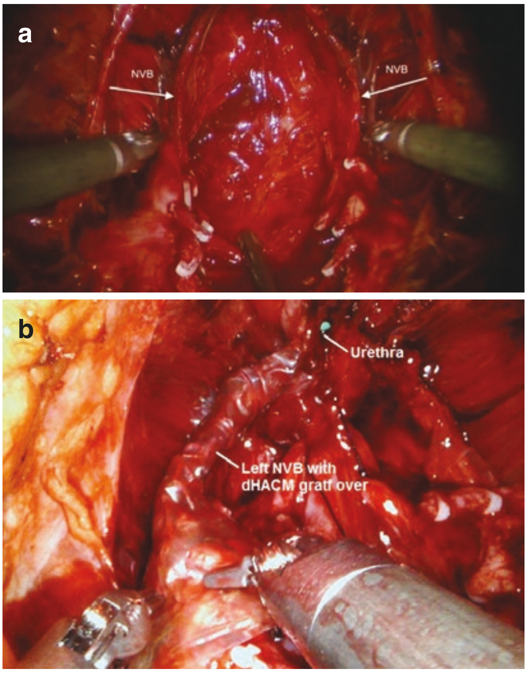

Fig. 28.1 Local application of dHACM allograft after bilateral NS procedure. (**a**) view of bilaterally completely spared both NVBs; (**b**) left NVB with the dHACM graft on top

scores were also higher for the dHACM group than for the no-dHACM group (mean score 16.2 vs. 9.1). In conclusion, our short-term results are encouraging for patients undergoing full NS RARP and dHACM placement.

Instant Toggling of Endoscope During RARP

With the introduction of the da Vinci Xi robotic surgical system some of its new applications have been built to try to achieve a more precise sparing procedure. For instance, the laparoscope has a digital end-mounted camera for improved vision. The scope can be placed into any of the robotic arms and has autofocus. The new endoscope is used to see deep inside the body, is far easier to set up and delivers sharp, high-definition 3-D images. We implemented this advanced imaging for clear visualization of the neurovascular bundle to initiate its dissection. The use of maneuver to rotate the 3D camera with 30-degree lens angles up to 180 degrees can facilitate a more direct view to

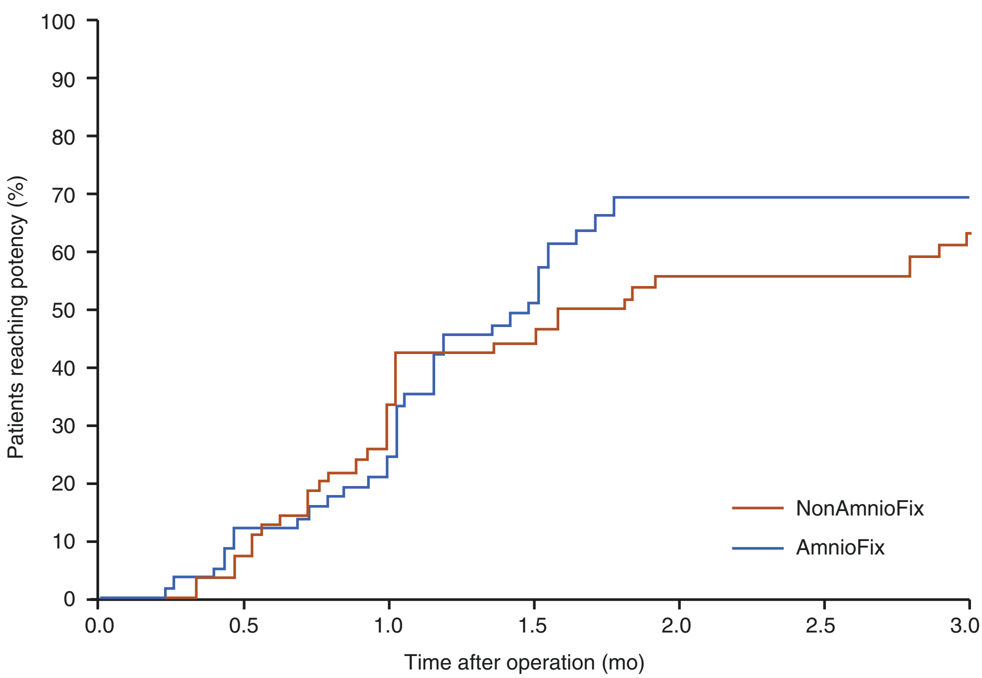

Fig. 28.2 Cumulative index curves showing time to potency. Time to reach potency: AmnioFix group, 1.34 month; non-AmnioFix group, 3.39 months (p = 0.007)

identify a route of NVB in order to start releasing its dissection from posterior surface (Fig. 28.3a). It is essential to fully dissect the posterior plane up to the apex and laterally to the bundles. Once this is accomplished, early release of NVB can then be performed. At the level of the apex and mid-portion of the prostate, the avascular plane between the neurovascular bundle and prostatic fascia is developed with caution. Then, the monopolar scissors are used to create the window to separate the prostate from the bundle. By rotating the camera back, it is feasible to maintain an interfacial approach to dissect the anterior and lateral surface of the prostate preserving neurovascular bundle (Fig. 28.3b). Stepwise procedure includes gentle dissection with sweeping motions of scissors, clear identification of the landmark artery and gentle dissection with preservation of the neurovascular bundle towards the plane of dissection initiated from the posterior surface before. The retrograde direction facilitates a more anatomical-based plane of dissection towards the prostatic pedicle. The path of the bundle is now delineated and focus can now turn to controlling the prostatic vascular pedicle.

Ultimately, this approach may provide the surgeon with guidance for exact placement of a first hem-o-lock clip to pedicle above the level of the released NVB. This technique allows complete NVB preservation without the use of any thermal energy, significant trauma, or inadvertent damage. Kumar et al. presented results of our first twenty patients using the instant toggling of endoscope during RARP. The mean time for NS was 12.3 min versus 18.1 min instandard procedure ($p < 0.005$). There were no intraoperative/postoperative complications.

The Application of Immunofluorence as a Novel Optical Imaging Tool to Better Visualize Landmark Artery

Since 2010, a near-infrared fluorescence (NIRF) camera was integrated into the da Vinci.

Si and the Xi systems, creating a combination of technically and minimally invasive advantages that have been embraced by several experienced surgeons (Fig. 28.4). Commonly used as a contrast agent the Indocyanine Green (ICG), is a vital fluorescent dye characterized by excellent tolerability, few side-effects, and low toxicity and allergic reactions. As a result of these characteristics, ICG have been utilized in several fields, in particular to assess microvascular circulation and organ vascularization.

Intra-operatively we injected intra-venously 0.75 ml of ICG before pedicle ligation and NVB dissection. The time to target vasculature of prostate was 20–40 s. The technique allowed us to identify the landmark artery in 17/20 (85%) patients (Fig. 28.5). In three patients we were unable to visualize the landmark artery due to large veins overlapping the view.

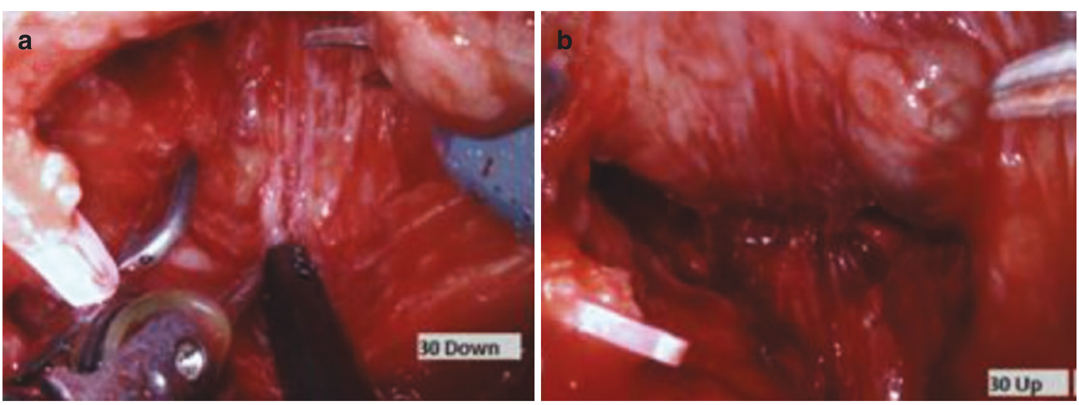

Fig. 28.3 Toggling of camera from 30° down (**a**) to up (**b**) in order to see the posterior aspects of the prostatic surface and urethra

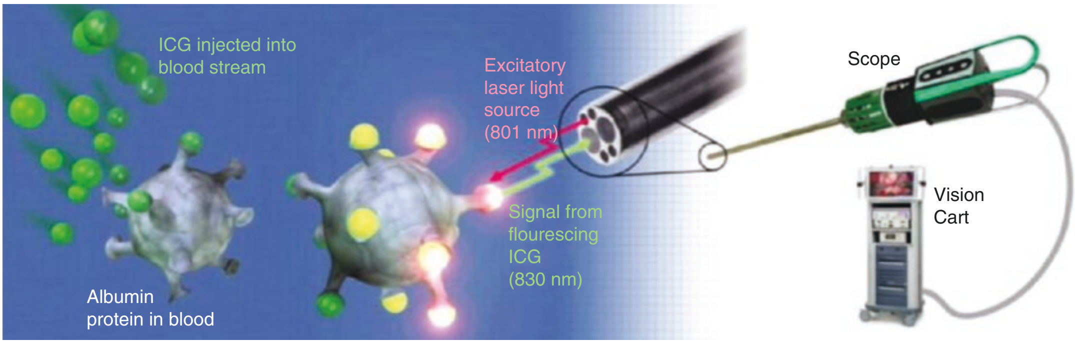

Fig. 28.4 The integration of Immunofluorescence into da Vinci Robot system

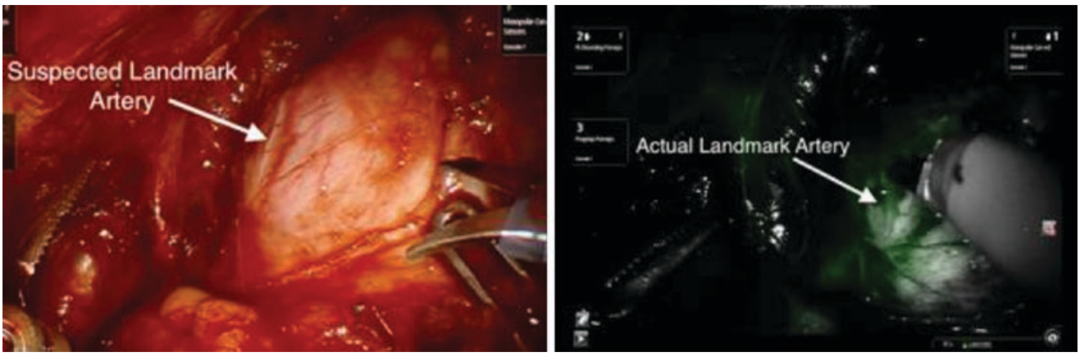

Fig. 28.5 The use of ICG optical imaging allowed more exactly verify a location and route of the landmark artery

Discussion

The introduction of the anatomical nerve-sparing technique has been one of the most significant landmarks in urology and the surgical management of prostate cancer. It has helped radical prostatectomy progress from a state where impotence was guaranteed to be one in which patients expect and demand to be completely potent after surgery. Age and preoperative baseline sexual function are important determinants for postoperative return of sexual function. Robotic surgery cannot improve on patient's sexual function. Unreasonable expectations from patients undergoing "innovative surgical" intervention and inadequate counseling on the part of physicians may contribute to patient's dissatisfaction [33].

Despite refinement in surgical techniques, sexual function outcomes remain widely variable, with reported rates ranging from 10 to 97% [34]. Reasons behind this discrepancy are multifactorial and may include differences in preoperative patient characteristics such as patient age, baseline erectile function, surgeon experience and technique, and quantity of nerves preserved. In addition, the liberal use of nonstandard sexual function definitions and reporting algorithms contribute further to this variability. Objective data using validated questionnaires and specific criteria as laid down by Mulhall [35] on nerve-sparing post-prostatectomy sexual function outcomes are the way forward if reasonable conclusions are to be made regarding outcomes.

Moreover, nerve sparing is not an all-or-none phenomenon. Bradford et al. [36] have shown that there is an incremental increase in return of sexual function based on the amount of nerves spared. Sixty patients who underwent bilateral unilateral and non-nerve-sparing surgery were analyzed with respect to pathology reports, neurovascular thickness, surgeons' intent at nerve sparing, and quality of life among each group.

Surgeon's intent regardless of the amount of neurovascular tissue identified on the radical prostatectomy specimen was predictive of potency.

Nerve Sparing and PSM

Surgical margin (SM) status is widely reported as a significant risk factor for prostate cancer recurrence following radical prostatectomy (RP) [37, 38]. It has been supposed that preserving the neurovascular bundle may compromise cancer control due to the limited surgical margin obtained with a resultant increase in treatment failure. Moreover, sparing the neurovascular bundles adjacent to the dorsolateral aspect of the prostate fascia further reduces the safety distance between cancerous nerves and prostatic tissue which is only millimeters away, even in non-nerve-sparing prostatectomy. Therefore, the safety of prostatectomy and nerve-sparing procedure in particular has often been equated with the incidence of positive margin.

Moreover, perineural tumor spread is a mechanism of capsule penetration, and the region of the prostate adjacent to the neurovascular bundles was found to be the most common site of capsular penetration [39]. Therefore, concerns exist, that some positive margins, occurring in 7–46% of cases after prostatectomy may be produced by nerve-sparing surgery [40, 41]. Early studies from Catalona et al. showed no higher incidence of positive margins in patients undergoing NS RP compared to non-NS RP.

Palisaar et al. [42] analyzed their historical series of patients who were candidates for nerve-sparing (NS) procedure with a contemporary cohort of patients. Out of 1343 patients analyzed. A total of 620 patients underwent non-NS prostatectomy. Nerve-sparing procedure was performed in $n=723$ patients (bilateral $n = 359$, unilateral $n = 364$). Pathologic T2 cancers in the non-NS vs. NS group showed a positive margin at the apex in 1.8% vs. 3.1%, pT3a cancers in 8.4% vs. 3.4%, and pT3b cancers in 6.2% vs. 3.8%, respectively. The percentage of positive margins in NS and non-NS cases located in the lateral aspect of the prostate specimen was similar in pT3a (4.6 vs. 3.9%) and pT3b (3.8 vs. 3.3%) stages. In patients with organ-confined cancer laterally located, positive margins were fivefold higher in the NS group (3.1 vs. 0.6%). Multivariate analysis proved NS RP to be an oncologically safe procedure in appropriately selected patients using a preoperative nomogram. Moreover, in such selected cases, there was no evidence that adequacy of tumor excision, and hence long-term oncologic control is compromised by NS procedure when the impact of a positive margin was evaluated comparing between patients undergoing NS and non-NS RP only.

The selection criteria for a nerve-sparing radical prostatectomy (NSRP) have not been thoroughly investigated and are based mainly on preoperative digital rectal examinations tumor volume and location on the biopsy and subjective intraoperative findings.

Graefen et al. [43] showed that the decision to spare the nerve may be based on the location of positive tumor cores without increasing the incidence of PSMs. Basing the indication for an NSRP on the results of preoperative systematic biopsies was safe according to margin status and postoperative PSA, when all patients with tumor in one of the three biopsy cores of each side of the prostate were excluded from an NS technique on that side. Such a strict approach excluded approximately 30% of patients from NSRP unnecessarily because of tumor findings on a prostate side where the cancer is still organ confined. The authors concluded by denoting that less strict criteria would be equally safe without denying nerve sparing to a substantial subset of patients.

Conclusion

Ultimately radical prostatectomy is an oncological surgery where cancer cure is the primary goal and continence and potency form important secondary goals. Achieving the trifecta is the aim of most patients undergoing prostatectomy. Nerve sparing can be done safely and effectively without compromising oncological safety. The basic principles of nerve sparing are reducing traction, reducing thermal injury, and preserving as much of the nerve bundle as possible. Each patient and each cancer are different, and the nerve sparing essentially has to be tailored on an individual patient basis. Preoperative biopsy grade, volume, and location of tumor on the biopsies as well as preoperative SHIM score as well as intraoperative findings are factors that need to be considered in nerve preservation (Figs. 28.6, 28.7, 28.8, 28.9, 28.10, 28.11, and 28.12).

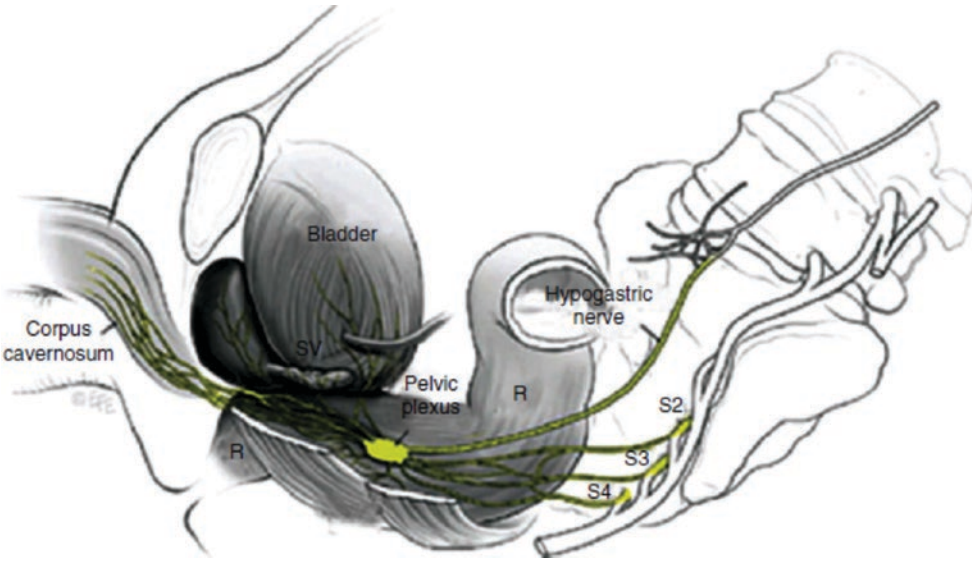

Fig. 28.6 The pelvic plexus and formation of NVB, reprinted from Costello et al. [9]

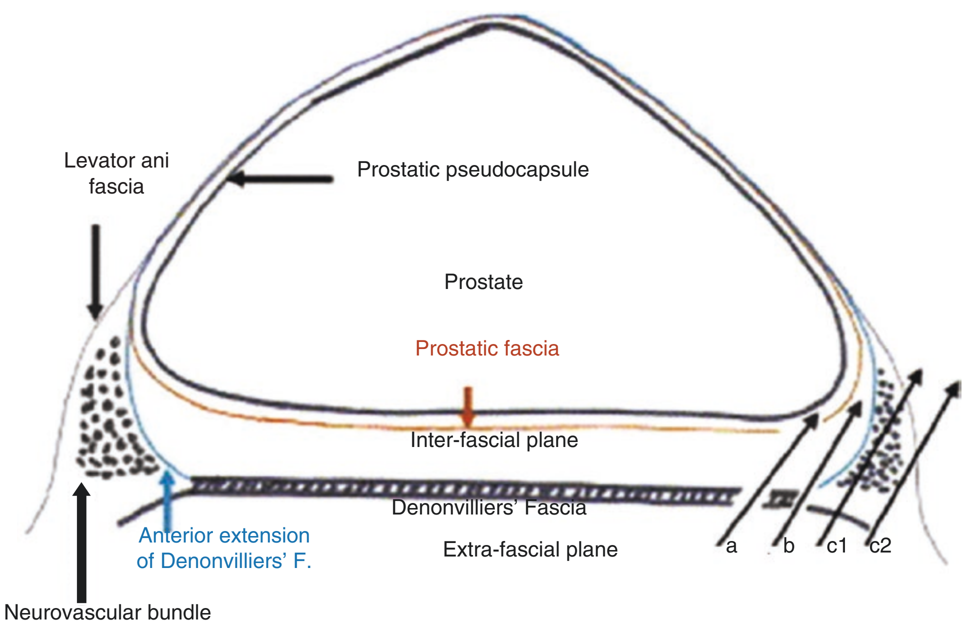

Fig. 28.7 Axial view of prostatic fascial anatomy. *a* intrafascial plane, *b* interfascial plane, *c1* extrafascial plane with partial preservation of neurovascular bundle, *c2* extrafascial plane with no preservation of neurovascular bundle [9]

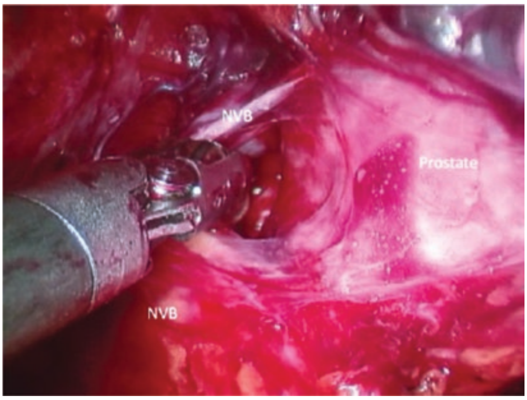

Fig. 28.8 Early retrograde release of the NVB. Scissor tips are spread in the plane between the prostate capsule and the NVB. The Maryland dissector is used to stabilize the NVB, while the scissors are used to push the prostate away from the NVB. A separation is created between the lateral prostatic capsule and the NVB. Minor non-arterial bleeding should be tolerated as it will stop

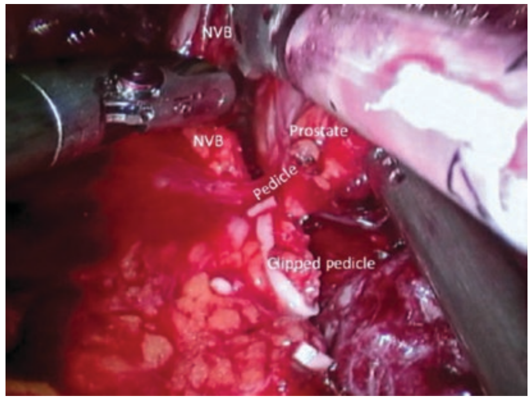

Fig. 28.10 Clipping of the pedicle. Complete path of the NVB is delineated from the apex to the base of the level of the prostate pedicle. The prostate is then rotated laterally and the pedicle is clipped under direct vision while clearly visualizing the path of the NVB at the base of the prostate; 100 mm hemlock clips are used to ligate the pedicle and are then divided with cold scissors

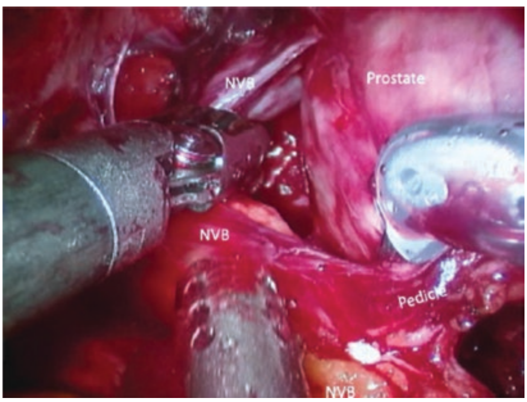

Fig. 28.9 Retrograde dissection to identify the prostate pedicle. The NVB is then released in a retrograde manner from apex to base to identify the path of the bundle. (Caution: the NVB kinks up and travels millimeters from the base of the prostate and therefore is at risk of being clipped if not being identified and released)

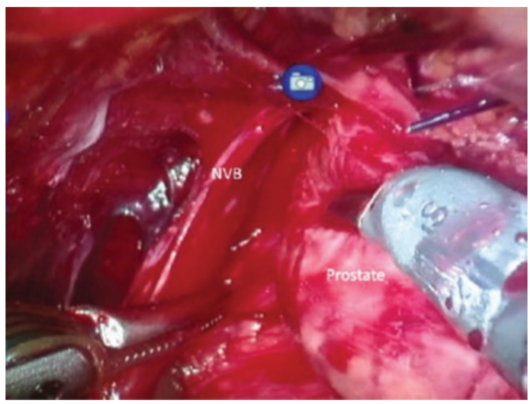

Fig. 28.11 The dissection of the NVB is extended toward the apex of the prostate and the pelvic floor. Once the prostatic pedicle is clipped, the rest of the NVB just peels away from the prostate with minimal bleeding

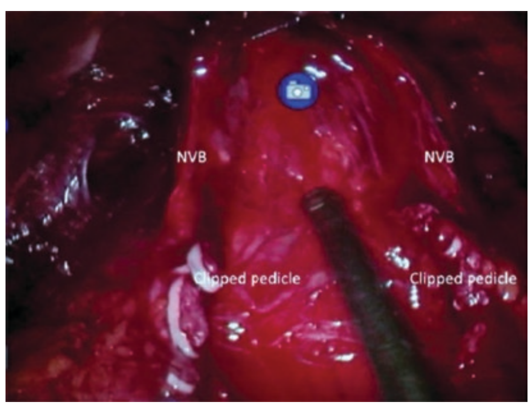

Fig. 28.12 Bilateral complete preservation of NVB

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29 Antegrade Robot-Assisted Radical Prostatectomy: Factors Impacting Potency Preservation

Thomas E. Ahlering, Anthony Costello, and Douglas Skarecky

Introduction

In the early 1980s, the presentation of an anatomical dissection of the neurovascular bundles (NVBs) described by Walsh and Donker [1] was one of the most significant landmark findings in urology. Preservation of sexual function continues as a formidable quality of life issue with this surgery. However, how to maximize preservation of sexual function remains a controversial and heated topic largely casting anatomic preservation versus surgical trauma or inflammation versus patient-related factors such as age, medical and psychological conditions, and others. In this chapter, we utilize a stepwise approach to examine our results in an effort to identify and stratify factors for their relative impact in preserving sexual function during antegrade cavernosal nerve sparing robot-assisted radical prostatectomy RARP.

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Cavernous Neuroanatomy

Walsh and Donker described the tortuous path of the pre-ganglionic myelinated parasympathetic cavernous nerves that run from the first ganglion in $S_{2\text{-}4}$ in the spinal cord through the pelvic plexus past the seminal vesicles and then along the posterolateral aspect of the prostate between the true capsule and the lateral prostatic fascia (the supralevator pathway). The nerves continue posterior and lateral to the urethra where they pierce the urogenital diaphragm and continue on below the pubic bone (the so-called infralevator pathway) where there are delicate neural interconnections at the penile hilum between the cavernous and dorsal nerves [2, 3]. Recently, Tewari and associates [4], Takenaka and associates [5], and Costello and associates [6] have described precise gross and histologic dissections of male cadavers defining the cranial and caudal paths of the cavernous nerves (Fig. 29.1).

In 2005, Costello and associates reported a detailed description of the plexus of nerves running within the NVB based upon a series of elegant microdissections in human cadavers [6]. They found multiple nerve branches (6–16 in number) that emanated from the pelvic plexus and spread significantly, with up to 3 cm separating the anterior and posterior nerve fibers, much like the findings of Takenaka and associates [5]. Importantly, they found in all 24 dissections, the NVB ran 0.5–2 cm inferior to

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_29

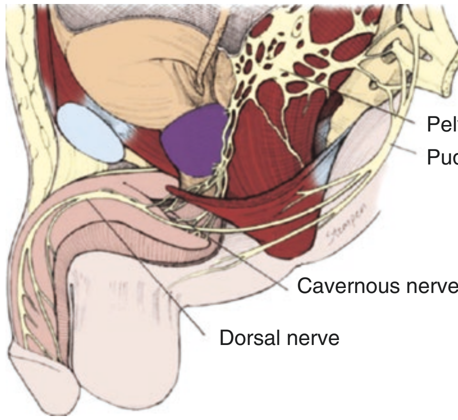


Fig. 29.1 Supralevator and infralevator neural pathways of the cavernous nerves (reproduced with courtesy of Springer)

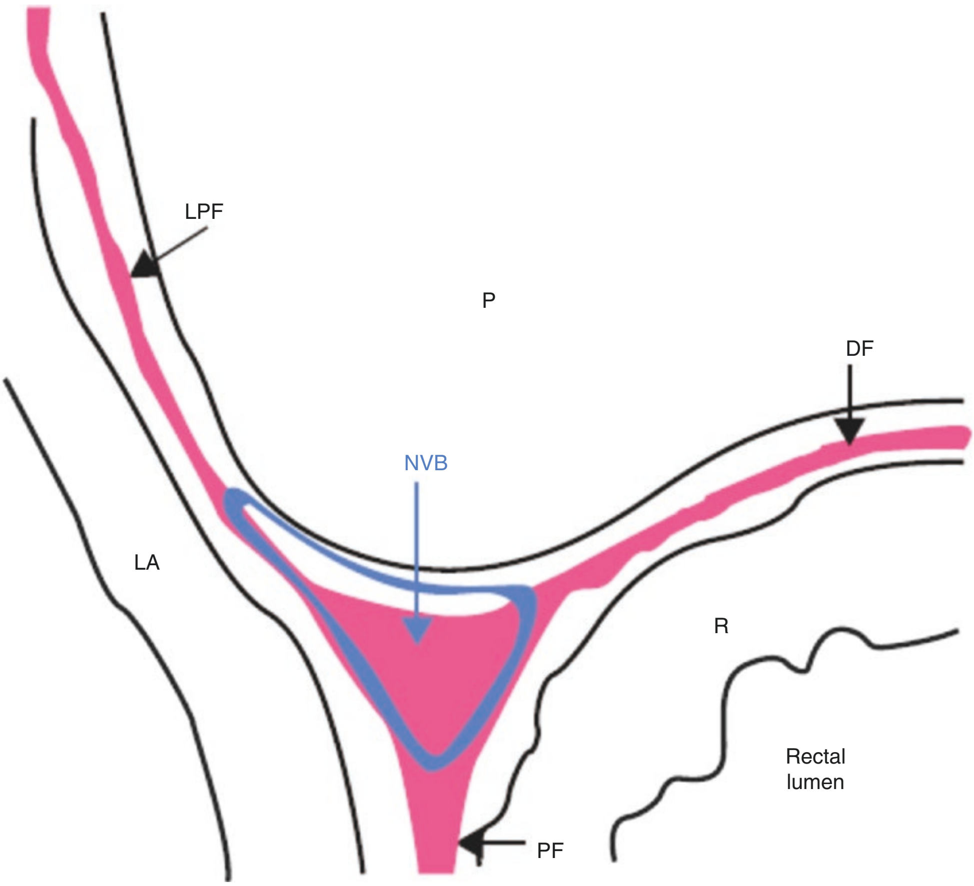


Fig. 29.2 The NVB courses along the prostatic postero-lateral border with the lateral pelvic, the pararectal and the Denonvilliers fascial boundries. *LA* Levator ani muscle, *LPF* Lateral Pelvic Fascia, *NVB* Neurovascular Bundle, *PF* Pararectal Fascia, *DF* Denovillier's Fascia, *R* Rectal wall

the tip of the seminal vesicle. Similar to Menon, Costello noted that the NVB courses along the posterolateral border of the prostate within the bounds of lateral pelvic fascia, the pararectal fascia, and Denonvilliers' fascia (Fig. 29.2). However, in distinction to Menon

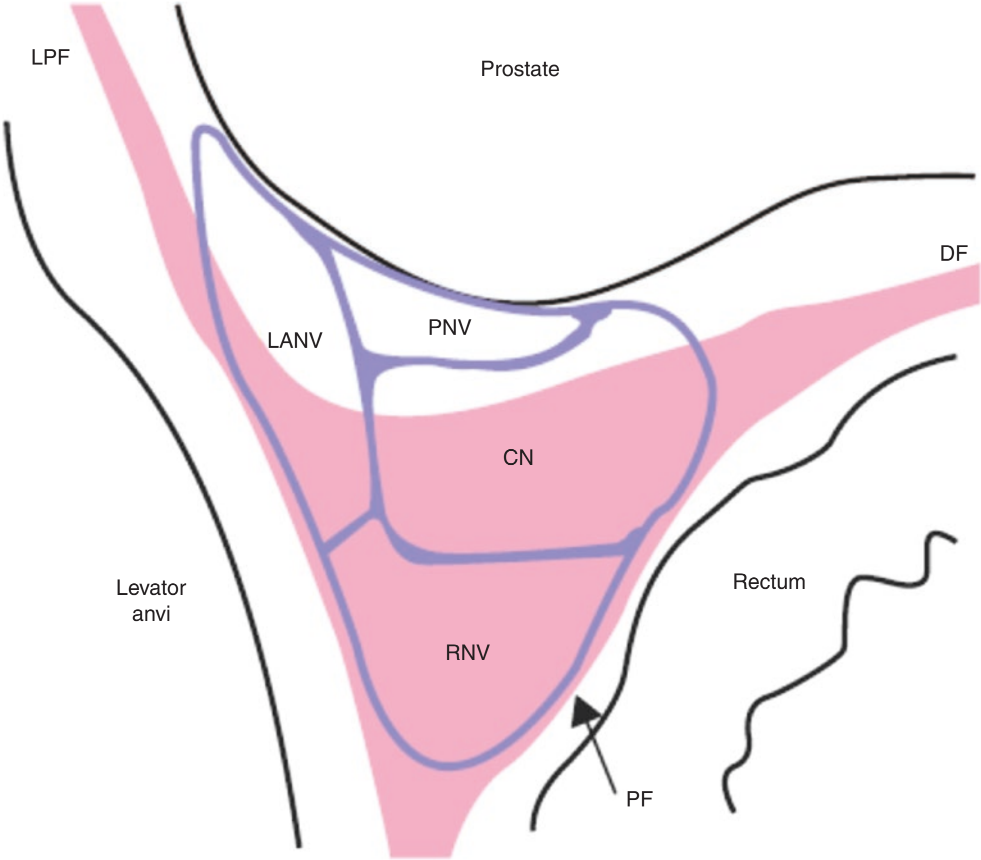


Fig. 29.3 Functional organization of the neurovascular bundle. *RNV* Neurovascular supply to the rectum, *LANV* Neurovascular supply to the levator ani, *PNV* Neurovascular supply to the prostate, *CN* Cavernosal nerves

and associates, they feel that the nerves located within the veil of Aphrodite innervate the prostate and are sympathetic in nature. They also noted branches to the levator ani and anterior rectum. Similar to Takenaka, Costello found that the nerves converge at the mid-prostate, forming a more condensed bundle and then diverge again when approaching the prostatic apex, where they divide into numerous small branches that descend along the posterolateral aspect of the membranous urethra before entering the second ganglion characteristic of the parasympathetic nervous system on the wall of the corpora cavernosa. At this point 2–4 mm post-ganglionic nerves then innervate the corporal bodies. Figure 29.3 demonstrates Costello's findings regarding the functional organization of the NVB.

However, it remains true that there is no question that although we have a reasonable understanding of the neuroanatomy of the cavernosal nerve, the results of potency preservation following open or robotic radical prostatectomy are immensely disappointing. This suggests that although physical preservation of the nerves is a critical component, other factors must play important roles accounting for the wide variability of "potency outcomes" experienced by individual surgeons. The issue of "potency outcomes" sparks two questions. First, why do some patients recover immediately and others take a year or longer? And secondly, what factor or factors impact who recovers? To address the first question on timing of recovery, we present our "timeline" observations we have seen over the years.

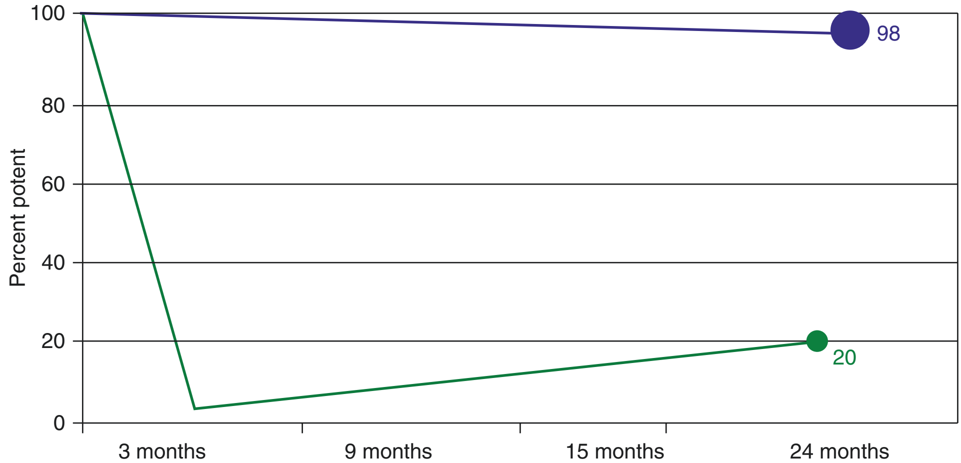


Fig. 29.4 - decline of potent men 24 months after radical prostatectomy (*large circle*) versus men with non- nerve sparing RARP (*small circle*)

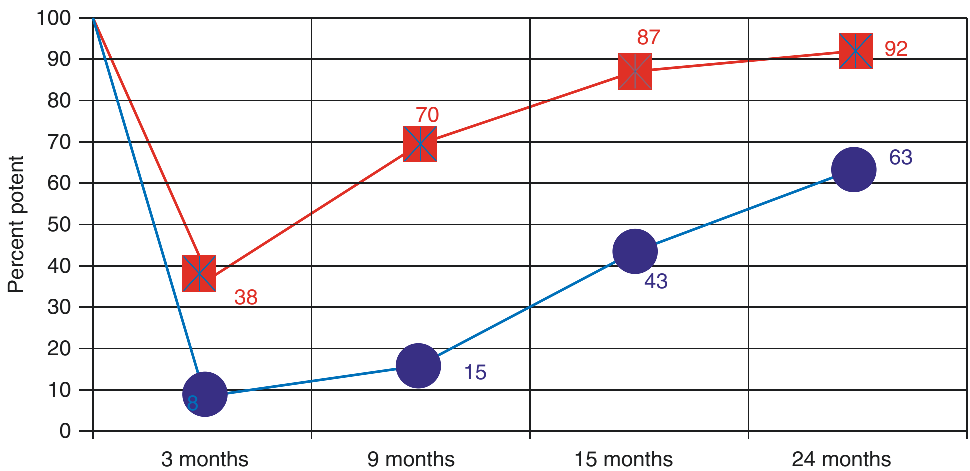
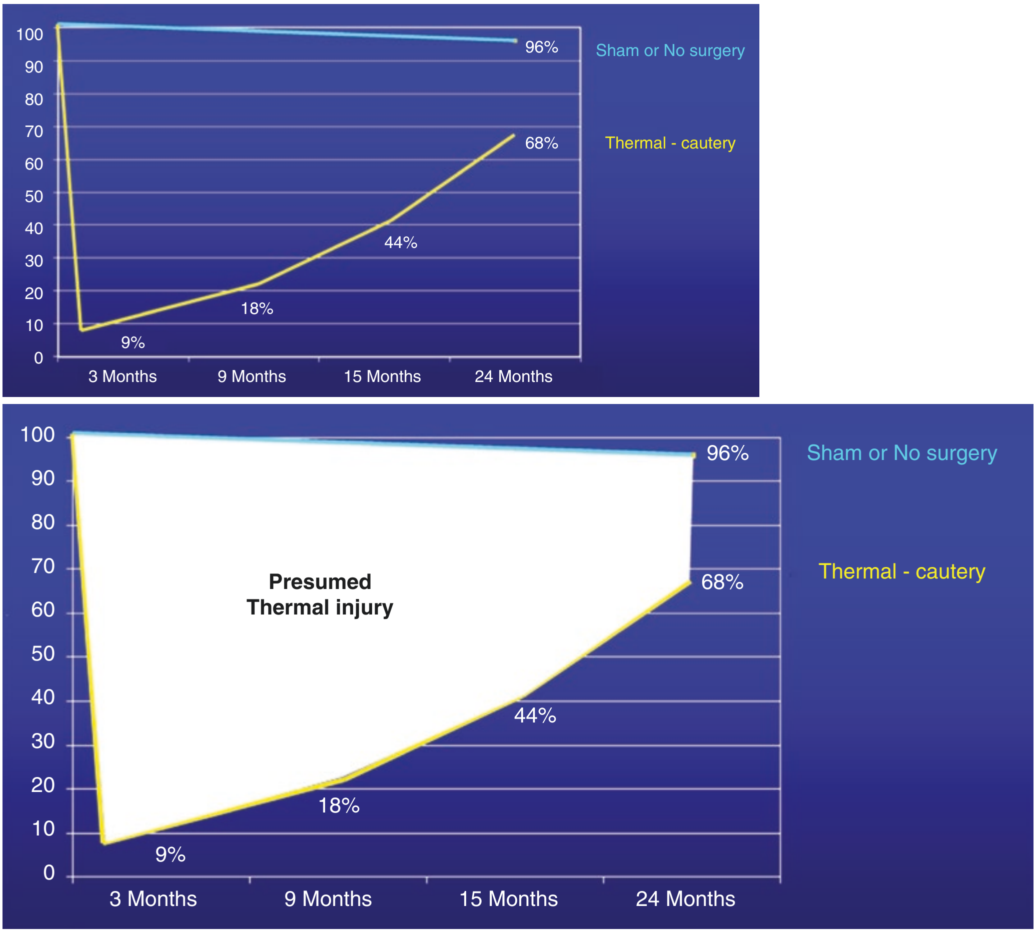


Fig. 29.5 Recovery of sexual function for potent men, aged ≤65 years using cautery (*circles*) versus Athermal NVB sparing (*squares*) [9, 11]

Observations on Time to Recovery of Sexual Function with Reference to Nerve Injury and Recovery

In a hypothetical group of potent (IIEF-5 22–25) men 65 and under, one would expect some level of decline over 2–3 years as diagramed in Fig. 29.4. In this figure, we also include anticipated return of sexual function assuming no attempt to spare the NVBs. However, in distinction to non-nerve sparing, wide excision (either uni- or bilateral) is likely a very different physical outcome as compared to "non-nerve sparing." Studies indicate potency results from as little as 7% to as high as 35% for "non-nerve sparing" [7, 8]. We selected 20% as a fairly neutral "compromised" result. In 2002, with our initial RARP experience we used cautery to hemostatically control the prostatic vascular pedicle (PVP), and the blue line in Fig. 29.5 depicts timeline recovery seen in the lower curve. Concern for cautery injury to the NVB when transecting the PVP resulted in the introduction of an "athermal"

a


b

Fig. 29.6 (**a**) Recovery timelines of initial 125 patients with cautery; (**b**) Quantified injury (presumably thermal); (**c**) Recovery timelines of subsequent 150–350 patients with no use of thermal injury; (**d**) Quantified injury due to traction, as there was no use of thermal injury; (**e**) Despite no thermal energy, there remains substantial traction injury

technique to transect the PVP during RARP initially using bulldog clamps as described by Ahlering and Gill and their associates [9, 10]. With athermal transection of the PVP, we noted two important findings. First a noteworthy increase in recovery of potency (Fig. 29.5) at 3 months from 8 to 38% [11] and subsequently sustained improvement in recovery of potency compared to the cautery group over 2 years [12, 13]. Due to the dramatic improvement in recovery of potency, the 'athermal' technique was adopted universally especially with introduction of effective laparoscopically placed surgical clips to control the PVP. Another important observation in Fig. 29.5 is the 2-year potency recovery using cautery (nearly 65%) which was rather surprising and suggested a transient and potentially recoverable injury even with thermal energy [13].

These finding begged for a physiologic explanation for what was accounting for the variability of early and delayed recovery (Fig. 29.6). The timelines suggested three levels of injury. Transient or no obvious injury where men were potent on their initial attempts to have intercourse; a second group who initially did not have adequate erections for intercourse but did recovery potency after a period of impotence recovered (usually fairly abruptly) around 9–15 months.

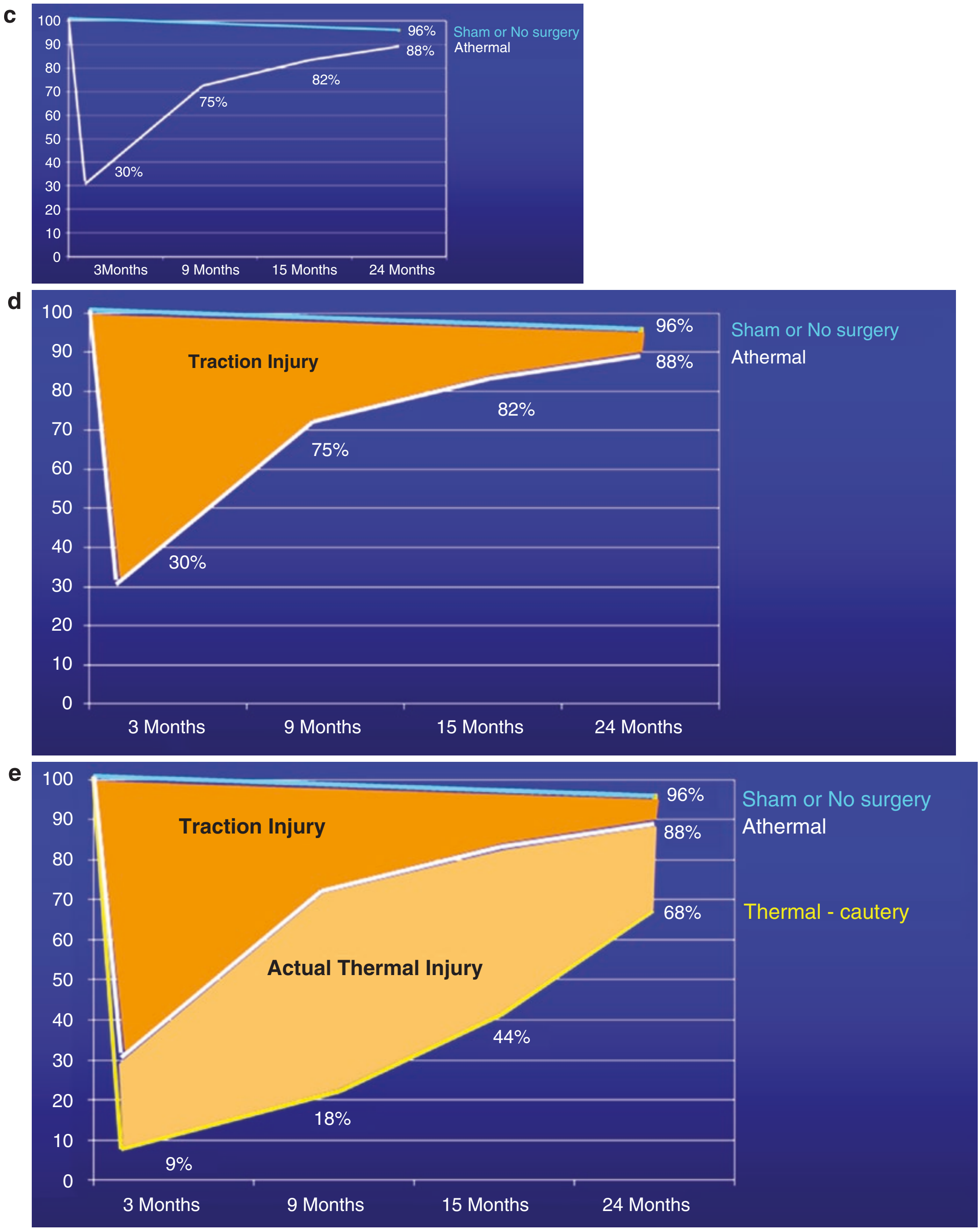


Fig. 29.6 (continued)

The third group was patients who had a permanent injury and never recovered.

In 2008 we proposed that the findings [14] were consistent with and best explained by the seminal work on peripheral nerve injuries (as opposed to central or spinal cord injuries) initially classified by Sir Herbert Seddon in 1943 [15]. According to his initial and simplified clas-

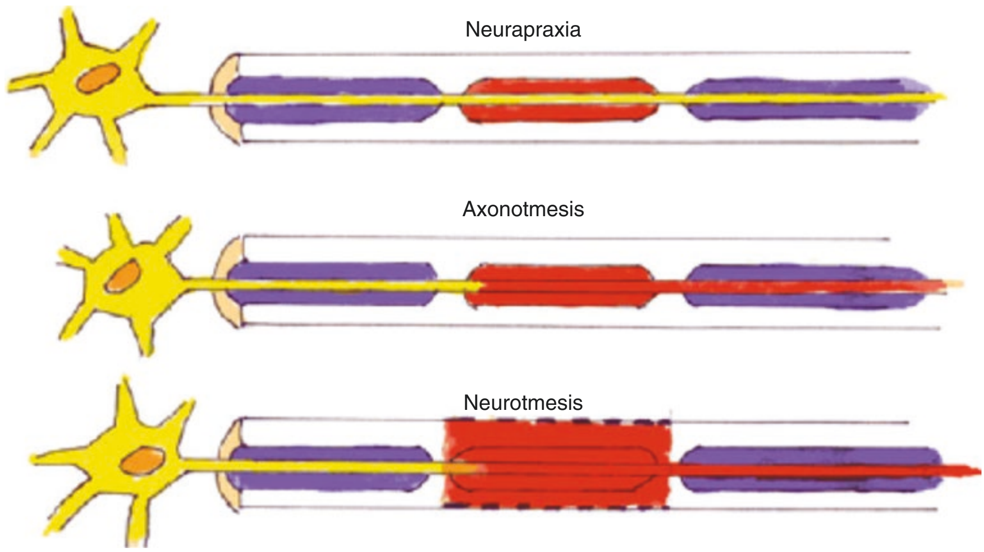


Fig. 29.7 Classification of nerve injury according to Seddon [12]

sification of injury, three categories of severity occur: ***neurapraxia*** is a mild injury due to nerve contusion from blunt impact or stretch injury to the nerve with no structural damage (Fig. 29.7). A concussion-like state results in a transient conduction block from which full recovery occurs within days to weeks. The second level of injury, ***axonotmesis*** is a moderately severe injury, which results in axonal disruption and Wallerian degeneration. In these injuries, the axon is disrupted, but the perineurium is preserved (Fig. 29.7). The nerve or axon will regenerate or regrow from the point of injury to the end organ assuming the perineurium is intact. Regrowth of the axon progresses at approximately 1 mm/day to in. per month and recovery takes 8–24 months. The last level, ***neurotmesis*** occurs after severe injury or laceration that transects the axon and perineurium completely with no capacity for regrowth of the axon. A neuroma or scar usually results. During radical prostatectomy, injury to the myelinated pre-ganglionic cavernosal nerves and neurovascular bundles such as excision, incision, severe stretch, or thermal injury occurs according to these mechanisms resulting in a spectrum of nerve injury.

Nerve Redundancy

An intriguing and important question is what evidence exists for a critical volume or percentage of nerve required for preservation of potency. Simply put, what impact does widely excising one of the NVBs have on potency? The fact that there is any recovery speaks to "systems redundancy." We compared potency outcomes in patients in whom we spared both nerves to those who had only one excised [16]. We queried what percent of recovery results following preservation of one versus two nerves (i.e., a doubling of nerve volume) and were there any differences in the quality of erections? We were quite specific about the definition of unilateral nerve sparing; we only included patients with a wide excision as unilateral. Any partial excisions were included in the bilateral preservation. In the first group, there were 38 (ten were unilateral) men who had cautery used during transection of the PVP and dissection of the NVB. In the second group, cautery-free technique was used and included 58 (19 were unilateral) men. The important finding was that when the nerve volume was doubled (2×), there was only a 15% improvement (1.15×)

in the cautery-free group and 36% (1.36×) demonstrating a remarkable amount of redundancy.

Further, of the men reporting erections satisfactory of intercourse (penetration), both groups showed that qualitatively the erection with one nerve was the similar as two nerves. The average postoperative IIEF-5 scores of both the uni- and bilateral were groups were similar (19.6 vs. 18.9, respectively, for cautery and 21.0 vs. 22.0, respectively, in the cautery-free group). In similar fashion, Walsh and associates [17] and Kundu and Catalona and associates [18] have reported their experience with unilateral nerve-sparing (UNS) surgery. In 1987, Walsh reported that 69% of men potent before RP who had unilateral wide excision were potent after RP, compared to 85% who had BNS. Kundu and associates reported a similar trend in overall potency rates at 18 months, of 53 and 76% after UNS and BNS RP, respectively. Recently in 2011, Kowalczyk and Hu and colleagues in multivariate analysis found no difference in potency outcomes between UNS versus BNS (OR: 2.07; 95% CI, 0.98–4.41) [19]. This data speaks very strongly to the existence of redundancy and also explains in part the subjective correlation of quantity of nerve sparing to the likelihood of potency recovery [20].

Practical Aspects of Thermal Injury

The use of thermal energy on or near the nerves can be mechanism of damage leading to delayed or impaired recovery of potency. Temperature elevations of as little as 4 °C (to 41 °C) can produce neural injury, and elevations to 45–55 °C coagulation occurs [21]. As temperatures continue to rise beyond that point, cell death occurs, with denaturation occurring at 57–60 °C and protein coagulation at 65 °C [22]. Donzelli and associates demonstrated that both monopolar and bipolar cautery causes primarily thermal injury to nearby neural tissue [23].

The potential role of the importance of thermal injury was demonstrated in a paper by Ong and associates that described the effects of electrocautery, and thermal injury on cavernous nerves was performed in a canine model [24]. In this study, monopolar electrocautery, bipolar electrocautery, and harmonic shears were compared to standard suture ligatures for unilateral NVB dissection. The contralateral bundle was not dissected and acted as an internal control. Upon cavernous nerve stimulation, only the energy-free (suture ligature) group maintained similar-to-baseline intracavernosal pressure responses immediately after dissection and 2 weeks later. The major weakness of this study maybe the short duration of follow up. The other modalities using thermal energy all resulted in a >95% decrease in cavernosal pressures. Histologic studies comparing the individual groups demonstrated an increased amount of inflammation associated with the use of heat and/or electrocautery. Because of these findings, it has been suggested that transection of the vascular pedicles should be accomplished without thermal energy, unless neutralizing thermo-protective simultaneous cold irrigation is used.

It has been demonstrated that electrocautery produces temperature elevations and thermal energy effects beyond the site of cautery. In essence, standard laws of thermodynamics apply. A study by Mandhani and colleagues measured temperature changes at the NVB during RARP with monopolar and bipolar cautery [25]. The average temperature rise with monopolar and bipolar cautery at the NVB during distant (>1 cm from the NVB) anterior bladder neck incision was 43.6 and 38.8 °C, respectively, after approximately 60s of cautery. During NVB dissection itself using both cautery modalities, the mean temperatures within the NVB measured within 1 cm of the cautery rose to 53.6 and 60.9 °C, respectively. The average time for the temperature to return to baseline with each modality was 3.4 and 6.4 s, respectively. The findings suggest that "dessicating" bipolar electrocautery raises temperatures more than monopolar cautery which is more efficient and hence shorter periods of application and lower temperatures. Further, Khan and associates [26] demonstrated the thermodynamic impact of heat-sink effect or adjacent arteries and veins. In a porcine model, they demonstrated that active blood flow through arteries and/or veins reliably completely dissipated heat spread as long as blood flow was present in the vessels. The study also demonstrated that when these same vessels were clipped stopping blood flow the adjacent thermal spread through muscle was exactly the same when the "heat-sink" vessels were not present. Zorn and colleagues have also nicely demonstrated that application of cold irrigation when applied concomitantly with cautery that thermal spread can be measurably reduced [27]. We recommend that the simplest solution is to avoid thermal energy altogether near the NVB; however, there is much evidence that if the laws of thermodynamics are observed thermal spread can be applied while keeping thermal spread to a minimum. In a systematic review and meta-analysis from 2012, Ficarra and associates [28] reported that thermal energy was safely applied without obvious deleterious potency outcomes. If one keeps in mind simple thermodynamic principles such as low wattage, short bursts, heat sinks, distance, etc., thermal spread can and Swill be minimized.

Traction Injury

A critical question is why some men have minimal reduction of erections following RARP versus a robust proportion of men who regain potency over the ensuing 12–24 months? A likely answer seems to be traction or stretch injury, an important mechanism of nerve injury studied in animals and seen all too frequently in the human complications such as traumatic injury or more urologically familiar femoral and other peripheral nerve stretch injuries. In May 2008, we published evidence suggesting that prostate size/weight played an important role supporting a traction mechanism. We looked specifically at 3-month potency outcomes in 139 men, 65 and under with IIEF-5 scores 22–25 [29]. Of note 53 or 38% were potent at 3-months suggesting minimal (or a neurapraxic) injury and 86 had not recovered. We felt that some factor should be found accounting for such a stark difference between 3-month and 1–2 year potency outcomes. We evaluated a large host of factors such as age, IIEF-5, BMI, medical comorbidities, medications, social factors (marital status, partner age, etc.), and perioperative factors. In univariate analysis, age and prostate weight were significant but in multivariate analysis, only prostate weight remained significant. The likely explanation not recovering by 3-months was traction as the data demonstrated the lowest risk of impotence was with the smallest prostates and a stepwise increase in impotence at 3 months over five increasing quintiles as the size/weight increased. The fact that the physical structure of the pre-ganglionic myelinated cavernosal nerve is preserved further supports traction injury which explains the usual recovery period of 9–24 months and explains why prostate size is not a significant factor for recovery at 12 months. The implied role of traction has been the focus of additional publications by Walsh and associates [30] in December 2008 and subsequently Hu and associates [19, 20]. The critical lesson for reducing traction injury is the neurosurgical principle of "dissecting the tumor (prostate) off of the nerve" as opposed to classical surgical training of "traction and counter-traction". In essence always be mindful of minimal contact/traction of the NVB.

Impact of Patient-Related Factors and Inflammatory Damage

A number of investigative studies have been published to assist in either preserving or hastening the return to potency post RP. Many of these studies are pilot trials with common weaknesses of small size, single surgeon, and younger aged potent men. These trials are generally serial in nature and use restrospective control groups. However, short term improvement of potency outcomes would be more compelling if they significantly improved long term potency outcomes. There are scant numbers of randomized controlled trials (RCT) which which are needed to support clinical acceptance of the devices/drugs/products presented. Also problematic are the definitions of potency used for success of the trial. Are simple erections sufficient success or should more stringent definitions be applied? With these caveats in mind, the following preliminary studies are presented but need further validation for clinical standard of care.

It is well known that younger and healthier men with normal sexual function (IIEF 22–25) will have a much greater chance of potency recovery following surgery than older men (>65 years) regardless of surgeon or technique [7, 8]. This begs the question why? One logical answer is acute surgical trauma and inflammation. There is no logical evidence that the surgical trauma generated to a 70 year old is different than a 45 year old. However there is some evidence that the inflammatory may be exaggerated as men age above 60s years [31]. Regardless for any given trauma, younger and healthier men will resist and or recover better. Again, this simple concept explains the ubiquitous surgical finding why clinical outcomes deteriorate with age in any given surgeon using a defined technique.

The inflammatory cascade includes activation of coagulation factors, proinflammatory cytokine formation, hypoxia, and microcirculatory impairment from endothelial damage, acidosis, free radical production, and apoptosis [32, 33]. Neutrophil and macrophage infiltration with subsequent release of proteolytic enzymes further contributes to tissue destruction [34, 35]. Theoretically, this secondary inflammatory cascade might be blocked (or at least mitigated) with the use of local tissue hypothermia. Hypothermia has been demonstrated to have a dramatic protective impact in numerous experimental injury models of the central and peripheral nervous systems. The use of mild to moderate hypothermia (i.e., 33–28 °C) has been shown to be effective in shielding neurons from damage. In a rabbit model of spinal cord ischemia, Isaka and colleagues applied trans-vertebral cold packs and infused cold saline into a cross-clamped aorta to produce spinal cord cooling [36]. A modest reduction in spinal cord temperature of just 4.3 °C completely prevented paraplegia compared to complete paraplegia in all of the control rabbits. We extensively explored regional local hypothermia to prevent trauma-induced inflammatory injury to the external urinary sphincter for continence and the neurovascular bundles for sexual function [37–39]. With regard to potency, in men with IIEF-5 scores of 22–25 aged 40–78, at 15-months the potency recovery rate with 4 °C. cooled hypothermic endorectal balloon was 83% compared to 66% in similarly aged controls. Consistent with the hypothesis that hypothermia reduces inflammatory injury particularly in older patients, we saw our greatest improvement in men over the age of 65 (hypothermia 70% vs. controls 30%).

However, we then put our concept of hypothermia to improve urinary continence and sexual function to a randomized controlled trial. This randomized controlled trial was planned with the intent to obtain FDA approval for clinical use of an endorectal cooling balloon (ECB) that cycled 4 °C saline through a balloon in the rectum—in essence sucking temperature away adjacent structures the external sphincter and NVBs.. The ECB was patented by the University of California in 2009; a license agreement to study and potentially market the device was instituted between Philips Health Care Inc. and the University of California, Irvine. An independent-statistical contractor with extensive FDA trial experience was contracted to power and implement the study design and randomization process. Critical to design was trying to select surgeons of high quality so we could minimize surgeon skill issues. Selecting high quality defaulted to very high volume surgeons with extensive case experience. Three external high volume centers (two from USA and one in Europe) were invited to contribute a total of five surgeons. Two centers contributed two surgeons: both centers contributed one surgeon with greater than 3500 case experience and one surgeon with greater than 500 cases experience. The remaining center contributed one surgeon with greater than 1500 cases. All surgeons performed between 100 and 300 cases per year. The PI was not included in the study. The study design called for double blinding of device use (patient and data collection). The study was powered to 200 patients with an anticipated dropout rate of 20%. The patients were consented the morning before surgery and the device inserted and removed in the operating room so patients were unaware of its use. Knowledge of device use was restricted to the operating room personnel only; recovery room and ward nursing staff were not informed of device use and instructed to indicate such if a patient inquired. The follow up continence data were collected by blinded third party contractors (one in Europe and one in the US). Follow up statistical analysis on the clinical outcomes was performed by a second independent contractor.

Despite our group's initial findings in 2009 demonstrating a benefit in favor of regional hypothermia with a reduction in median time to continence and improved overall continence, this multi-intuitional randomized control trial did not validate those findings. In the initial study, having one surgeon perform all the procedures may have eliminated what we believe to be a significant confounding factor in the present study: inter-surgeon variability in technique and outcomes. A clear and problematic difference in continence rates by surgeon, particularly in the initial 6 months essentially eliminated the concept of a randomized trial of comparing the device. Because in this RCT we measured variable surgeon outcomes. Any analysis of device capability was lost. After adjusted analysis, only one surgeon experienced a trend towards improved continence. Given our initial power calculation, the significant difference between surgeons would have required 200 patients to be randomized per surgeon to potentially discern relevant statistical significance. The remaining surgeons, however, demonstrated no evidence of benefit in unadjusted or adjusted analysis.

The results highlight the limitations and inherent challenges of conducting randomized control trials in the context of surgery. Importantly, several articles have noted difficulties of conducting RCTs of surgical intervention [40–42]. There has been discussion in the literature that the nature of surgery does not lend well to evaluation of new techniques via RCT [43–45]. RCTs have been seen as the "gold standard" in medical research due its ability to eliminate selection bias when conducted correctly. Evidence has shown, however, that when done improperly (for example, by not double-blinding or inadequate allocation concealment), an RCT can yield heavily exaggerated results [44]. Another important issue with "surgical" RCTs, as in this study, we had two variables (potentially) impacting continence outcomes—a medical device and variable surgeon skill/technique. With respect to RARP it is well documented that incontinence and erectile dysfunction rates vary greatly among surgeons and across techniques [45].

Conclusion

The present understanding of the neuroanatomy of the cavernosal nerves and efforts to technically preserve the nerves during radical prostatectomy appears to be nearly maximized. Further, evidence for and an understanding of redundancy strongly dilutes substantial impact of further "nerve" preservation schemes significantly improving potency outcomes. As noted above with our experience with hypothermia, we now believe that focusing on surgeon skill and technically mitigating injury is the critical factors to improve outcomes. Care should be taken to avoid or minimize heat spreading to the NVBs as well as focusing on methods to reduce traction. Lastly, there may be a role to explore novel therapies to help protect the NVBs before, during, and after surgery.

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30 Experimental Techniques of Nerve Regeneration in the Neurovascular Bundle

Francesco Porpiglia, Riccardo Bertolo,
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Introduction

Over the last two decades the knowledge of the anatomical structures surrounding the prostate has increased, together with the development of surgical technique of radical prostatectomy.

In this field the robotic system has certainly played a crucial role, thanks to the undoubted advantages such as the image magnification, the three-dimensional view and the improved surgeon's dexterity thanks to the miniaturized instruments.

Notwithstanding the above mentioned advantages, in patients who undergo robot-assisted radical prostatectomy (RARP), even with meticulous anatomical preservation of the urethral-sphincter complex and substantial preservation of the peri-prostatic neurovascular bundles (NVBs), there still remains a period of convalescence characterized by urinary incontinence and unrecovered potency [1].

Such a delay is probably due to the stunning of the anatomical structures and due to an inflammatory response caused by injury from traction of the NVBs [2]. Moreover, a complex mix of injuries from stretching, electro-cautery and transection act on the integrity of NVBs during surgery for prostate cancer.

Indeed, the physical tractions of the NVBs can be minimized by the surgeon with consistent experience but cannot be fully eliminated during the mobilization of the prostate [3].

In summary, we cannot wait for further innovations of the nerve-sparing (NS) technique, but we have to look for different possible solutions aimed to promote the neuro-regeneration or eventually to act for neuro-protection.

These kind of solutions can be investigated either in the field of biological ones or bioengineering ones. The purpose of this chapter will be to give the reader a state-of-the art about the available experimental techniques proposed for nerve regeneration in the neuro-vascular bundle after RARP.

Autologous Nerve Grafts

Resecting both nerves has been reported to eliminate spontaneous erections and to ablate the response to sildenafil [4–6]. The interposition of nerve grafts to replace the resected cavernous nerves during radical prostatectomy has been reported to increase the chance of a recovery of the erectile function than without grafts.

The reconstruction of the nerves would theoretically be the logical solution to help patients in

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_30

achieving a more physiological erection. The improved outcomes recorded after nerve grafting are presumed to result from the effectiveness of the graft in helping the axonal regeneration.

Indeed, the interposition of a nerve graft provides a conduit for regenerating axons to eventually re-connect with the distal nerve stump. The ideal nerve graft should be long enough to cover the gap and minimize any tension after the repair. Its diameter should be slightly larger than the transected end in order to capture and channel the regenerating axons into the distal stump. However, the only method to confirm actual nerve regeneration would be the postmortem examination by resecting the length of the grafted neurovascular bundle and microscopically evaluating the eventual axonal regrowth. Using autologous nerve grafts minimizes the risk of rejection. Somatic nerves can be used to replace resected autonomic nerves and are more readily accessible in most instances [7]. Nerves other than the sural one have been used, including the genitofemoral nerve and ilio-inguinal nerve, but sural nerve has been the most popularly used [8–10].

Sural Nerve Grafting

The sural nerve is a purely sensory nerve and its removal will result in a small deficit on the dorsolateral foot area. It is widely used for interposition grafting. The sural nerve sensory to the anterolateral skin of the foot is the preferred donor site because of its accessibility and long length [11, 12].

The nerve is harvested through an incision at the level of the ankle, with higher counterincisions for more length [12]. Complications following the harvesting have been rarely reported. The eventual major risk, that is anyway a treatable problem, is the rare formation of a painful neuroma at the proximal cut end of the nerve. The decreased sensation is not clinically relevant.

Published Experiences—Open Surgery

Kim et al. first described the successful use of the interposition of the sural nerve graft for the treatment of erectile dysfunction following the complete sacrifice of the neuro-vascular bundles. Since then, overall published results have been inconsistent [11]. Davis et al. in a randomized controlled trial compared the outcomes of 45 patients who underwent unilateral sacrifice of the neuro-vascular bundles with sural nerve grafting with those of a cohort of 21 patients who underwent radical prostatectomy with unilateral neurovascular bundle sacrifice without reconstruction of the nerves [13]. This study was powered to detect a difference of 50%, but failed to show a superiority of unilateral grafting.

The matter with sural nerve grafting is that it represents an additional procedure. Indeed, the traditional approach involves the harvesting of the nerve and the performance of the anastomosis by the same surgical team.

This often results in a prolonged anesthesia and an interrupted work-flow.

With the increased operative time and the little benefits as shown by Davis et al., the utility of sural nerve grafting, especially when performed unilaterally, appeared minimal at its best.

However, where bilateral wide excision was warranted, sural nerve grafting was felt to be worth the effort if it could be completed accomplished with minimal morbidity, inconvenience and disruption of the surgical procedure.

As such, in a serie published in 2014 by Siddiqui and colleagues, erectile function recovery after unilateral sural nerve grafting was 28% vs. 30% in bilateral sural nerve grafting.

In this case, a multidisciplinary approach was employed by including in the surgical team a plastic surgeon to harvest the graft. With both teams working simultaneously, excellent nerve graft material was collected without disrupting the pelvic dissection and with minimal prolongation of the total operative time.

In this serie the mean surgical time was around 160 min. It was highly comparable to the mean operative time reported in a review including 30 series from high volume centers (with more than 250 cases performed per year) [14]. In summary, it was similar to that of retropubic RP without SNG.

One limitation of the existing literature for sural nerve grafting is the lack of adequate follow-up and inconsistent definition of EF recovery [15].

The process of graft-assisted regeneration is not only dependent on the quality of graft, but also on the time required for graft aided regeneration, which typically extends to a year [16].

Hence, optimal nerve graft quality, techniques and adequate follow-up are critical for reliable assessment of the utility of sural nerve grafting.

Published Experiences—Minimally-Invasive Approach

Concerning the minimally-invasive approach, this technique has been anecdotally reported.

Turk et al. [17], using a laparoscopic approach in 15 men, described the grafting as carried out either unilaterally or bilaterally; the anastomosis was made completely intracorporeally by 6/0 polypropylene with two sutures. Kaouk [18] described the feasibility of the technique using a robotic-assisted approach.

Porpiglia et al. [19] investigated the outcomes of unilateral SNG during laparoscopic radical prostatectomy in 15 patients. Follow-up was 18 months.

Their data concluded that SNG during laparoscopic radical prostatectomy is feasible and safe. Notwithstanding the feasibility and the safety of the procedure, Authors could not conclude that sural nerve grafting was more effective than preserving the neurovascular bundle alone.

Another Group from Chicago analyzed the results of sural nerve grafting during robot-assisted radical prostatectomy. Twenty-seven men who underwent RARP with SNG, either bilateral (4) or unilateral (23), with a 2 years follow-up were evaluated [20]. Despite the initial optimism regarding SNG, long-term functional outcomes were disappointing, particularly when bilateral SNG was performed.

Allogenic Grafts

The interposition of autologous nerve implants, as the sural nerve as reported, is the only used reconstruction treatment following excision of the neurovascular bundle in men up to date. Axon regeneration is however delayed, as newly implanted axon fragments must first be broken down by Wallerian degeneration. Further on, it harbors disadvantages in form of the additional surgical intervention, the morbidity of nerve extraction and the risk of neurinoma.

Better results may be achieved by using pre-degenerated grafts like Avance® [20] in which the axons have already been enzymatically degenerated [21]. The tubular form allows invagination of nerve fibres and reduces formation of painful neurinoma (Fig. 30.1) [22].

In 1998 Zou et al. described inhibiting influence of chondroitin sulphate – proteoglycans on the regeneration of peripheral nerves [23]. Krekoski, Neubauer et al. showed that axonal regeneration in decellularised nerve grafts could be improved by treatment of grafts with chondroitinase to digest chondroitin sulphate—

Fig. 30.1 Allograft Avance® in the reservoir to thaw. Grafts are fitted epineural with the Premilene® 7–0 tether

proteoglycans and that the effective length of a nerve graft can be increased [24, 25]. Avance® is pretreated with chondroitinase in an enzymatic process.

By bridging the defect in the neurovascular bundle with a nerve graft, a postoperative erection permitting satisfactory sexual activity could be achieved [11, 13, 15, 26, 27]. Success rates in various studies in the past few years have however varied greatly, the majority being uncontrolled, retrospective and with small cohorts. Additionally, it remains unclear if postoperative erections following unilateral nerve sparing with contralateral nerve grafting are caused by nerve sparing or implantation. Therefore the true benefit of nerve grafting remains unproven.

In a prospective, randomized and single-blind clinical phase-IV study, Vollmer and colleagues [28] reported results about allografts after robot-assisted laparoscopic radical prostatectomy with total excision of both the neurovascular bundles.

Follow-up lasted 24 months postoperatively with quality of life questionnaires, including IIEF scores. Primary outcome was defined as spontaneous erections eligible for sexual intercourse with or without PDE5 inhibitors (IIEF-6 $\geq$ 21).

From January 2011 to December 2014 Authors included 26 patients. Despite a significant longer operation time, implantation caused no adverse events. Some details of the surgical technique were showed in Figs. 30.2 and 30.3. The trial demonstrated that the surgical technique

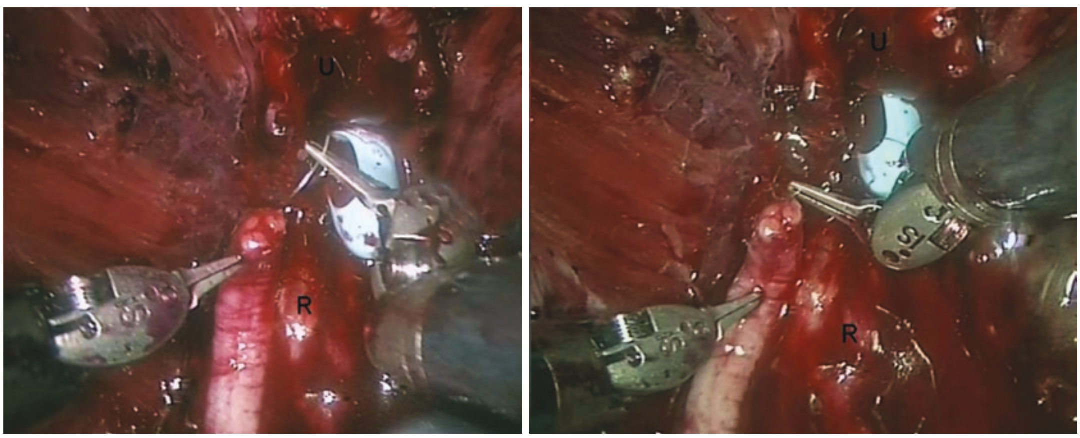

Fig. 30.2 Epineural stitch technique for anastomosis of allograft Avance® with distal ending of left neurovascular bundle (R: Rectum, U: Urethra)

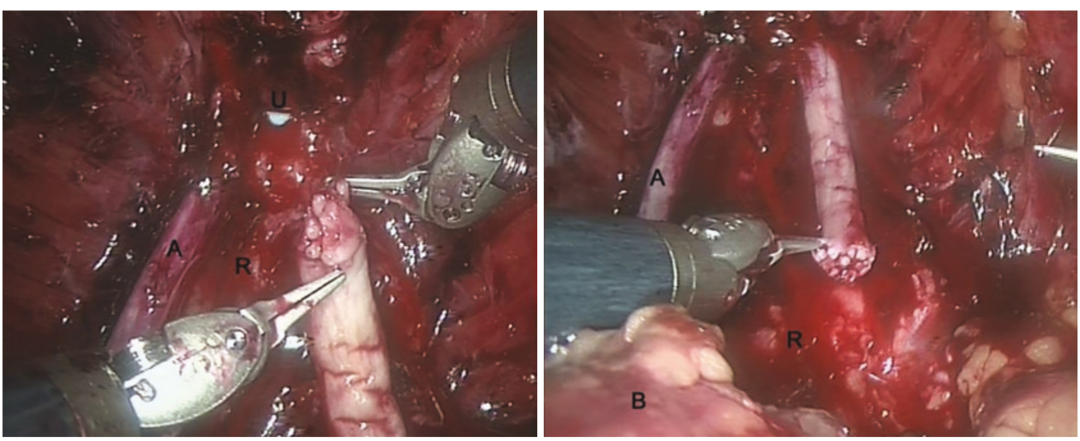

Fig. 30.3 Implantation of allograft Avance® on the right side (R: Rectum, B: Bladder, A: Avance®)

is safe and feasible. No significant differences relating the primary outcome were displayed between the study groups.

Discussion

In the field of peripheral nerves, the possibility to regain nerve function after trauma is dependent on the severity of the suffered damage. Spontaneous recovery is possible only if the continuity of the nerve is maintained. In case of a complete nerve transection, a surgical intervention is required for re-establishing the continuity between the proximal and the distal stump.

Autologous nerve grafts (auto-graft) would be the 'gold standard' technique for repairing peripheral nerve defects, consisting in the use of healthy nerve fragment of sensory origin (usually the sural nerve) for bridging the gap [2]. However, this practice presents some disadvantages: it requires an additional incision for removing the healthy sensory nerve, leading to a residue sensory deficit; yet, graft material is limited especially in case of an extended nerve lesion.

In the field of prostate surgery is not a "one-nerve-only" damage; indeed the anatomy of neuronal structures surrounding the prostate is very complex, neuronal fibers are autonomic and it is impossible to identify a single fiber to be reconstructed.

As a matter of the fact, previous experiences tried as above described to transfer the concept of using sural nerve grafting to radical prostatectomy, with no really consistent results, regardless the technique, regardless the approach.

In parallel with such attempts, nerve sparing techniques improved a lot, reaching their acme with the advent of robotics, thanks to the undoubted advantages from using the robotic system in terms of image magnification with the derived improved knowledge about the anatomy of the neurovascular bundles and the different "shades" of nerve-sparing (Fig. 30.4).

Moreover, some Authors proposed other helpful systems aimed to maximize nerves preservation during radical prostatectomy. For example, Tewari and colleagues used a traction monitor to quantify the intraoperative mechanical force exerted on the NVB that leads to ischemic nerve injury [29]. Finley et al. tested regional hypothermia performed a rectal cooling balloon with good results on recovery of urinary continence only [30]. In summary, urological community is still waiting for consistent innovations able to prevent NVB neuropraxia induced by surgery.

As an alternative to nerves grafting, a variety of biomaterials for nerve reconstruction/regeneration have been developed [3, 30].

New Perspectives

Growth Factors and Enriched Membranes

The use of growth factors and anti-inflammatory substances for prostatic NVB regeneration has been proposed [31]: specifically, the use of dehydrated human amnion/chorion membranes (dHACM) has been described by Patel and colleague as a source of implantable neurotrophic factors and cytokines [32, 33]. The group applied the membranes in a cohort of 58 patients who underwent full nerve sparing RARP.

The study cohort was computer-matched with a similar group of patients who did not receive the membranes. With no significant differences between the groups in terms of preoperative and intraoperative results and no morbidities, Patel and coworkers showed an earlier return of continence in the "grafted" group (1.21 vs. 1.83 mo; $p = 0.033$) and a faster return of potency (1.34 vs. 3.39; $p = 0.007$), with a higher rate of potent patients at 8 weeks in the grafted group (65.5% vs. 51.7%). The conclusion of the study was that the placement of amnion/chorion membranes facilitates an earlier return of both continence and potency.

The possible explanation of the results obtained by Patel could be the presence of neurotrophic factors in the dHACM able to promote nerve cell survival and maintain target organ function by facilitating axon regeneration [34]. Indeed, Authors mentioned a number of recent experimental studies using neurotrophic growth factors and dHACM that provided encouraging data regarding the potential to rehabilitate nerves after injury.

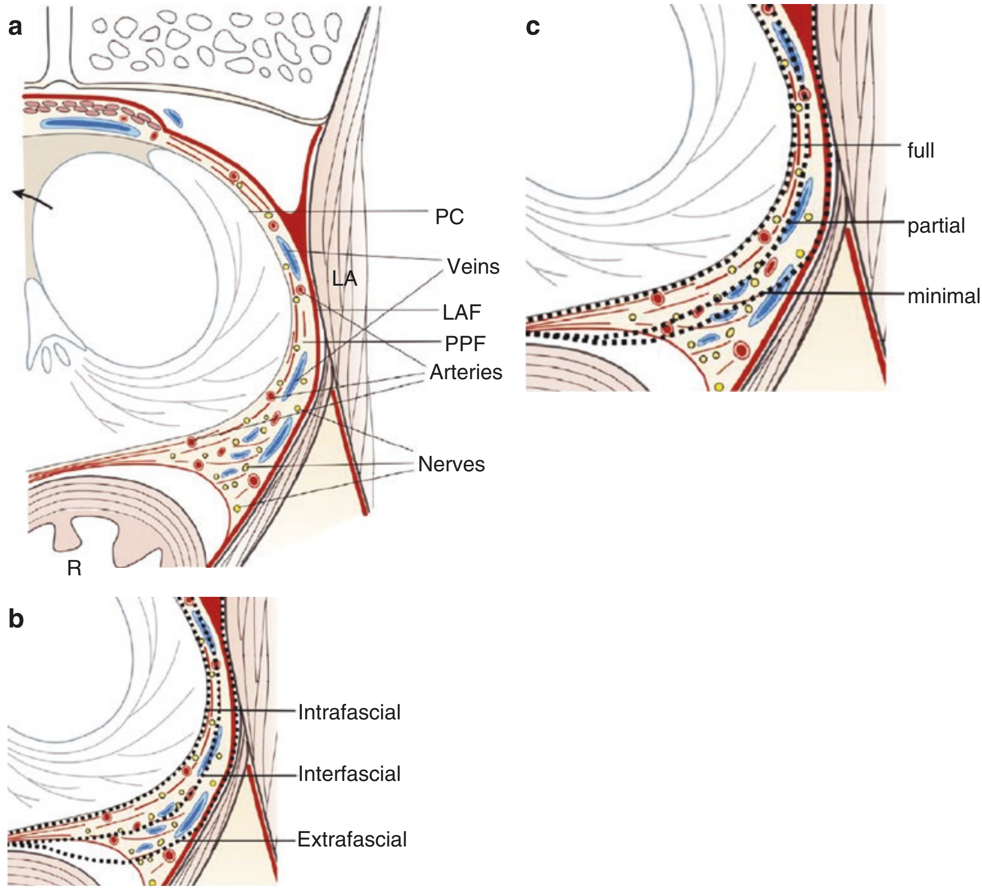

Fig. 30.4 (**a**) Overview of an axial section of the prostatic and periprostatic fascia at midprostate. (**b**) Enlarged axial section with three dissection planes: intrafascial, interfascial, and extrafascial. (**c**) Enlarged axial section with three dissection planes according to the Pasadena consensus panel: full, partial, and minimal nerve sparing. *LA* levator ani muscle; *LAF* = levator ani fascia; *PC* pseudocapsule of prostate; *PPF* periprostatic fascia; *R* rectum. Adapted from "A critical analysis of the current knowledge of surgical anatomy of the prostate related to optimisation of cancer control and preservation of continence and erection in candidates for radical prostatectomy: an update" by Walz et al. Eur Urol. 2016;70(2):301–11

The bilayered amnion and chorion membrane graft they used had nonviable cells and an array of growth factors.

Data were encouraging for the study of anti-inflammatory agents at the site of the prostatic NVB. However, their study had several limitations; it was an observational study with retrospective data collection and was subject to patient recall bias.

Nevertheless, the lack of prospective randomization was partially compensated by the propensity matching.

Authors did not report long-term oncologic results yet. In summary, a longer follow-up is required to evaluate future outcomes for our cohort. Moreover, it is important to certify that the growth factors contained in the dHCAM are inert with the potential tumor re-growth, as the membranes are placed next to the site where the tumor was before the surgery.

The Chitosan Membranes

Chitosan (CS), as a natural polysaccharide, has recently attracted more and more attention due to its good biocompatibility, biodegradability, non-toxicity, readily availability and unique physicochemical properties [35, 36].

Recent in vitro studies revealed the suitability of CS membranes as substrate for survival and oriented Schwann cell (SC) growth [37] as well as survival and differentiation of neuronal cells [38, 39]. CS-based bioengineering scaffolds have been widely used for neural repair in different animal models [40]. CS-based nerve conduits, alone or in combination with other biomaterials, have been found to bridge efficiently peripheral nerve defects [41, 42].

Consistent enhancement in functional and morphological nerve regeneration has been demonstrated (Figs. 30.5 and 30.6) [43].

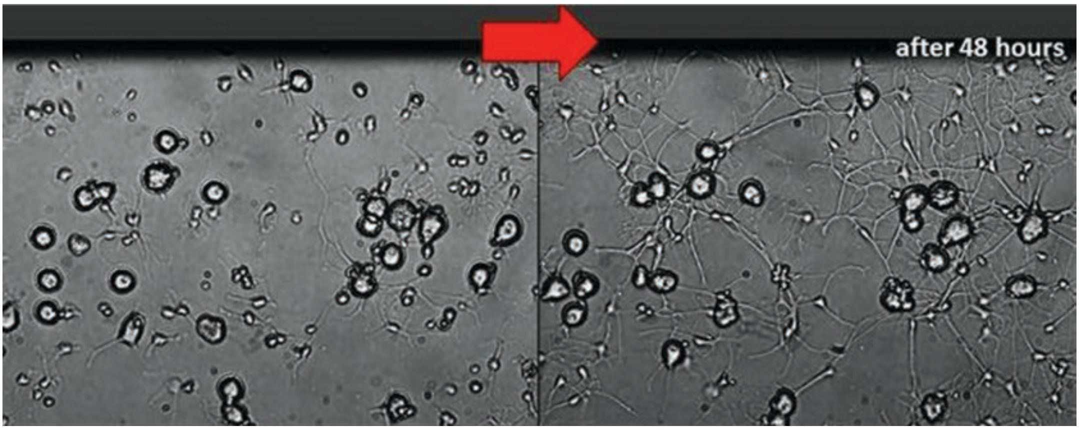

Fig. 30.5 Scanning electron microscopy of a 48 h long time lapse of neuronal cells growing on the chitosan scaffold. It is evident that sprouting is increased on the chitosan

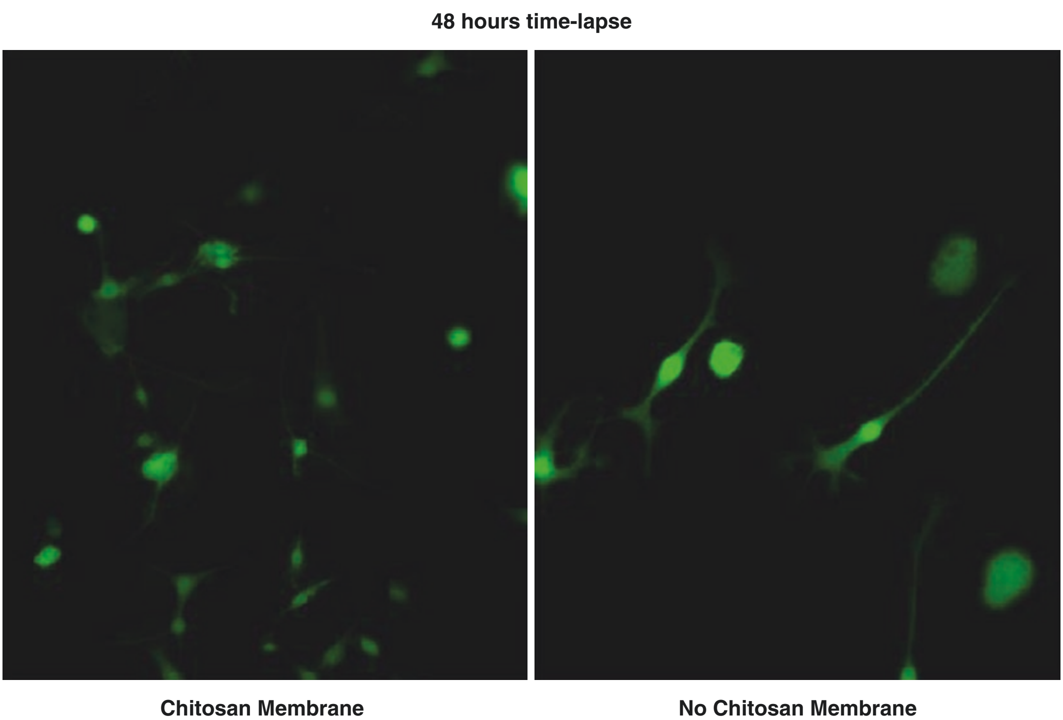

Fig. 30.6 Scanning electron microscopy with fluorescence of a 48 h long time lapse of neuronal cells growing on the chitosan scaffold. It is evident that sprouting is increased on the chitosan

Fig. 30.7 Chitosan membrane has been discarded from the packaging and it is ready to be used. It can be put into saline solution before being introduced into the patient abdominal cavity. Micro-holes are evident on the surface of the membrane

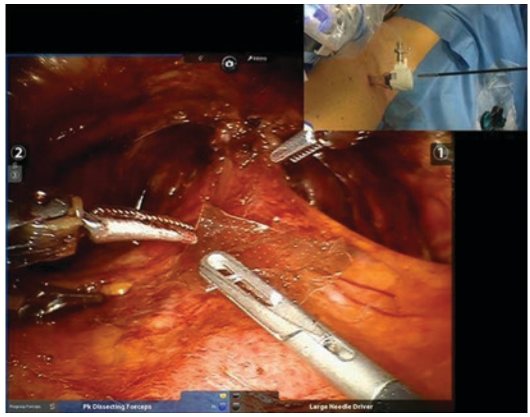

Fig. 30.8 Chitosan membrane is introduced through the assistant port into the abdominal cavity by a laparosopic grasper

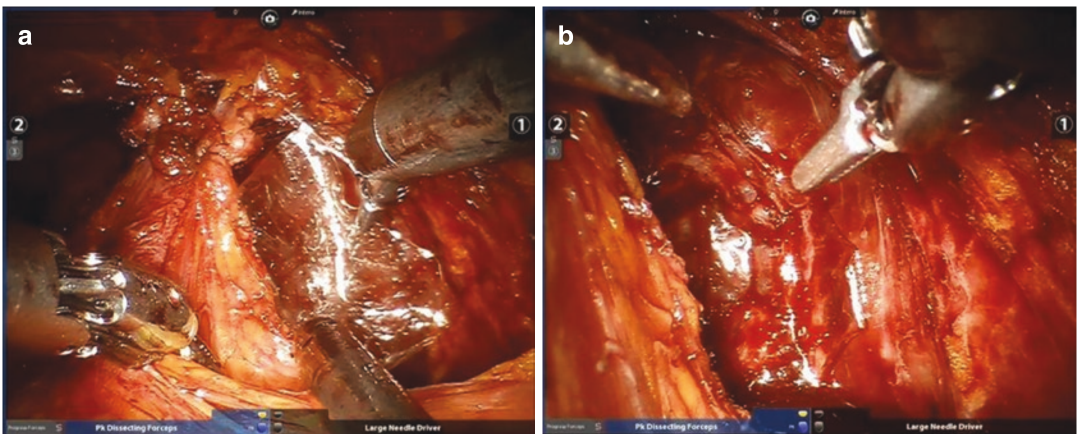

Fig. 30.9 Chitosan membrane is grasped by the robotic instrument (**a**) and correctly deposited on the neurovascular bundle (**b**)

Try to give a contribution in this field Porpiglia and co-workers looked for an inert scaffold for neural regeneration. After the good results of chitosan in form of a cylinder to promote somatic nerves re-growth they tried chitosan during robot-assisted radical prostatectomy. Due to the anatomy of prostatic NVB, chitosan was used in form of a different shape. Indeed, it was produced in form of a thin square, with micro holes (Fig. 30.7). The application of Chitosan Membranes was reported to be easy and safe in almost all the patients. They described it was not mandatory the perfect adhesion of the membrane to the bundle. Rather, the membrane should be just deposited on the NVB, because its intrinsic property of working as scaffold and driving the neural regeneration requires it (Figs. 30.8 and 30.9).

After applying Chitosan Membranes in more than a hundred patients, neither complications nor adverse events were recorded. Moreover, the length of the operative time was not significantly affected with respect to a standard procedure.

Concerning functional outcomes, preliminary reports about potency data after the application of Chitosan Membranes on the NVBs after NS RARP were satisfactory, with a trend towards a faster recovery of erectile function with respect to previous experience [44].

A frequent question on chitosan-based medical products is whether they are able to induce allergic reactions in patients known to have shellfish allergy. To the best of the knowledge, allergic reactions to chitosan medical devices are not known. There have been sporadic reports of cases of allergic reactions to nonmedical products (e.g. dietary supplement, cosmetics) that contain chitosan whereupon in these cases a causal relationship with the ingredient chitosan is not clear.

The chitosan used for the production of the membranes was prepared in multiple controlled processing steps where the starting material was chitin from *Pandalus borealis*, which was processed under defined conditions. Chitin was freed of proteins and minerals by treatments with dilute alkaline and acidic solutions, and then converted to chitosan by hydrolysis for several hours and at high temperatures. These hydrolysis conditions were able to cause a denaturation and destruction of proteins and nucleic acids, so that allergic reactions to such treated chitosan could be excluded even in patients with known shellfish allergy who previously had anaphylactic reactions when in contact with shellfish [45].

The study was not devoid of limitations; it was an observational study with prospective collection of data but no comparative cohort was included. This would have added value to the study but the paper reported the phase II study pre-CE mark achievement.

The best candidates for receiving the membrane still have to be investigated. The effect of such membranes is both neuro-protective and neuro-regenerative. Porpiglia et al. assumed that in patients who underwent bilateral intrafascial NS no loss of neural tissue occurred: these kind of patients would benefit of the eventual neuro-protective property of the chitosan membranes. Conversely, Authors would expect a more consistent contribution in fasting the potency recovery in patients who undergo partial NS techniques (with loss of neural tissue): in this cohort the neuro-regenerative effect of the membranes could be the key point.

For this preliminary experimental study, long-term oncological data are being recorded too, and longer follow-up is required to evaluate future outcomes.

Conclusions

Many improvements are ongoing in the field of the techniques for maximize neuro-regeneration following robot-assisted radical prostatectomy. Results are promising in most of the cases. We sincerely believe that the technology available during the surgery has reached its acme, and the same is for the technique of nerve sparing allowed by the technologies nowadays available. It is in the hands of the above-mentioned experimental techniques of nerve regeneration in the neurovascular bundles the ideal goal to increase the performance of nerve sparing robot-assisted radical prostatectomy in the potency recovery outcomes in, hopefully, a near future.

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31 The Apical Dissection

Walter Artibani and Giovanni Cacciamani

Introduction

Prostate apex dissection during radical prostatectomy (RP) is a critical step in order to assure proper oncologic and functional outcomes. Full knowledge of the surgical anatomy of the prostate apex such as shape variations, attachments to pelvic floor musculature, peri-prostatic fasciae, junction with membranous urethra, neural and vascular anatomy) is a prerequisite to achieve an effective surgical dissection.

Effective anatomic and functional sparing of membranous urethra length has been demonstrated to be an important determinant of postoperative continence recovery [1, 2]; nevertheless, different prostatic apex shapes can make difficult obtaining an adequate urethral length following the surgical procedure.

Anatomic prostate shape and apex variations have been comprehensively described by *Myers et al.*, reporting that the overlap of the prostate on the membranous urethra can be classified as anterior, posterior or both anterior and posterior [3] (Fig. 31.1).

The potential effects of the anatomic variations of the prostate and its surrounding structures performing a RP have been evaluated. It has been reported that variations of the prostate apex shape may significantly affect the continence recovery following RP and that a preoperative evaluation of this anatomical aspect using MRI scan represents a useful pre-operative planning tool and predictor on functional outcomes [4].

The goals of a proper prostate apex dissection are the following: (1) radical removal of prostate apex, without any prostatic tissue left behind, and with negative apical margins; (2) maximal preservation of the membranous urethra both in its length as well as in its anterior, lateral and posterior segments; (3) a nerve-sparing procedure, whenever possible, gently dissecting out from the apex the neurovascular bundles concentrated at 5 and 7 o'clock; and (4) the careful sparing of any accessory/aberrant pudendal artery. An efficient and successful management of the dorsal vascular complex (Santorini plexus) is instrumental to attain perfect vision of the surgical field.

Robot-assisted laparoscopic radical prostatectomy (RARP) represents nowadays a reliable procedure in order to consistently achieve those goals. Actually, RARP has contributed to redescribe details of surgical anatomy of the prostate and surrounding structures as a result of the tenfold magnified tridimensional depiction: some anatomical features were never seen formerly with comparable accuracy [5–9].

A variety of techniques have been described, via intraperitoneal (anterior and posterior

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_31

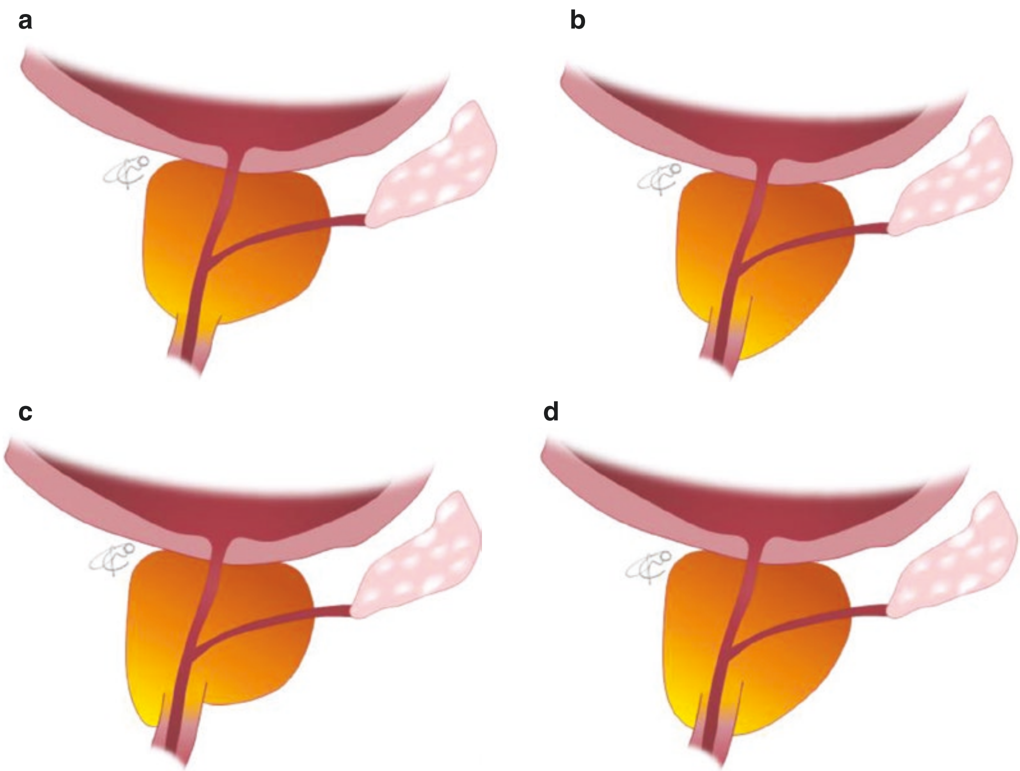

Fig. 31.1 (**a**) Apex without membranous urethra overlapping; (**b**) apex overlapping membranous urethra posteriorly; (**c**) apex overlapping membranous urethra anteriorly; (**d**) prostatic apex overlapping membranous urethra both anteriorly and posteriorly

approach, Rectius sparing procedure) or extraperitoneal approach, using three, four-armed and Single Port da Vinci equipment, with different stepwise sequential approaches (for instance, sewing the dorsal venous complex as a first step, or leaving its section and suture as one of the last steps of the procedure).

We describe here our technique with a specific focus on apical dissection.

Patients selection was based on clinical staging (prostate biopsy outcome: Gleason score, number and location of positive cores; PSA; DRE; almost routinely prostate multiparametric MRI). A nerve-sparing procedure was planned in patients with low/intermediate risk according to D'Amico and no capsular involvement at mMRI. The size of the prostate, the presence of a median lobe and the apex shape were also taken into account [10–16].

Clip-Less RARP

We use routinely the four-armed da Vinci SI™ system (Intuitive Surgical, Sunnyvale, California), via a six-port intraperitoneal approach.

The patient is padded at pressure points, fixed to the table, placed in lithotomy position with steep Trendelenburg (33°). An 18-F Foley catheter is inserted in the bladder.

One bedside assistant trained in laparoscopy assists at the patient's left side and an adjunctive beside assistant on the right side. A paraumbilical 12-mm trocar is used for the robotic camera. Two 8-mm robotic trocars are placed laterally to the rectus muscles halfway from the umbilicus and the pubic bone and halfway between the umbilicus and the anterior superior iliac spine, 9 cm from the camera trocar. A 12-mm AirSeal® trocar is placed two cm left to the anterior superior iliac spine. A 8-mm robotic trocar is placed 2 cm right to the anterior superior iliac spine. A 5-mm trocar port for the suction device is placed 3 cm lateral to the camera port.

We use the following EndoWrist™ robotic instruments: a monopolar curved articulated scissors in the right robotic arm, a Maryland Bipolar Forceps™ in the left robotic arm, a Prograsp™ in the fourth arm, one needle driver. A laparoscopic suction device and one Johann graspers are used by the bedside assistant.

We use a 0° lens throughout the entire routine procedure. In those cases where we perform Rectius sparing we use also 30° down and up lens.

Our procedure is clip-less; we do apply monopolar pinpoint precise punctual short-term (less than 1 s) diathermy (25–30 Watt) using one open branch of the scissors.

The following steps are sequentially performed before apical dissection.

After careful exploration of the abdominal cavity and release of any sigmoid or ileal adhesions, we enter the Retzius by a transverse peritoneal incision side-to-side from the right to the left umbilical ligament, transecting the urachus in the midline and extending the dissection laterally down along the umbilical ligaments until the vas deferens. The bladder is bluntly mobilized downwards, developing adequate space at the prostatic area.

We then carefully remove the adipose tissue delineating the anterior surface of the prostate, the endopelvic fascia and pubo-prostatic ligaments, observing carefully for accessory pudendal arteries (which if present should be preserved whenever possible). The fat tissue is easily detachable from the prostate and the endopelvic fascia, while it is more fixed to the bladder wall: this can help identify the prostatic-vesical junction.

The superficial dorsal vein is coagulated and divided.

We immediately approach the bladder neck without opening the endopelvic fascia or suturing the dorsal vein complex. We outline the prostate-bladder junction by moving the catheter balloon and grasping the anterior bladder wall in the midline. The catheter balloon is then deflated in order to avoid anatomic distortion. We transect the detrusor apron with an inverted V incision, opening the anterior bladder neck from 10 to 2 o'clock.

The catheter tip is attracted out and grasped using the fourth arm Prograsp™; a firm traction is applied internally and externally in order to elevate the prostate and expose the open bladder neck.

The posterior bladder neck lip is explored, checking for median lobe and position of ureteric orifices. The spatial direction of the trigone is variable and can differ based on prostate size and shape: usually it is slightly oblique, but it can appear horizontal due to prostate hypertrophy, or can be deformed by a median lobe; sometimes it is vertical or, in the case of a very small prostate, a caudal indentation can be present, producing an acute caudal angle. The spatial direction of the trigone is important in planning the direction of the posterior transection of the bladder neck and the separation by sharp and blunt dissection of the trigone from the cranial posterior base of the prostate.

The posterior bladder neck and the trigone are dissected away from the prostate, dividing the vesico-prostatic muscle and the fibro-adipose tissue layer laying beneath (often incorrectly described as anterior layer of Denonvilliers' fascia) exposing the vasa and the seminal vesicles.

Posterior bladder neck dissection is a difficult step: the key points to be considered are the thickness of the bladder wall and the direction/conformation of the trigone. The vesico-prostatic muscle is composed of longitudinal muscle fibers going from the outer bladder wall towards the base of the prostate. After dividing transversally this longitudinal muscular tissue, a deeper fibro-adipose layer must be divided in order to see the vasa.

Each vas is dissected carefully and mobilized as much as possible, separated from the vesicle which is simultaneously dissected medially and laterally. The vas is transected and its cranial edge is grasped using the fourth arm Prograsp™ and retracted upwards with a twisting manoeuvre which facilitates the exposition and dissection of the tip of the seminal vesicle. We never spare the seminal vesicle tip. The dissection is done very close to the vesicle's wall in order to spare all the surrounding tissue which is notoriously rich in nervous fibers. The vesiculo-deferential arteries are coagulated (pin-point short-term cautery) and divided.

Both seminal vesicles are grasped and retracted upwards. The space between the prostate and the rectum is developed following a plane anterior to the Denonvilliers' fascia. The midline plane is avascular and usually very easy to dissect bluntly; the plane is developed as lateral as possible taking care not to damage the medial edge of the postero-lateral neurovascular bundle.

We then perform a so called 'high anterior release', incising the prostatic fascia anterolaterally (10 and 2 o'clock position) and detaching the anterolateral tissue surrounding the prostate. We search for contact with the prostate following an intra-fascial or inter-fascial plane. Counter-traction grasping the opposite seminal vesicle using the fourth arm Prograsp™ facilitates this manoeuvre. The dissection goes millimeter per millimeter down towards the apex of the prostate.

We then approach the supero-lateral pedicle of the prostate, precisely cauterizing and transecting small vessels entering the prostate. The correct plane is found and followed alternating between a superior, lateral and medial approach: the posterolateral neurovascular bundles are fully released towards the prostate apex. After intra−/inter-fascial dissection, the preserved tissue appears covered with a whitish 'fascial' thin layer. The didactic distinction between intra-fascial and inter-fascial dissection is not always feasible: there are individual variations of the multilayered peri-prostatic fasciae, and often it is difficult to follow exactly the same plane from the base to the apex of the prostate.

At this point, prostate and seminal vesicles are completely released from the bladder, the vascular pedicles, the neurovascular bundles and the rectum: the only remaining attachments are the dorsal vascular complex, the apex and the membranous urethra.

Therefore, Santorini plexus control and apical dissection are the last steps in our procedure.

Apical Dissection

An adequate cranial traction is achieved grasping the prostate base using the fourth arm Prograsp™.

The two anterolateral incisions of the ventral peri-prostatic fascia are well visible (Fig. 31.1a) A midline side-to-side transversal incision joining their medial edges divides the dorsal vascular complex (Fig. 31.1b). Inconstantly one or two small arteries are encountered and coagulated. The venous bleeding is usually minor, thanks also to the temporary increase, the CO_2 pressure (up to 18 mmHg) controlled hypotension and minimized suction (Fig. 31.2).

The plane between the dorsal vascular complex and the fibro-muscular stroma of the ventral prostate is meticulously dissected anteriorly and anterolaterally. The shape of the prostate is carefully exposed, identifying notches and lips (Fig. 31.3a).

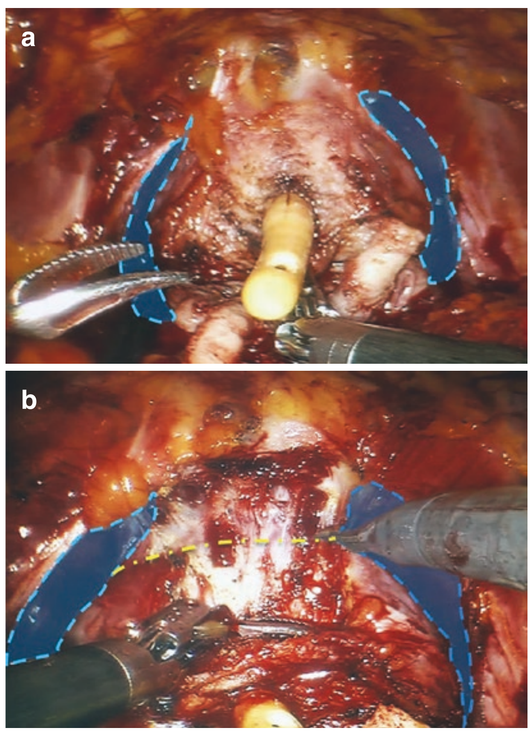

Fig. 31.2 (**a**) The two anterolateral incisions of the ventral peri-prostatic fascia are well visible; (**b**) a midline side-to-side transversal incision joining their medial edges divides the dorsal vascular complex

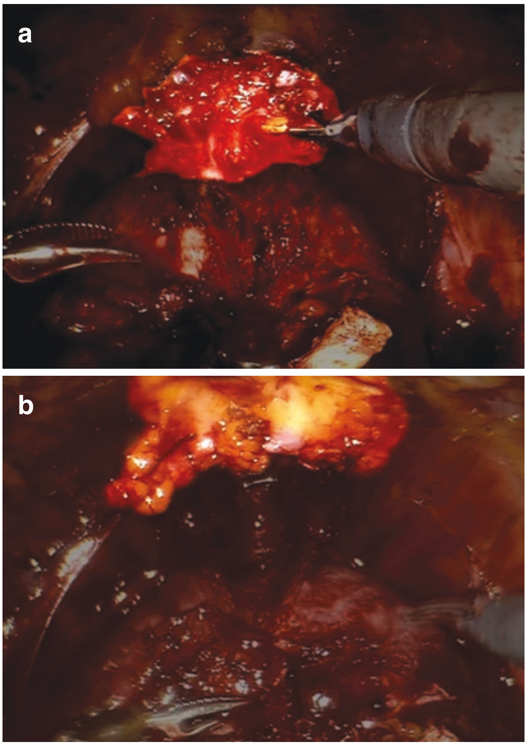

Fig. 31.3 (**a**) Meticulous dissection of the dorsal vascular complex and fibro-muscular stroma of the ventral prostate; (**b**) the selective suture of the dorsal vascular complex allows to release the prostate, attached only to the membranous urethra

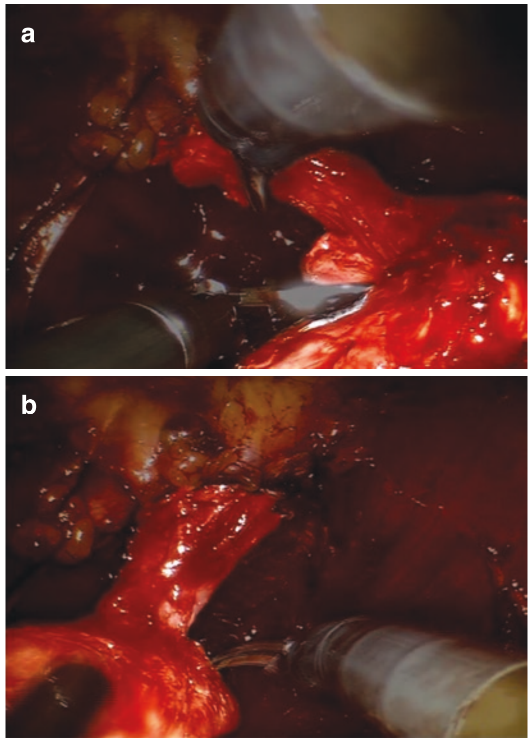

Fig. 31.4 (**a**, **b**) The shape of the prostate is carefully exposed identifying notches and lips; the apex is dissected laterally from the antero-medial components of levator ani

Robotic instruments are now changed, introducing the needle driver on the left arm and replacing the monopolar scissor with the Prograsp™. A horizontal ultraprecise overrunning suture of the dorsal vascular (Fig. 31.3b) complex is accomplished (Polisorb 3-0 needle ½ 22 mm). The manoeuvre is facilitated by cranial traction on the prostate and external upwards pressure on the perineum. The CO_2 pressure is lowered and the absence of any bleeding is tested. The field is cleaned by alternate irrigation and suction.

The robotic instruments are changed again reinserting scissors on the right maintaining the needle driver on the left.

Laterally, the apex is dissected from the antero-medial components of levator ani (levator prostatae, Muller/Walsh ligaments, levator urethrae) (Fig. 31.4a).

Due to the high transverse incision of prostatic fascia in the midline, the puboprostatic ligaments are fully preserved. Therefore, the urethral suspensory mechanism of the urethra to the pubic bone is left intact.

The muscle fibers, covering as a cup the anterior and lateral segment of the apex, are bluntly pushed towards the urethra. The prostatic urethral junction is now delineated anterolaterally, and the pubo-perinealis muscle is smoothly dissected.

A gentle rotation of the prostate on its axis provides a perfect view of the posterolateral and posterior segments of the apex, allowing ultraprecise circumferential dissection (Fig. 31.4b). The posterior attachments to the end of Denonvilliers' fascia are swept out from the prostatic apex. Great attention is applied on avoiding apical fissures or lacerations as well as on respecting all the surrounding structures because at this level the distal neurovascular bundles and nerves to the external urethral sphincter complex are very close and easily damageable.

At this moment, the prostate is almost completely released, attached only to the membranous urethra.

Following the individual apex shape, further 'intra-prostatic' dissection of the membranous urethra is pursued in order to maximize its length and preservation (Fig. 31.5a), without jeopardizing radicality. Initial urethral transection is performed with a catheter inside, which allows a better outline of the border between the urethra and the apex. The anterior/superior wall of the urethra is transected from 2 to 10 o'clock, leaving a safe 1–2-mm margin on the prostate apex: the thick rhabdosphincter is visible and underneath the longitudinal fires of the smooth sphincter. The catheter is now visible (Fig. 31.5b) and is retracted in order to visualize the lumen of the posterior urethral wall: the 'crista urethralis' and 'plicae colliculi' are visible (Fig. 31.5c). The lateral and posterior transection is facilitated by the seven degrees of freedom of the scissors allowing ultraprecise division at a 90° angle (Fig. 31.5d). This is particularly important in some variations of the prostatic apex with posterior apical overlap or with lateral asymmetry. The perfect view of the different texture of urethral and prostatic tissue and the ideal motion capacity of scissors allow a meticulous and effective performance of this delicate manoeuvre, without applying undue traction.

Finally, the retro-urethralis tissue is transected following a cranial horizontal direction in order to preserve the posterior support to the urethra.

The completely released prostate is stored in an endo-bag inserted through the left 12-mm trocar.

The haemostasis is controlled and any bleeder is selectively sutured.

Finally, we perform a modified fascial posterior reconstruction in accordance with the technique described by Rocco et al. together with the subsequent urethro-vesical anastomosis in accordance with the technique described by Van Velthoven using a single 3.0, 16 cm + 16 cm of

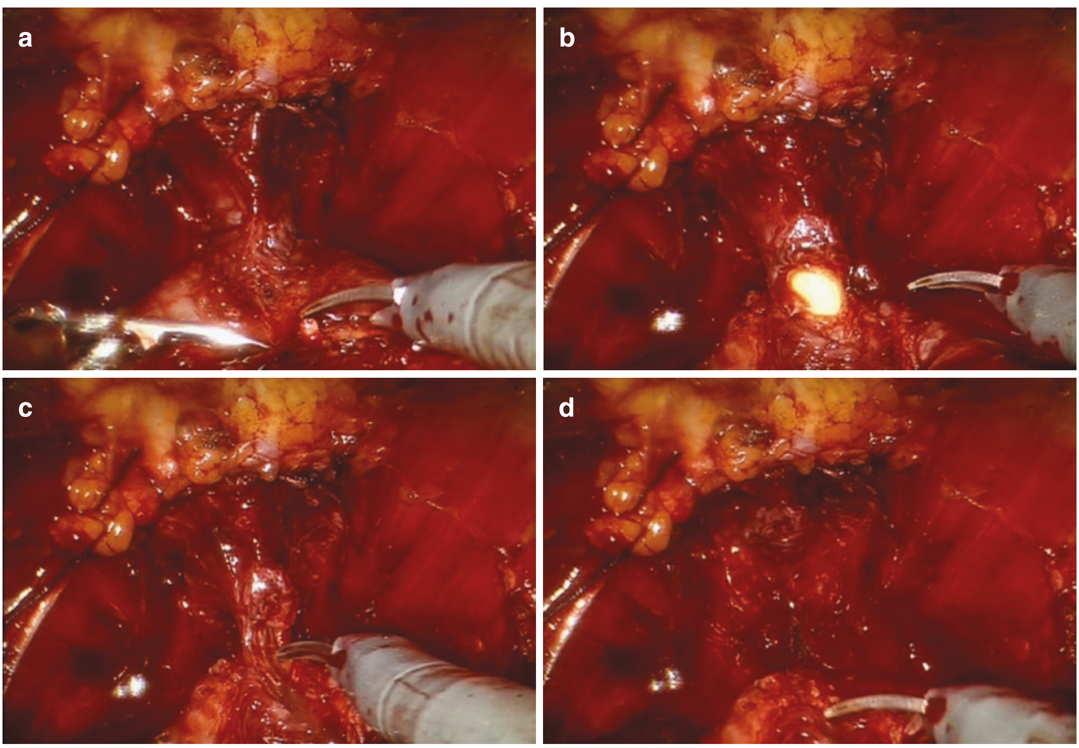

Fig. 31.5 (**a**) Anterior transection of the urethra; (**b**) lateral transection of the urethra; (**c**, **d**) posterior transection of the urethra

length bi-directional barbed suture equipped with 17 mm needles.

The anastomosis starts with three posterior passages per side, which include in adjunct to the urethral and bladder neck walls, on the urethral side the reconstructed fascial support, and on the bladder neck side the edge of vesico-prostatic muscle lying behind the trigone. The passages are meticulous at 5 and 7 o'clock positions preventing as much as possible damage to the neurovascular bundles. The anastomosis is concluded by means of an anterior fascial reconstruction suturing the edge of detrusor apron to the preserved urethra-prostatic ligaments.

The bladder is filled with 150 mL of saline solution in order to verify whether the suture is watertight.

Following the outcome of an institutional prospective randomized control trial (under publication) comparing drain with no-drain police, we don't use routinely any drain.

No heparin is administered if there are no risk factors and lymphadenectomy was not performed.

Early mobilisation (after 6 h) and elastic compression stockings are adopted. The patient is discharged on the third-fourth POD and the catheter is removed on the 12th post op day without cystography.

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Posterior Reconstruction of the Rhabdosphincter

Bernardo Rocco, Angelica A.C. Grasso, Elisa De Lorenzis, Marco Sandri, and Giampaolo Bianchi

Introduction

Urinary incontinence is still one of the major drawbacks following radical prostatectomy. It is considered even more bothersome than erectile dysfunction, even if its incidence is lower. According to the 2015 EAU guidelines mean continence rates at 12 months range from 89 to 100% for patients treated with robot-assisted RP (RARP) to 80–97% for patients treated with retropubic RP [1].

Furthermore, the time for continence recovery remains a major issue, and most of the series consider a definitive evaluation of continence not before 12 months [2, 3].

Stress incontinence is the type of incontinence most frequently observed after radical prostatectomy, even if a considerable number of patients present a mixed urge and stress syndrome [2, 4].

Only a limited number of patients have been found to suffer from urge incontinence alone [3, 5].

The anatomical basis of stress incontinence after radical prostatectomy is not completely clarified even if many authors agree that a sphincter deficiency may be considered one of the most relevant causes of postoperative incontinence.

In 2006, based on accurate anatomical studies, our group described a technical modification of the original Walsh technique focused on faster continence recovery: the posterior reconstruction of the rhabdosphincter [6].

Anatomo-Physiological Background and Surgical Concept

The sphincter is shaped like a horseshoe and surrounds about two-thirds of the urethra, anteriorly and laterally. The sphincter muscle fibres, therefore, spread over both the anterior face and the sides of the prostate. On the dorsal side, according to Myers, Oelrich, Strasser [7–9], there is little or no muscular component, it being made up of connective tissue supporting the medial fibrous raphe (Fig. 32.1).

Particularly, the caudal part of the sphincter appears with greater amount of muscular fibres in the anterior lateral aspects, whereas posteriorly it seems markedly thinner or absent. In our studies, few striated muscular fibres seem

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_32

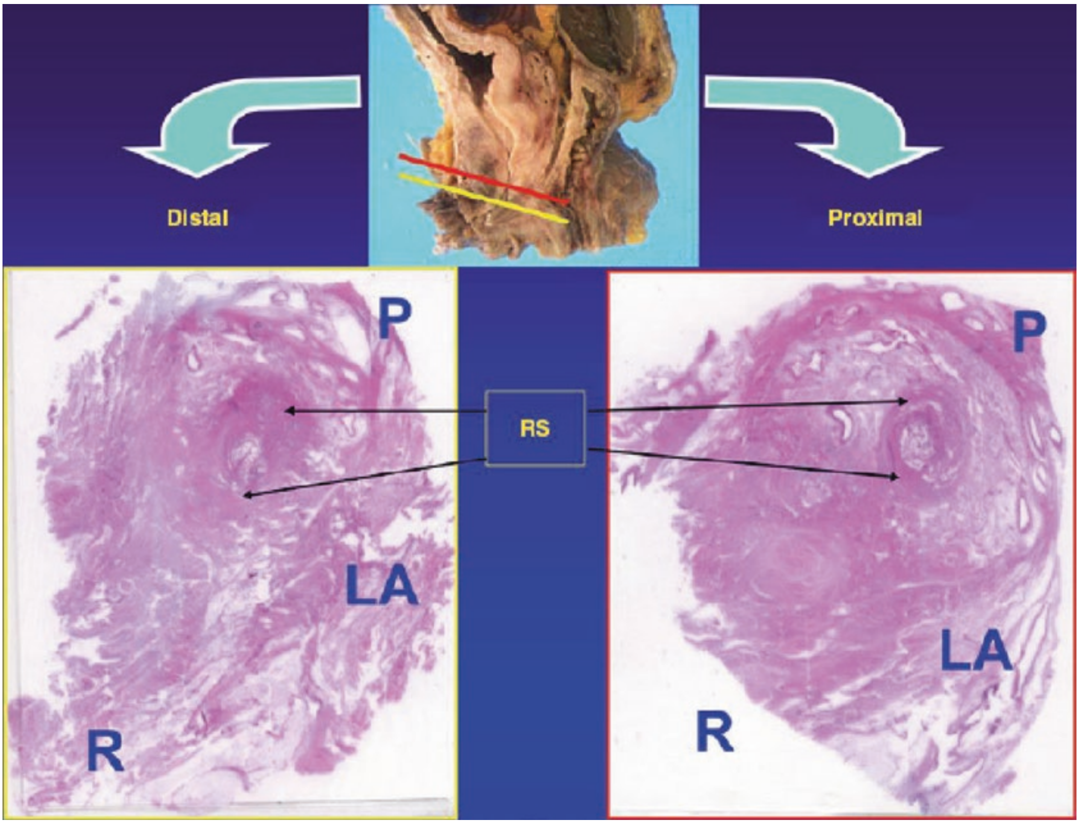

Fig. 32.1 Anatomical and pathological studies showing the relationship between the rhabdosphincter (*RS*), the prostate (*P*), the levator ani (*LA*) and the recturm (*R*)

present in the posterior portion of the sphincter as well [6].

Burnett and Mostwin [10] claim that the striated sphincter together with the pubo-urethral ligaments have a tonic effect, compressing the urethro-prostatic complex towards the pubis during the period of urine collection in the bladder and releasing the complex towards the perineum during micturition.

According to Lowe [11], the action of the sphincter involves the contraction of the horseshoe-shaped fibres ventrodorsally so that the anterior face of the urethra comes against the posterior face; the posterior wall of the urethra is set on a strong dorsal support plane, the medial-posterior raphe inserted 'hanging' in the aponeurosis of Denonvilliers cranially and in the central tendon of the perineum caudally: this structure which forms a solid posterior support plane of paramount importance for the action of the rhabdosphincter (Fig. 32.2).

Denonvilliers' fascia, the prostate dorsal aspect and the posterior median raphe with the connected rhabdosphincter dorsal wall form a unique musculofascial plate extending from the peritoneum of the pouch of Douglas to the perineal membrane and the central tendon of the perineum. The musculofascial plate is an important support structure in the pelvis that appears to serve as a fixation point for the muscle fibres of the rhabdosphincter [7]. The musculofascial plate is a dynamic suspensory system for

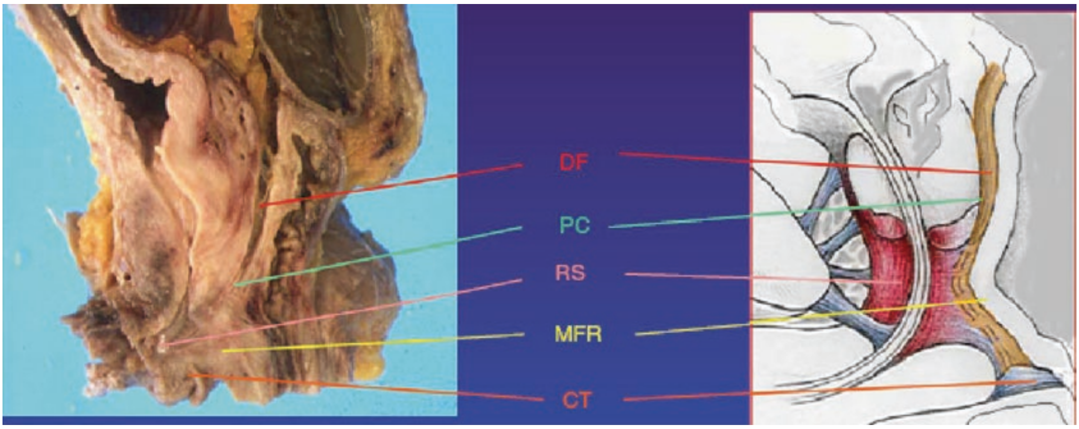

Fig. 32.2 Anatomy and function of the rhabdosphincter (*RS*). Median fibrous raphe (*MFR*) is the fulcrum of the contraction of anterior walls of RS. The posterior wall of RS and the median fibrous raphe are in line with: Denonvilliers fascia (*DF*), posterior aspect of the prostatic capsule (*PC*), cranially, and central tendon (*CT*) of perineum, caudally. These structures constitute a fibrous septum extending from peritoneum to central tendon providing support to the static system of the pelvis (Burnett and Mostwin [11] and Rocco et al. [17])

the prostatomembranous urethra. The rhabdosphincter has the shape of a non-coaxial cylinder wrapping the urethra in craniocaudal sense. This description supercedes the idea of a mainly horizontal structure as previously described [8, 9].

As a result of the resection of the cranial end of the striated sphincter and the urethra, at the moment of the apical dissection, the urethrosphincteric complex which has lost its cranial anchorage, tends to retract elastically in a caudal direction due to the action of the longitudinal muscular fibres of the urethral wall, thus causing the anatomical shortening of the complex itself: it has been commonly observed that, after removal of the prostate gland, to make it easier to trace the urethra and construct the urethro-vesical anastomosis, it is necessary to push back the perineum with a swab to find the urethral stump.

The degree of shortening of the urethrosphincteric complex is not equal if the anterolateral and posterolateral faces of the complex are considered: ventrally, the complex is fairly firmly attached to the pubis by the anterior, middle and posterior pubo-urethral (puboprostatic) ligaments which support the complex for its full craniocaudal length; many authors affirm that the conservation of the posterior pubo-urethral or puboprostatic ligaments during apical dissection improves the state of post-operative continence [12].

Dorsally, the complex is 'hooked on' like an elastic band at its cranial extremity by means of the connexion with the prostrate and with the aponeurosis of Denonvilliers: it tends, therefore, to slide towards the perineum due to the retraction of the smooth longitudinal fibres. The extent of the caudal slipping of the urethro-sphincteric complex is probably linked to the method of preparation and level of incision of the urethroprostatic fascia on which, on each side, are the insertions of the lateral fibrous muscle ramifications of the rhabdosphincter.

The overall effect on the male pelvis of the removal of the prostato-vesicular block, with extirpation of the urethro-prostatic fascia reflexion and detachment of the medial fibrous raphe from the aponeurosis of Denonvilliers, is represented by the postero-caudal prolapse of the perineal membrane and the caudal sliding and anatomical shortening of the urethro-sphincteric complex, especially on the dorsal side.

In summary, the effects of prostate removal are the following (Fig. 32.3):

1. Posterior raphe break: loss of the posterior support for an effective U-S contraction
2. Urethro-sphincteric retraction and shortening
3. Perineal prolapse and distal sliding of U-S-complex

To overcome the effects of prostate removal, we designed a new surgical technique aimed to (Fig. 32.4):

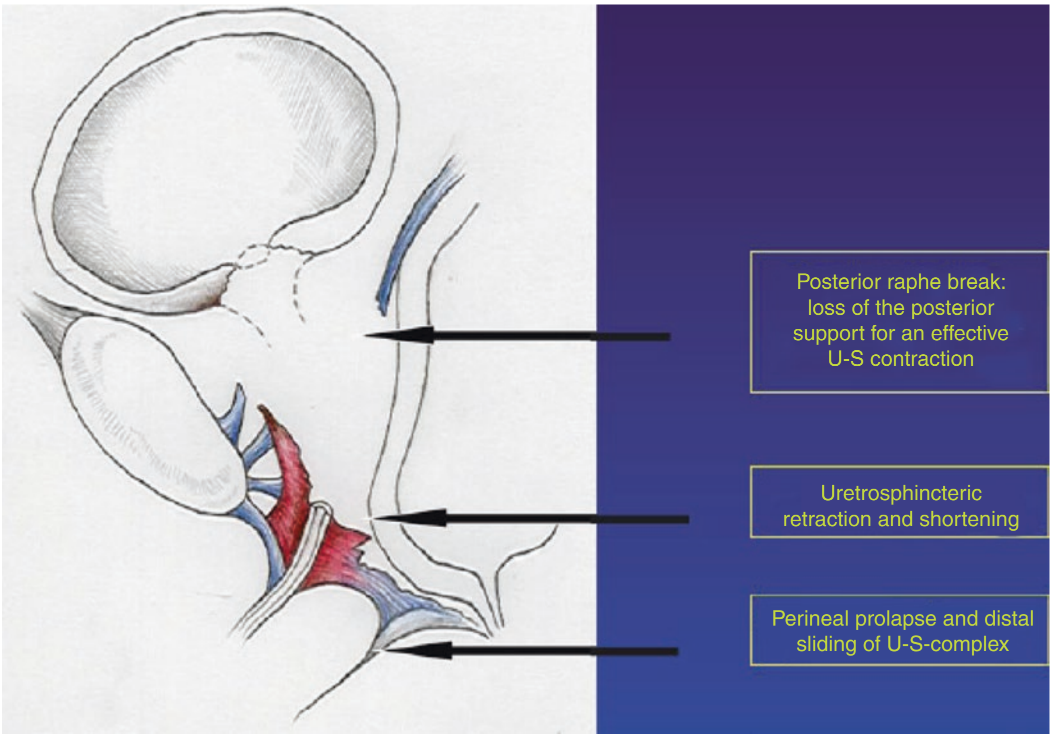

Fig. 32.3 Consequences of the removal of the prostate on the static system of the pelvis

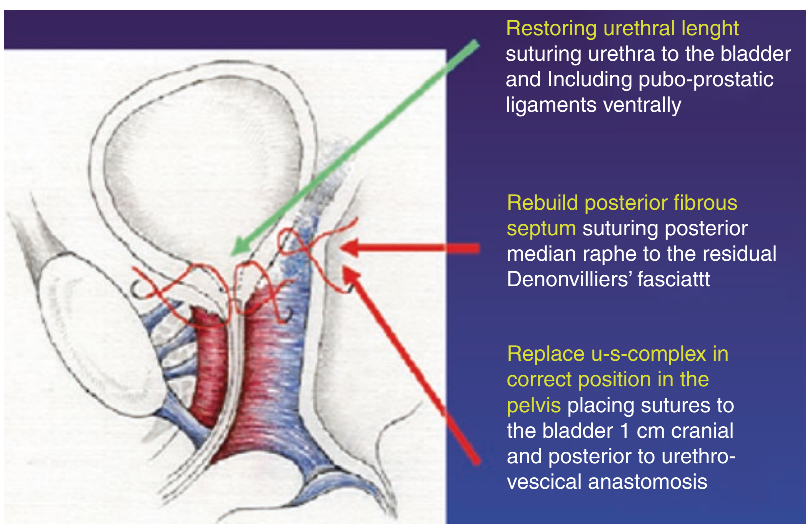

Fig. 32.4 Aims and steps of the present technique

- Restore urethral length, suturing the urethra to the bladder and including puboprostatic ligaments ventrally
- Rebuild posterior fibrous septum suturing posterior median raphe to the residual Denonvilliers' fascia
- Replace U-S-complex in correct position in the pelvis placing sutures to the bladder 1 cm cranial and posterior to urethro-vesical anastomosis

Description of the Original Technique of Posterior Reconstruction and Its Development

The original technique was published in 2006, and it was presented as a modification of the radical retropubic prostatectomy, with two simple steps:

1. Before proceeding to vesicourethral anastomosis, the posterior median raphe is fixed to the residual Denonvilliers' fascia using two previously placed marking sutures. By doing this, the posterior wall of the sphincter is elongated cranially; the urethral circumference is not involved by these sutures.
2. To suspend the urethral sphincteric complex from the bladder, the posterior median raphe joined to Denonvilliers' fascia is now attached to the posterior bladder wall with two sutures applied about 1–2 cm cranial and dorsal to the new bladder neck. Thus, the dorsal aspect of the bladder is used as the new cranial insertion of the sphincter and posterior median raphe, serving as an anchor for sphincter fixation (Fig. 32.5).

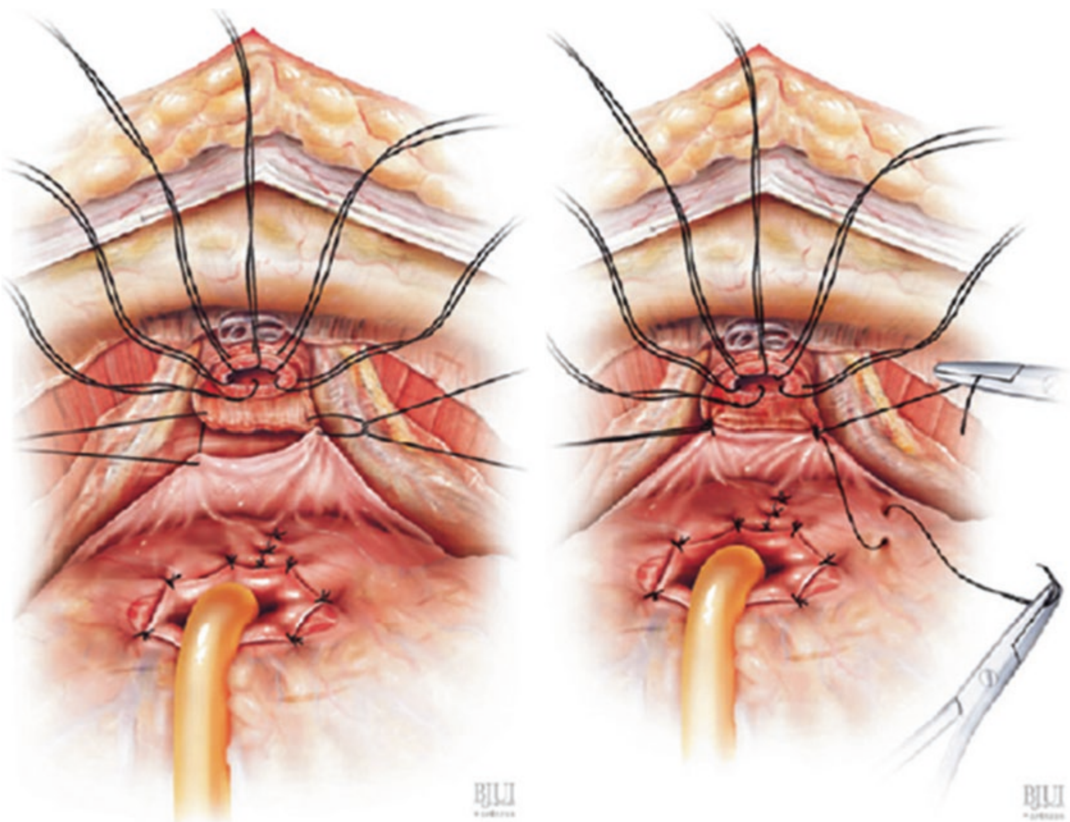

Fig. 32.5 The posterior reconstruction technique. First the remnant of the Denonvilliers' fascia is sutured to the urethra, and to bladder, about 2 cm below the bladder neck

Subsequently, the new bladder neck is anastomosed to the urethra with six to eight polyglactin 3-0 sutures. The anterior sutures include the puboprostatic ligaments, and the posterior sutures join the urethra to the new bladder neck without involving the posterior median raphe.

In 2007, the technical modification for the laparoscopic approach was presented with the cooperation of Dr. Gaboardi: the remnant of the Denonvilliers' fascia was joined to the posterior portion of the rhabdosphincter and immediately tightened with two separate stitches. A further step was done subsequently anchoring the new posterior plane 1–2 cm dorsally and cranially to the bladder neck with the previously passed sutures. The anastomosis was then performed with six separate stitches [13].

In 2008, Coughlin and Patel presented a modification of the laparoscopic technique for the robotic setting: two running sutures tightened together by the tail instead of two separate sutures; the first suture was used to join Denonvilliers' remnant with the posterior part or the rhabdosphincter, whereas the second was used to join the new plane to the usual position 1–2 cm cranially to the bladder neck. A subsequent modified van Velthoven anastomosis was performed [14].

Coelho and Patel published a further modification of this technique subsequently in 2010. In fact, even if the double running suture was useful to perform a more robust approximation of the structures involved in the reconstruction, the drawback was that most of the time the second layer was responsible for the creation of a 'step' between bladder neck and urethra, with a somewhat odd approximation and difficult anastomosis.

They modified the second layer with a suture that included posterior bladder neck and posterior urethra. Such reconstruction, allowed for a more even approximation of the structures, allowing for a much easier and robust van Velthoven anastomosis [15] (Fig. 32.6).

Further modifications have been described, conceptually based on the Rocco principle, with controversial results.

Results

Since its description, in 2006, the technique of posterior reconstruction has been studied and modified by several authors; Table 32.1 summarizes the most relevant studies.

A recent meta-analysis published by our group [34] showed the outcomes of urinary continence in the studies included in the table, at 3–7, 30, 45–75 90, 180 days and 1 year after removal of urinary catheter in patients undergoing RP (ORP, LRP or RARP) with or without posterior reconstruction of the rhabdosphincter.

Of the 21 papers considered in the meta-analysis, five studies did not show any significant advantage in terms of postoperative urinary continence secondary to the PR of the sphincteric complex.

However, most publications showed, although with different levels of evidence, a significant advantage associated with the PR of the sphincter for postoperative urinary continence at different time intervals.

The combined analysis of all studies, regardless of the surgical approach, showed an overall statistically significant advantage in the rate of postoperative urinary continence in favour of the application of the technique of PR at 3–7 days after catheter removal (RR 1.90, 95% CI 1:25–2:90; $P = 0.003$), at 30 days after catheter removal (RR 1.77, 95% CI).

1.43–2.20; $P < 0.001$) and at 90 days after catheter removal (RR 1.32, 95% CI 1.10–1.59; $P = 0.003$). A smaller but still significant advantage in terms of urinary continence associated with PR at 180 days after catheter removal emerged (RR 1.13; 95% CI 1.02–1.26; $P = 0.025$).

Considering peri-anastomotic urinary leakage: a statistically significant advantage on the reduction of the risk at postoperative cystogram was observed in the group of patients treated with PR compared with the group of patients not undergoing PR.

As for the incidence of positive margins, the overall meta-analysis of data in the various studies showed a rate of PSM comparable in the group of patients undergoing posterior reconstruction and in the group of patients undergoing standard RP [34].

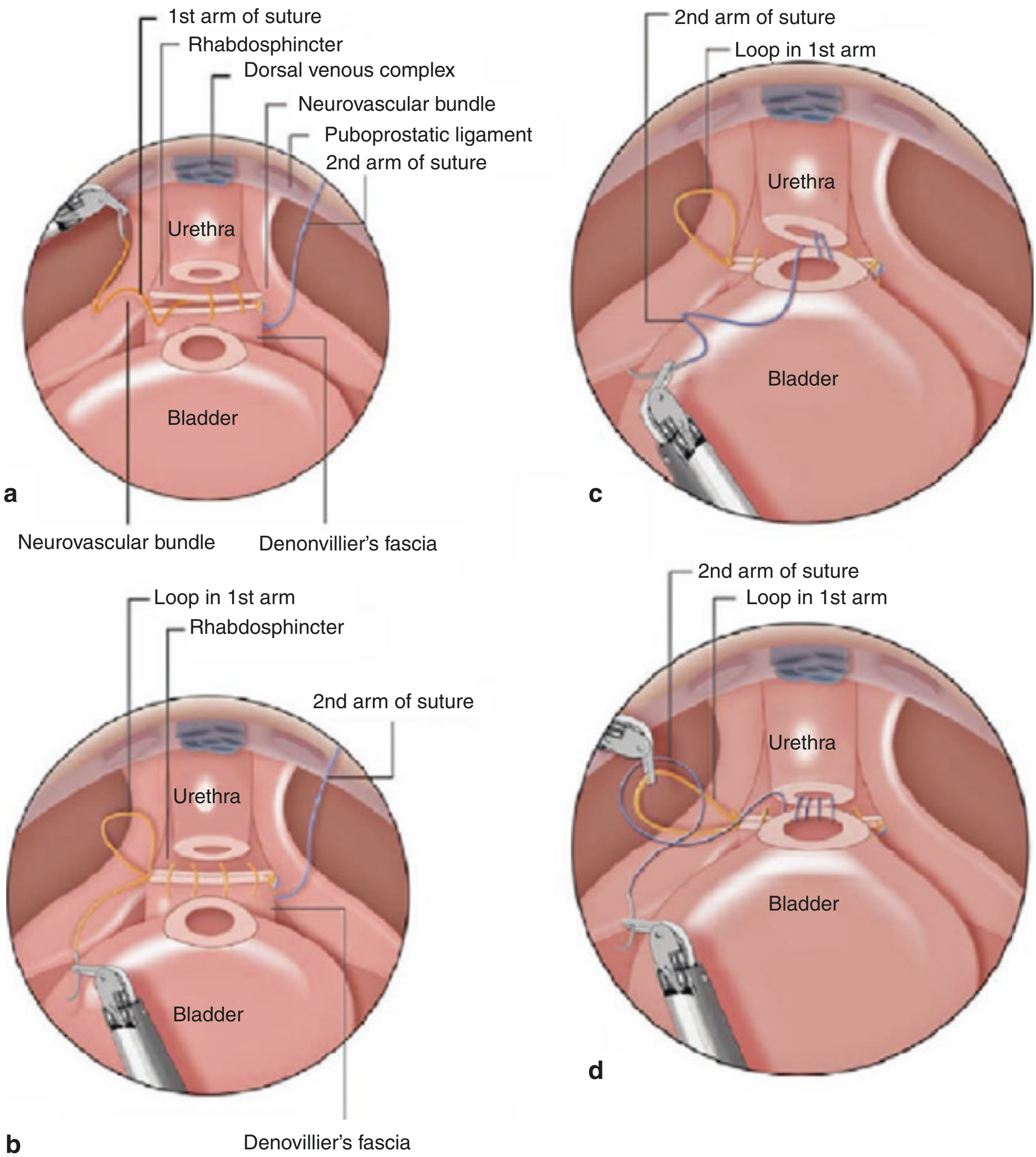

Fig. 32.6 (**a**) First layer of posterior reconstruction. (**b**) The free edge of the remaining Denonvillier's fascia is approximated to the posterior aspect of the rhabdosphincter. (**c**) Second layer of posterior reconstruction. (**d**) The posterior lip of the bladder neck and vesicoprostatic muscle are sutured to the posterior urethral edge

Table 32.1 Studies comparing cohorts of patients who underwent RP with or without posterior reconstruction of the rhabdosphincter, urinary continence results at 3–7 days, 30 days, 45–75 days, 3 months, 6 months and one year after removal of urinary catheter

Authors	Study design	Surgical approach	No. of patients subjected or not of posterior reconstruction		Continence definition	Method used to evaluate the postoperative continence recovery	Continence recovery 3–7 days after catheter removal		Continence recovery 30 days after catheter removal		Continence recovery 45–75 days after catheter removal		Continence recovery 90 days after catheter removal		Continence recovery 180 days after catheter removal		Continence recovery 1 year after catheter removal	
			PR	No PR			PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR
Rocco et al. [6]	Retrospective	ORP	161	50	0–1 pad per day	ICIQ– Short Form phone interview	72.0%	14.0%	78.8%	30.0%	–		86.3%	46.0%	–		96.0%	90.0%
							(p < 0.001)		*(p < 0.001)*				*(p < 0.001)*				*(p = 0.59)*	
Rocco et al. [16]	Retrospective	ORP	250	50	0–1 pad per day	Medical Examination, Pad test, ICIQ questionnaire – Short Form	62.4%	14.0%	74.0%	30.0%	–		85.2%	46.0%	–		94.0%	90.0%
							(p < 0.001)		*(p < 0.001)*				*(p < 0.001)*				*(p = 0.59)*	
Rocco et al. [13]	Prospective	LRP	31	31	0–1 pad per day	External interviewer	74.2%	25%	83.8%	32.3%	–		92.3%	76.9%	–		–	
							(p = 0.0004)		*(p = 0.0001)*				*(p = 0.25)*					
Tewari et al. [17]	Retrospective	RARP	182	214	0–1 pad per day	External interviewer	38.4%	13.5%	82.5%	35.2%	–		91.3%	50.2%	97.1%	62%	–	
							(p < 0.01)		*(p < 0.01)*				*(p < 0.01)*		*(p < 0.01)*			
Menon et al. [18]	Prospective-randomized	RARP	59	57	0–1 pad per day, leakage ≤30 gr per day	–	1°gpo: 34% 26% 2°gpo: 46% 49% 7°gpo: 54% 51% *(p > 0.1)*		80% 74% *(p > 0.1)*		–		–		–		–	
Nguyen et al. [19]	Retrospective	LRP e RARP	32	30	0–1 pad per day	Phone interview/ Questionnaire about the n° of pad used	34%	3%	56%	17%	–		–		–		–	
							(p = 0.007)		*(p = 0.006)*									
Krane et al. [20]	Retrospective	RARP	34	37	0–1 pad per day	Medical Examination	–		–		85.0% 86.0% *(p = 1)*		–		–		–	
Kim et al. [21]	Retrospective	RARP	25	25	0 pad per day	EPIC Questionnaire	24% 36% *(p = 0.54)*		72% 68% *(p = 1)*		–		84% 76% *(p = 0.73)*		96% 96% (p = 1)		–	

Joshi et al. [22]	Prospective	RARP	53	54	0 pad per day, no leakage	EORTC questionnaire, Quality of Life-Core 30, Prostate Cancer Module	–		–		–		75% 69% ($p = 0.391$)		51% 43% ($p = 0.686$)		–	
Coelho et al. [15]	Prospective	RARP	473	330	0 pad per day	EPIC questionnaire	28.7% 22.7% ($p = 0.045$)		51.6% 42.7% ($p = 0.016$)		–		91.1% 91.8% ($p = 0.908$)		97% 96.3% ($p = 0.741$)		–	
Sutherland et al. [23]	Prospective-randomized	RARP	47	47	0–1 pad per day	EPIC questionnaire: pads weight in 24 h	–		($p = 0.3$)		–		($p = 0.14$)		–		–	
Brien et al. [24]	Retrospective	RARP	31	58	Pre- and post-operative RAND-UCLA score	RAND-UCLA QoL and AUA symptom scores	–		–		–		64% 50% ($p = 0.05$)		69% 62% ($p = 0.27$)		–	
Atug et al. [25]	Retrospective	RARP	125	120	0 pad per day	–	71.2%	23.3%	72.8%	49.1%	–		80.8%	76.6%	84.8%	80.8%	91.2%	88.3%
							($p < 0.0001$)		($p = 0.0002$)				($p = 0.518$)		($p = 0.5$)		($p = 0.5$)	
Hurtes et al. [26]	Prospective-randomized	RARP	39	33	0 pad per day, no leakage	UCLA Prostate Cancer Index scoring system	–		26.5%	7.1%	–		45.2%	15.4%	65.4%	57.9%	–	
									($p = 0.047$)				($p = 0.016$)		($p = 0.62$)			
Sano et al. [27]	Prospective	LRP	25	23	0–1 pad per day	–	–		44%	0%	–		60%	30.4%	72%	52.2%	88%	56.5%
									($p = 0.0003$)				($p = 0.049$)		($p = 0.23$)		($p = 0.022$)	
Simone et al. [28]	Retrospective	LRP	155	125	0 pad per day	EPIC questionnaire	–		($p = 0.04$)		–		86.5% 73.6% ($p = 0.039$)		92.3% 80.8% ($p = 0.034$)		–	
Gondo et al. [29]	Retrospective	RARP	160	39	0–1 pad per day	Medical Examination	48.7%	15.4%	75% 20.5% ($p = 0.0003$)		86.9%	53.9%	91.2%	71.8%	95.6%	79.5%	96.3%	87.2%
You et al. [30]	Retrospective	RARP	28	31	0–1 pad per day	Questionnaire ICIQ	–		57.2% 35.5% ($p < 0.001$)		–		89.2% 71% ($p < 0.092$)		92.8% 87.5% ($p = 0.1$)		94.5% 92.1% ($p = 0.15$)	
Anceschi et al. [31]	Retrospective	LRP	52	54	0 pad per day, no leakage	Questioner ICIQ e SF36	19% 22%		69% 37%		–		86%	54%	67%	70%	73%	72%
							($p = 0.657$)		($p = 0.028$)				($p = 0.006$)		($p > 0.25$)		($p > 0.82$)	
Ito et al. [32]	Retrospective	LRP	19	13	0–1 pad per day	UCLA Prostate Cancer Index scoring system	–		($p = 0.01$)		–		($p = 0.002$)		($p = 0.0048$)		94.7% 76.9% ($p = 0.48$)	
Daouacher et al. [33]	Prospective	LRP	99	99	0–1 pad per day	Questionnaire IPSS			33%	16%	–		66%	44%	81%	67%	92%	80%
							–		($p = 0.007$)				($p = 0.002$)		($p = 0.034$)		($p = 0.024$)	

Comments

The assumptions upon which the PRORS technique is based have been accurately anatomically investigated; the shape of the sphincter and its insertion, the structures involved in the posterior backboard were previously thoroughly analyzed by relevant authors, such as Myers, Oelrich, Strasser, Burnett and Mostwin [7–10]. The key principle of the reconstruction is to reattach the Denonvilliers' fascia and the posterior part of the rhabdosphincter, originally connected through the prostatic fascia. Second, to reposition the urethrosphincteric complex in the right anatomical position to allow a correct contraction mechanism.

The technique has been described in an open surgical environment with significant benefit on early continence recovery. Nevertheless, the impact on earlier continence recovery of PRORS techniques have been progressively more evident as the surgical approach to prostate cancer moved from the open setting to the robotic approach through laparoscopy. The better preservation of the periprostatic tissue and fasciae due to a more conservative surgical approach can be a partial explanation.

Individual modifications can omit some of the basic clues of the technique: for example, Menon et al. only performed the first step of reconstruction originally described [18]. After reconstructing the Denonvillier's fascia and the posterior wall of the striated sphincter, it is mandatory to suture the reconstructed sphincter to the posterior bladder wall or to the bladder neck. This is really important because it increases the functional length of the posterior urethra and stabilizes the sphincteric complex in its anatomic position in the pelvic floor. In the same way, in the study published by Joshi et al. [22], only the first step of the reconstruction was performed, suturing the distal cut of the Denonvillier's fascia and the median fibrous raphe to the rhabdosphincter. At the present time, the technique that we consider more appropriate for the robotic setting and that we currently perform is the one described by Coelho et al. on European urology.

If there are controversial results on PRORS impact in terms of continence recovery, both the studies by Menon and Coelho dealing with this topic agree on a significant reduction in terms of anastomotic leakage and time to catheter removal. A further advantage, according to some authors is the possibility of performing a completely tension free anastomosis with a double posterior layer. Finally, at least to our knowledge, no specific complication related this technique has been published so far.

Gautam et al. tried to review all the reconstructive techniques and published outcomes of PRR, concluding that further research and randomised trials were needed to draw firm conclusions on the efficacy of the various techniques [35].

Conclusion

PRORS is a surgical modification of the original Walsh technique that has been suggested to reduce time to continence recovery. Over the years, it has been modified to be adapted to different surgical techniques due to the minimal invasive approach, laparoscopy first and then robotics. Notwithstanding many articles and different studies performed by several authors on this technique, conclusive results cannot be drawn, because of methodological flaws and lack of surgical standardization.

Beyond continence recovery, other possible advantages are tension free anastomosis, reduced anastomotic leakage and absence of reported complications.

Further high-quality, unbiased studies are required to allow firm conclusions to be drawn. To better assess the effectiveness of the PR in facilitating an earlier recovery of postoperative urinary continence, a multicentre randomized controlled trial is ongoing. (ClinicalTrials.gov Identifier: NCT01809522).

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33 The Urethrovesical Anastomosis

Ahmed Ghazi and Jean V. Joseph

Introduction

The urethrovesical anastomosis (UVA) is one of the most critical and technically demanding steps during a radical prostatectomy. The adequacy of the anastomosis can impact the patient's recovery in both short and long terms. An optimal anastomotic closure involves creating a watertight, tension-free anastomosis with mucosal apposition and correct realignment of the bladder and urethra, without compromising the integrity of the external sphincter [1]. Before the advent of minimal invasive laparoscopic surgery, the UVA was performed with difficulty as a result of suboptimal vision of a retracted urethral stump under the pubic symphysis, in addition to unfavorable ergonomics. This was generally accomplished by placing four to eight interrupted sutures between the bladder neck and urethra, which were subsequently tied after all sutures were positioned [2].

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The Urethrovesical Anastomosis in the Era of Laparoscopic Surgery

The introduction of laparoscopy in the early 1990s allowed the surgeon to perform the anastomosis under direct vision through the laparoscope, unlike open surgery where the surgeon could not view the anastomosis once the bladder was brought down to the urethra. However, the skills required for intracorporeal suturing rendered the anastomosis a very tedious task during laparoscopy. The initial publication of laparoscopic radical prostatectomy (LRP) by Schuessler et al. in 1992 stated that the anastomosis required the greatest amount of time, taking twice as long as the removal of the prostate [3]. This was largely responsible for the abandonment of the technique. Nearly 7 years later, Vallancien et al. resurrected LRP reporting reasonable outcomes estimating their learning curve to be at 50–60 cases [4]. They used 6–8 polyglactin 3–0 interrupted sutures tied intracorporeally over an 18Fr Foley catheter. In their view, the UVA was difficult for a number of reasons. These included suture placement in both the bladder neck and the urethra and the need for multiple intracorporeal knots. Of concern was that the anastomosis occurred late in the procedure when surgeon fatigue was more problematic. It was apparent that for both ergonomic reasons and exceedingly time-consuming endo-

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_33

scopic knot tying, the techniques used in open surgery were not optimal for laparoscopic surgery. The difficulties encountered in completing the UVA during laparoscopic surgery prompted the innovation of other techniques with minimal intracorporeal knot tying. Hoznek et al. [5] described a running-suture technique during LRP (Figs. 33.1 and 33.2), which incorporated

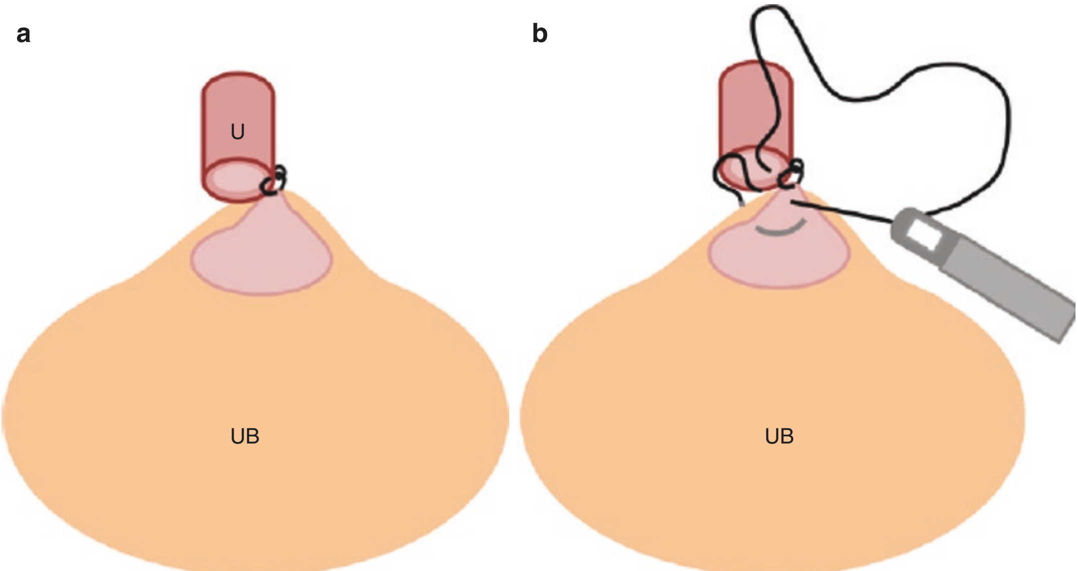

Fig. 33.1 Vesicourethral anastomosis with posterior and anterior hemi-circumferential running suture. (**a**) Starter knot at 3-o'clock position, (**b**) start of posterior running suture (bladder outside in and urethra inside out) at 4 o'clock. *UB* urinary bladder, *U* urethra

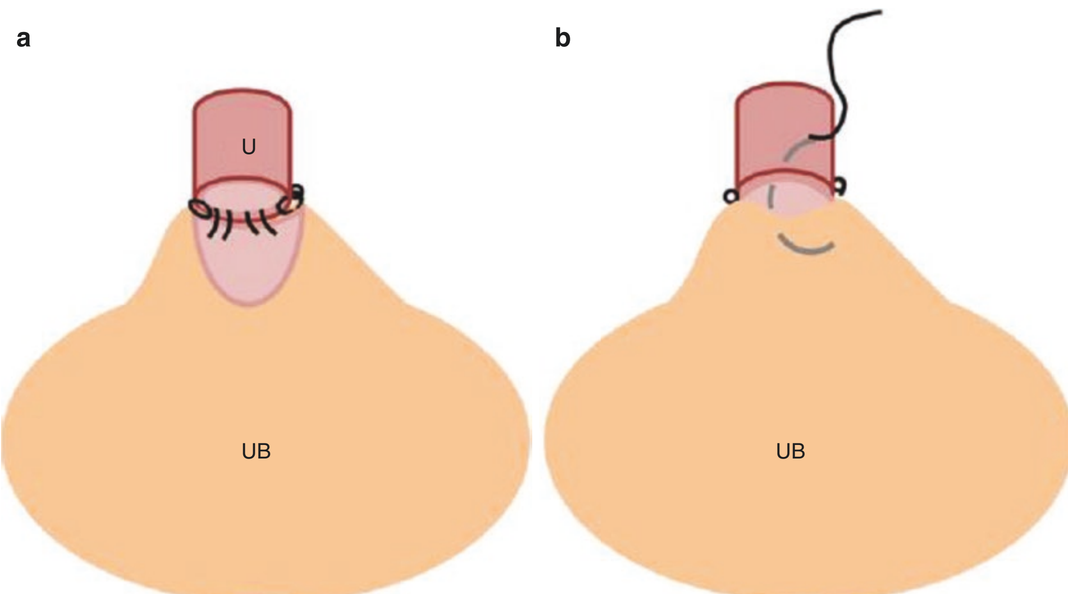

Fig. 33.2 Vesicourethral anastomosis with posterior and anterior hemi-circumferential running suture. (**a**) Extramural completion of posterior suture line, (**b**) placement of second running suture. *UB* urinary bladder, *U* urethra

two hemicircle sutures with three intracorporeal knots. The bladder neck was approximated to the urethra at the 3:00-o'clock position with an initial suture, followed by two running sutures for the posterior and anterior wall, respectively, each ending with an intracorporeal knot.

The introduction of the running, double-armed, single-knot suture technique revolutionized the UVA during radical prostatectomy. Van Velthoven et al. [6] described using two 6-in. monofilament sutures of polyglycolic acid (one dyed and one undyed for identification purposes) tied together prepared extracorporeally (Fig. 33.3). Both sutures are passed through the posterior bladder neck (outside in, at the 5:30–6:30-o'clock positions) and subsequently placed in their corresponding position in the urethra. One end of the suture is continued in a clockwise direction and the other in the opposite direction in a continuous manner. As the posterior aspect of the anastomosis is completed on each side, the surgeon gently pulls on both sutures parachuting the posterior bladder neck to the posterior urethra. The sutures are continued until both ends meet and are tied together at the 12-o'clock position. This solitary intracorporeal knot, like the initial knot, rested on the exterior of the bladder. This technique offered a watertight, reproducible, and efficient anastomosis that was less time-consuming. Although it was rapidly adopted by other laparoscopic surgeons, the novice laparoscopic urologist standing at the patient's bedside still struggled with the difficulty of negotiating complex angles using non-articulating instruments.

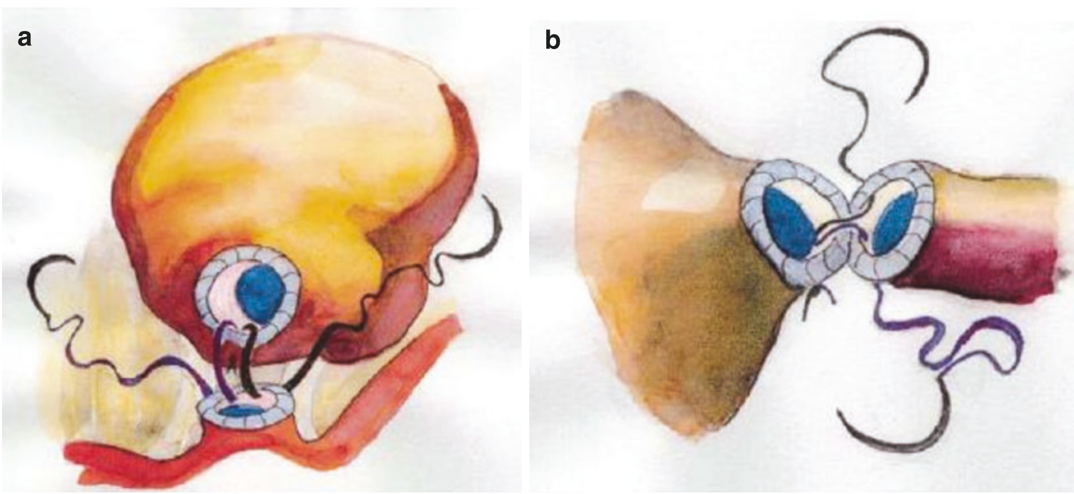

Fig. 33.3 Technique for performing the running single-knot anastomosis. (**a**) The two sutures have been passed outside in on the bladder and inside out on the urethra at the 5:30 and 6:30-o'clock position, respectively; the extracorporeal knot joining both sutures together sit at the 6:00-o'clock position. (**b**) Transverse view highlighting the single knot at the 6:00-o'clock position. (**c**) One suture is run clockwise, and the opposite suture is run counter-clockwise to the 9:00 and 3:00-o'clock positions, respectively. (**d**) A transition suture taken in the background suture, such that the suture now runs outside in on the urethra and inside out on the bladder. A similar transition stitch will be done with the suture in the foreground. At this point, the catheter can be placed in the bladder. (**e**) As a result of the transition stitches, the single intracorporeal knot resides on the outside of the bladder at the 12:00-o'clock position. (**f**) Side view showing the two knots, one at the 6:00-o'clock and one at the 12:00-o'clock position, both lying on the extravesical surface (Printed with permission from [6])

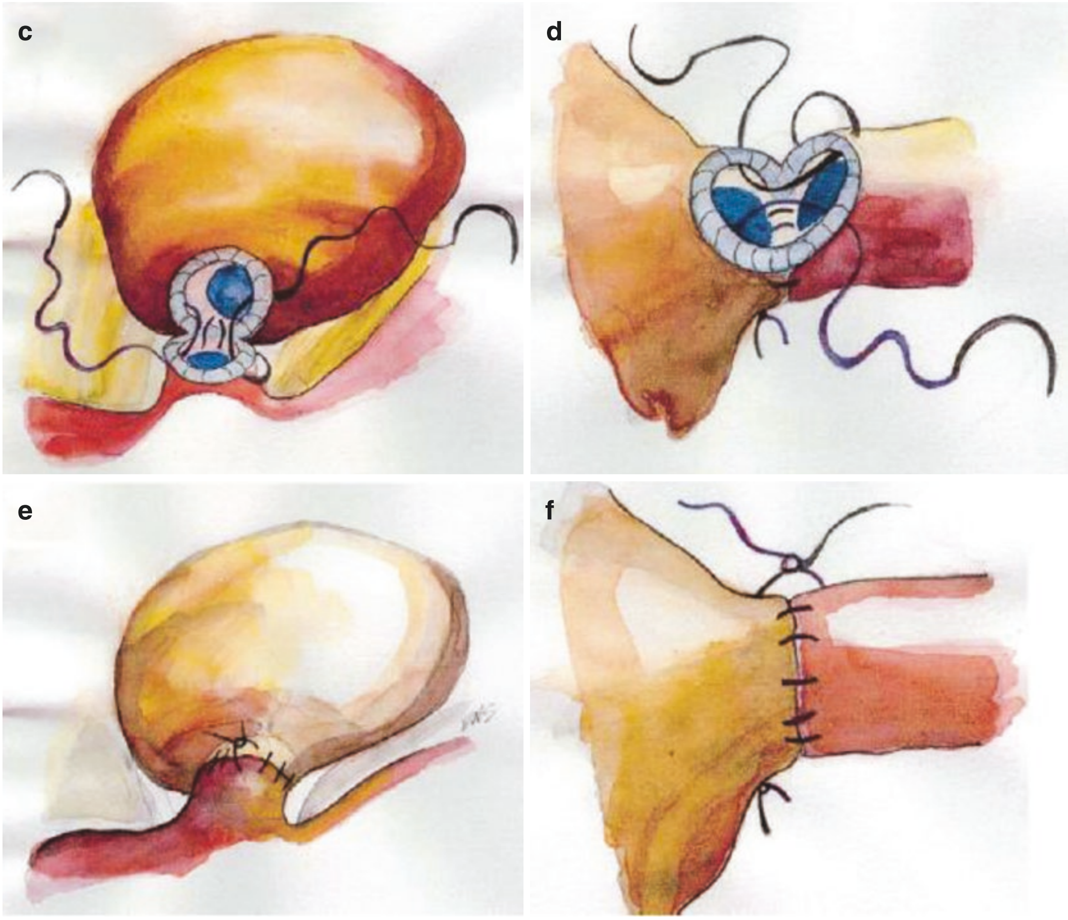

Fig. 33.3 (continued)

The Vesicourethral Anastomosis in the Era of Robot-Assisted Surgery

The introduction of robotic assistance offered the benefits of improved dexterity, precision, and control during minimally invasive laparoscopic surgery, providing the surgeon with a magnified, stereoscopic view of tissue planes [7]. The da Vinci Robotic System's proprietary EndoWrist technology allowed suturing of the UVA with tremor filtration facilitating placement of each suture. This enabled surgeons with limited suturing experience to master a difficult technical step, at the end of a challenging procedure. Furthermore, the surgeon was now seated at the console, with head and forearm rested comfortably which minimized fatigue.

Ahlering et al. reported their initial eight cases of robot-assisted radical prostatectomy (RARP) [6] followed by a series of 45 patients [8] using the continuous single-knot suture technique. Anastomosis times ranged from 21 min in the last ten cases to 50 min in the first five cases. The authors concluded that 8–12 cases were sufficient to successfully transfer a laparoscopically naive yet experienced open surgeon to a laparoscopic environment using the robotic interface. This simple technique was later popularized by Menon and coworkers [9] from the Vattikuti Urology Institute in Detroit, following an early experience with the

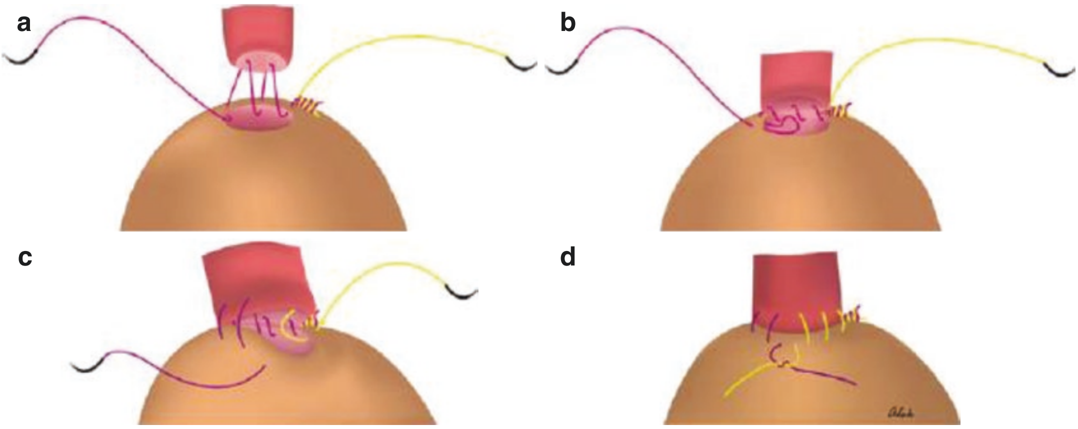

Fig. 33.4 (**a**) Posterior wall with anticlockwise dyed Monocryl arm of suture. (**b**) Change of direction of needle passage at transition of anterior and posterior walls. (**c**) Clockwise stitches with undyed Monocryl arm of suture. (**d**) Completion of anastomosis (Printed with permission from [9])

interrupted technique. The authors reported technical tips for dissecting the prostatic apex and prostatovesical junction during RARP as well as a modified single running-suture UVA, with subtle differences in execution from the original technique (Fig. 33.4). Modifications included running one arm on the posterior bladder wall starting at the 4-o'clock position with the right assistant "following" to maintain tension on the suture. After the posterior urethral wall is approximated to the bladder neck in its entirety, the direction of the suture is then changed from outside in on the bladder to inside out. The suture is run clockwise up to 11-o'clock position and handed to the left assistant to hold with gentle, approximating traction. The undyed arm is then run counterclockwise from 4 to 11 o'clock, where both arms of the suture are tied to each other. The mean time for the UVA was 13 min. Twenty percent of patients had mild leak on cystography and were treated by prolonged catheterization up to 7 days. Two patients had urinary retention within a week of removing the catheter and had to be re-catheterized. Ninety-six percent were continent at 3 months, and the remaining 4% used a thin pad for security. These reports and several others [10, 11] cemented the single running suture as one of the main techniques for performing the UVA during RARP.

Modifications to the Single-Knot, Running Suture

Modifications to this technique have been made in pursuit of increased efficiency while preserving safety and anastomosis integrity. A major drawback of this technique is the need to maintain tension on the suture line to keep the opposing edges of the bladder and urethra approximated following cinching of the posterior bladder lip to the urethra. In addition, a traditional monofilament suture has a tendency to slip, forcing the surgeon to retighten the anastomosis with every throw and revisit each throw several times throughout the anastomosis to ensure integrity and avoid potential anastomotic leaks. Assistants have been used to holding the suture in place between throws [9], but this necessitates experienced assistants performing delicate retraction. To avoid posterior slippage, tearing of urethral tissue, suture breakage, prolonged anastomotic times, and postoperative urinary leakage several modifications were described. Ball and colleagues [12] described using a Lapra-Ty to hold the posterior approximation tight (Fig. 33.5). Berry and coworkers [13] described using three posterior interrupted sutures for the same purpose (Fig. 33.6). Unlike sutures secured with standard surgical knots, the

Lapra-Ty clip can be further cinched if needed, by pulling the suture and placing an additional clip under the previous one in cases of suboptimal closure [14, 15]. Drawbacks of the preceding techniques include reliance on the assistant, a foreign body adjacent to the UVA, and sutures tied within the bladder, respectively.

More recently, the introduction of a self-locking barbed suture for the UVA has proved to ameliorate drawbacks of traditional monofilament sutures during this technique for UVA. The barbed suture prevents slippage and obviates the need for assistance, as well as the frequent revisiting of each throw. The barbs also perform the function of Lapra-Ty clips without introducing a foreign body into the area of the anastomosis (Fig. 33.7). The barbs of these sutures are either unidirectional (V-Loc, absorbable wound closure device, Covidien, Mansfield, MA) or bidirectional (Quill Sutures, Research Triangle Park, NC). Moran and colleagues [16] used a bidirectional barbed suture to perform UVA in an inanimate model and demonstrated that anastomosis with the barbed suture was faster, with no difference in subjective assessment of the quality of the anastomosis. The barbed suture line held against disruption even with intentional cutting of every fourth and every other suture compared to complete disruption of a

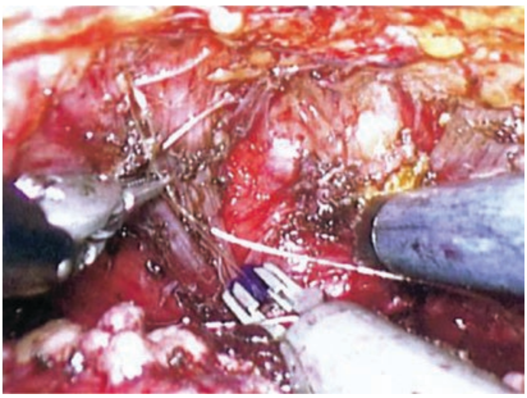

Fig. 33.5 Lapra-Ty placement to secure anastomosis (Printed with permission from [12])

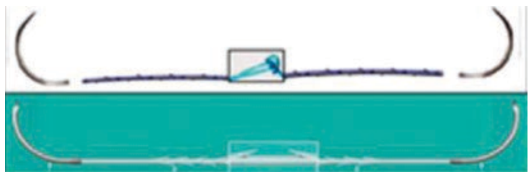

Fig. 33.7 The unidirectional (V-Loc, glycolic acid-trimethylene carbonate, Covidien, Norwalk, CT, USA) above and bidirectional (Quill SRS, polyglycolic acid-polycaprolactone, Angiotech pharma, Vancouver, Canada) barbed sutures below (Printed with permission from [20])

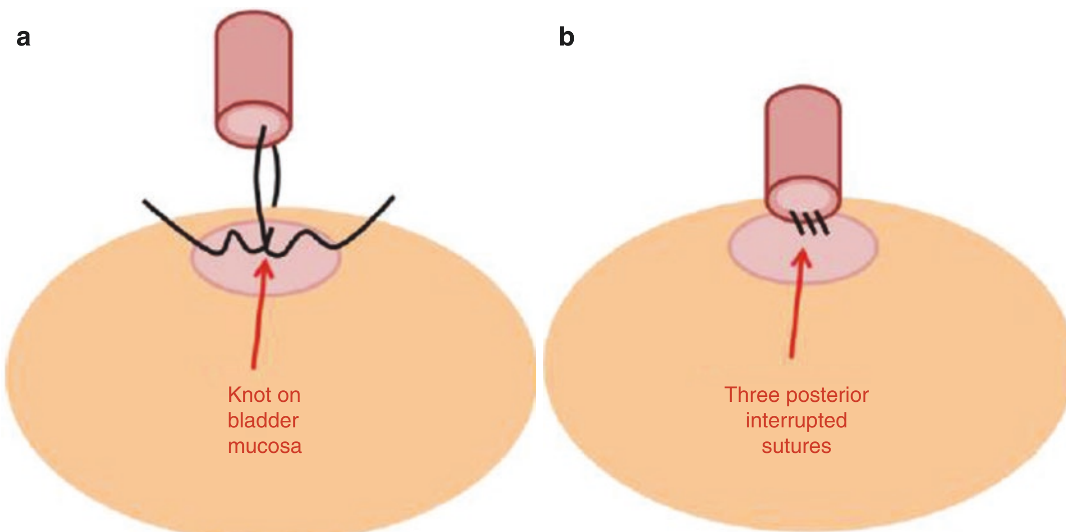

Fig. 33.6 UVA combining running and interrupted sutures. (**a**) Posterior suture placed on bladder mucosa. (**b**) Completion of left lateral posterior urethra suture with three knots on posterior bladder wall

Monocryl suture line. Kaul et al. reported the use of a unidirectional barbed suture for UVA during RARP in 51 consecutive patients [17]. The anastomotic times were reduced to a mean of 11 min and to <10 min in 45% of cases. There were no reports of intraoperative or cystography-detected urinary leak after removal of the catheter despite elimination of the final knot, and complete reliance on the barbs hold the suture in place. Tewari et al. [18] reported an improvement in surgical times by more than 40%, using the same suture for UVA during RARP in 50 consecutive patients. Only one patient had a clinically insignificant cystogram-detected urinary extravasation that necessitated delayed catheter removal. A potential drawback of the barbed suture is the tendency to cause ischemia and tissue necrosis with overtightening. This was demonstrated in a prospective RCT [19], comparing a surgeon-specific RARP anastomosis (running technique using two sutures and three knots) using either barbed polyglyconate (n = 45) or polyglactin 910 (n = 36) sutures. The barbed suture group showed higher rates of cystogram-detected urinary extravasation (20.0% vs. 2.8%) and longer catheterization times (11.1 day vs. 8.3 day). On approximation, only to the point of bladder and urethral tissue approximation in the last 16 cases the rate of urine leak was reduced from 27.5 (first 29 cases) to 6.3%. The authors recommend the use of a barbed suture only in specific cases (large bladder neck, novice surgeons, and in training settings) as the costs of the barbed suture (×6 of polyglactin 910) did not outweigh its benefits.

Anastomotic Techniques

In general, there are three types of vesicourethral anastomosis that have been described: interrupted, running or continuous, and semicontinuous.

We use a semicontinuous suturing technique. Two 2-0 Polygalactin sutures on an RB-1 needle (Ethicon) are used. This needle is small and allows full rotation in very tight spaces. The sutures are cut to about one and a half the trocar length. Two running sutures are used for the entire anastomosis, one for the anterior and the other for the posterior. The first suture is placed at the 5-o'clock position in the urethra and tied to its corresponding position at the bladder neck (Fig. 33.8). This suture is carried out in a clockwise direction approximating the bladder neck to the urethra ending at the 11-o'clock position (Fig. 33.9). The initial needle starts in the urethral lumen to obtain adequate urethral tissue, and the knot placed either inside or outside the bladder. These sutures are absorbable and dissolve quickly making the location of the knot inconsequential.

The posterior suture line must be completely secure, and all areas of suture looseness eliminated to prevent urine leakage. This area is inaccessible once the anterior anastomotic line suturing is begun. Three to five passes are generally necessary between the 5 and 7-o'clock positions to bring the posterior bladder neck

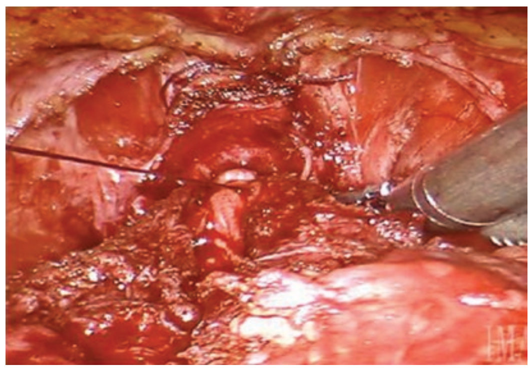

Fig. 33.8 Semicontinuous anastomosis, two separate sutures are used to complete the anastomosis. The posterior layer starts at the 5-o'clock position

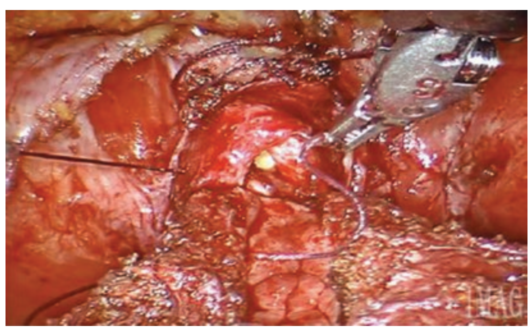

Fig. 33.9 The posterior layer is carried out in a clockwise direction from the 5-o'clock to the 11-o'clock position

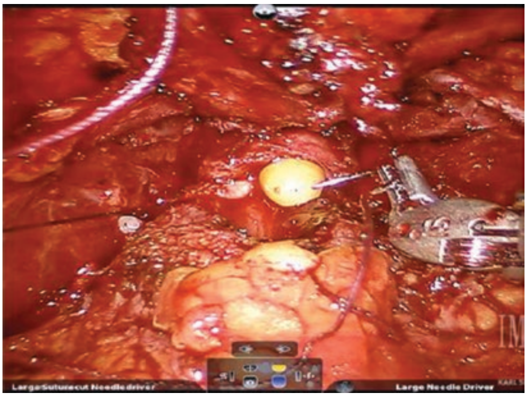

Fig. 33.10 Foley catheter is withdrawn by assistant as surgeon passes needle into urethra encompassing all layers

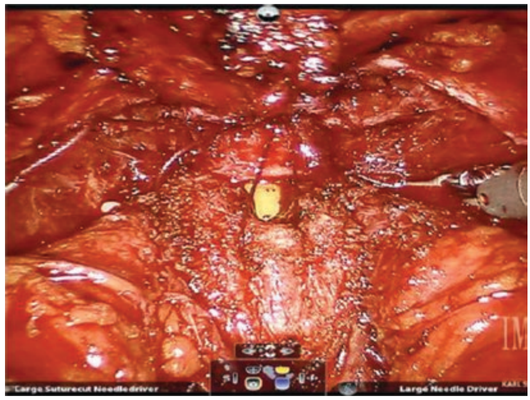

Fig. 33.11 Completion of UVA. Foley entering bladder under direct vision

in continuity with the urethra. The location of the DaVinci surgical cart makes access to the patient's penis difficult to maneuver a rigid urethral sound. The latter is also potentially traumatic, causing us to prefer the soft Foley catheter used initially for bladder drainage as a urethral guide. The daVinci Xi system allows side docking which can potentially allow easier access to the perineum. Proper coordination is necessary between the surgeon at the console and the bedside assistant to avoid suturing the catheter in place. The Foley catheter is withdrawn as the surgeon advances the needle in the urethra (Fig. 33.10). When the sutures are placed correctly, the Foley catheter is seen coursing easily into the bladder. With poor approximation, the catheter may enter in the posterior bladder neck. This can be corrected if detected immediately. Following completion of the posterior suture line, the anterior aspect of the anastomosis is carried out starting from the 5 to the 11 o'clock in a counterclockwise direction, using the second suture. The first pass is made through the bladder (outside in) and into the corresponding position of the urethra (inside out) with the knot placed outside of the anastomosis. Six to eight passes may be necessary. Prior to tying the anterior suture at the 11-o'clock position, a new Foley catheter (16–20 Fr) is inserted into the bladder under direct vision (Fig. 33.11). Once the sutures are tied, the balloon is inflated to 30 cc. The bladder is irrigated to remove clots and ensure proper distension. Influx of fluid at the bladder neck with bladder distension indicates the presence of a leak. With a large influx of fluid, and absent bladder distension, improper catheter location must be ruled out. A total of 200 cc of saline is used to fill the bladder with the balloon of the catheter away from the anastomosis. It is preferable to irrigate the bladder prior to balloon inflation. Pulling the balloon to the bladder neck or placing the catheter on traction does not allow proper testing of the integrity of the anastomosis.

The semicontinuous technique is our preferred approach as it allows completion of the anastomosis in a very time-efficient manner. It avoids reliance on a single suture line, which can be broken leading to complete anastomotic disruption. Furthermore, it ensures tight approximation of the posterior lip of the anastomosis under direct vision before starting the anterior anastomosis.

On the other hand, a continuous anastomosis is often perceived as the fastest way to complete the UVA. It, however, has a number of shortcomings, which can lead to significant complications both intraoperative and postoperatively. As the posterior aspect of the anastomosis is completed on each side, the surgeon often pulls on the two sutures, parachuting the bladder neck to the posterior urethra. This can be associated with disruption of the urethral passes. Bladder neck approximation must be ensured with each pass to eliminate urethral disruption. The circular anastomosis is associated with potential tissue ischemia which can lead to bladder neck contracture in the postoperative period. Tissue approximation is the goal as opposed to tissue tightness. An accordion-like tension can result from a circular running anastomosis and must be avoided to lessen the risk of leakage.

The interrupted technique ensures tissue approximation with each suture. Loosening of the suture line which can be seen with the semicontinuous and continuous approaches is avoided, limiting the potential for urinary leakage. This method of suturing, however, is lengthy and requires the use of several needles to carry out the procedure. Alternatively, a single needle on a long suture can be used, but this increases the complexity of the procedure, as the surgeon maneuvers an excessively long suture. The main advantage of this technique is that it eliminates the potential for radial force disruption inherent in approximating different tubular structures of different consistency and diameter.

For procedures such as perineal and Retzius sparing prostatectomy, the anterior wall of the anastomosis is completed prior to the posterior wall closure.

Reconstruction of Periprostatic Tissues

Several periprostatic reconstruction techniques have been described. One of the most widely used is the posterior rhabdosphincter reconstruction, advocated by Rocco and colleagues [21, 22]. This reconstruction will be discussed in details in a chapter dedicated to its original description and evolution. Based on cadaveric studies, the concept of preserving the "puboprostatic collar" (puboprostatic ligament and fascial tendinous arch of the pelvis) and "puboperineoplasty" (approximation of the puboprostatic ligaments to the anterior aspect of the UVA and reattachment of the arcus tendineus to the lateral aspect of the bladder neck) was introduced in 50 consecutive men undergoing RARP [23]. UVA was performed in a continuous running fashion using 9-in. dyed and undyed 3-0 Monocryl sutures in a running manner. Reconstruction of the arcus tendineus was achieved using a running suture approximating the bladder to the arcus tendineus, puboprostatic ligaments, puboperinealis muscle, and midline connective tissue on either side, using a 2-0 Vicryl on an RB1 needle (Fig. 33.12). The authors reported continence rates after catheter removal of 29% within the first week, 62% within 4–6 weeks, 88% within 12 weeks, and 95% within 16 weeks. The drawback of this technique was the theoretical higher risk of apical positive margins, which the authors did not encounter. Taking it one step further, the authors further combined ventral re-suspension of the anastomosis and distal bladder neck to Rocco's posterior reconstruction, a complex seven-step technique they coined the "total reconstruction of the vesicourethral junction" [24]. In this study, 700 patients were prospectively evaluated in which 214 patients served as a control group, 304 underwent only the previously described anterior reconstruction, and 182 received a total reconstructive procedure. Using standardized questionnaires, the total reconstruction group had continence rates of 38, 83, 91 and 97% at 1, 6, 12, and 24 weeks, respectively. At all the follow-up intervals, the continence rate was significantly less in the control group than in the anterior reconstruction and the total reconstruction group ($p < 0.01$). In contrast, another group [25] showed no improvement in continence rates with reconstruction of the posterior rhabdosphincter and puboprostatic collar. They randomized 116 consecutive patients undergoing RARP to UVA with or without periprostatic reconstruction. They found no statistical difference in the urinary continence rates at 1, 2, 7, and 30 days after the procedure. However, they did note a decrease in the incidence of urinary leak, which is a known risk factor for developing bladder neck contracture and urinary incontinence. The technique utilized 2, 3-0 double-armed monofilament sutures. The first

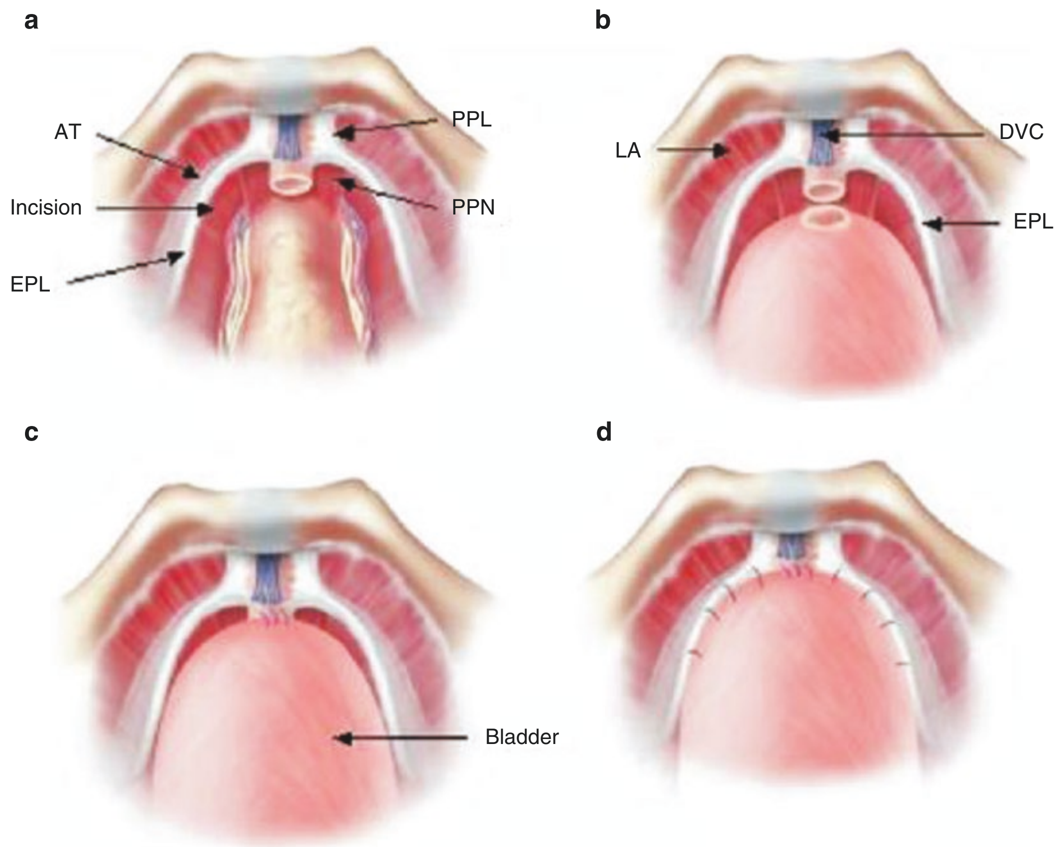

Fig. 33.12 (**a**) Incision of endopelvic fascia (*EPL*) medial to white line. *AT* arcus tendineus, *PPL* puboprostatic ligaments, *PPN* puboperinealis muscle. (**b**) Preserved collar of tissues around urethra after removal of prostate. This collar comprises the puboprostatic ligaments, endopelvic fascia (*EPL*), and arcus tendinous, which form the fascioligamentous component of the puboprostatic musculoligamentous complex. *DVC* dorsal vein complex, *LA* levator ani. (**c**) Vesicourethral anastomosis with 3-0 sutures. (**d**) Final picture after anastomosis is suspended by three 3-0 sutures on either side (Printed with permission from [23])

suture was used to create a posterior plate (posterior reconstruction) from right to left, after which the suture was tied or locked and held with gentle traction by the second assistant. The UVA (inner layer) was then completed as previously described [9]. Finally the outer layer was completed by suturing the puboprostatic ligament to the anterior pubovesical collar (Fig. 33.13). Cystograms were done at 7 days after surgery, and the catheter was removed if there was no leak or a small contained extravasation. At long-term 2-year follow-up, no statistical significance existed among both groups of the same cohort regarding continence or development of bladder neck contracture [26]. Recently [27], a periurethral suspension technique was evaluated in 94 RALP patients. This was found to have statistically significantly higher continence rates 3 months postoperatively than in patients without the suspension suture (92.8% vs. 83%; $p = 0.013$). The suture is passed between the urethra and the dorsal vein complex and through the periosteum of the pubic bone, providing support to the posterior urethra (Figs. 33.14, 33.15, and 33.16). The interval to recovery of continence was also statistically significantly lower in the suspension group.

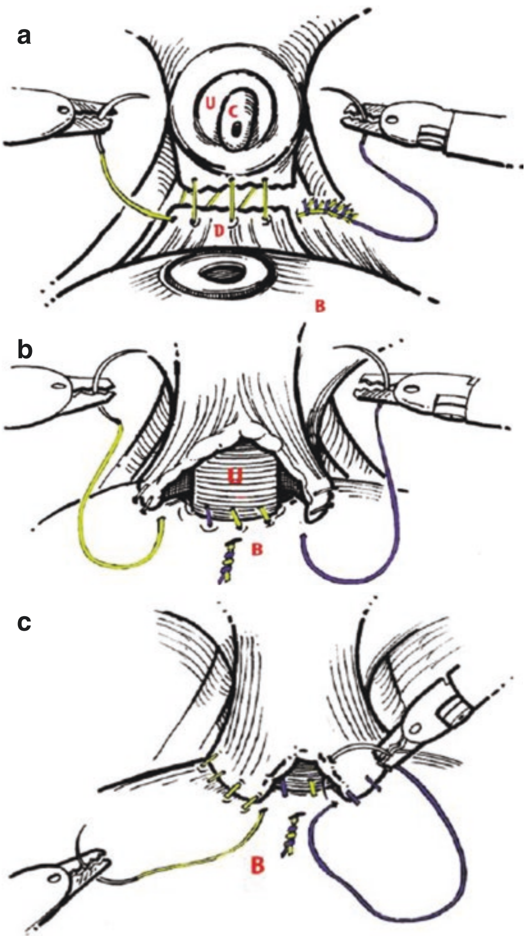

Fig. 33.13 (**a**) Posterior external layer approximating Denonvilliers fascia and posterior rhabdosphincter. Following reconstruction between 5 and 8-o'clock positions formal urethrovesical anastomosis (or internal layer) is begun. (**b**) After completion of urethrovesical anastomosis lateral aspects of external layer are completed in stepwise fashion from 8 to 11-o'clock position on left side and from 5 to 1-o'clock position on right side. (**c**) Anterior pubovesical collar reconstruction is completed approximating puboprostatic ligaments to midline anterior bladder tissue. *B* bladder, *U* urethra, *C* Foley catheter, *D* Denonvilliers fascia (Printed with permission from [25])

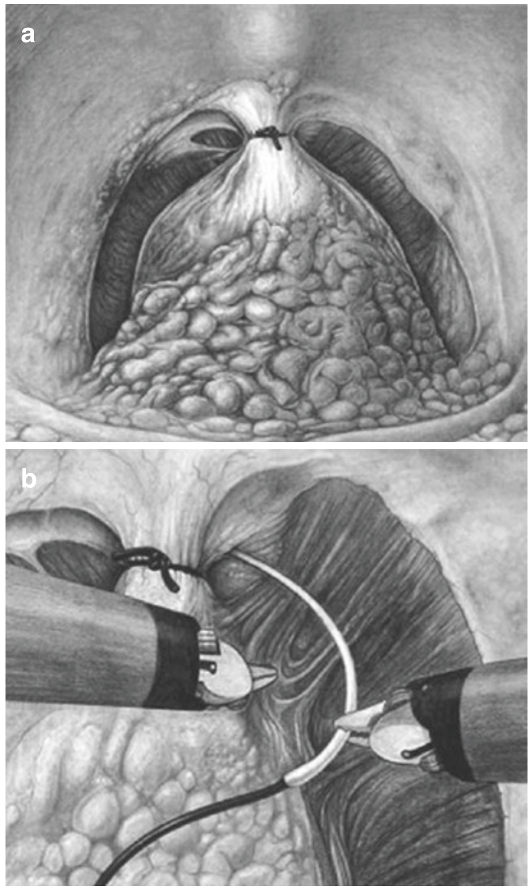

Fig. 33.14 (**a**) Vision after the endopelvic fascia has been opened and the dorsal venous complex ligated; (**b**) CT-1 needle held at a 908 angle passed from right to left between the urethra and dorsal venous complex (Printed with permission from [27])

Complications

Complications associated with the UVA, however, can be associated with significant morbidity, lengthening the recovery period. These complications can be divided into intraoperative and postoperative.

Intraoperative

Blood loss can be a significant intraoperative problem that can complicate the completion of the anastomosis. Toward the end of the procedure, adequate hemostasis is required for proper recognition of the anatomy and adequate suture placement. Uncontrolled dorsal vein bleeding can result from dislodgement of the dorsal vein suture or placement of the anterior sutures through the overlying dorsal vein bundle. Avoiding a large needle sweep or using a small needle (e.g., RB-1) can generally avoid encompassing the dorsal vein in the anastomotic suture.

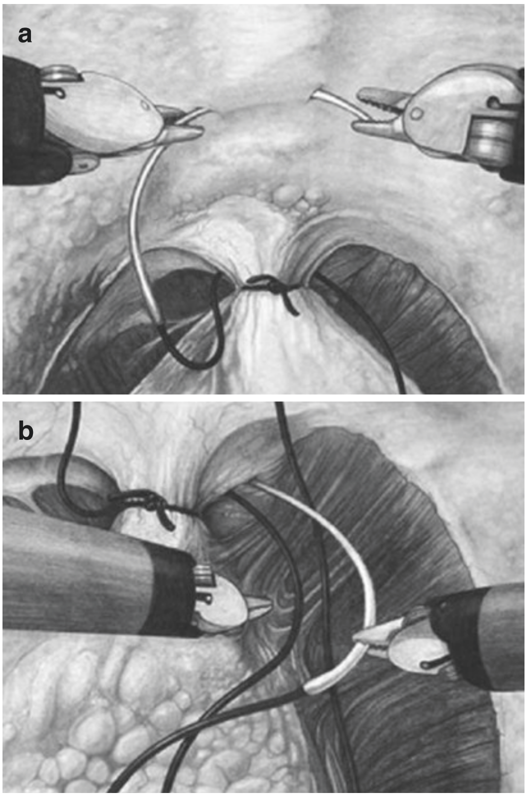

Fig. 33.15 (**a**) Stitch placed through the periosteum on the retropubis; (**b**) second pass through the dorsal venous complex (Printed with permission from [27])

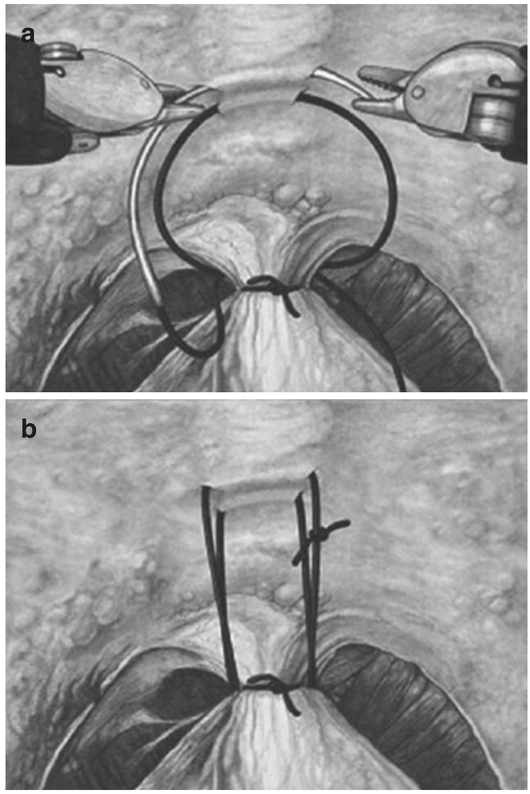

Fig. 33.16 (**a**) Second pass through the dorsal venous complex and the periosteum on the retropubis; (**b**) the final stitch is tied (Printed with permission from [27])

Urethral closure is possible without a proper guide for the needle entering the urethra. Two sides of the urethral wall can be caught with the suture, effectively closing the urethral lumen. Difficult insertion of the Foley catheter should alert one to such possible complication. As described above, the needle is inserted in the urethra under guidance of a urethral sound or Foley catheter. Similar to urethral closure, the anastomotic needle can encompass more than one side of the bladder neck. This is more likely with closure of the anterior wall, when the tip of the needle is poorly visualized as it courses away from the camera view.

Ureteral injury can occur both during the bladder neck dissection and the UVA. During either step, visualization of the trigone with efflux of urine from both ureters is necessary to avoid such complication. To facilitate ureteral visualization, when the ureteral orifices are close to the bladder neck, we recommend the administration of intravenous indigo carmine (5 cc) when ureteral compromise is suspected. Additionally, the absence of urine with proper hydration, or accumulation of urine outside of the bladder, should raise one's suspicion of a ureteral injury during the earlier parts of the procedure. With identification of an injury, ureteroneocystostomy should be considered prior to the completion of the UVA. Intraoperative recognition of a ureteral injury is the most important aspect of management. One should take the necessary steps to ensure ureteral integrity prior to proceeding with placement of the posterior anastomotic sutures.

Rectal injury can occur with the posterior suture placement. This can be due to poor visualization of the bladder neck. It can also occur if a large needle is used to capture the posterior urethra. Sutures encompassing the adventitial layer of the rectal wall can be of no consequence. A suture, however, involving all layers of the rectum can potentially lead to devastating infectious complications or rectourethral fistula.

Improper Foley placement can result from poor approximation of the posterior bladder neck to the posterior urethra. Inflation of the balloon in that location can lead to further disruption of the bladder neck. When detected intraoperatively, a catheter guide can be used to push the catheter anteriorly through the bladder neck. In the postoperative period, flexible cystoscopy may be necessary to help visualize and access the bladder neck. Once identified, a guide wire can be inserted into the bladder over which a catheter is inserted. This complication is best avoided by adequately visualizing entrance of the catheter into the bladder prior to the completion of the vesicourethral anastomosis. Irrigating the bladder under laparoscopic visualization helps ensure proper positioning of the Foley catheter.

Postoperative

Bleeding can result in the postoperative period as a result of an anterior anastomotic suture placed through the dorsal vein. This is often not a problem intraoperatively as the pneumoperitoneum serves to tamponade the site of the injury. With reversal of the pneumoperitoneum, this can present as brisk bleeding via the Foley catheter. If unsuspected, it may result in a significant pelvic hematoma compromising the healing process. Inflating the Foley balloon with about 30 cc of fluid and placing the Foley catheter on traction generally suffice to control such bleeding.

Urine leakage can present as high drain output in the postoperative period. A high drain output, with a low urinary catheter output often indicates urinary leakage. A high creatinine content of the drain fluid is diagnostic of this condition. When a drain is not placed, if the leak is significant, it often presents as a urinoma, when the procedure is done via an extraperitoneal route. Urine ascites can ensue with the transperitoneal technique.

Ureteral obstruction, if not diagnosed intraoperatively can present with a plethora of symptoms. Low urine output, flank pain, renal colic and associated symptoms such as nausea and vomiting can be the presenting symptoms. Based on the length of time the ureter is obstructed, different degrees of hydroneprosis can be evident on imaging studies. Both antegrade and retrograde management are possible. In the immediate period, with a recently completed anastomosis and possible bleeding at the anastomotic line, retrograde management can be challenging. Disruption of the anastomosis with application of pressure in a retrograde.

direction can be a sifnificant problem. Antegrade placement of a ureteral stent is perhaps the easiest way to address this, particularly significant hydronephrosis is present. This can lead to resolution of the obstructed state without the need for additional interventionl.

Urine leakage results from a poorly constructed or disrupted anastomosis. Inadequate suture placement can lead to poor tissue apposition with overriding tissue edges. This can cause leakage which is generally self-limiting in nature and evident only with high pressure. Bladder irrigation can easily demonstrate breaches in the water tightness of the anastomosis, to help decide on corrective measures. With urethral catheter obstruction postoperatively, mild leakage at sites of poor tissue apposition can become significant, resulting in high urine output via the drain.

In the long term, a disrupted anastomosis can lead to urinary incontinence, the most feared and disabling complication associated with prostatectomy. In the setting of a large urine leak, the edges of the bladder neck and urethra are not in continuity to facilitate healing. With the two edges far from one another, the healing phase is prolonged and rather occurs via "secondary intention." Urine leakage is also associated with fibrosis of the bladder neck, limiting its compliance, impacting subsequent continence recovery.

Bladder neck contracture is another postoperative complication that can develop at anytime during the postoperative period following catheter removal. Ischemia at the bladder neck and urethral edges are the likely culprit, in the face of a tension-free mucosa to mucosa anastomosis. We recommend transecting the bladder neck and urethra sharply without the use of cautery to avoid tissue ischemia. Management of this complication is beyond the scope of this chapter.

Neurovascular bundle injury can occur during completion of the anastomosis. The visualization afforded by the robot allows proper dissection and delineation of the neurovascular bundles, decreasing the incidence of postoperative impotence. The latter, however, can result from poor anastomotic suture placement on the urethra. The proximity of the neurovascular bundles to the urethra places them at significant risk for injury. A poor urethral stump, retracting in the pelvic diaphragm with the pneumoperitoneum, can lead to this complication. The needle can be inadvertently placed through the bundle, as the surgeon attempts a large sweep through the urethra. Using a smaller needle and a urethral guide can help avoid such complication, with a previously well-preserved neurovascular bundle.

Summary

RARP is now a preferred way to manage localized cancer of the prostate, in men who are suitable surgical candidates at a number of medical centers worldwide. The technology offers great advantages. Its proper use in skilled hands remains the only way for men affected by prostate cancer to receive the greatest benefits. The UVA is a key reconstructive step of the procedure which the robot facilitates. The different techniques used offer both advantages and disadvantages. With continued technological improvements and refinement of surgical skills, achievement of the triad of cancer control, preservation of continence, and erectile function will maintain radical prostatectomy as the most effective option for most men faced with this common disease.

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34 Anterior Reconstruction After Radical Prostatectomy

Francesco Porpiglia, Riccardo Bertolo, and Cristian Fiori

Introduction

When treating localised prostate cancer, excellent oncological outcomes with low rate of complications are nowadays possible with radical prostatectomy (RP) [1, 2].

However, functional outcomes in terms of continence and potency recovery are still less enthusiastic. Indeed, in patients who do not early recover continence quality of everyday life is markedly reduced, especially in younger and more active ones [3].

The proportion of continent patients at 1 year after surgery ranges from 70 to 100% in the available Literature (Fig. 34.1) [4].

Such disparities in the literature are probably due to either non-homogeneous definition of continence or measurement methods (questionnaires, number of pads, pad test).

Several factors have been identified as leading to, including patient characteristics (body mass index, age, prostate volume, and comorbidities), experience of the surgeon, and surgical precision [5].

No effects of pelvic floor muscle exercise before surgery on the urinary incontinence post radical prostatectomy has been definitely proved [6].

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The advent of minimally invasive approaches, especially the robot-assisted one, has facilitated new surgical techniques, resection, and, of note, the reconstruction phase after RP. This crucial phase should be aimed to improve functional outcomes [7].

A number of papers and reviews with promising results in this direction have been recently published. The time to have continence back is been gradually reducing to 3–6 months, resulting in clear benefits for patients [5]. Some surgeons are trying to push over their technique of robot-assisted RP (RARP) in order to maximize the functional outcome and anticipate continence recovery [8, 9].

There are a number of steps and techniques for improving continence after RARP: preservation of the bladder neck, nerve-sparing (NS) technique, preservation of the maximum urethral length, preservation of the puboprostatic ligaments and of the endopelvic fascia, reconstruction of the posterior rhabdosphincter, anterior reconstruction, and suture of the arcus tendineus to the bladder neck [10, 11].

The literature analysis is difficult as the effect of these steps has been rarely analysed in a separate fashion and compared to other alternatives.

The present chapter will try to cover the topic of anterior reconstruction, focusing on the anatomical rationale, the previously reported techniques and the outcomes of such a step.

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_34

First author	Cases, *n*	Study design	Continence definition	Data collection	Urinary continence rates, %			
					1 mo to 3 mo	6 mo	12 mo	24–36 mo
Chung, 2011 [30]	Transperitoneal, 105	Historical control	0 pad	Validated questionnaire	90	95	97	–
	Extraperitoneal, 155				92	97	99	
Freire, 2009 [32]	Bladder neck preservation, 348	Prospective compartive	0 pad	Validated questionnaire	66	–	86	100
	Standard, 271				26		81	96
Finley, 2009 [13]	Cooling, 114	Prospective compartive	0 pad	Validated questionnaire	61	–	91	–
	Standard, 141				84		100	
Lei, 2011 [31]	Selective suturing DVC, 240	Prospective comparative	0 pad	Validated questionnaire	–	61	70	–
	Standard, 303					40	74	
Sammon, 2011 [33]	Barbed monofilament	RCT	0 pad	Validated questionnaire	51	–	–	–
	Standard monofilament				50			

DVC = dorsal venous complex; RCT = randomized controlled trial.

Fig. 34.1 Prospective and retrospective studies comparing different robot-assisted radical prostatectomy surgical techniques. From the Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy by Ficarra et al. Eur Urol. 2012;62:405–17

Fig. 34.2 Preferences of robotic surgeons for the reconstructive steps of RARP. Adapted from The European Association of Urology Robotic Urology Section (ERUS) survey of robot-assisted radical prostatectomy (RARP) by Ficarra et al. BJU Int. 2013;111:596–603

Step of procedure	Frequencies, *n* (%)
Posterior reconstruction:	
always performed	60 (51.7)
never performed	33 (28.4)
sometimes	23 (19.8)
Anterior reconstruction:	
never performed	71 (61.2)
Patel technique	23 (19.8)
Tewari technique	8 (6.9)
other technique	14 (12)
Urethrovesical anastomosis:	
running suture	112 (96.6)
interrupted sutures	4 (3.4)
Use of Barbed sutures:	
no	60 (51.7)
yes	56 (48.3)

Current Practice in Reconstruction after RARP: A Snapshot

The European Association of Urology Robotic Urology Section (ERUS) recently published a survey that was sent by e-mail to 145 robotic surgeons who were included in the mailing-list of ERUS members, working in different urological institutions [12]. Participating surgeons were invited to answer a multiple-choice questionnaire including 24-items evaluating the main RARP surgical steps. Among these steps, also reconstructive steps were included.

The survey documented a great variability in the posterior and/or anterior reconstruction steps during RARP technique.

Although better results for urinary continence recovery were reported after the use of anterior reconstruction techniques with or without posterior reconstruction [4], only 40% of robotic surgeons answered that they use a periurethral suspension suture [13] or an anterior reconstruction technique according to Tewari et al. [14].

More than 60% of the surgeons involved do not perform any anterior reconstruction technique (Fig. 34.2).

Anatomical and Surgical Principles During Radical Prostatectomy

One of the most important aspects in order to obtain the best outcomes from reconstructive surgery should be a careful extirpative phase. When talking about anterior reconstruction following RARP, the dissection of the prostatic apex is certainly a crucial step that will predict the quality of the reconstruction [8].

Going towards the end of RP, to complete the prostatectomy itself the surgeon has to get the ventral aspect of the gland. At this point, the visceral layer of the endopelvic fascia and the underlying apron are still covering the anterior surface of the prostate: they are incised while sparing the pubo-prostatic ligaments, if possible.

The smooth muscular fibers arising from the peri-urethral structures and entering the apex of the prostate are microdissected via both blunt and sharp dissection, with minimal use of electrocauterization, in order to ensure the maximum preservation of the anatomical structures. Finally, the apex is freed even in its lateral aspects, and the urethra is incised at the level of the genital ridge, trying to preserve the maximal urethral lenght (Fig. 34.3).

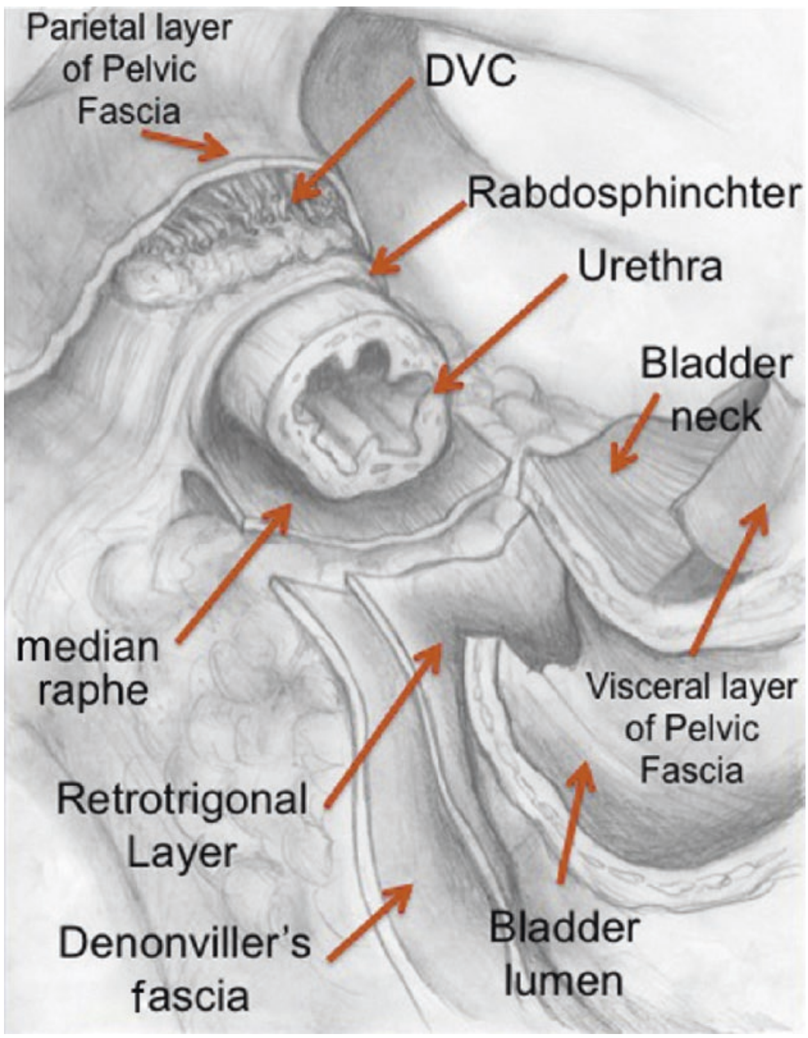

Fig. 34.3 Operative field at the end of the extirpative phase. Anatomical landmarks are reported in the figure. *DVC* deep venous complex. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

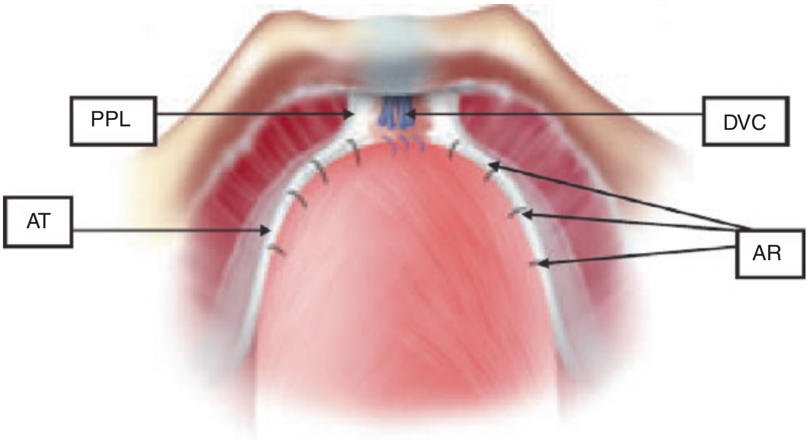

Fig. 34.4 Re-attach the arcus tendineus and puboprostatic plate to the bladder neck once anastomosis is completed. *PPL* puboprostatic ligaments, *AT* arcus tendineus, *DVC* dorsal vein complex, *AR* anterior reconstruction. From Total reconstruction of the vesico-urethral junction by Tewari et al. BJU Int. 2008;101:871–77

Anterior Reconstruction: The Tewari's Technique

Tewari et al. [14] described the reattachment of the arcus tendineus and the pubo-prostatic plate to the bladder neck once the anastomosis is completed as one of the last but not least fundamental components in order to maximize continence recovery after RARP (Fig. 34.4) [15].

In the proposed technique for achieving the total reconstruction of the vesico-urethral junction Tewari et al. described the following components: (1) minimal distal incision of the endopelvic fascia; (2) preservation of the pubo-perinealis; (3) preservation of pubo-prostatic ligaments; (4) placement of a pubo-prostatic ligament-sparing dorsal venous suture; (5) watertight anastomosis; (6) ref.-ixation of the pubo-prostatic ligaments to the anterior aspect of the vesico-urethral anastomosis; (7) reattachment of the arcus tendineus to the lateral aspect of the bladder neck [16].

Authors showed that the continence rates for the total reconstruction technique were 38%, 83%, 91% and 97% at 1, 6, 12 and 24 weeks, respectively, and this technique provided a statistically significant early return to continence compared with the standard technique or with only the anterior reconstructive technique.

Anterior Reconstruction: The Porpiglia's Technique

Beginning from the right side and moving left, the muscular fibers of the anterior surface of the bladder are sutured to the previously dissected peri-urethral tissue, which is located between the urethra and the deep venous complex (Figs. 34.5 and 34.6), both to restore the original anatomy by reallocating it towards the abdominal cavity and to reinforce the anastomosis. This kind of suture can nowadays be easily performed using barbed sutures, able to be self-retaining and eliminating the need of knots tying. Using the same running suture and returning to the starting point, the visceral layer of the endopelvic fascia and the underlying apron, still covering the anterior surface of the bladder, are sutured to the portion of the endopelvic fascia that covers the deep venous complex while involving the pubo-prostatic ligaments (Figs. 34.7 and 34.8) such that they can now work as "pubo-vescical" ligaments. A single 3/0 monofilament stitch can be performed at the end of the running suture in order to secure it (Fig. 34.9).

At the end of the reconstructive phase, the anastomosis is protected posteriorly if posterior reconstruction has been performed and anteriorly if anterior reconstruction has been performed as described. In case of both posterior and anterior

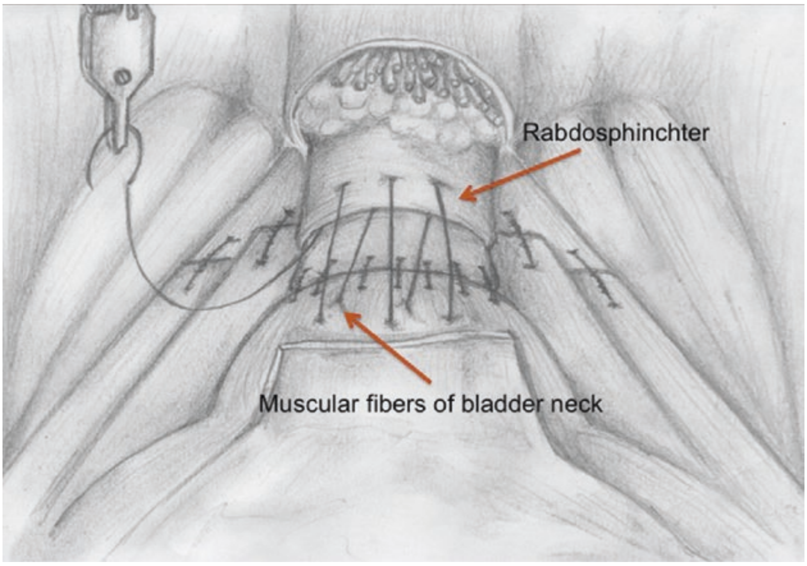

Fig. 34.5 Frontal view. Beginning from the right side and moving to the left, the muscular fibers of the bladder are 3/0 "barbed" running sutured to the previously dissected peri-urethral tissue located between the urethra and the deep venous complex both to restore the original anatomy by reallocating it towards the abdominal cavity and to reinforce the anastomosis. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

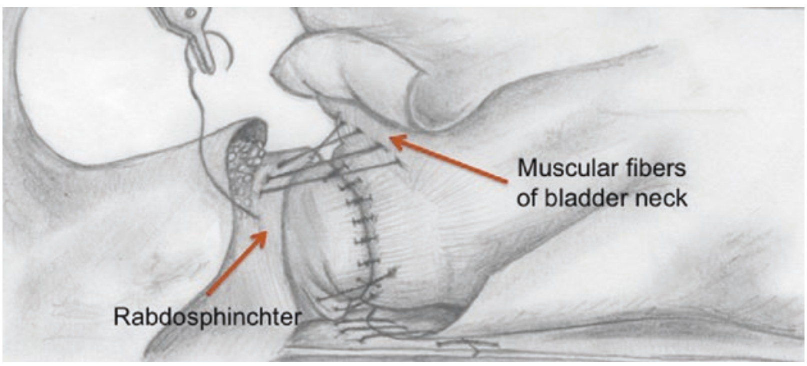

Fig. 34.6 Lateral view. Beginning from the right side and moving to the left, the muscular fibers of the bladder are 3/0 "barbed" running sutured to the previously dissected peri-urethral tissue located between the urethra and the deep venous complex both to restore the original anatomy by reallocating it towards the abdominal cavity and to reinforce the anastomosis. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

reconstruction have been performed, we can talk about a full restoration of the anatomy of the peri-urethral structures (Fig. 34.10).

In summary, the two cornerstones of the technique are the anatomical dissection of the prostatic apex (which allows for the maximum preservation of the peri-urethral tissue and urethral length) and the restoration of the anatomy of the peri-urethral structures by protecting the anastomosis adding two anterior layers to the more commonly performed posterior layers, which allows for a "tension-free" anastomosis.

The series showed mean continence rates immediately after catheter removal and at 1 week, 4 week, 12 week, and 24 week after RARP of 71.8%, 77.8%, 89.3%, 94.4%, and 98.0%, respectively [8].

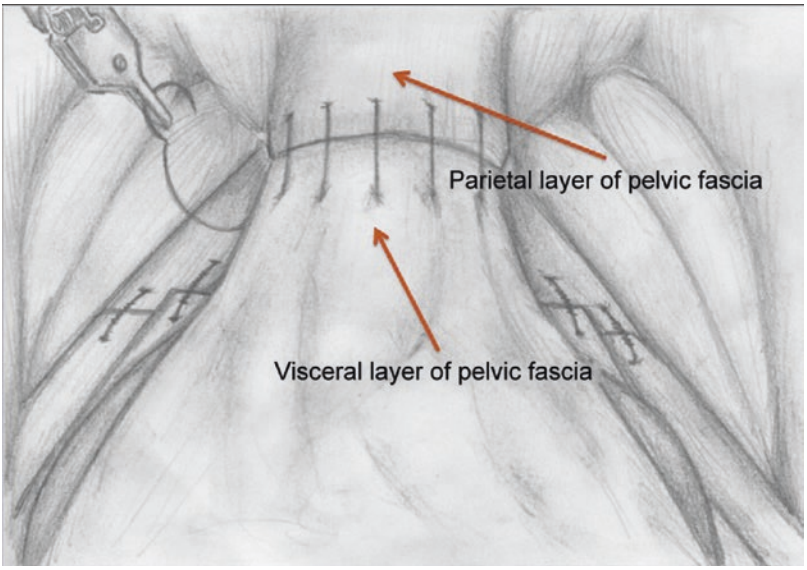

Fig. 34.7 Frontal view. Moving from left to right, the visceral layer of the endopelvic fascia and the underlying apron, still covering the anterior surface of the bladder, are sutured to the portion of the endopelvic fascia that covers the deep venous complex while involving the puboprostatic ligaments such that they can be renamed "pubovescical" ligaments. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

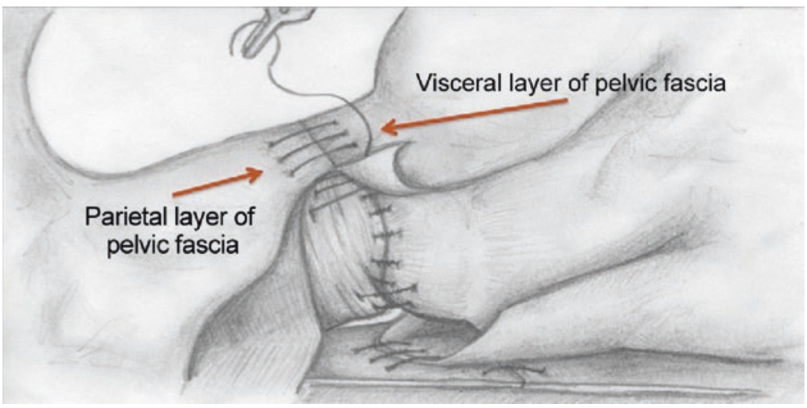

Fig. 34.8 Lateral view. Moving from left to right, the visceral layer of the endopelvic fascia and the underlying apron, still covering the anterior surface of the bladder, are sutured to the portion of the endopelvic fascia that covers the deep venous complex while involving the puboprostatic ligaments such that they can be renamed "pubovescical" ligaments. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

Anterior Suspension: An Anatomical Support for the Urethra

An alternative management of the anterior aspect after radical prostatectomy is the anterior suspension. This cannot be considered as an anterior reconstruction and it is beyond the goal of this chapter. Nevertheless, in order to be complete, we tried to summarize some brief concepts regarding the anterior suspension.

According to Patel et al. [13], the anterior suspension provides an anatomical support for the urethra (Fig. 34.11), which allows the urethral length to be maximized during apex dissection and either the urethra or the rhabdosphincter to be stabilized in their anatomical position. The notion of stabilizing the urethra on the peri-urethral structures to achieve better continence rates was first applied by Sugimura et al. [17] during open RP.

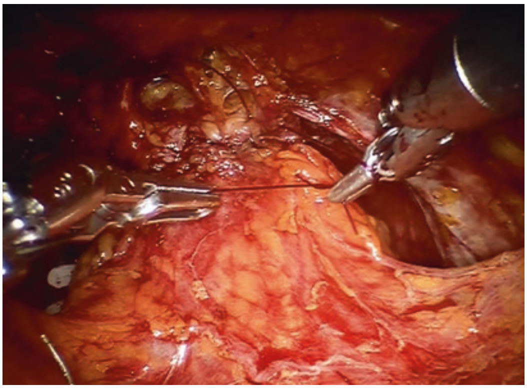

Fig. 34.9 A single 3/0 monofilament stitch can be performed at the end of the anterior running suture in order to secure it

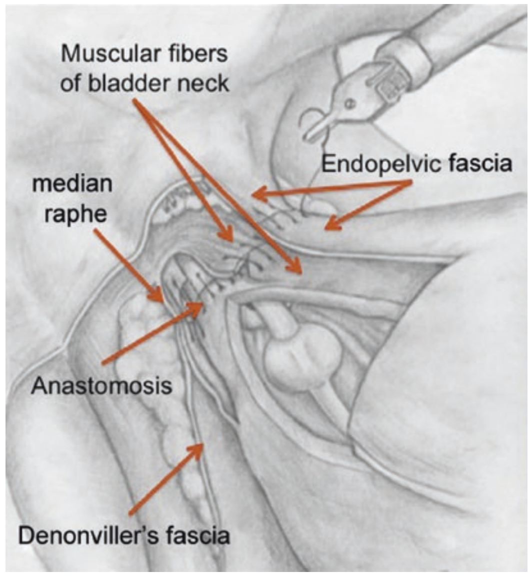

Fig. 34.10 At the end of the reconstructive phase, the anastomosis is protected by three posterior layers and two anterior layers, with a full restoration of the anatomy of the peri-urethral structures. From Total anatomical reconstruction during robot-assisted radical prostatectomy: implications on early recovery of urinary continence by Porpiglia et al. Eur Urol. 2016;69:485–95

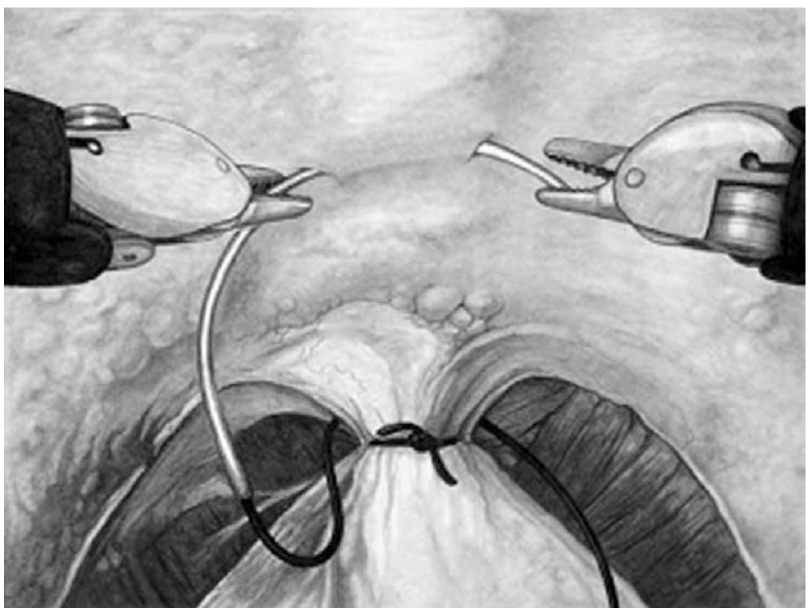

Fig. 34.11 Stitch placed through the periostium on the retropubis for the anterior suspension. Adapted from Periurethral suspension stitch during robot-assisted laparoscopic radical prostatectomy: description of the technique and continence outcomes by Patel et al. Eur Urol. 2009;56:472–78

Noguchi et al. evolved the technique to include the anterior suspension stitch anchored to the pubic bone, which resulted in significantly improved continence rates in the patients who received this treatment [18]. Subsequently, the technique was simplified and reproduced during RARP in a non-randomized prospective study by Patel et al. [19], who reported significant differences in the continence rates at the third month postoperatively in patients who received anterior suspension.

Anterior Reconstruction: Looking at the Functional Outcomes

A few comparative studies have evaluated the impact of the different surgical techniques on urinary continence recovery after RARP.

As a general statement, patients who possess both anterior and posterior support of the urethral continence mechanism are supposed to experience reduced tension on the vesico-urethral anastomosis and its prevented disruption in the event of a pelvic haematoma [20–23].

On the other side, analyzing literature data posterior musculofascial reconstruction with or without anterior reconstruction was associated with a small advantage in terms of urinary continence recovery at 1 month after RARP.

Indeed, the bladder neck preservation, the puboprostatic ligaments sparing technique, the selective deep venous complex division, nerve-sparing technique and posterior musculofascial reconstruction as well as anterior reconstruction have been all mentioned as surgical aspects potentially able to reduce the risk of urinary incontinence after RARP.

However, only a few comparative studies analyzed the impact of some of these surgical aspects on urinary continence recovery but rarely separately evaluated the effect of anterior reconstruction on continence recovery.

Looking at the reconstructive steps of the RARP, the role of posterior and/or anterior reconstruction on early urinary continence recovery remains one of the most investigated surgical aspects.

Different anterior reconstruction techniques were described. In 2008, Tewari et al. described the total reconstruction of the vesico-urethral junction technique combining the posterior reconstruction to the reattachment of the arcus tendineus and pubo-prostatic plate to the bladder neck once anastomosis is completed [14].

In the same year, Menon et al. described the double-layer (with peri-prostatic tissue reconstruction) urethro-vesical anastomosis [24]. In 2009, Patel described the anterior reconstruction using the peri-urethral suspension stitch [13]. This technique was found to be associated to a significantly better urinary continence recovery at 1 month and 3 months in comparison with the standard technique.

Nevertheless, as stated above in the dedicated paragraph, the concept of the anterior peri-urethral suspension as proposed by Patel et al. seems to differ from the total reconstruction of vesico-urethral anastomosis described by Tewari et al. and Porpiglia et al. [8, 13, 14, 24].

Take Home Messages

- The complete anatomical reconstruction of the peri-urethral structures was associated with a significant advantage in urinary continence at both 1 month and 3 months after RARP [8, 14], but no substantial differences were noted after a longer follow-up.
- Therefore, even if we still miss dedicated study analysing the effect of anterior reconstruction, we can conclude that the anterior reconstruction combined with the posterior reconstruction of the rhabdosphincter seems to offer some advantages to improve urinary continence recovery (Fig. 34.12).

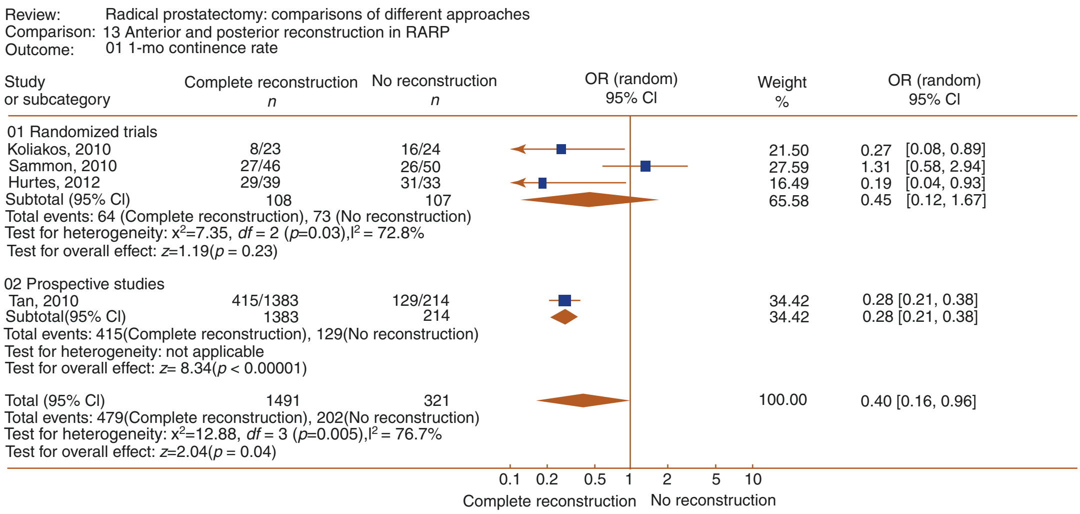

Fig. 34.12 Cumulative analysis of robot-assisted radical prostatectomy studies comparing complete (anterior plus posterior) reconstruction versus standard technique in terms of 1-mo urinary continence recovery. *CI* confidence interval, *OR* odds ratio, *RARP* robot-assisted radical prostatectomy. Adapted from the Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy by Ficarra et al. From Eur Urol. 2012;62:405–17

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35 Radical Prostatectomy Through the Posterior Technique

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Abbreviations

AP	Prostatic apex
B	Bladder
BN	Bladder neck
C	Catheter
G	Graft
ML	Median lobe
NVB	Neurovascular bundles
P	Prostate
SP	Santorini plexus
SPT	Sovrapubic tube
SV	Seminal vesicles
U	Urethra

Introduction and Anatomical Rationale

In the early 2000s, radical prostatectomy had a quick evolution thanks to the advent of laparoscopy first, and robotic surgery following [1, 2].

Beginning our robotic experience with the Montsouris approach, which provided for a preliminary incision in the rectovesical pouch, we developed the original idea to perform the whole radical prostatectomy through the Douglas space.

The very first case of Retzius-Sparing prostatectomy (RSP) was performed in January 2010, after 2 unsuccessful tries (in both cases because of fear of damages due to inexperience) that were converted to the standard approach through the Retzius space [3].

The anatomical rationale for this kind of approach is very strong. The classical anatomical studies by Patrick Walsh [4] report and demonstrate the incontrovertible role of the neurovascular bundle in maintaining the post-prostatectomy erectile function; nevertheless, several other structures have been advocated to play a role in continence and potency preservation; as they lay in the Retzius-space and need to be crossed to reach the prostate, sparing the Retzius-space could be the best way to obtain good functional results.

Briefly, the *endopelvic fascia* is the first anatomical structure met during radical prostatectomy. Several evidences report that sparing the endopelvic fascia could result in a quicker recovery of urinary continence, but data are controversial [5, 6].

The *Santorini plexus* is usually sectioned during the standard RARP technique (and potentially sutured for hemostatic purposes); the *pubo-prostatic ligaments* can be sectioned or preserved. More than assuring a lower blood loss (in RARP blood loss is almost constantly low), leaving intact those

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_35

structures, it allows the preservation of the anatomical support to the bladder and of the small arteries running through the plexus [7]. Puboprostatic ligaments are important fixity means of the urinary continence system; a huge number of studies confirmed that their preservation improves the time of urinary continence recovery [8].

The prostate is surrounded by a *network of vascular and nervous fibers* in its whole circumference. Studies conducted on fetal and adult cadavers not only confirmed this data, but also analysed the territory innervated by those nerves, showing that they run straight towards the urethral sphincter and the corpora cavernosa [9]. Finally, the presence of *accessory pudendal arteries* varies from 4 to 75% [10, 11]. The role of these arteries is to provide a supplementary penile blood supply, but their effective importance in erectile function maintenance is currently debated [12, 13].

Technique

Currently, all versions of the Da Vinci robot (Intuitive Surgical, Sunnyvale, California, USA) have been used to perform Retzius-sparing prostatectomy. Up-to-date, more than 1200 cases have been operated in our institution, and thousands of cases have been operated throughout the world.

In our institution the technique for RSP is structured as follows:

- The patient is put in the standard 30° Trendelenburg position, with the arms fixed along the body. The Da Vinci robot can be front-docked with legs spread with the Si system, or side-docked with both the Si or Xi. Several devices can be used in order to avoid slipping of the patient and traction of the brachial plexus.
- Usually, in non-operated patients, a Veress needle is inserted to induce the pneumoperitoneum; a standard Hasson technique is used in patients with suspect of adhesions. Six laparoscopic trocars are inserted. We use to have the table-side assistant on the right and the fourth arm on the left; the main operative arms have the monopolar scissors on the right and the bipolar Maryland on the left. The grasper (usually a Cadiere forceps) is kept in the medial left arm, while the Maryland is in the lateral arm. Figure 35.1 shows the standard disposition of the arms: 1 and 3 are quite symmetrical, while 2 is the grasper, making mostly upwards and downwards tractions. Other experiences (Koon Rha, Seul, South Korea—personal communication) have already been made with the fourth arm on the right side, depending on surgeon's preferences.
- The initial set up is with a 30° lens-down during seminal vesicles isolation, while the lens is turned up during all the following steps. After freeing adhesions of the sigma and left colon, it can be useful to put a stay suture with a Ethilon 2–0 straight needle coming from the 5 mm assistant port and stretching the epiploic appendixes surrounding the colon backwards; this step comes from an original idea of Prof. Vito Pansadoro.
- The grasper lifts up the peritoneum covering the bladder. The parietal peritoneum is then incised about 1 cm over the reflection of the Douglas space. Seminal vesicles and deferens vasa are isolated and incised, possibly with small clips and avoiding cautery, especially at the tip of the vesicles. Hem-o-loks in this step

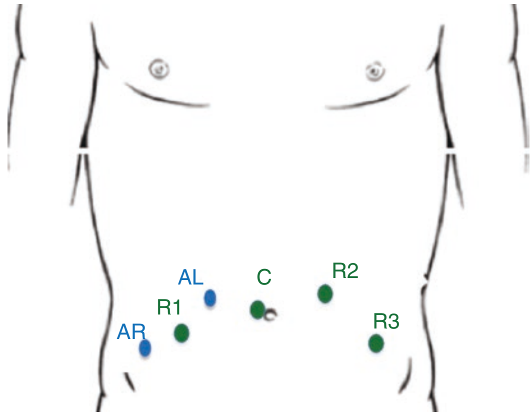

Fig. 35.1 Standard trocar positioning for Retzius-sparing Prostatectomy with the Da Vinci Si system. The grasper is usually put on the arm 2, while the Maryland on the arm 3 (*A* assistant, *R* robotic arm)

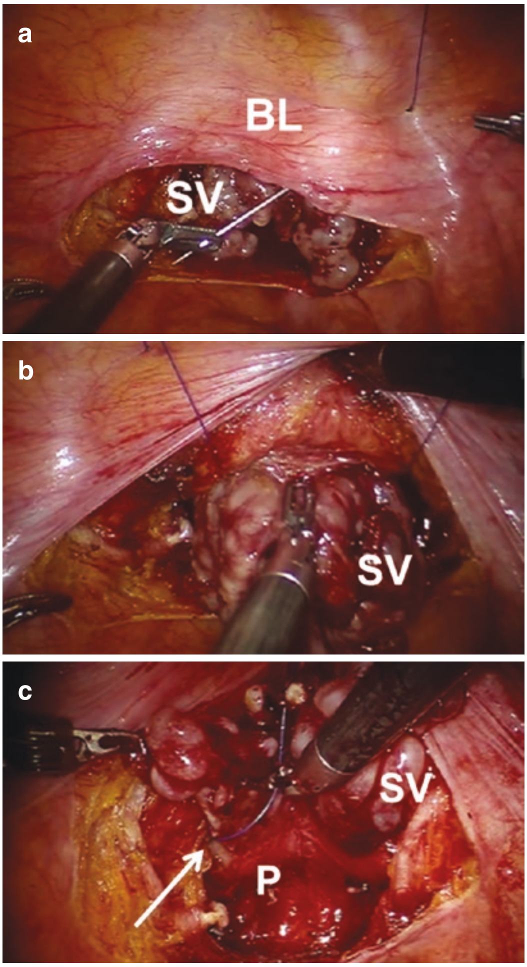

Fig. 35.2 Transabdominal stitches: the stitches are passed 1 cm above the pubis in order to suspend the bladder and gain space (**a**); the Cadiere is used to retract upwards the seminal vesicles (**b**), that are hooked to the stitch (**c**) (*BL* bladder, *SV* seminal vesicle, *P* prostate)

can be used, but they occupy a large room for the small surgical field. As such, currently we prefer to use Aesculap BBraun DS clips, which have a quite good strength in a small space.

- Two transabdominal prepubic Ethilon 2–0 stitches are positioned laterally at the level of the deferens incision in order to stably lift the bladder and improve the space in the surgical field (Fig. 35.2). This step is not performed by several other surgeons (e.g. Mani Menon in Detroit and Koon Rha, personal communications), but we think it very useful in order to make the bladder neck dissection easier.

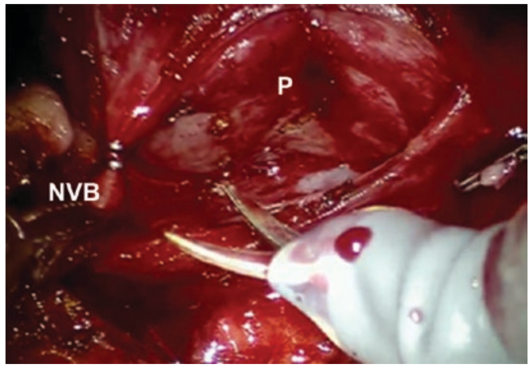

Fig. 35.3 Pedicles and neurovascular bundles isolation. The left pedicle has been clipped and the bundle is visible (*P* prostate, *NVB* neurovascular bundle)

- The deferenses are lifted upwards by the Cadiere grasper, and the Denonvillier's fascia is separated by the postero-lateral surface of the prostate in an antegrade direction, reaching the prostatic apex, maintaining an intra-, inter- or extrafascial plane according to the oncological situation. In case of adherences, palpable disease or doubts the surgeon chooses to follow wider dissection planes.
- The lateral pedicles are isolated, clipped and sectioned, and the neurovascular bundles are completely, partially spared or dissected according to the oncological situation (Fig. 35.3).
- The grasper traction is moved towards left or right in order to improve lateral exposition and to allow blunt dissection of the lateral aspects of the prostate.
- The prostate is pushed downwards by the grasper and the vesicoprostatic junction is identified, isolated and sectioned, sparing the bladder neck in most cases. Moreover, in order to facilitate the identification of the bladder neck orifice during the initial steps of the anastomosis, two short quickly absorbable 3–0 stay stitches are positioned at 6 and 12 o'clock (Fig. 35.4).
- The anterior surface of the prostate is bluntly isolated from the Santorini plexus without any incision. In case of extrafascial dissections, it is frequent to open some venous vessels. In this cases, suction should be avoided and irrigation with saline water or with glycine solution allows improved vision. Glycine irrigation

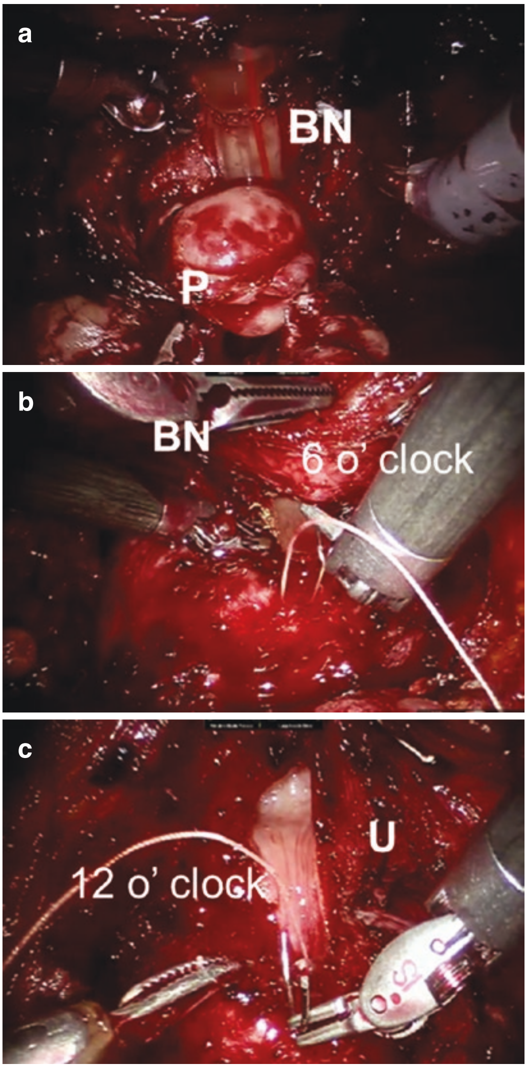

Fig. 35.4 Bladder neck isolation (**a**). After surrounding the bladder neck with the Maryland, it is opened and two stay sutures are positioned in order to facilitate the anastomosis. The first one at 6 o'clock (**b**), the second one at 12 o'clock (**c**)

allows also to continue coagulation without difficulties. In case of locally advanced anterior prostate cancer, the Santorini plexus can be partially or completely resected.

- The apex is finally isolated and the urethra is incised. The prostate is positioned into an endobag.
- Hemostatic control is performed, using small clips, monopolar or bipolar cautery or other hemostatic agents (Floseal, Surgiflo or others). The surgical field is reduced to the stamp of the prostate, especially in the full (360°) intrafascial dissections. In the correctly selected cases, this approach allows to have a really full intrafascial nerve-sparing dissection (Fig. 35.5).
- The anastomosis is performed using a modified Van Velthoven suture. We use two 3–0 barbed sutures (V-Loc, Covidien), starting the anastomosis from the 12 o'clock position up to the left anterior lateral quarter. If the bladder neck has been spared, three passages are enough to reach the 9 o'clock position; the right half circle of the suture is then performed up to 6 o'clock; finally, the last posterior left quarter from 9 to 6 o'clock is completed.

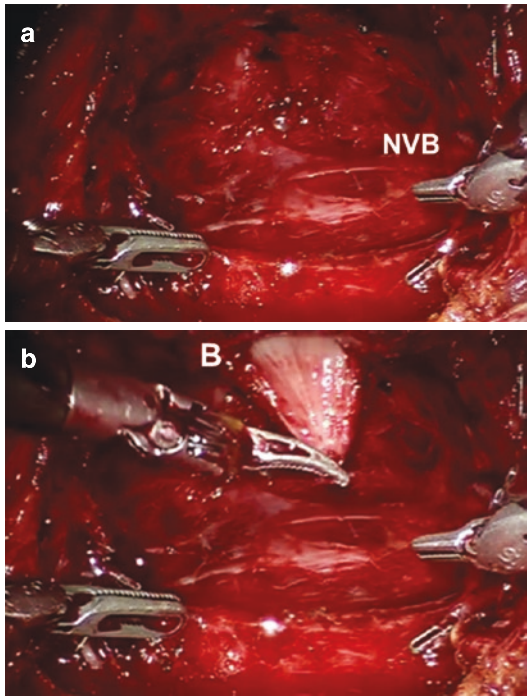

Fig. 35.5 Prostatic fossa: the negative stamp of the prostate is visible, with a 360° intrafascial dissection and the neurovascular bundle (NVB) visible (**a**). The 12 o'clock stitch is retraced downwards to open the bladder neck (BN) and begin the anastomosis (**b**)

We suggest not to complete immediately the left lateral half-circle, because the surgical field becomes too closed and giving the first right half-circle stitches it can result very difficult. The

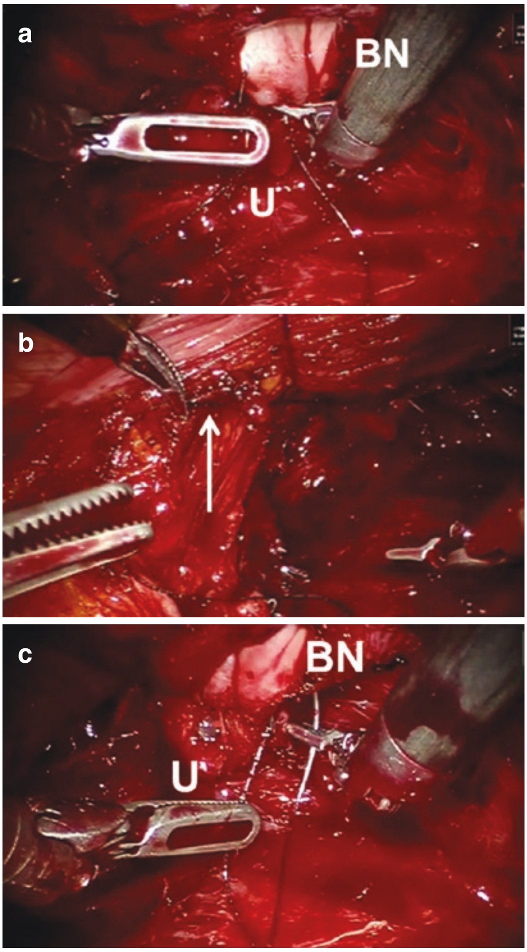

Fig. 35.6 The Anastomosis begins with the anterior left quarter (**a**); the Maryland is used to keep the left suture away from the field while completing the right side (**b**); the right half of the suture is then performed (**c**) (*BN* bladder neck, *U* urethra)

Maryland is used to hold the left suture away, while the right side of the anastomosis is completed (Fig. 35.6).

Suprapubic Tube

Starting from 2012, after having completed 200 RSPs, we began to use a suprapubic tube (SPT) as urinary drainage instead of the urethral catheter in all cases with no major contraindications (bladder cancer history, non-watertight anastomosis). The rationale to use this kind of drainage is to foster early discharge, as the SPT is better tolerated by patients than the urethral catheter (UC); moreover, involuntary traction of the catheter against the anastomosis at home can results in damage to the anastomosis and consequent urethral stenosis, while traction on the SPT does not result in any damage. Usually we fill the bladder with 300 cc saline at the end of the anastomosis; if it comes out to be watertight, we insert a 14 Ch 2-way balloon Foley SPT. We recommend not to use smaller SPTs or non-balloon single way catheters, as in case of bleeding from the bladder wall it is enough to gently retract the balloon against the wall to solve the problem.

Table 35.1 SupraPubic Tube (SPT) versus Urethral Catheter (UC) discomfort. Visual Analogue Scale results

	Urethral catheter	Suprapubic tube	
Question	Median (IQR)	Median (IQR)	p value
Overall postoperative pain	3 (1–5)	3 (1–4)	0.461
Urinary drain-related pain	3 (1–4)	1 (0–3)	0.001
Catheter removal-related pain	1 (0–2)	1 (0–2)	0.151

At the beginning of our experience, we compared the discomfort of the two different drainages, confirming that the SPT is better tolerated than the UC, without differences in complications (Table 35.1) [14].

Moreover, a further advantage of the SPT is the postoperative management: in case of urinary retention it is sufficient to open the SPT again, without the need of any kind of urethral or anastomotic instrumentation (e.g. removing catheter and inserting it again).

Starting in middle 2016, we began closing the SPT in POD2 in selected patients; roughly 65% of them will be able to remove the SPT the day after, being discharged in POD3 without any tube.

Lymphadenectomy

In case of intermediate or high risk prostate cancer cases, according to the EAU or AUA guidelines [15, 16], an external and internal iliac and obturator lymph node dissection (LND) can be performed. No additional difficulties are met during LND, and it is usually performed after radical prostatectomy. In order to reduce the risk of lyhmpocele, our current practice is to fix the peritoneum open with some clips that have the effect of a peritoneal fenestration.

Results

Perioperative Outcomes

Currently, in our institution the RSP is performed by different surgeons and more than 1200 cases have been operated on. Generally, RSP is quite a quick surgery, as no Retzius-space dissection and no deep venous complex isolation and control are needed.

Beyond the first 100 cases, median console time was 120 min in our early experience; in the second generation learning curves, it took less than 30 cases to reach 120 min.

In the first 1000 patients, we rarely experienced major intraoperative complications: most of them occurred during lymph node dissection (1 ureteral lesion, 1 obturator nerve lesion, 3 hypogastric branch lesions that required intraoperative transfusions). No intraoperative complication was directly imputable to the technique (in particular, no rectal lesions occurred up-to-date).

Up to case 1000, we elected to perform cystogram in all patients; currently, we are changing our practice and have began performing cystogram only in patients who have a UC and not a SPT. In fact, SPT is currently our guarantee that the anastomosis has been checked as waterproof with 300 cc of saline solution. In those cases, in our experience, only 1 patient out of more than 600 had a contrast leakage.

Median catheter removal is POD 7 both for SPT (IQR 7–8) and UC (IQR 7–10) patients, with an acute urinary retention rate of 2.2% for SPT and 1.6% for UC (p = NS).

Postoperative complications were graded according to Clavien-Dindo classification [17]. Table 35.2 depicts the complications reported in our series.

Table 35.2 Postoperative complications according to Clavien-Dindo classification in the first 700 patients (minimum 1-year follow-up)

Clavien-Dindo grade	Rate
Overall	91 complications in 76 pts. (19%)
I–II	3% AUR
	3.4% Bleeding w/ transfusions
	1.2% Fever
	3.2% Lymphorrhea
	0.2% Urosepsis
	1.9% DVT
	0.1% Temporary neurological deficiency of the peroneal nerve (due to surgical position)
IIIa	5.7% Percutaneous drainage of lymphocele
	0.4% Embolization of bleeding vessels
IIIb	1.5% Surgical correction of laparocele
	0.4% Small bowel resection for perforation
	0.1% Reoperation for retained drain
	0.3% Reoperation for bleeding w/ hematoma
IV–V	0%

Oncological Results

Stratifying our series according to the EAU oncological risk classification [15], we operated only low risk patients in the first 50 cases; afterwards, we extended the indication also to intermediate and high risk patients. In the first 1200 patients, we operated 40.3% of low risk, 44.6% of intermediate and 15.1% of high risk patients.

After the first 100 cases, where the standardization of the procedure was paid in terms of a high positive surgical margin (PSM) rate (21% in pT2 cases), our PSM rate was quite similar to the standard RARP.

Our overall PSMs are 28.9%. Differentiating the results per pathological stage, we had positive surgical margins in 12.3% of pT2 patients (10% of focal, 2.3% non-focal ones), 41% of pT3 ones. Most of the PSMs were located at the prostate apex (46%) and posterolateral region (bundle region 32%) and came from more aggressive disease (Gleason >6 in 68% of cases).

At a median follow-up of 22 months on the first 700 patients (including all risks and the learning curve), radiotherapy was performed in an adjuvant setting in 14.2% of patients (for adverse pathological features: pT2 with extended PSM, pT3a with PSM, all pT3b) and as a salvage treatment in 7% of patients. Biochemical disease-free survival (bDFS) was 81%.

Two patients had a clinical progression with hormone-resistant metastatic disease and died after chemotherapy at a follow-up of 36 and 60 months, respectively.

Functional Results

Functional results are clearly dependent on the oncological feasibility of an anatomically conservative surgery; we will follow the recommendations of the Pasadena Consensus Conference [18] in defining full-, partial-, and non-nerve-sparing procedures.

Within 7 days after catheter removal, 87.2% of patients were continent using no pad or one 24 h dry safety pad. At a median follow-up of 30 months, 94.9% of patients are continent (no pad) in the complete series; we observed no continence improvements after the first 12 months.

Up-to-date, 1 anastomotic stricture occurred, in a patient who had an accidental UC self-extraction with the balloon fully inflated on POD6.

Subdividing our patients according to the anatomical damage during surgery (fully, partial and non-nerve-sparing approach), we can recognize different continence recovery patterns (Fig. 35.7a).

Considering our whole series, at a median follow-up of 30 months, 48% of patients are potent (with or without PDE5i).

Selecting the preoperatively potent patients <65 years old undergoing fully intrafascial nerve-sparing surgery, 38% reported to have had the first sexual intercourse within one month from surgery. This figure rose up to 65% at 3 months, and 77% at 6 months, 81% at 12 months, with a median time to erectile function recovery of 48 days (Fig. 35.7b).

Finally, we achieved the trifecta outcome (continence, potency and 1-year free from biochemical relapse) in 45% of cases; considering only preoperatively potent patients, the rate raised up to 65% of cases.

We have to highlight that in this series we included all indications for radical prostatectomy. In fact, after an initial 6-months period in which only selected low risk patients were operated on, all patients undergoing radical prostatectomy were operated through this approach.

In particular, we operated more than 50 patients had previous *major abdominal surgery* (pancreaticoduodenectomy, liver transplant, hemicolectomy, sigmoid or rectal resection, previous temporary ileostomy, abdominal trauma, abdominal aortic aneurysm correction, and so on); in these cases we had 2 intraoperatively corrected ileal lesions and 2 unrecognized bowel lesions that needed a postoperative laparotomy. More than 100 patients had a *median lobe*; in our experience, median lobes are easily recognized from the posterior and lateral aspects of the bladder neck. Up-to-date, a formal bladder neck reconstruction with a lateral or posterior suture was needed in less than five cases. The *largest prostate* removed during RSP weighted 300 g. Cases with very large prostates (>100 g, about 6% in our experience) are not for beginners, but with some tips and tricks and following a posterior dissection that extends gradually and symmetrically towards the lateral aspects of the prostate, the surgery is accomplished without complications. More than 50 RSPs were performed in patients after TURP, HoLEP or simple prostatectomy. The RSP has the advantage of using a different surgical plan and approaching the trigone from behind. Up-to-date, we did not have any ureteral orifice lesion and we did not need to put stents during RSP for prostate cancer (only one case of stenting before RSP for bulky seminal vesicle sarcoma). We performed 8 RSPs in patients with a kidney transplant (8 cases– 1 with bilateral kidney transplant). Usually, radical prostatectomy is a really challenging procedure for these patients, as the kidney occupies a vital space for surgery and the new ureter has an unpredictable course and could be damaged during the procedure. On the contrary, RSP allows to perform the whole surgery passing through a vir-

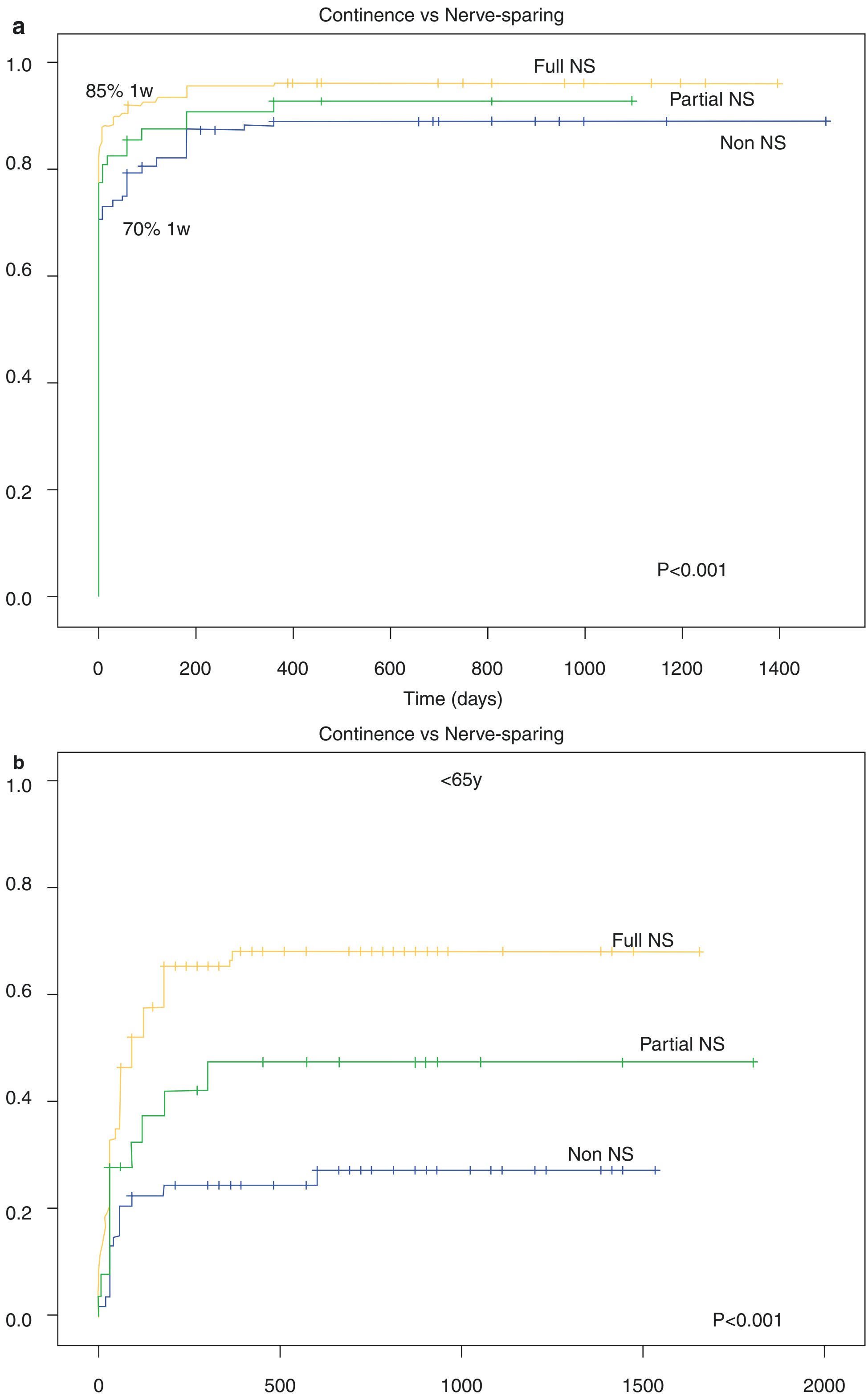

Fig. 35.7 Kaplan-Meier curves estimating continence recovery in the whole series (**a**) and potency recovery in patients <65 years old (**b**) stratified for nerve-sparing approach (full, partial or non nerve-sparing)

gin surgical space. After positioning the trocars (the trocars near to the transplanted kidney should be placed carefully and a little bit more medial than usual), the surgeon performs a standard RSP without any adjunctive difficulty. Until today, only 2 salvage prostatectomies occurred (1 after HIFU treatment, 1 after radiotherapy). In both cases, an extrafascial non-nerve-sparing surgery has been performed. The radio-recurrent case has been complicated by a prolonged UC time (20 days) and pulmonary embolism successfully treated.

Considerations and Diffusion of the Technique

The main strength points of RSP are rapidity of execution, the low complication rate, and the good functional results. The main reasons for this success should be found in the anatomical respect of the surrounding structures. In fact, looking at the possibility that important vessels and nerves could be present in the anterior layers that cover the prostate and that are usually disrupted during the standard RARP procedures (e.g. in the Santorini plexus), we do believe that the only procedure deserving the denomination of "full nerve-sparing" should be the 360° intrafascial dissection of the RSP; on the contrary, the other so-called "full nerve-sparing" surgeries miss at their best one quarter of the 360° of the prostate surroundings [19].

For these reasons, the RSP is currently spreading worldwide, with a jeopardized diffusion. The first inputs for a diffusion of the technique were the live surgery demonstrations during the most important world congresses. This allowed urological robotic surgeons coming from all over the world to replicate the technique. As time passes by, new surgeons modify the original technique and perform it by themselves without the need to be proctored [20, 21]. YouTube, video Journals and web based transmissions permit to have all the instruments to begin such an activity without the need of a formal proctor. We know that currently in Europe, Asia, North and South America there are centers performing the RSP on a regular basis; several groups published new data confirming our enthusiastic functional results, especially concerning continence [22–24].

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Radical Prostatectomy in Locally Advanced Prostate Cancer

36

Aldo Brassetti and Vito Pansadoro

Indications to Surgery

Although in the prostate-specific antigen (PSA) era most of patients are diagnosed with a low-risk localized prostate cancer (PCa), still 10–30% of the screened men will have a locally advanced disease (clinical stage (cT) ≥ 3a) at presentation [1, 2]. Considering the well-documented high risk of recurrence, these patients were historically ideal candidates for systemic therapies [1]. Although a consensus regarding the best treatment option for these patients is still missing, most of them will undergo radiation combined with androgen deprivation therapy (ADT) [3–5].

However, it has been proven that patients harboring high-risk/locally-advanced PCa are those who will more likely benefit from active treatment. Their risk of recurrence and cancer-specific mortality (CSM), in fact, is the highest immediately after surgery but it substantially decreases over time, highlighting the curative efficacy of local treatment [6].

Mounting evidences support the use of multimodality approaches to treat locally advanced prostate cancer (LA-PCa), combining androgen deprivation therapy with local treatments like radiotherapy (RT) and/or radical prostatectomy (RP) [7]. It has been reported that, in selected men treated with RP for LA-PCa, adjuvant RT or ADT confers a significant survival advantage [8–10]. Additionally, it has been shown that patients with high-risk prostate cancer (HR-PCa) (PSA > 20 ng/mL, Gleason score ≥ 8, cT ≥ 2c) [11] initially treated with RP could have a reduced risk of progression and cancer-specific mortality (CSM) than those who received RT [12]. When assessing the pathological results and rates of treatment failure after RP for HR-PCa, Walz concluded that a non-negligible proportion of these patients benefit from surgical treatment because they have favorable pathological stage or remain free of biochemical recurrence [13].

Radical Prostatectomy is mainly proposed to patients with localized disease. The surgical treatment of cT ≥ 3a PCa has traditionally been discouraged, mainly because of increased risk of positive surgical margins, nodal metastases and/or distant relapse [7]. Therefore, it was rarely offered (2.8% in 2001) to patients with a clinical suspicion of locally advanced tumor [14]. Noteworthy, when assessing thve impact of preoperative parameters in predicting HR-PCa prognosis, clinical stage revealed to be the least (Fig. 36.1) [13, 15]. This evidence can be explained considering that 23–40% of patients with a clinically suspected LA-PCa will be downstaged (pT ≤ 2c) on pathological examination [2, 14, 16].

We have multiple evidences today supporting the surgical approach with excellent long term cancer control (Table 36.1) [2, 16–20]. In 2005, Ward highlighted that patients undergoing open

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_36

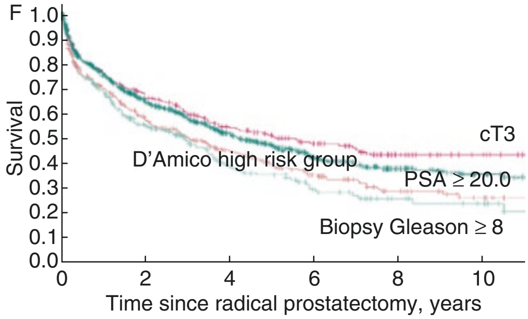

Fig. 36.1 Comparison of the biochemical recurrence-free survival rates according to the four preoperative parameters defining HR-PCa (from [13])

RP for locally advanced tumors had oncological outcomes similar to those with localized diseases [14]. The 5, 10 and 15 year disease free survival (DFS) after RP for LA-PCa were 85%, 73% and 67%, respectively. Biochemical recurrence free survival (BCRFS) were 58%, 43% and 38% for cT3 patients and 74%, 61% and 52% for cT2 patients. The overall survival (OS) (90%, 76%, 53%) and cancer-specific survival (CSS) (95%, 90%, 79%) for patients with locally advanced disease at 5, 10 and 15 year. were only moderately lower than those in patients with cT2 disease (95%, 82% and 61%, and 99%, 96% and 92%, respectively) during the same period [14].

Similar results were further published by Gözen on a laparoscopic series [2]. The authors reported a 5 and 10 year. CSS rate of 99.8% and 97.4%, respectively, in patients with cT3 PCa. The OS rates at the same time points were 99.1 and 93.4% [2].

Progress in surgical techniques, has reduced the complication rate also in this special setting, making it comparable to the organ-confined tumors. Regardless the technique, in fact, postoperative continence rates are between 60 and 97% [1, 2, 16].

Nowadays, the robotic approach is the most widely adopted for patients with localized PCa, accounting for more than 85% of surgeries in the USA [21]. Recently, this surgical procedure has been demonstrated as a safe and oncological-effective treatment even in HR tumors [22, 23]. In the hands of experienced surgeons, the advantage brought by the robotic surgical system in terms of tissue magnification, tridimensional view and higher degree of movement may result in a reduced intraoperative blood loss and optimal cancer control even in LA-PCa. Data from a recent multicenter study reported an overall 10% complication rate, being 2.2% grade III/IV according to the Clavien-Dindo classification system. The median intraoperative blood loss was 200 mL with less than 5% of patients requiring transfusions. Encouraging were also data on cancer control, with 30% of positive surgical margin, 40% of node involvement (with a median of 16 nodes removed during extended lymph node dissection) and 63.3% 3-year BCRFS. The 12-mo continence rate was acceptable (64%), considering the negative impact of the systematic neurovascular bundles transection performed during Extra Fascial Robot-assisted Radical Prostatectomy (EF-RARP) [16].

Surgical Anatomy

Despite the vast literature on the anatomy of pelvic fasciae, there is no consensus over the peri-prostatic structures nomenclature and orientation.

It is not the purpose of this chapter to describe the somehow complex pelvic anatomy but we need to clarify some points in order to illustrate the surgical technique of ER-RARP, whose aim is to remove the prostate and the seminal vesicles (SVs), still contained inside their fasciae (Fig. 36.2).

Pelvic fasciae are either parietal or visceral; together they support and define the pelvis structures [24, 25].

Parietal Pelvic Fascia

Despite the profusion of names (*parietal pelvic fascia, levator ani fascia, endopelvic fascia*), this anatomical structure is well recognized in the literature and its description is standardized. It is a discrete organized sheet of connective tissue that lines the walls and floor of the pelvis, covering the obturator internus, piriformis, levator ani and coccygeus muscles. It is continuous with the transversalis fascia and it fuses to the periosteum of the hipbones [24, 26–28].

Descending laterally to the bladder, it forms a white line of condensation termed *arcus tendineus*

Table 36.1 Results of series evaluating oncologic outcomes of RP in the management of patients with clinically suspected LA-PCa

	Technique	Patients, n	Neoadjuvant therapies, %	Follow-up, mo	Nodes removed, n	Positive surgical margins, %	Adjuvant therapies, %	Oncologic outcomes
Van Poppel et al. [18]	Open	158	0	30[a]	NA	60	30.3	3-year BCR-free survival: 40%
Carver et al. [20]	Open	176	36	76.8[a]	NA	27	0	10-year BCR-free survival: 44% 10-year CR-free survival: 76%
Xylinas et al. [17]	Open (n = 77), laparoscopic (n = 23)	100	0	69[b]	NA	61	31	5-year BCR-free survival: 45% 5-year CSM-free survival: 90%
Mitchell et al. [19]	Open	843	24	171[b]	NA	56	ADT: 40.8; RT: 12.9	20-year LR-free survival: 76% 20-year SP-free survival: 72% 20-year CSM-free survival: 81%
Gozen et al. [2]	Laparoscopic	492	NA	104[b]	NA	38.2	ADT: 49.2; RT:15.9	10-year CSM-free survival: 97.4%
Gandaglia et al. [16]	Robotic	94	10.6	23.5[b]	13.9[b]	32.3	20.2	3-year BCR-free survival: 63.3% 3-year CR-free survival: 95.8%

NA not available, *ADT* androgen deprivation therapy, *RT* radio therapy, *BCR* biochemical recurrence, *CR* clinical recurrence, *CSM* cancer-specific mortality, *LR* local recurrence, *SP* systemic progression

[a]Mean

[b]Median

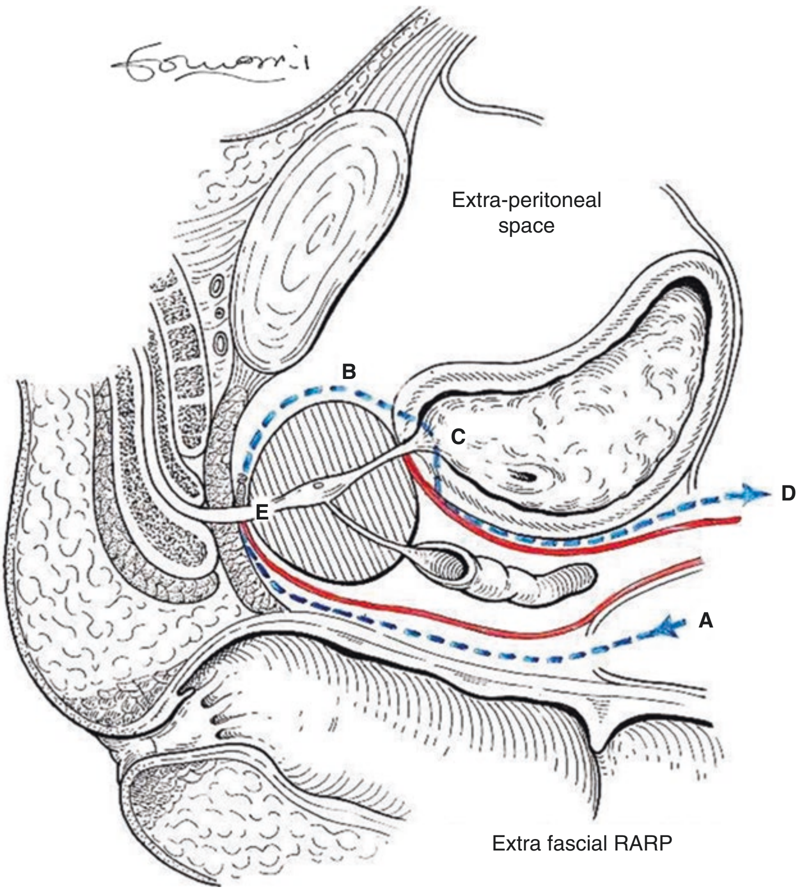

Fig. 36.2 Surgical strategy of the EF-RALP. (**a**) The peritoneum is incised at the level of the Douglas' pouch and the surgical plane between prostate and rectum is developed with blunt dissection, avoiding any injury of the prostatoseminal vesical fascia (posterior Denonvilliers' fascia) and the rectal wall. (**b**) Incising the peritoneum laterally to each umbilical ligament, the access to the retropubic (Retzius') space is obtained. With blunt dissection through the fatty tissue, the surgical plane is developed until the prostatic reflection of the endopelvic fascia is identified. (**c**) The bladder neck dissection is performed until the vesicoprostatic muscle (anterior Denonvilliers' fascia) is encountered and (**d**) followed cranially, to prepare the seminal vesicles (SVs). Prostate and seminal vesicles are removed, still contained inside their fasciae

fasciae pelvis that stretches from the puboprostatic ligaments to the ischial spine [26]. At this level, another sheet of connective tissue sweeps up medially, covering the anterior surface of the prostate. When the endopelvic fascia (EPF) is incised just lateral to the arcus tendineus, the bare underlying levator ani muscle fibers are seen. Then, the lateral surface of the prostate appears covered by the *levator ani fascia* (parietal in origin) that belongs to the namesake muscle that has just been displaced laterally [24]. Underneath, the prostate gland is covered by the so called *prostatic visceral fascia (PVF)* that tethers the neurovascular bundles (NVBs).

Prostatic Visceral Fascia

It is not actually a discrete organized structure but rather an adipose fibrofatty sheat completely covering the prostate, containing neurovascular supply to the gland [24]. It shows a great homogeneity in its muscle content and density with the prostate stroma so that a true *prostatic capsule* underneath cannot be identified [29, 30].

Its thickness varies according to the amount of vessels and nerves it contains, being higher on either side of the prostate, posterolateral. It also extends cranially, filling the space between the prostate, the SVs and the urinary bladder [31]. Anteriorly it fuses with the prostatic reflection of the endopelvic fascia, posteriorly with the *Denonvillier's fascia* [24, 32].

Prostatoseminal Vesicular Fascia

Eponymically known as Denonvillier's fascia (DF) (Fig. v), it is conventionally thought to develop by obliteration of the rectovesical peritoneal pouch [24, 28]. It represents an important barrier to the spread of prostatic and rectal malignancies [26].

This fascia, indeed, completely covers the posterior aspect of the prostate and SVs, extending distally, posterior to the prostate apex and membranous urethra and ending in the perineal body (central tendon of the perineum), just above the recto-urethralis muscle [24, 33]. It is separated from the rectal fascia propria by a prerectal cleavage plane, which proceeds distally from the end point of the peritoneal cul-de-sac (rectovesical pouch, Douglas' pouch) [24].

Medially it fuses with the fibromuscular stroma of the prostate, while laterally it is separated from the stroma with the intervening space being filled with the adipose fibrofatty tissue of the prostatic visceral fascia embedding the NVBs [34]. It has not a defined lateral edge: rather, it becomes continuous with the prostatic reflection of the endopelvic fascia [35].

Mostly single-layered, it is frequently multilayered over the seminal vesicles because of a predominance of smooth muscle fibers. It has been therefore suggested to distinguish a fascial leaf that lays posteriorly to the prostate and the SVs, and another leaf that only covers the anterior aspect of the seminal vesicles (Fig. 36.3). Recent evidences, however, have referred this lat-

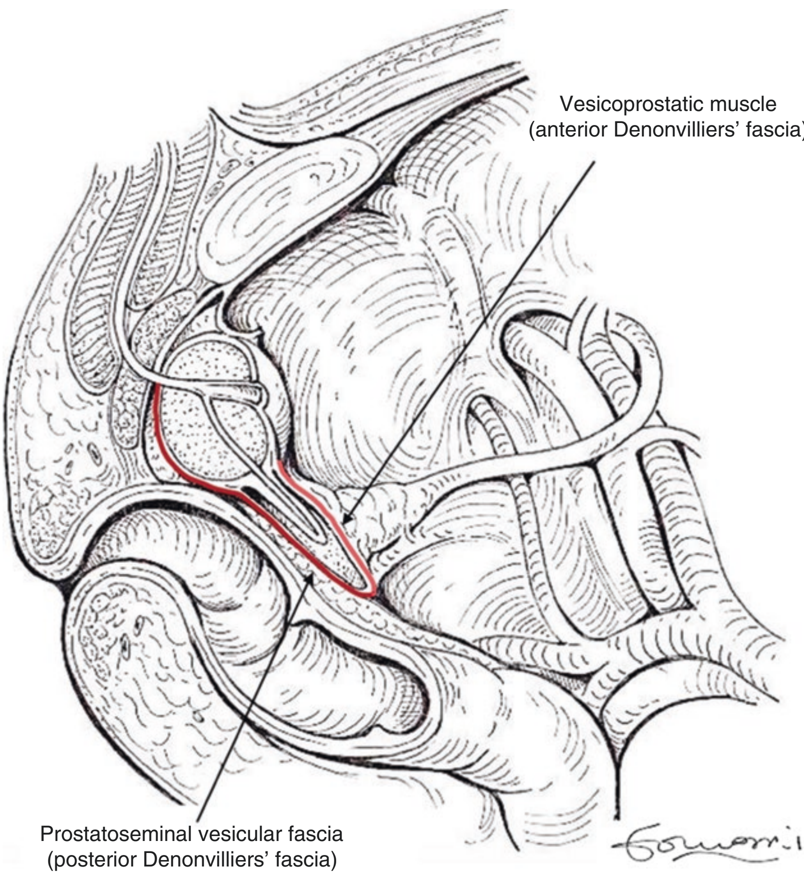

Fig. 36.3 Surgical anatomy of the Prostate. The bladder was removed. The two layers of the Denonvilliers' fascia (prostatoseminal vesicular fascia and vesicoprostatic muscle) are highlighted

ter leaf to the *posterior layer of the detrusor apron (vesicoprostatic muscle (VPM))* [36]. Divided the posterior bladder neck, this leaf represents a crucial landmark while performing EF-RALP.

Detrusor apron

Firstly described by Myers [26], it consists of a loose conglomeration of longitudinal smooth muscle bands and veins, originated from the detrusor muscle and extended in front of the anterior commissure of the prostate. It represents a direct continuity of the anterior bladder wall with the pubis, via the pubo-prostatic ligaments [37]. The dorsal vascular complex passes between them [24].

Surgical Technique: The Extra Fascial Robot-Assisted Radical Prostatectomy

Surgery is performed under general anesthesia with endotracheal intubation and full muscle relaxation; combining epidural pain killers administration is advisable, resulting in faster emerging from sedation and less pain on awakening [38].

The patient lays in supine position, 30° Trendelenburg, with the arms alongside the body and the legs slightly abducted. A 16 Ch Foley catheter is inserted. A skin incision is performed 3–5 cm above the umbilicus and a Veress needle is inserted to create a 16 mmHg pneumoperitoneum for the further installation of the 12 mm trocar for the scope. The Hasson's minilaparotomy is preferred if there is a risk of periumbilical adherences. Five other ports are placed as per conventional transperitoneal pelvic surgery (Fig. 36.4).

Step 1: development of the posterior plane

The procedure starts at the level of Douglas pouch. It is important to displace the sigmoid from the operating field without keeping one instrument busy. Therefore, the assistant introduces one straight needle trough the pararectal

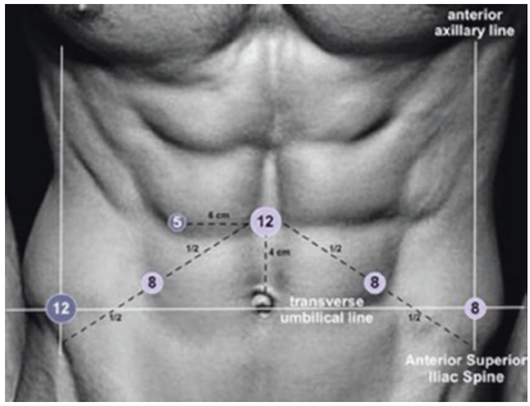

Fig. 36.4 Trocars' position

5 mm trocar. The surgeon passes the needle through the epiploic appendix of the sigmoid and the needle is extracted again through the same 5 mm trocar. By removing the trocar which is then reintroduced we can dislodge the sigmoid cranially saving one instrument. With the third robotic arm holding a ProGrasp™ forceps, the peritoneum at the anterior edge of the rectovesical (Douglas') pouch is retracted ventrally. Few centimeters distally, a peritoneal incision is performed between the rectum and the complex of the seminal vesicle and the vas (Fig. 36.5a) and the prostatoseminal vesicular fascia (PSVF) is identified. The avascular prerectal cleavage plane separating the Denonvillier's from the rectal fascia propria is bluntly developed distally (Fig. 36.5b). Toggling the camera, the 30° lens is rotated upwards to better visualize the PSVF that represents the inviolable anatomical landmark during the posterior dissection. With blunt dissection and bipolar coagulation, the cleavage plane is expanded laterally until the levator ani muscle is encountered on both sides (Fig. 36.5c). At this point the dissection is extended distally, reaching the prostatic apex.

Step 2: extended pelvic lymph node dissection and development of the Retzius space

The peritoneum is incised laterally to the right umbilical ligament. The vas deferens on the same side is identified coagulated and cut. With blunt dissection, the right half of the Retzius space is developed until the EPF is recognized. Once the EPF is identified, a longitudinal incision is

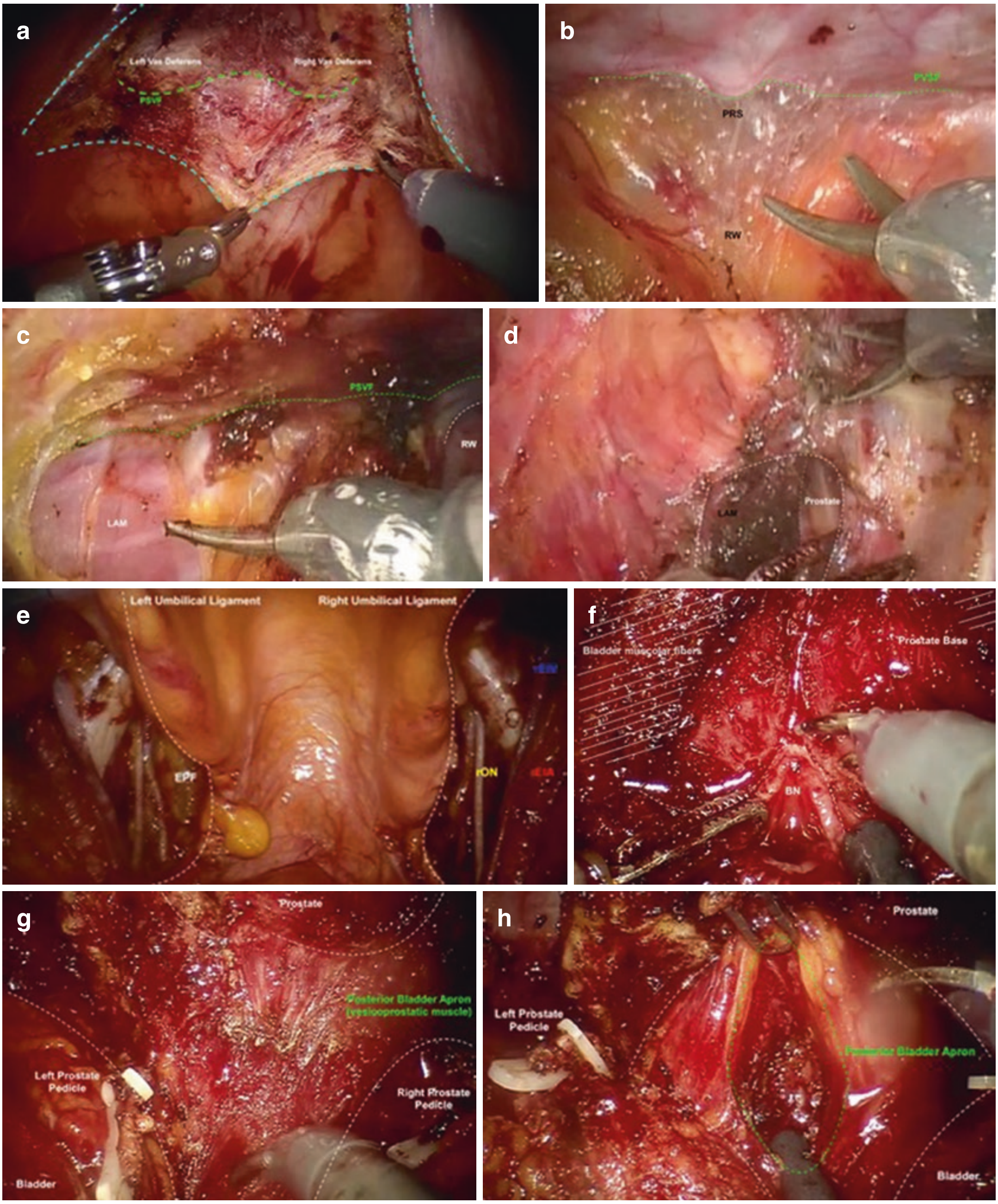

Fig. 36.5 Main surgical steps of the EF-RARP. (**a**) Peritoneal incision at the Douglas' pouch. (**b**) Blunt dissection of the areolar tissue of the prerectal space (PRS), avoiding any injury of the prostatoseminal vesical fascia (PSVF) and the rectal wall (RW). (**c**) The dissection plane is extended laterally, finding the levator ani muscle. (**d**) Incising the prostatic reflection of the endopelvic fascia (EPF), the bare fibers of the levator ani muscle (LAM) are encountered. (**e**) The bladder is taken down dividing the urachus and the umbilical ligaments. (**f**) The posterior aspect of the bladder neck is raised up, to facilitate the correct identification of the surgical plane between the bladder and the prostate. (**g**) Once the posterior bladder neck dissection is completed, the vesicoprostatic muscle is encountered and followed cranially, to prepare the seminal vesicles still inside their fascia. (**h**) Moving cranially, the apex of the seminal vesicles is reached and the tissue is clipped and cut. (**i**) The peritoneum of the Douglas' pouch is sutured to the recto-urethralis muscle; (**j**) with the same barbed stitch, also the sub-trigonal lamina prorpia of the bladder neck is brought distally

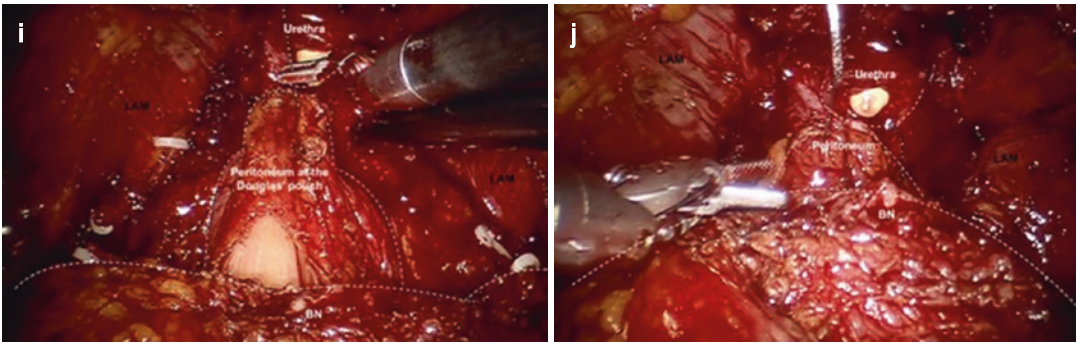

Fig. 36.5 (continued)

performed, finding the previously prepared medial aspect of the bare levator ani muscle (Fig. 36.5d). Thereafter, an extended pelvic lymph node dissection is performed. Before starting the dissection, the ureter needs to be identified and a vessel-loop can be passed. The lymphadenectomy will include the common iliac vessels, the internal and external iliac vessels, the Marcille fossa and the obturator fossa.

The same surgical steps are repeated contralaterally.

Step 3: bladder neck dissection

The urachus and the median umbilical ligaments are coagulated with bipolar cautery and cut. The bladder is then mobilized, staying in the correct plane by following the areolar tissue (Fig. 36.5e).

A gentle traction with the ProGrasp™ on the anterior bladder wall, on the midline, creates a little tension on the area of the bladder neck, in order to better identify the incision line between the bladder and the prostate. Pulling the catheter with the balloon still inflated, may further help to identify the incision site. Any kind of extensive defattening of the anterior aspect of the prostate, usually performed to better expose the bladder apron, is here strongly discouraged since the embedded lymphatic tissue, eventually involved by metastatic cells, should be found on the specimen at the end of the procedure.

With sharp dissection, the surgical plane between prostate and bladder is developed trying to respect, as much as possible, the anatomical boundaries of the prostate. The perforating vessels occasionally encountered are controlled combining monopolar and bipolar cautery. After the bladder neck is opened the catheter is retracted with the ProGrasp™, lifting the prostate.

A hemostatic suture of the prostatic vascular pedicles is recommended, thus avoiding the use of clips in proximity of the future anastomosis.

Once the posterior aspect of the urethra is exposed and cold cut, the posterior aspect of the bladder neck is raised up, to facilitate the correct identification of the surgical plane between the bladder and the prostate (Fig. 36.5f). After the incision is completed, the vesicoprostatic muscle is encountered and followed cranially, in order to prepare the seminal vesicles still inside their fascia (Fig. 36.5g). Moving cranially, the apex of the seminal vesicles is reached and the tissue is clipped and cut (Fig. 36.5h).

A neck-sparing approach is not recommended in patients with a LA disease, although it can be attempted in selected cases, with a preoperative magnetic resonance proving the absence of cancer involvement of the prostate at its base.

Step 4: prostate detachment

The posterolateral mobilization of the prostate is completed dividing the remnants of the prostatic pedicles between clips.

The third arm is then used to retract the prostate cranially, creating a little tension on the puboprostatic ligaments and the DVC. The tissue covering the anterior distal part of the prostate is thereafter dissected combining cold cat and monopolar energy, sparing the peri-sphincteric structures. The limit between the prostatic apex and the membranous urethra is carefully identified, prepared and cold cut. The bleeding from the transected DVC is easily controlled, during the procedure, rising the abdominal pressure up to 18 mmHg; once the prostate is freed, a hemostatic running suture with a barbed thread is performed.

To completely mobilize the prostate, the gland is retracted laterally and the remnants of the PSVF, still attached just underneath the membranous urethra, are cold cut.

Step 5: urethra-vesical anastomosis

After the prostate is removed, a modified posterior reconstruction on two layers is performed, approaching the bladder neck to the urethral stump. Completely missing the PSVF, the peritoneum, previously incised at the level of the Douglas' pouch, is sutured to the distal insertion of the recto-urethralis muscle (Fig. 36.5i). With the same barbed thread, also the sub-trigonal lamina propria of the bladder neck is brought distally (Fig. 36.5j). The anastomosis is performed with a second barbed running suture.

A drainage is left in place for 24 h.

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37 Outcome Measures After Robot-Assisted Radical Prostatectomy

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Introduction

Prostate cancer is the third most common malignancy in men, with half a million new diagnoses each year worldwide. Further, it is the second leading cause of death from cancer in American men [1]. First described by Terence Millin in 1945, the open radical retropubic prostatectomy was not widely adopted as the gold standard until the 1980s when Walsh and colleagues described anatomic steps delineating the dorsal vein complex (DVC) and the cavernosal nerves, thereby reducing blood loss and allowing more precise transection of the prostatic vascular pedicles and dissection of the neurovascular bundle (NVB) [2, 3]. Applying minimally invasive techniques to prostate surgery, the first laparoscopic radical prostatectomy (LRP) was reported by Schuessler, Clayman, and Kavoussi in 1992 [4]. A decade later, the technically challenging demands of pure LRP led Menon, Tewari, and Ahlering to transition to the new robotic surgical systems that, in contrast to laparoscopy, allowed for magnified, three-dimensional views with full-range motion surgical arms and articulating instruments whose movements could be controlled intuitively. The minimally invasive robot-assisted laparoscopic prostatectomy (RARP) has challenged the open radical retropubic prostatectomy (RRP) as the gold standard treatment for organ-confined disease. Certainly, RARP has generated great enthusiasm among surgeons and patients alike due to its minimally invasive nature and its excellent short-term outcomes compared to the open and standard laparoscopic approach; but we must ask ourselves seriously—has the robot fulfilled the promise to be equivalent or better than open surgery?

This chapter will discuss operative, perioperative, oncologic, and quality of life outcome measures with RARP.

Operative Results

Blood Loss and Transfusion

As noted above, improved anatomical understanding has led to decreased blood loss in RRP. Further improvements have been noted as the pneumoperitoneum induced in RARP provides a significant reduction in intraoperative blood loss thereby improving operative field visualization for more precise anatomical dissection. The reported estimated blood loss (EBL) in robotic series ranges from 75 to 800 mL (overall series mean of 271 mL) with most series reporting <200 mL EBL (Table 37.1). In comparison, RRP series report from 600 to 1030 mL EBL (Table 37.2). Blood transfusion rates now

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_37

Table 37.1 Pathologic outcomes of robotic radical prostatectomy series

Authors	*N*	Age (years)	OR time (h)	EBL (mL)	Tx. rate	Anastomosis	Open conv. rate	Margin positive rate							Gleason <7/≥7	Mean F/up (months)	PSA progression-free rate (<0.1 ng/mL)
								Overall	pT2a	pT2b	pT2c	pT3a	pT3b	pT4			
Bhandari et al. [5]	300	60.3	2.96	109	0%	Running	0%	na	na	na	na	na	na	na	na	na	na
Patel et al. [6]	200	59.5	2.35	75	0%	Running	0%	10.5%	5.7%			28.5%	20%	33%	na	9.7	95%
Borin et al. [7]	200	60.3	na	108	na	Running	na	7.5	na			na		na	na	na	na
Menon/Tewari [8]	200	59.9	160 min	153	0	Running		6.0%	na			na		na	na	na	na
Patel et al. [9]	1500	60.7	105 min	111	0	Running	0.6%	9.3	4.0			34		40	na	na	na
Murphy et al. [10]	400	60.2	186 min	na	2.5%	Running	0.25%	19.2	9.6			42.3		na	na	22	86.6%
Menon et al. [11]	2766	60.2	154 min	100	1.5%	Running	0.1%	na	13.0			35		na	na	22	84% 5 year
Menon et al. [12]	1384	60.0	na	na	na	Running	na	25.1	na			na		na	na	60.2	86.6%
Novara et al. [13]	na	na	152 min	166	2%	na	na	na	na			na		na	na	na	na

OR time operative time, *Tx rate* transfusion rate, *RRP* radical retropubic prostatectomy, *EBL* estimated blood loss

Table 37.2 Open radical prostatectomy series

Institution	*n*	Age (years)	Method	Oper. time (h)	EBL (mL)	Transfusion rate	Hospital days	Margin post rate	Follow-up (months)	Continence rate	Criteria	Erectile function (bns/uns)	PSA progression-free rate (<0.2 ng/mL)	Complication rate total, major/minor
Johns Hopkins [14]	2404	59	RRP	na	na	na	na	na	75	na	na	na	74%	na
NYU [15]	1000	60.3	RRP	na	819	9.7%	2.3	19.9%	na	na	na	na	na	7%
Washington Univ. [16]	1342	na	RRP	na	na	11.5%	na	na	na	na	na	na	na	7.4%, 2.4%/5.0%
Washington Univ. [17]	1870	63	RRP	na	na	na	na	na	18	92%	0 pads	68%/47%	na	10%
Washington Univ. [18]	3477	61	RRP	na	na	na	na		18	93%	0 Pads		na	9%
Mayo Clinic [19]	3170	66	RRP	na	600–1030	5–31%	na	24%	60	na	na	na	52% at 10 year	na
Baylor [20]	1000	62.9	RRP	na	na	na	na	12.8%	53.2	na	na	na	75% (<0.4 ng/mL)	na
Memorial Sloan-Kettering Cancer Center, New York [21]	1746	na	RRP	na	na	na	na	12%	72	na	na	na	75% at 15 year	na
University of Padu, Italy [22]	985	64.5	RRP	na	750	na	na	13.7%	95.5	79.9%	0 pads	na	na	na
Memorial Sloan-Kettering Cancer Center, New York [23]	1577	58	RRP	na	na	na	na	11%	23.5	94%	0 pads	67% 3 year	91% at 5 year	na

RRP radical retropubic prostatectomy, *RPP* radical perineal prostatectomy, *EBL* estimated blood loss, *bns* bilateral nerve sparing, *uns* unilateral nerve sparing average 1–4% (range 0–17%) for RARP versus 32% (range 3–67%) for RRP, thus greatly reducing the risks of hepatitis B and C or HIV infection, transfusion reaction, or anaphylaxis associated with transfusions [24, 25]. These results likely reflect that the pneumoperitoneum tamponades bleeding venous channels that otherwise may continue to ooze during standard open surgery. A precise measure and comparison of estimated blood loss during robotic or open prostatectomy is difficult due to the inherent subjectivity.

Convalescence

The length of hospital stay (LOS) is often used as an instrument to measure recovery as it generally correlates with the patient's time to return to basic activities. In practice, LOS is driven several factors including cultural differences, healthcare systems, patient socioeconomic status, surgeon practice patterns, and thus it is difficult to compare LOS, particularly between countries. Still, in the United States, most RARP series report a LOS of 0.96–1.2 days, while the average hospitalization after open RRP is between 2 and 3 days. Both Liu et al., and Trinh et al., more recently re-demonstrated decreased LOS with fewer overall complications with RARP as compared to RRP [26, 27]. A shorter hospital stay is advantageous to decrease the risk of nosocomial infections and minimize hospital costs. In a Swedish study, Hohwü et al. reported that patients who underwent RARP had shorter postoperative hospital stay and less need for paid sick leave than patients who underwent an RRP. The average time to return to work was 11 days for RARP versus 49 days undergoing open RP [28]. In a similar study by Plym et al., men returned to work after RARP within a median 35 vs. 48 days after RRP, representing a fourfold faster time to recovery within the first month after surgery [29].

Complications

Novara and colleagues completed a more recent meta-analysis comparing RRP, LRP and RARP. According to this review of data published between 2008 and 2011, there was a mean complication rate of 9% (range 3–26%) for RARP. Most complications were low grade. Overall complications between RRP and RARP were noted to be similar (OR: 1.25; 95% CI, 0.53–2.93; p = 0.61). The authors noted that surgical experience, clinical patient characteristics, and cancer characteristics may play a role in the risk of complications [13]. Minor and major complication rates of open and robotic prostatectomy series are listed on Tables 37.1, 37.2, 37.3, and 37.4. As not every series reports all complications, meaningful comparisons are rare. However, the overall complication rates appear to be less in the robotic series.

As in open surgery, complications in laparoscopic prostatectomy are related to surgeon experience and occur more readily during the early stages of the learning curve. A multi-institutional study evaluated perioperative and late complications of 1130 RARPs performed by three surgeons. Overall complication rates varied from 8.8 to 13.9%, with an average of 11.3%. There were no mortalities and only one conversion from RARP to open RRP for the whole series. Overall there were 17 major complications (1.5%) and 81 minor complications (7.2%). Major perioperative complications dropped significantly to less than 0.7% when surgeon experience exceeded 200 cases [36]. Similarly, Coehlo et al. reported the early complications of a single-surgeon outcome of 2500 RARP performed between 2002 and 2009. Rates for Clavien grades 1 and 2 were 4% and grades 3 + 4a were 1%. No Clavien 4b or 5 complications were observed. While overall complication rates were 9.3% in the initial 300 cases, for cases 2100 and above the complication rate fell to 3.3% [37].

Table 37.3 Functional outcomes of robot assisted radical prostatectomy series

Authors	*n*	Age (years)	[b]Hospital days	[a]Days with catheter	Time of assessment from surgery (months)	Continence rate	Criteria	Erectile function (bns/uns)	Complication rate total, major/minor
Bhandari et al. [5]	300	60.3	1.2	6.9	na	na	na	na	5.7%
Patel et al. [6]	200	59.5	1.1	7.9	12	98%	0 pads	na	na
Borin et al. [7]	200	60.3	1	na	3	91%	0 pads	na	na
Menon/ Tewari et al. [8]	200	59.9	1.2	7	6	96%	0 or pad use for protection only	<60 year 64% >60 year 38%	4.0%
Patel et al. [9]	1500	60.7	1 (97%)	6.3	na	na	na	na	4.3%
Murphy et al. [10]	400	60.2	3.1	8.2	12	91.4%	0 pads	62%	15.75% 10.5%/5.25%
Menon et al. [11]	2766	60.2	1.14	10	28	93%	≤1 pad	79.2%	na
Menon et al. [12]	1384	60.0	na	na	na	na	na	na	na

[a]Assessed with validated patient questionnaire
[b]Length of hospital stay for 95/100 patients

Table 37.4 Comparison of complication rates between recent large studies with long-term follow-up for assessing late complications

	Constantinides et al. [30]	Carlsson et al. [31]	Rabbani et al. [32]	Rabbani et al. [32]	Hruza et al. [33]	Agarwal et al. [34]	Carlsson et al. [31]	Liss et al. [35]
Year	2008	2010	2010	2010	2010	2011	2010	2011
Surgery	OPEN	OPEN	OPEN	LAP	LAP	RARP	RARP	RARP
N total patients	995	485	3458	1134	2200	3317	1253	1000
N complications	268	159	950	442		326	197	105
% Patients w/ complications[a]	26.9	32.8	27.5	39.0	32.4	10.4	15.7	10.5
FU	36.8 months	30 months	36.9 months	36.9 months	50 months	24.2 months	19 months	40 months
Complications by Clavien score category								
% Minors								
1	3.4%	7.4%	23.2%	44.2%	6.8%	*7.2%*	0.5%	1.3%
2	3.9%	24.3%			14.9%		4.8%	1.7%
% Majors								
3	15.4%	13.5%	16.5%	13.0%	9.8%	*3.8%*	4.0%	6.6%
4	3.8%	1.4%			1.5%		0.2%	0.8%
5	0.3%	0.2%			0.1%		0%	0

[a]Multiple complications within one patient counted only as one

Table 37.5 Liss et al.: Reduction of major/minor Complications through specific interventional techniques [35]

Complications	Clavien	Old rate	Resolution	New rate	*Adjusted-p-value*
Corneal abrasion	1	4/200 (2.0%)	*Foam-based safety goggles*	1/800 (0.1%)	*0.030*
Fossa strictures	3a	10/165 (6.1%)	*Avoidance ≥ 20F Catheters*	1/835 (0.1%)	*0.031*
Bladder neck contractions (BNC)	3a/3b	6/592 (1.0%)	*Addition of 'Rocco' Stitch to Van Velthoven Single knot Anastomosis*	1/408 (0.2%)	*0.052*
Camera site hernias	3b	40/735 (5.4%)	*Transverse Incision*	1/265 (0.4%)	*<0.001*
Pulmonary embolus	4a	5/190 (2.6%)	*Thigh-high pneumatic compression early and persistent ambulation*	0/810 (0%)	*0.863*

Changes in operative technique further improves complication rates after RARP. Reporting on their 1000 case experience, Liss et al. noted that combined intraoperative and early complications were 0.8% high risk (≥Clavien 3) and 2.3% low risk (≤Clavien 2). Similar to the above studies, half of the intraoperative or early complications and a quarter of the late complications occurred in the first 200 RARP cases. These observations invoked deliberate changes in operative technique designed to decrease side effects and complications. Thus Liss et al. applied an active approach, introducing discrete technical changes not simply related to the learning curve to correct a wide range of Clavien complications (Table 37.5) [35].

Common Perioperative Complications

In their systemic analysis, Novara et al. found that the most common complications following RARP are lymphocele/lymphorrea (3.1%), urine leak (1.8%), and re-operation (1.6%) [13]. While lymphocele formation is relatively common in pelvic surgery, the incidence of clinically symptomatic lymphocele following RARP is low and may be avoided by meticulous attention to sealing lymph vessels during nodal dissection [38]. Detection on ultrasound or computed tomography imaging is facile, and though most lymphoceles are self-resolving, if needed drainage via ultrasonic guidance may be employed. In Coelho et al.'s study, anastomotic leakage varied from 4% in the early cases to 0.3% in the later cases, redemonstrating the importance of surgeon experience for minimizing complications [37]. Finally, a recent analysis of the NSQIP database showed reoperation rates were significantly lower for patients undergoing radical prostatectomy via minimally invasive techniques (including robot-assisted and laparoscopic techniques) as compared to RRP (1.1% vs. 1.5%). Bleeding, wound dehiscence, and urinary retention were the most common reasons for reoperation [39].

Rare Perioperative Complications

Rectal Injuries

Though relatively rare, rectal injuries convert the case classification from clean contaminated to contaminated, increasing risks for abscess or fistula formation, sepsis and even death. Rectal injuries most commonly occur during the dissection of the prostatic apex. If not completely mobilized off of the posterior aspect of the prostate, the rectum that remains adherent to the apex is at risk of injury during transection of the urethra. It is also particularly vulnerable when performing non-nerve-sparing RARP for aggressive high-risk prostate cancer or while performing wide resection of the NVBs particularly at the apex. Historic rates for RRP were as high as 9%, although contemporary rates near 0.5% [40–42]. Menon et al. reviewed their single institutional outcome of 4400 men undergoing RARP and found that the average rate of rectal injury to be 0.2% [43].The authors noted additionally difficulty in the setting of prior extensive prostate biopsies or peri-prostatic extension, i.e. factors obscuring proper identifications of operative planes. Certainly, in our experience the key is to use the perirectal fat as a guide to stay in the correct plane, dissecting close to the prostatic surface.

Bladder Neck Contractures

Incidence of bladder neck contractures are low in both RRP and RARP, though significantly lower in RARP (1.4% vs. 2.6%) [44]. The introduction of the van Velthoven single knot anastomosis in 2003 allowed for the creation of a running urethral anastomosis in a tension-free manner. The critical benefit of this technique is that the initial tension of approximating the bladder to the urethra is dispersed over 10 needle holes rather than two with interrupted techniques. It is simple and creates a watertight anastomosis with only one intracorporeal knot required. We have employed the van Velthoven technique from case 1 with a bladder neck contracture (BNC) rate of <1% [45].

A second critical improvement to the reconstruction anastamosis of the bladder to the urethra is the Rocco stitch first described in 2006 [46]. The Rocco stitch is an extremely valuable addition by markedly improving the ease of performing the van Velthoven stitch by reducing tension, and hemostatic in our experience, greatly reducing ER and clinic visits for hematuria and clot retention. Incorporating the second addition of the Rocco stitch has lead to a very low bladder neck contracture rate (2/500).

Fossa Navicularis Contracture

While also infrequent, fossa navicularis strictures may result in acute onset urinary obstructive symptoms, and worsening IPSS or urinary flow pattern changes requiring subsequent intervention. A high incidence of fossa strictures has been reported to be an iatrogenic effect of using larger caliber (>18Fr) catheters during stapling of the DVC [47]. It is noteworthy that using a smaller 18F catheter size eliminated these strictures (from 6.9% with 22F to 0.9% in the 18F group).

Incisional Hernia

RARP has historically used a vertical incision for the camera port above or below the navel. The camera incision is also the port used to extract the prostate. Though the incidence of incisional hernias (IH) has low reported rates in literature, data is handicapped by incomplete or short follow-up. Beck et al. proposed a simple modification to reduce the incidence of incisional hernias and improve cosmesis [48]. The rate of IH in midline incision varies with the method of reporting, as low as 4.9% (36/735) relying on patient ad hoc self-reporting or as high as 9.4% (18/192) if queried by email. Only one incisional hernia occurred in the transverse group—0.6% (1/165), although the average follow-up is much shorter in this group (2.8 year vs. 0.8 year), with no difference in baseline factors between groups. Midline incisions conferred a *risk hazard of 11.0* compared to transverse incision. Baseline factors that appear to influence the development of incisional hernias in vertical incisions at the camera port include direction prostate weight, older age, IIEF-5, and BMI. Transverse closures had much smaller scar width (Fig. 37.1), which we feel

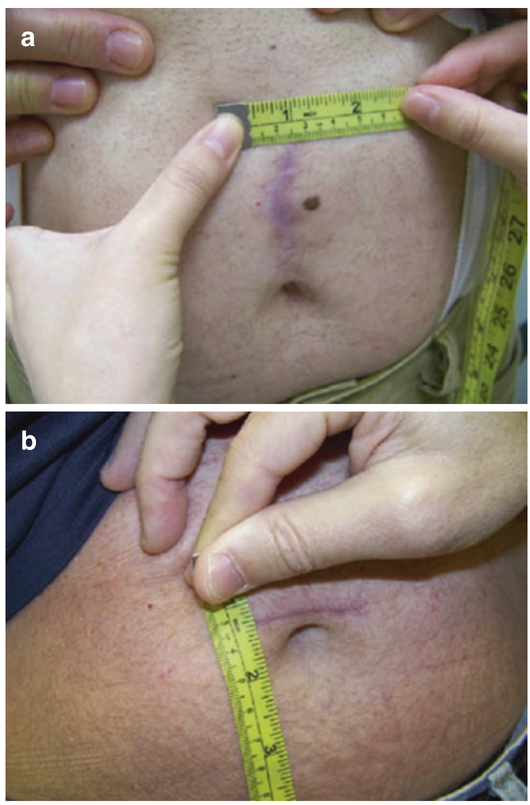

Fig. 37.1 Examples of a transverse versus midline incision scar

reflects less tension on the skin and hence the fascial closure which reasonably appears to have resulted in fewer incisional hernias.

Oncological Control

Surgical Margins and PSA Recurrence

Regardless of surgical approach, the cornerstone oncologic principle of the radical prostatectomy is the complete removal of the prostate gland. Cancer control is commonly assessed by positive surgical margin (PSM) status of the prostate specimen and presence of biochemical recurrence (BCR).

Surgical Margins

In general caution is advised when interpreting the PSM rates, since the determination of positive surgical margins is not standardized to allow a qualitative comparison between institutions. In the least, comparisons should only be performed after adjustment of relevant covariates. For example, comparing combined pT2 and pT3 rates of differing groups can be very misleading if the ratios are biased to greater inclusion of pT2 cases which have significantly lower PSM rates than pT3 cases. Therefore, it is best to compare pT2 to pT2 rates alone to capture the rate of "surgeon error"—since these are organ-confined cases.

Keeping the above limitations in mind, Walsh and colleagues reported overall PSMs of 1.5% for RRP, while most other open prostatectomy centers reported rates from 12.8 to 43.1%, with an overall average of 21.6% (Table 37.2) [49]. The overall positive surgical margin frequency in RARP series is similar to the open literature with a range of 10.5–20% and an average of 15%. For organ-confined disease (pT2), PSMs range from 4.5 to 10.6%, while for pT3 disease they range from 20 to 47% (Table 37.1). In a direct comparison of PSM rates between RRP and RARP at five institutions, Ficarra et al. reported that RRP rates averaged 22.4% versus 14% in RARP, with a relative risk of 1.6 with open surgery. For non-comparative studies, RRP PSM rates ranged from 12 to 37% and RARP from 9.4 to 21% [50].

An important aspect of radical prostatectomy is the reduction of iatrogenic positive surgical margins (PSM) in otherwise organ-confined prostate cancer. The goal of achieving a "zero" pT2 margin positivity rate reflects a difficult technical challenge, but represents theoretical perfection of surgical technique that is free of iatrogenic error. It has been shown that surgical margin status decreases with operative experience and is affected by clinical stage, serum PSA, and biopsy Gleason score [51]. Further, the majority of PSM in most reported series of either RRP or RARP occur in the apex of the prostate and the posterolateral margins [52]. With refinement of technique, the frequency of PSM should continue decrease. Ahlering et al. reported several technical methods to aid in the apical dissection and minimize the risk of PSM: removal of all fat overlying the DVC and prostate, division of the puboprostatic ligaments, dissection of the levator fibers to expose and increase the DVC length, and division of the DVC using a laparoscopic vascular stapler. By implementing these techniques, Ahlering reduced his overall PSM from 36 to 16.7% and reduced pT2 PSM from 27.3 to 4.7% ($p = 0.003$) [53]. Continuing to refine this meticulous apical dissection, our team showed that an even more aggressive urethral resection resulted in marked reduction in overall PSM rates without a significant change in time to continence or overall continence [7].

5 and 10 Year Biochemical (PSA) Recurrence Findings for RARP

Four long term studies representing the early learning curve of RARP reported very similar biochemical recurrence (BCR) free survival rates. Menon et al. reported the first medium term, 5 year follow-up (median 60.2 months) after RARP in 2010 [43]. In 1384 cases, the 5 year BCR free survival (BCRFS) was 87%. In a Swedish study including 944 men with a median follow up of 6.3 years, Wiklund and colleagues reported an overall BCRFS of 87.1% at 5 years, 84.5% at 7 years, and 82.6% at 9 years [54]. Their results were strengthened by the comprehensive availability of follow up PSA results via the Swedish Registries. In a smaller study of 184 men with a median follow up of 67.5 months, Suardi and colleagues reported a 86% 5-year BCRFS [55]. In Ahlering's, UC Irvine series of 433 consecutive patients, 63% (n = 272) with ≥5 years follow-up and 88% (n = 391) with ≥3 years follow-up, BCRFS was 86% [56]. Even when those patients receiving adjuvant therapy were included in the analysis, overall BCRFS was 84%. The most important risk factors for BCR progression are high Gleason grade and pathologic stage pT3b or seminal vesicle involvement [54, 56]. These results compare favorably to the RRP data with BCRFS ranging from 78 to 92% [13].

As with any new technology, comparison to the standard operative technique is imperative to justify the continuance of the new technology. In order for RARP to continue gain widespread acceptance as the alternative to the current gold standard, oncologic outcomes cannot be compromised—to date they have not been. Initial 5 year oncologic control outcomes with RARP are at least comparable to the open approach. The first of the 10 year studies of oncological outcomes revealed similar results to open RRP, with BCRFS at 73% and cancer specific survival at 98.8%. The numeric value of the detectable PSAs and severity of disease were independent predictors of the men who required salvage therapy [57]. Longer follow-up with larger numbers and standardized review methods will help confirm the efficacy of robot assistance in treating organ-confined prostate cancer.

Quality of Life

Continence

The return of urinary continence after radical prostatectomy is of great concern for the patient's quality of life as they age and also to the surgeon as a marker of operative technique. The continence rates of various open and robotic prostatectomy series are listed in Tables 37.2 and 37.3. Although no standard definition of continence was used, most open contemporary series report continence rates ranging from 69.9 to 96% (Table 37.2). A more recent meta-analysis by Ficarra and colleagues revealed 12-month urinary continence rates following RARP, using no pad or safety pad as the continence definition, ranged from 8% to 11%, with a mean value of 9% [58]. In a single-institution prospective comparative study, Tewari and colleagues noted a faster return to continence in the RARP group compared to the open RRP group (50% continence rate at 44 days vs. 160 days, respectively) [8].

As noted prior, caution should be exercised when comparing continence rates between series, as there is a lack of standardization in the definition of continence. Wide variation in continence rates between centers can be attributed to multiple variables including the use of different continence questionnaires, data collection and interpretation, patient and surgeon subjectivity, patient demographics, and surgical experience. Self-administered questionnaires consistently report poorer outcomes compared with the clinical interview which many institutions use to report their results [59].

While older definitions of continence were 0-1 pad, the study of RARP outcomes has emphasized is the importance of defining continence as the need for no pads. Liss et al. reported on the impact of urinary continence on quality of life for men following RARP based on how many pads they wear (0, security, 1, 2, 3+) [60]. As shown in Fig. 37.2 men requiring no pads were pleased with their urinary QOL (mean QOL score of 1)

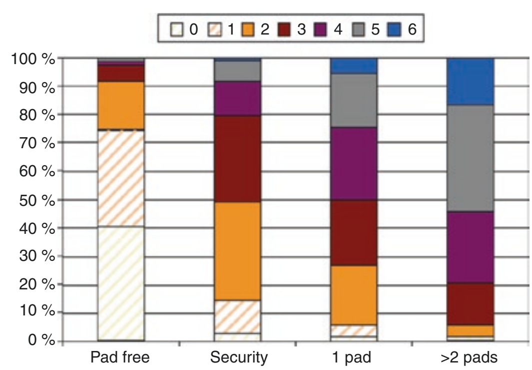

Fig. 37.2 Distribution of bother scores by patient self-reported pad usage: *0* delighted, *1* pleased, *2* mostly satisfied, *3* mixed, *4* mostly dissatisfied, *5* unhappy, *6* terrible [60]

whereas men wearing either a security pad or one pad reported a mixed (3) QOL. Nearly 75% of pad-free men were delighted or pleased versus ≤15% for any pad user. Surprisingly 50% of security and 75% of single pad users had mixed to terrible bother scores. Clinically speaking, men did not see a relevant difference between a security pad and one pad.

A standardized "no-pad" continence definition and rigorous standardized data collection with validated questionnaires will be instrumental in making accurate comparisons between surgical techniques and institutions. With ≥6-months follow-up, the urinary continence rates in reported RARP series range from 85 to 98%. Patel and co-workers reported no-pad continence rates of 27% immediately after catheter removal, 47% at 1 month, 82% at 3 months, 89% at 6 months, 92% at 9 months, and 98% at 1 year [6]. Menon and associates reported similar results, with a 96% pad-free continence rate at 3 months [61]. Walsh and co-workers reported pad-free continence rates of 54, 80, and 93% at 3, 6, and 12 months postoperative, respectively [49]. In our initial experience of 185 RARPs, 80% were pad-free and 15% used a security pad or one pad per day at 3 months. The overall pad-free continence rate was 85% at 6 months and 92% at 1 year [62]. More recently, our pad-free continence rates are 50% at 1 month, 8% at 3 months, 95% at 9 months, and 97% at 1 year. Ficarra and colleagues revealed 12-month urinary continence rates following RARP using the no pad definition ranged from 4 to 31%, with a mean value of 16% [58].

Historically, improvement in the understanding of the anatomy of the prostate, puboprostatic ligaments, DVC, urinary sphincter and the intrapelvic branch of the pudendal nerve and intrapelvic branches of the pelvic plexus have led to improvements in overall continence rates following RRP [46, 63–65]. Additionally, there appear to be patient characteristics like age, SHIM, and BMI which can independently influence postoperative continence results, though the exact relationship between these variables and resulting urinary continence following protate surgery is not clear [66, 67]. It is possible that the observed improved rates of continence in robotic series is due to decreased blood loss and improved visualization allowing the surgeon to better identify and preserve the urethral sphincter and length, and levator muscles. This allows a more precise anatomical dissection of the prostatic apex and the urethral stump, and assists in performing a watertight urethrovesical anastomosis with mucosa-to-mucosa approximation.

Potency

Preservation of sexual function has significant impact on quality of life in men undergoing radical prostatectomy. Improvements in surgical technique, largely indebted to the anatomical principles described by Walsh in the early 1980s, have drastically reduced postoperative impotence [68, 69]. This conceptual work has been extended by RARP as noted in the previous potency chapters. An important caveat is that, reporting variability makes true comparisons between series and operative technique a daunting task. It is widely accepted that postoperative potency is greatly influenced by preoperative patient characteristics, with younger patients and higher baseline sexual function having better outcomes. Intraoperative factors such as number of NVBs preserved, surgeon experience, and nerve injury clearly influence potency. Therefore to adequately compare potency rates between series, all of these factors must be accounted for.

Notwithstanding the above, currently reported potency rates after open RRP range from 8.2 to 86%, with higher volume centers obtaining better outcomes (Table 37.2). Walsh and co-workers reported potency rates of 38, 54, 73, and 86% at 1, 3, 12, and 18 months following RRP, respectively. When stratified by age, patients under age 50 had a 90% potency rate with either unilateral or bilateral NVB preservation [49]. Ficarra et al. report 12- and 24-month potency rates for all RRP, LRP and RARP ranged from 54% to 90% and from 63% to 94%, respectively. Noting wide variability in potency outcomes, the authors report mean values of the 3-, 6-, 12-, and

24-month potency recovery rates at 50%, 65%, 70%, and 79%, respectively. Comparing 12-month potency rates after RARP to RRP, they noted superior outcomes following RARP [70]. In our experience, at 9 months, 95% preserve erectile function patients when SHIM = 25 (age independent), 75% for SHIM ≥ 22, and 50% for SHIM ≥ 15. Note we are proponents of penile rehab with phosphodiesterase 5-inhibitors.

Definitions of Nerve Injury and Evolving Surgical Technique for Nerve Preservation

An improved understanding of the pathophysiology of nerve injury offers the opportunity for further technical improvements. Moreover, just as RARP has catalized standardization of data collection with regard to definitions of urinary continence, it has also precipitated an re-evaluation of nerve injury during radical prostatectomy.

Sir Herbert Seddon's seminal work defined three classes of peripheral nerve injury: neuropraxia, axonotmesis, neurotmesis [71].

Neurapraxia is caused by blunt impact or stretch injury to the nerve without structural damage (Fig. 37.3, top), resulting in a short-term conduction block. ***Axonotmesis*** secondary to more severe traumatic or thermal injury results in axonal disruption and Wallerian degeneration, a more severe type of nerve injury (Fig. 37.3, middle). In both cases, the perinuerium is preserved and thus the nerve retains the ability to recover and regenerate. In *neurapraxia*, full recovery is expected in days to weeks. For *axonotmesis*, regrowth of the axon may vary from 8 to 24 months.

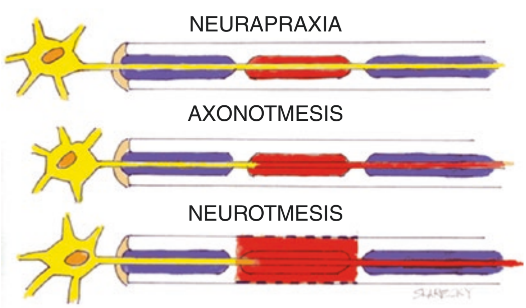

Fig. 37.3 Seddon's three classes of axonal injury, neuropracia, axonotmesis, neurotmesis

The third, and most severe nerve injury, ***Neurotmesis***, results from a severe injury or laceration that cuts across both axon and perinuerium, eliminating any scaffolding for re-growth of the axon (Fig. 37.3, bottom). This results in neuronal death and scar formation, with little chance for re-growth or meaningful functional recovery.

Thus the mainstay to nerve preservation is avoiding nerve transection (and therefore irreversible nerve injury) followed by reduction of traumatic or thermal injury. Menon and colleagues identified an accessory lattice of nerves on the ventral and lateral prostatic fascia (the veil of Aphrodite) which they hypothesize may be critical in the return of erectile function after RARP. In a selected subset of 35 patients in which the veil of Aphrodite was preserved, 95% had erections strong enough for intercourse at 1 year and presented in an earlier chapter [72].

In their literature review, El-Hakim and Tewari reported that at an average of 7.7 months post-RARP, 49.5% of patients were having intercourse and 79% had return of erections, with or without medical assistance [73]. These results underline the importance of avoiding blunt, thermal or traction injuries resulting in neuropraxia or axonotmesis. Techniques such as bipolar electrocautery, harmonic scalpel, and Ligasure have been introduced in an attempt to reduce thermal and stray electrical injury to the NVBs. However, in a dog model, Ong et al. demonstrated significant decreases in erectile response when using monopolar and bipolar hemostatic cautery in close proximity to the NVBs [74]. We previously described the cautery-free, clip-free dissection of the cavernous nerves to decrease nerve injury during RARP and hence improve potency [75]. That technique involves placing a bulldog clamps on the lateral pedicles prior to cautery-free, sharp dissection of the pedicles and the NVBs of the prostate. Figure 37.4 shows a more comprehensive 2-year follow-up of prepotent men aged ≤65. Besides the immediate improvement at 3 months, at year two, potency rates for men with thermal cautery (68%) approach athermal rates of ~90%, implying transient nerve damage inflicted by thermal techniques. The eradication

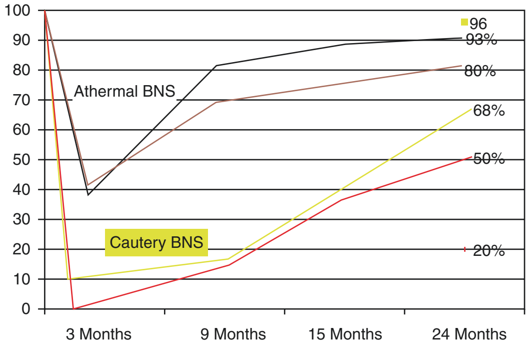

Fig. 37.4 Time to recovery of sexual function for bi- and unilateral nerve sparing using either bipolar cauter (*thermal*) or bulldoge (*athermal*) techniqu for men with IIEF-5 ≥ 22 and age ≤ 65 with RARP [36]

of cautery during NVB dissection in now widely accepted in RARP for significant improvement in short and long term potency. Regardless of the specific surgical technique used to preserve the NVBs, to help maintain sexual function, electrocautery should be minimal or avoided to prevent thermal spread and injury of the nerves. It is our strong opinion that minimizing traction injury and tension forces on the nerves is critical to neuronal recovery and potency.

Looking Forward: Standardization in Potency Definitions and Outcomes

Just as in the case of urinary continence, current literature is hampered by a lack of a standardized definition of potency. The majority of studies define potency as "erections sufficient for sexual function". In a third meta-analysis by Ficarra et al. only 31 of 184 studies met inclusion criteria/Even within the limited number of studies that met inclusion criteria, they found considerable variation in reporting from the simple definition of 'potent' or erections, sufficient, satisfactory, etc. [70].

Careful, consistent collection of validated self-reported baseline and follow-up questionnaires is required for assessment and subsequent understanding of sexual outcomes following RARP. Improved outcomes are contingent upon the establishment of a surgical database of pre-operative demographics and post-operative outcomes for critical self-evaluation. Not only will the standardization of data collection offer the opportunity for better understanding, it will allow for individual self-assessment allowing individual surgeons to measure their own outcomes against published results. Comparing outcomes, the surgeon may identify particular areas for technical improvement.

The use of pre- and post-validated questionnaires such as the 5-item International Index of Erectile Function (IIEF-5) also known as the Sexual Health Inventory for Men (SHIM) are not currently uniformly used. Rosen et al. demonstrated that a preoperative IIEF-5 score of 22–25 was highly predictive of recovery of erectile function [76]. In our experience, a baseline IIEF-5 below 15 indicates poor chance of normal erectile function post-operatively. Further, patients who are potent with and without the aid of medications or erectile dysfunction devices should be appropriately stratified. We routinely subtract seven points from a baseline IEFF-5 on medications to establish true baseline function. In this regard, the use of validated questionnaires and standardized reporting algorithms are essential to the acquisition of accurate data which can then be used to correlate erectile function with operative technique.

Finally, defining "recovery" of potency requires a quantitative and a qualitative assessment. By posing two yes or no questions from the EPIC questionnaire, (1) "Are your erections adequate for vaginal penetration?" and (2) "Are your erections satisfactory?" (with or without PDE5 inhibitors) quantitative insight into the recovery of potency may be assessed [77]. The IIEF-5 may be used for qualitative assessment and facile comparison to pre-operative function. Moreover, patient reported percentage of their baseline erectile function postoperatively is helpful in the early months following surgery to monitor progress of return of function.

Lower Urinary Tract Symptoms (LUTS)

Intuitively, removal of the prostate by radical prostatectomy should provide relief some patients from obstructive urinary symptoms, however

RARP does carry a risk of provoking irritative symptoms and incontinence. Although the indication for RARP is oncologic control, the secondary effect of appears to provide significant relief of LUTS in men with more severe symptoms preoperatively [78]. After RARP, the 63% of men with moderate and severe LUTS found significant improvement in QOL with AUAss declining by 7.9 points beginning at 3 months and persisting through 5 years. Urinary QOL scores significantly improved at 3 months from 2.7 to 2.3, stabilizing at 15 months to 1.5, or between '*Pleased*' and '*Mostly satisfied*'. These results are comparable to 1 year declines in AUA ≤ 7 vs. AUA ≥ 8 scores of 0.7 and 5.4 for RRP and 0.3 and 11.2 for RARP [15, 78].

Men presenting with prostate cancer with symptoms of moderate to severe LUTS should be counseled regarding the potential QOL benefits after RARP, particularly when discussing alternative treatment options. It is important that men be advised that in choosing an active surviellance, radiation or hormonal therapies remain at risk for declining urinary function in the form of reduced daily QOL and the subsequent risk of treatment by TURP or chronic α-blocker therapies. In general, RARP can mitigate LUTS progression in 89% of men, and reverses it in 68% particularly in those with moderate to severe LUTS with this effect persisting for 4 years or greater [78].

The "Trifecta" and "Pentafacta"

As PSA screening has led to the early detection of prostate cancer in young, healthy men, the bar for surgical success has been raised by surgeons and patients alike. In the 2000s the concept of the "Trifecta" was introduced: consisting of progression-free PSA, achieving continence, and potency. Unfortunately, to it as the "gold standard," the Trifecta has some weaknesses. Namely, impotent or men with ED are generally excluded from analysis. Additionally, men who are at higher risk of extra-prostatic extension and BCR undergoing non-bilateral nerve sparing procedure skew Trifecta results and are generally excluded from analysis as well. Thus the majority of the men at risk for QOL failure presenting for RARP are excluded from studies evaluating the Trifecta, leading to inflated "excellent" and misleading results for the "average" men considering treatment [79]. Further, Vickers suggests that the Trifecta statistically invalid, mainly driven by potency, overly weighted by short term outcomes. Katz et al., also question the validity of whether QOL outcomes are truly equal in value to survival [80]. Most importantly, PSA progression-free rates decline with time as noted in Menon et al., BCR free rates from 95%, 91%, at years 1, 3, to 87% and 81%, 5 and 7 years [12]. Hence, trifecta overstates success at 1–2 years as BCR rates deteriorate with time. Moreover, Patel et al., argue that Trifecta still fails to adequately meet the expectations of young patients undergoing RARP. The authors propose the addition of two variables to the traditional trifecta: no complications following prostatectomy and negative surgical margins. Evaluating the outcomes of 1111 consecutive cases, they found that while trifecta rates at 12 months were 83.1%, "pentafecta" rates was significantly lower, 70.8%. They contend that the Pentafacta more accurately reflects the expectations of patients and should be taken into account during patient counseling and pre-operative decision-making [81]. Surely, the Pentafacta still faces similar limitations previously identified for the Trifecta.

The Future

Centers of Excellence

Recently there have been suggestions that only "Centers of Excellence" perform RARP. Surgeons should be prepared that patients will increasingly utilize the internet and other media to 'shop' for the best oncological and QOL outcomes. In the near future, we can forsee that it will become essential that surgeons report their outcomes to stay competitive. We suggest that surgeons assemble programs of at a minimum of 6–12 month followup intervals of continence, sexual function and BCR. There are now automatic email programs that can be utilized for this tracking. The advantages for the patient and surgeon are invaluable. By tracking their outcomes, surgeons may continually refine their skillset in the long term learning curve to achieve excellence in both oncology and QOL outcomes.

Technological Advancements

Currently, there is one surgical robot available on the United States market, which is currently in its third generation. The introduction of the DaVinci Xi in 2014, represented multiple changes including the inclusion of a new overhead instrument arm to facilitate anatomical access from any position without the need for patient or surgical cart repositioning, the ability to attach the endoscope to any arm, and change the angle of the lens with the click of a button on the console or camera itself, smaller, thinner arms with newly designed joints to offer greater range of motion, longer instrument shafts to improve operative reach, and conversion of all ports, including the camera port, to 8 mm. Importantly, continued development of the surgical simulator allows surgeons the opportunity to practice on the console. The DaVinci Xi also has features to enable perioperative staff to practice with a patient cart simulator. These changes in theory will improve the overall efficiency of the surgery for the surgeon, assistant and operative staff.

Notably, a number of companies are in the process of developing alternative surgical robot systems for adoption into the European and United States markets. Based on similar concepts to the DaVinci system of robotic arms and articulating instruments, these companies aim to leverage improved economics, offering cheaper alternatives to currently available systems in an effort to broaden access to robotic surgery. It is imperative that these technological advancements and the introduction of new surgical systems are rigorously evaluated.

Conclusion

Robotic-assisted radical prostatectomy has shown to be an easily acquired laparoscopic technique, with shorter learning curves that rivals the open procedure as best practice. We have witnessed a paradigm shift from open to robotic radical prostatectomy as the procedure of choice worldwide. When compared to the open approach, early studies indicate that robotic prostatectomy has equal outcomes in short-term oncological control, continence, and potency with potentially favorable perioperative outcomes such as in blood loss and transfusion rates, minor complications, narcotic use, convalescence, and length of hospital stay. Initial, long-term oncologic and quality of life outcomes have also demonstrated similar outcomes to the open radical prostatectomy.

Still, in light of present day open radical prostatectomy, in order to determine the true place of robotics in the surgical pantheon, validated questionnaires and analog assessment scales are essential to determine true functional results and need to be combined with careful long-term follow-up of oncologic outcomes. Prospective cooperative interinstitutional studies of this nature are now being reported by early adopters. Continued efforts are essential for both evaluation of and improvements in surgical technique. Now, a decade and a half old, the long-term outcomes of robotic prostatectomy are beginning to emerge, and evidence-based accounting of this and other robotic techniques will clarify if this is a true technical advancement leading to both comparable or superior oncologic and quality of life outcomes.

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38 Urinary Incontinence After Robot-Assisted Laparoscopic Radical Prostatectomy

Kevin G. Chan and Timothy G. Wilson

Introduction

Urinary incontinence following radical prostatectomy continues to be a significant problem despite improving surgical techniques. Robotic surgical techniques have the potential to improve urinary outcome measurements even more than their open predecessors. Improved visualization and precision of dissection with robotic technology offer a truly anatomic approach. The main purpose of this chapter is to summarize the status of urinary outcomes following robotic-assisted laparoscopic radical prostatectomy as well as to discuss the most current therapies used in the treatment of post-prostatectomy urinary incontinence. We also discuss the etiology of post-prostatectomy urinary incontinence, contributing risk factors, and the evaluation for incontinence as they are intimately related to prostatic surgical technique and incontinence interventions.

Incidence of Urinary Incontinence Following Radical Prostatectomy

The incidence of urinary incontinence following radical prostatectomy varies widely depending on the definition of incontinence used, era in which that data was collected, and variations of surgical technique. Open radical retropubic prostatectomy continues to be the gold standard by which all other techniques are compared. To examine the incidence of urinary incontinence following robotic-assisted laparoscopic radical prostatectomy (RALRP), one must evaluate outcomes in relation to the established open standards. Table 38.1 summarizes representative reports of urinary continence rates following radical retropubic prostatectomy, radical perineal prostatectomy, laparoscopic radical prostatectomy, and robotic-assisted laparoscopic radical prostatectomy.

As open and laparoscopic techniques have been refined, two areas of urinary continence continue to improve, overall continence rate and time to continence. These are the two areas that may ultimately demonstrate the benefit of robotic technology in radical prostate surgery. When evaluating overall continence rate, it is most accurate to compare 2-year outcomes. Multiple long-term reports have shown a relatively small but statistically significant improvement in continence from the 1-year- to the 2-year follow-up [11, 12]. Time to continence is an outcome in radical prostatectomy series that has only been recently assessed with the development of competing techniques.

Table 38.1 summarizes radical prostatectomy continence outcomes from large contemporary open retropubic and perineal series as well as laparoscopic and robotic-assisted laparoscopic

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_38

Table 38.1 Incidence of urinary incontinence following radical prostatectomy

Author	Approach	Year	No. of cases	Definition of continence	% Continent at 1 month	% Continent at 3 months	% Continent at 6 months	% Continent at 12 months	% Continent at 24 months
Rocco et al. [1]	Retropubic	2007	250	One pad or less/day	74	85	NR	94	NR
Marien and Lepor [2]	Retropubic	2008	610	"Total urinary control" or "occasional urinary dribbling"[a]	NR	NR	NR	NR	97
Harris [3]	Perineal	2006	704	No pads	52	71	85	94	NR
Martis et al. [4]	Perineal	2007	100	No pads	NR	NR	74	NR	96
Goeman et al. [5]	Laparo scopic	2006	550	No pads	NR	NR	NR	83	91
Takenaka et al. [5, 6]	Laparo scopic	2009	135	No pads	13	41	63	79	NR
Stolzenburg et al. [7]	Laparo scopic	2009	2400	No pads	NR	72	81	95	NR
Potdevin et al. [8]	Robotic	2009	147	No pads	47	76	93	NR	NR
Reynolds et al. [9]	Robotic	2009	198–679[b]	One pad or less/day	20	52	75	88	90
Menon et al. [10]	Robotic	2007	1110	One pad or less/day	NR	NR	NR	95	NR

NR not reported
[a]University of California Los Angeles Prostate Cancer Index
[b]Sample size was variable at different intervals of follow-up

series. Regardless of approach, we observe high overall continence rates as well as high early continence rates. Overall, 2-year continence rates ranged from 90 to 97%. More remarkable are the 3-month continence rates in these series which range from 41 to 85%. Time to continence is an exciting and intriguing area of study when evaluating the various radical prostatectomy techniques.

Mechanism of Urinary Incontinence Following Radical Prostatectomy

To evaluate the mechanism of urinary incontinence following radical prostatectomy, we must rely on data obtained from open radical prostatectomy series. The three major causes of urinary incontinence following radical prostatectomy include bladder dysfunction, sphincteric dysfunction, and overflow incontinence, although a combination of mechanisms may be present.

Most evidence supports the idea that post radical prostatectomy urinary incontinence is primarily due to sphincteric dysfunction. While bladder dysfunction, either a loss of compliance or detrusor over activity, may be present in a significant number of patients after radical prostatectomy, its influence on urinary incontinence is debated.

Several studies have urodynamically evaluated radical prostatectomy patients preoperatively and postoperatively. Majoros et al. evaluated their patients at a relatively early period postoperatively (2 months) and found sphincteric dysfunction in 90% of their incontinent patients. Isolated bladder dysfunction was rarely a cause of incontinence [13]. Kleinhans et al. also urodynamically evaluated radical prostatectomy patients preoperatively and postoperatively (mean 7.6 months after surgery) and found that all incontinent patients had sphincteric weakness [14]. A similar study by Pfister et al. showed sphincteric dysfunction in 85% of incontinent patients at 3 months after surgery [15].

Ficazzola et al. prospectively evaluated 60 incontinent patients with video urodynamics at least 6 months following radical retropubic prostatectomy. Sphincteric dysfunction was detected in 90% of patients. Forty-five percent of patients were found to have some component of bladder dysfunction, but only 3% of incontinent patients had bladder dysfunction alone [16]. Leach et al., evaluating incontinent patients following one of a variety of prostate procedures, reported that 56% of prostate cancer surgery patients had a "major component of high-pressure bladder." However, in this same group of patients, 82% had a component of sphincteric dysfunction. In addition, anticholinergic medication alone rarely cured a patient (4.7%).

The mechanism of post radical prostatectomy urinary incontinence has also been studied at the neuroanatomical level. These studies have been performed under the basic premise that the male rhabdosphincter is the primary source of continence in men following radical prostatectomy. It has long been known to be innervated by somatic branches of the pudendal nerve. Several groups have proposed additional neural pathways to the rhabdosphincter that could potentially be damaged during radical prostatectomy.

Narayan et al. demonstrated a neural branch to the rhabdosphincter that arises from the dorsal nerve of the penis and enters the infraprostatic urethra at the 9–12 o'clock positions and 1–3 o'clock positions [17]. While the dorsal nerve of the penis does arise from the pudendal nerve, its function is primarily sensory, and this branch to the rhabdosphincter may be a part of the urinary guarding reflex pathway [18]. Hollabaugh et al. demonstrated that parasympathetic fibers arising from the inferior hypogastric plexus, continuing as the pelvic nerve, course inferolateral to penetrate the prostate and rhabdosphincter [19]. These branches may also play a role in the urinary guarding reflex pathway but may also be damaged during radical prostatectomy. Further supporting this theory, John et al., measuring sensory thresholds at the bladder neck and proximal membranous urethra, showed a significantly higher sensory threshold in incontinent patients after radical prostatectomy [20]. This suggests that potential damage to branches leading to the rhabdosphincter during radical prostatectomy decreases afferent nerve conduction that may be part of a reflex pathway.

Overflow incontinence secondary to anatomic obstruction from a urethrovesical anastomotic stricture is not uncommon. Its incidence has been reported to be 4.5–27.9% [12, 21, 22]. Sacco et al. additionally found a 33.8% stricture rate among their incontinent patients [12]. Our series of laparoscopic and robotic-assisted laparoscopic radical prostatectomies showed a bladder neck contracture rate of 2.2 and 0.6%, respectively, suggesting a possible advantage with a robotic technique [23]. Nonetheless, this evidence supports the multifactorial nature of incontinence following radical prostatectomy and supports the need for diligent and complete evaluation of all incontinent patients after radical prostatectomy.

Risk Factors for Urinary Incontinence Following Radical Prostatectomy

While the data regarding risk factors for urinary incontinence following radical prostatectomy is rapidly accumulating, it remains difficult to draw many definite conclusions. Even the most commonly identified risk factors remain controversial. Age and nerve sparing status continue to be the most debated predictors for post-prostatectomy urinary incontinence. We will also discuss several other factors that may ultimately be found to influence continence rates after radical prostatectomy including previous prostatic surgery, certain urethral and prostatic measurements, presence of a urethrovesical anastomotic stricture, obesity, and prostate size.

Age was identified by Eastham et al. in a multivariate analysis to significantly influence continence rates, and this finding was reproduced by others [12, 24]. Eastham had reported that 15% of their patients were over the age of 69 which is a somewhat higher proportion than most series. Another multivariate analysis of 742 patients, including 26% of whom were older than 70 years old, did not find age to be a risk factor [25]. The two series, however, are truly not comparable. Eastham's group only had 10% non-nerve sparing patients, whereas Wille's group had approximately 90% non-nerve sparing patients. Another recent report by Burkhard et al. did not demonstrate age to be significant risk factor in a series of 536 patients. While the proportion of non-nerve sparing patients was similar to that of Eastham's, it is unclear how many patients over 70 there were in the Burkhard group [26]. Interestingly, Twiss et al. showed that patients under the age of 50 did not experience an improved continence rate, suggesting that the age threshold, if it exists, is beyond 50 years old [27]. The literature specifically regarding robotic-assisted laparoscopic radical prostatectomy (RALRP) also supports age as a risk factor for post-prostatectomy urinary incontinence. Novara et al. evaluated 308 consecutive patients who underwent RALRP, and age was identified as an independent predictor of 12-month continence on multivariable analysis [28]. Ultimately, the evidence suggests increased rates of urinary incontinence with advancing age following radical prostatectomy, but the data is not conclusive.

Nerve sparing status is another controversial risk factor for urinary incontinence. Eastham identified nerve sparing status as a risk factor at a period within which nerve sparing was relatively newly established [24]. Other large contemporary open series have subsequently reproduced these findings [12, 26]. Most reports that have contradicted these findings have either been small in size or had a disproportionately small number of non-nerve sparing patients [2, 11, 25, 29]. In a contemporary radical perineal prostatectomy series, nerve sparing proved to be an independent predictor of earlier recovery of continence on multivariate analysis [30]. With specific regards to RALRP, Berry et al. evaluated 628 patients undergoing open, laparoscopic, or robotic radical prostatectomy, and regardless of technique, the bilateral nerve sparing cohort demonstrated improved 3-month continence rates ($p = 0.007$) and no significant differences at 6 months and longer [31]. The evidence suggests that nerve sparing status may at least improve early continence rates and may ultimately improve total continence rates.

Several urethral measurements have been identified as potential risk factors for urinary incontinence following prostatic surgery. Coakley et al. found that patients with longer preoperative membranous urethral lengths, measured by MRI, were shown by multivariate analysis to have a significantly shorter time to stable postoperative continence [32]. Paparel et al. recently corroborated these results finding that both preoperative and postoperative membranous urethral length were significantly associated with time to recovery of continence [33]. Another multivariate analysis, by Oefelein, found that longer prostatic urethral length, measured by transrectal ultrasound, was significantly associated with a prolonged time to urinary continence [22]. Finally, Lee et al. demonstrated that patients with a prostatic apex that did not anteriorly or posteriorly overlap the membranous urethra, as shown by preoperative MRI, had a significantly earlier return of urinary continence [34]. While each of the urethral parameters evaluated were different, they all related to an improved intraoperative ability to preserve membranous urethral length during surgery which may ultimately be shown to shorten time to continence.

Contemporary open and laparoscopic radical prostatectomy series suggest a relationship between prostate gland size and time to urinary continence. This may be related to increased operative difficulty in nerve and sphincter preservation. In a multivariable analysis of 1422 patients who underwent open or laparoscopic radical prostatectomy, there was a small but not statistically significant relationship found between pathologic prostate weight and 1 year continence rates ($p = 0.08$) [35]. Konety et al., utilizing the CaPSURE national disease registry of men with prostate cancer, found that men with prostate volumes greater than 50 g on transrectal ultrasound had lower rates of continence at

6 months and 1 year after radical prostatectomy, but at 2 years, this difference equalized [36]. Milhoua et al. reported in 137 patients undergoing laparoscopic radical prostatectomy that patients with pathologic prostate weights of greater than 70 g had a significantly delayed time to continence [37]. Thus, while prostate size may not influence final continence status, the evidence suggests it may influence time to continence.

The relationship between obesity, as measured by body mass index (BMI), and post-prostatectomy urinary incontinence remains to be defined. Ahlering et al., in a robotic radical prostatectomy series of 100 patients, found that patients with a body mass index (BMI) of <30 had a significantly improved continence rate compared to those with a BMI of 30 or greater [38]. Wolin et al., in a report specifically evaluating the role of obesity in post-prostatectomy incontinence, found that at 58 weeks, the rates of incontinence were higher in obese (BMI > 30) men (31%) than in nonobese men (18%) ($p = 0.05$) [39]. However, there are a robust number of reports in both the open and robotic radical prostatectomy series that demonstrate no correlation between BMI and postoperative continence status [2, 28, 40].

Previous transurethral prostate surgery has been examined in numerous series. While it always appears to be mentioned in any discussion of risk factors for urinary incontinence, the evidence does not really support this. The majority of series demonstrate that previous prostate surgery does not significantly influence continence outcomes [12, 24, 25]. Colombo et al. reported a series of 109 radical retropubic prostatectomy patients who underwent previous transurethral (71 patients) or open prostatectomy (38 patients) for benign disease. The continence rates at 6 and 12 months were 74 and 86%, respectively. There did not appear to be a statistically significant difference to their retrospectively matched controls [41]. Previous transurethral prostate surgery does not appear to be a risk factor for urinary incontinence following radical prostatectomy.

The presence of a urethrovesical anastomotic stricture appears to be a significant risk factor for urinary incontinence [12, 24]. This may ultimately be due to the fibrosis incorporating the external sphincter or related to the treatment of the stricture. Interestingly, it has also been suggested that anastomotic stricture may be related to surgical technique. Hu et al. reported on an analysis of 8837 patients from the United States Surveillance, Epidemiology, and End Results (SEER)-Medicare data, and found a significantly lower anastomotic stricture rate in patients undergoing minimally invasive radical prostatectomy (with or without robotic assistance) compared with those undergoing open radical prostatectomy [42]. This finding was also corroborated in a single surgeon series of 200 consecutive radical prostatectomies, 100 open, and 100 robotic, where there were no anastomotic strictures in the robotic group compared to 9 patients in the open group [43]. This may potentially be explained by the improved vision and precision of the anastomotic technique provided with minimally invasive approach. However, with the relatively small numbers of patients with both incontinence and anastomotic strictures, this correlation of surgical approach, anastomotic stricture, and continence status may be difficult to demonstrate.

Evaluation for Urinary Incontinence Following Radical Prostatectomy

Evaluation of post radical prostatectomy urinary incontinence is based on the etiology of the incontinence as well as the treatment options available. Our standard evaluation includes a thorough history to elicit the volume of incontinence, type of incontinence, storage symptoms, and voiding symptoms. A voiding diary and questionnaire such as the International Consultation on Incontinence Questionnaire-Short Form (ICIQ-SF) will help in quantifying the problem. The history will commonly paint a clinical picture of classic stress urinary incontinence, urge incontinence that may be related to overflow incontinence or detrusor overactivity or a mixture of stress and urge incontinence. The standardized 1-h pad test is also useful in assessing the incontinence.

Objective evaluation, in addition to physical examination, includes flexible cystourethroscopy and multichannel urodynamic evaluation. Cystourethroscopy is critical to evaluate the degree and sustainability of volitional external sphincter coaptation which can aid in identifying those patients who may be a candidate for a male sling procedure. Cystourethroscopy is also important to rule out urethrovesical anastomotic strictures. In addition, other less common findings of an obstructing bladder neck stone, urethral stricture, or bladder mass may be identified as the etiology of the incontinence.

A multichannel urodynamic evaluation including the minimum of a complex cystometrogram, pressure-flow study, and electromyelogram is also performed. The main purpose of this evaluation is to evaluate for detrusor hypoactivity or detrusor overactivity. With male slings as a major part of the armamentarium for incontinence treatment, it is important to demonstrate normal detrusor function prior to placement or risk permanent urinary retention. If the urodynamic evaluation demonstrates evidence of detrusor overactivity, this may direct treatment toward a trial of anticholinergic therapy before considering surgical intervention.

Management of Urinary Incontinence Following Radical Prostatectomy

There is a range of therapies available for the patient with post radical prostatectomy urinary incontinence. Ultimately, treatment options depend on the results of their incontinence evaluations.

Detrusor Overactivity

If a component of detrusor overactivity is identified by either subjective or objective assessment, it is most reasonable to offer a trial of anticholinergic therapy prior to possible surgical intervention [16, 44]. If isolated detrusor overactivity is identified with no evidence of stress urinary incontinence, and that patient fails medical therapy, one may consider second-line therapies for overactive bladder such as sacral neural modulation or intravesical botulinum toxin injection.

Urethrovesical Anastomotic Strictures

If a urethrovesical anastomotic stricture is identified, transurethral incision of the stricture is indicated. We generally perform this with either a holmium laser or cold knife. The patient then undergoes repeat cystoscopy in 6 months to ensure that the stricture is resolved and stable prior to any incontinence intervention. Often, treatment of these strictures leads to subsequent stress incontinence or unveils stress incontinence that was not assessable with the stricture present. Managing this incontinence with surgical intervention can be very troublesome because of the possibility of recurrent stricture which would then be difficult to treat.

Management of urinary incontinence associated with problematic recurrent urethral stricture has been attempted by a range of interventions. The simplest measure would be clean intermittent catheterization or a self-dilation regimen. We have found that hydrophilic catheters do well for this particular problem. Multiple groups have described the method of Urolume™ stent (American Medical Systems) placement followed by placement of an artificial urinary sphincter 6 weeks to 3 months later [45–47]. This is performed in patients with a completely obliterated urethral lumen who fail at least one recanalization and self-calibration course. This technique has achieved moderately good results with intermediate follow-up. Complex abdominoperineal, transpubic, and perineal approaches to these troublesome strictures have also been described with good success and sometimes required a subsequent artificial urinary sphincter [48, 49]. Ultimately, a supravesical continent or incontinent urinary diversion may be required if other means fail.

Post-Prostatectomy Stress Urinary Incontinence

Once urinary incontinence due to sphincteric dysfunction has been identified by subjective or objective assessment, a range of treatment options are available. Stress urinary incontinence identified within the first year after radical prostatectomy is generally treated with noninvasive behavior therapy techniques.

There can be significant improvement seen in the first to the second year postoperatively [11]. If one sees slow but gradual improvement, it would not be unreasonable to continue observing the patient up to 2 years. If there is a significant degree of incontinence or patient dissatisfaction at 1 year despite completing a course behavioral therapy, we would proceed with evaluation for incontinence and surgical intervention.

Behavioral Therapy

Behavioral therapy for urinary incontinence includes pelvic floor exercises (PFE) with or without biofeedback (BFD) and with or without electrical stimulation (ES). Pelvic floor exercises generally include multiple sessions of formal instruction by a physical therapist. Biofeedback is performed by using either an anal pressure probe or patch electrode to transmit a visual display to the patient that the appropriate muscular contraction is being performed. In theory, this visual reinforcement is thought to improve the patient's quality of exercise. Electrical stimulation utilizes an electric current sent to the pelvis to stimulate contraction of the pelvic floor musculature. In theory, this is helpful in patients who are initially unable to volitionally contract the appropriate pelvic floor muscles or to improve awareness of the muscles they should be working.

There have been numerous reports on the role of behavioral therapy in post-prostatectomy stress urinary incontinence. Multiple studies have shown an improvement in time to continence with the use of PFEs, but not an overall change in long-term continence outcome [50–52]. The adjunctive use of biofeedback or electrical stimulation does not appear to add any benefit over PFEs alone [52–54].

Medical Therapy

At this time, there is no pharmacologic treatment approved for stress urinary incontinence in men. However, duloxetine has been approved for use in women for the treatment of moderate and severe stress urinary incontinence by the European Medicines Agency since August of 2004. Duloxetine is a balanced and potent inhibitor of serotonin and norepinephrine reuptake. Duloxetine has been found to increase bladder capacity and increase periurethral striated muscle electromyographic activity in cats through a central neural mechanism [55]. The increased concentration of serotonin and norepinephrine is thought to raise the activity of pudendal motor neurons, leading to an increase in striated urethral sphincter tone and detrusor relaxation.

Three phase three double-blind, placebo-controlled studies involving 1635 women in North America, South America, Europe, Australia, and Africa all showed significant improvement in stress urinary incontinence vs. placebo [56–59]. While efficacy was clearly demonstrated in these studies, there were two other notable findings, a high discontinuation rate and a high placebo response. The common side effects were nausea, fatigue, insomnia, dry mouth, and constipation. The discontinuation rate due to side effects ranged from 17 to 24%. With regards to placebo response, 33–43% of patients who received placebo had 50–100% decreases in incontinence episode frequency.

There have been some early studies looking specifically at the off-label use of duloxetine for the treatment of post-prostatectomy urinary incontinence. Filacamo et al. evaluated 112 patients undergoing radical prostatectomy and randomized patients to pelvic floor muscle training with or without duloxetine [60]. There appeared to be some benefit from duloxetine up to 16 weeks, but the results reversed at the 20th week. Shortly after discontinuing the medication, continence rates were actually worse in the duloxetine treatment group at 20 and

24 weeks. A more recent prospective, placebo-controlled, double-blind, randomized, superiority study in men with mild to moderate stress urinary incontinence at least 1 year after surgery showed significantly reduced incontinence in patients taking duloxetine compared to placebo at 12 weeks of follow-up [61]. Unfortunately, the data regarding duloxetine in men with post-prostatectomy urinary incontinence remains limited to small, off-label, short-term studies.

The central acting role of duloxetine, the relatively high discontinuation rate due to side effects, and the high placebo responses in the three phase three studies will likely play an important role in determining the efficacy of duloxetine in men with post-prostatectomy urinary incontinence. The proposed central acting mechanism of duloxetine requires intact innervation of the external sphincter. The integrity of this neural pathway after radical prostatectomy is uncertain. Secondly, high discontinuation rates due to side effects will make a potential prophylactic role after surgery difficult. Finally, most radical prostatectomy patients recover their urinary control within 1 year. The presence of a large placebo response in previous studies necessitates large randomized, double-blind, placebo-controlled trials in men to accurately evaluate the efficacy of medical therapy.

Transurethral Injection Therapy

Transurethral injection therapy for post-prostatectomy urinary incontinence has been described using polytetrafluoroethylene, polydimethylsiloxane (Macroplastique®), zirconium carbon-coated beads (Durasphere™), and glutaraldehyde cross-linked collagen. Animal studies demonstrating granuloma and emboli formation led to the discontinuation of polytetrafluoroethylene injections in the United States of America [62]. While Durasphere™ and collagen are equally available, most of the long-term published reports utilize only collagen.

Skin testing is required 1 month prior to collagen injection. Then using either local or general anesthetic, collagen is injected submucosally under direct vision at the urethra proximal to the external sphincter at the right and left sides or using a four-quadrant technique (at the 2, 4, 8, and 10 o'clock positions) [63, 64]. Side effects are usually minor but include self-limiting hematuria, transient urinary retention, and urinary tract infection [65].

Urinary continence outcomes using transurethral collagen have been disappointing in terms of overall continence rate as well as durability of response as shown in Table 38.2. Short-term reports have demonstrated cure/marked improvement rates as high as 66 or 75% social continence [63, 64]. However, reports with longer follow-up have demonstrated a 2% cure rate at 1 year and 15–44% cured/greatly improved rate overall [65–67]. Despite its overall poor outcomes, transurethral collagen does have a role in the select patient. These include patients with significant comorbidities that would not tolerate general anesthesia and patients with detrusor hypoactivity and mild incontinence.

Table 38.2 Outcomes for collagen injection for post-prostatectomy urinary incontinence

Author	Year	No. of patients	Mean follow-up (months)	Median follow-up (months)	% Cure/improved (%)	Mean duration of response (months)
Aboseif et al. [64]	1996	72	10	NR	66	NR
Faerber and Richardson [65]	1997	47	38	NR	15	NR
Smith et al. [66]	1998	62	NR	29	39	17.5
Westney et al. [67]	2005	322	40	NR	44	7.3

NR not reported

Male Slings

The concept of upward compression of the bulbous urethra for the treatment of post-prostatectomy urinary incontinence was initially introduced in 1972 by Joseph Kaufman [68]. However, it was not until the late 1990s that male slings were revisited with Schaffer et al. presenting their series of bulbourethral slings in men with post-prostatectomy urinary incontinence. Since that time, there has been a rapid resurgence in the development of male slings. Currently, there are three types of slings available in the treatment of post-prostatectomy urinary incontinence: compressive slings, functional slings, and adjustable slings. Male slings play an important role as an intermediate alternative to the artificial urinary sphincter. There are two important caveats when considering a male sling. First, there is a strong body of evidence that shows patients with a history of previous radiation have significantly worse outcomes with slings, regardless of sling type [69–71]. The second important caveat is that there should be no evidence of detrusor areflexia. In such cases, an artificial sphincter should be considered, or one could proceed with a sling as long as the patient has the expectation for the high possibility of permanently requiring clean intermittent catheterization.

The technique of bulbourethral sling utilizing retropubic needle passage was originally described by Schaeffer [72]. Briefly, it involves placement of a suprapubic catheter and two separate incisions. Three tetrafluoroethylene bolsters are placed beneath the bulbar urethra through a perineal incision. Nonabsorbable sutures attached to each end of the bolsters are then passed from the perineal incision to a suprapubic incision using a modified Stamey needle. The sutures are then tensioned to 60 cm of H_2O and tied over the rectus fascia. Retightening involves reopening the suprapubic incision and retying the nonabsorbable sutures. Similar slings using a strip of polypropylene or a composite of polypropylene and porcine skin collagen as the sling material instead of tetrafluoroethylene have also been described [73, 74]. Complications for the bulbourethral sling using retropubic needle passage include prolonged perineal pain (12–100%), urethral erosion/infection requiring removal (8–11%), urinary retention requiring tension release (6%), transient retention (2%), and unrecognized suture in bladder (2%) [72, 74–76].

The technique of the bone-anchored sling, also known as the InVance™ male sling, was originally described by Comiter [77]. Briefly, it involves an approximately 4-cm incision in the perineum. The urethra is minimally dissected down to expose fat around the bulbospongiosus or to expose the bulbospongiosus muscle itself. A 2-cm dissection of the medial aspects of the descending pubic rami is performed, and titanium bone screws loaded with a pair polypropylene sutures are inserted on the pubic rami symmetrically using either a four or six-suture technique. The sutures are then used to tie down either a synthetic, absorbable, or composite piece of mesh that compresses the bulbar urethra to a pressure of 60 cm of H_2O. Complications for the bone-anchored sling include transient perineal pain/scrotal numbness (19–73%), transient urinary retention (4–12%), infection/urethral erosion (2–8%) requiring removal, screw dislodgement requiring reoperation (4%), and perineal hematoma (rare) [69, 77–82].

The first functional retrourethral transobturator sling was described by Rehder and Gozzi and is available as the AdVance® sling (American Medical Systems, Minnetonka, MN) [83]. This sling utilizes a polypropylene mesh placed through a perineal incision and passed bilaterally through a transobturator route. This "functional" sling is thought to reposition the bulbar urethra into the pelvis, reestablishing support to the external sphincter previously provided by the prostate. There also appears to be a passive compressive component that likely contributes to its effectiveness. Common complications include transient urinary retention (21%) and mild perineal discomfort for 4–6 weeks. (2%) Major complications appear rare. In a series of 230 patient treated with the Advance sling, three patients (1%) required reoperation due to complication (unrecognized urethral injury, urethral obstruction, and pubic syphilitic) [84]. Other male transobturator slings are in development, but their data is still preliminary.

There are three adjustable slings currently available for the treatment of post-prostatectomy urinary incontinence: the Adjustable Continence Therapy (ProACT®; Uromedica, Plymouth, MN), the Remeex® sling (Neomedic International, Barcelona, Spain), and the Argus® (Promedon SA; Cordoba, Argentina) adjustable bulbourethral sling.

The ProACT sling utilizes two silicone balloons placed on both sides of the bladder neck, with each balloon connected to a titanium port placed in the scrotum. Open and ultrasound-guided percutaneous placement techniques have been described [85, 86]. Adjustments are made percutaneously by using the percutaneous ports in the scrotum, typically requiring an average of 3.3–3.6 adjustments to achieve a satisfactory result [71, 87]. The common complications with the ProACT sling in more contemporary series include intraoperative bladder perforations (2–2.5%), device migration (4.8–5%), erosions (3.2%), wound infections (8%), and temporary urinary retention (1–6%) [71, 87].

The Remeex sling utilizes a monofilament suburethral sling (placed perineally) that is attached to a regulator with monofilament tensioning sutures (placed suprapubically). Adjustments are made by reopening the suprapubic incision under local anesthesia and changing the tension using a screwdriver-type device. Common complications include intraoperative bladder perforation (10%), device infection (4%), mild perineal hematoma (6%), and urethral erosion (2%) [88]. Bladder perforations are managed by simply performing an additional suture passage at the time of surgery. Device infection and urethral erosion require device removal.

The Argus system is also placed with a combined suprapubic and perineal approach utilizing silicone cushions to compress the urethra, tensioning silicone columns brought from the perineum to the suprapubic incision, and silicone washers maintain tension. Loosening is performed under general anesthesia, and tightening is performed using local anesthesia. Common complications include urethral erosion (13%), transient perineal discomfort (15%), device infection (3%), and bladder perforation (5%). The urethral erosions and device infections are treated with explantation.

In terms of outcome, Table 38.3 summarizes intermediate-term results for the various slings. Although the definition of "cure" may vary somewhat between studies, we observe relatively high cure rates with all the male slings, ranging from 52 to 81%. Dikranian et al. demonstrated an improved performance with synthetic, nonabsorbable mesh over absorbable mesh with the bone-anchored sling [89]. Synthetic, nonabsorbable components appear to be important concepts in male sling material.

Currently, there appears to be a trend away from the bone-anchored sling in favor of the functional transobturator sling. This may due to high rates of prolonged perineal pain seen in most series. This pain is thought to be related to perineal nerve compression, a problem that seems to be avoided with the transobturator sling. The experience with adjustable slings is still early, but the concept of adjustable urethral tensioning combined with minimally invasive approaches make adjustable slings a promising option. Overall, the male sling has established itself as a first-line surgical intervention in the treatment of post-prostatectomy urinary incontinence.

Artificial Urinary Sphincter

The artificial urinary sphincter (AUS) has long been the gold standard for the treatment of post-prostatectomy urinary incontinence. Research has moved toward finding alternative, less invasive methods at treating incontinence, but the artificial urinary sphincter continues to be one of the mainstays of urinary incontinence treatment.

Table 38.4 summarizes urinary outcomes with the artificial urinary sphincter. The number of cured patients (19–20%) appears to be somewhat low for a treatment considered the "gold standard." However, improvement rates (70–72%) seem to bring patient satisfaction rates to an impressive 90%.

Table 38.3 Outcomes for male slings for post-prostatectomy urinary incontinence

Author	Year	Type	Sling material	No. of patients	Mean follow-up (months)	Median follow-up (months)	% Cured	% Improved	% Social continence
Dikranian et al. [89]	2004	Perineal bone anchored	Porcine	20	18	NR	56	31	NR
		Perineal bone anchored	Synthetic	16	18	NR	87	13	NR
Comiter [80]	2005	Perineal bone anchored	Synthetic	48	NR	48	65	15	NR
Guimarães et al. [69]	2008	Perineal bone anchored	Synthetic	62	28	NR	65	23	NR
Giberti et al. [82]	2009	Perineal bone anchored	Synthetic	40	35	NR	55	13	NR
John [74]	2004	Retropubic needle passage	Porcine/synthetic composite	19	NR	14	69	6	NR
Stern et al. [75]	2005	Retropubic needle passage	Synthetic	71	48	NR	81	NR	NR
Migliari et al. [76]	2006	Retropubic needle passage	Synthetic	49	32	NR	NR	NR	63
Cornu et al. [70]	2009	Transobturator	Synthetic	102	13	13	63	18	NR
Bauer et al. [90]	2010	Transobturator	Synthetic	126	27	27	52	24	NR
Gilling et al. [87]	2008	ProACT®	Synthetic	33	52	NR	62	NR	NR
Gregori et al. [71]	2010	ProACT®	Synthetic	62	25	NR	66	26	NR
Sousa-Escandón [88]	2007	Remeex®	Synthetic	51	NR	32	65	20	NR
Hübner et al. [91]	2010	Argus®	Synthetic	101	25	26	79	NR	NR

NR not reported

Table 38.4 Outcomes for artificial urinary sphincter for post-prostatectomy urinary incontinence

Author	Year	No. of patients	Mean follow-up (months)	Median follow-up (months)	% Cured	% Improved	Social continence	Patient satisfaction (%)
Litwiller et al. [92]	1996	65	28	NR	20	72	NR	90
Klijn et al. [93]	1998	27	35	NR	NR	NR	81%	NR
Walsh et al. [94]	2002	98	44	47	19	70	NR	89–92

NR not reported

The well-known complications with the AUS include infection/urethral erosion (3–12%) and mechanical malfunction (1–9%). Additionally, the reoperation rate for the AUS ranges from 18 to 36%. There appears to be a 50% 5-year revision-free rate [92–95]. Even with the high need for revision, Litwiller et al. still found a 90% patient satisfaction rate in patients undergoing revision [92].

The emergence of the male sling has brought forward a nice intermediate option for those patients suffering from mild urinary incontinence, or those with moderate to severe urinary incontinence that are hesitant to undergo an artificial urinary sphincter. The higher degree of complexity associated with the AUS combined with its high reoperation rate make it a much less attractive option than a male sling. However, the AUS will continue to have its role in the post-prostatectomy patient with severe urinary incontinence, those with incontinence refractory to a sling, patients with a history of pelvic irradiation, and those with detrusor areflexia or hypoactivity.

Conclusions

Urinary outcomes following robotic-assisted laparoscopic radical prostatectomy are remarkably good. It will be exciting to track the course of overall continence rates and time to continence parameters to accurately measure the benefit of robotic technology in the execution of the anatomic radical prostatectomy. Related to this are preoperative risk factors for urinary incontinence that may ultimately be counteracted with improved surgical technique. Incontinence intervention has made great progress. Behavioral therapies accelerate the recovery of urinary continence. The developments of the suburethral and transobturator male slings provide an excellent option for surgical correction, not readily available a few years ago. While time to continence rates continue to improve following RALRP, there remains a stable subgroup of patients that will benefit from the advances we make in incontinence surgery.

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39 Erectile Dysfunction and Penile Rehabilitation After Robot-Assisted Radical Prostatectomy

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Introduction

Radical prostatectomy is one of the treatments of choice in patients with clinically localized prostate cancer and a life expectancy >10 years according to international guidelines. Although this surgical approach is characterized by excellent oncologic outcomes at long-term follow-up, one of the most common complications after radical prostatectomy is represented by erectile dysfunction (ED) [1]. Refinements in the surgical technique such as the introduction of nerve-sparing approaches helped physicians to reduce the incidence of post-operative ED. However, the prevalence of this condition still ranges between 20 and 80% at long-term follow-up [1–3]. Of note, variations in reported erectile function (EF) recovery rates after surgery depend on several factors such as EF recovery definition, baseline characteristics of patients undergoing surgery, preoperative EF, the follow-up duration and the surgical approach adopted. For example, over the last few years several authors demonstrated that baseline characteristics and preoperative functional status play a major role in the subsequent recovery of EF after radical prostatectomy. Similarly, the adoption of minimally invasive surgical techniques might have an impact on postoperative functional outcomes. Nonetheless, the proportion of patients who fail to recover EF after radical prostatectomy is still not negligible. As such, the concept of penile rehabilitation was introduced as a way to maximize the recovery of EF and, in turn, to reduce the risk of post-surgical ED in prostate cancer patients undergoing radical prostatectomy [4]. In particular, penile rehabilitation is defined as the adoption of any possible intervention in combination or alone that can help patients to achieve an erection sufficient for a satisfactory sexual intercourse and, possibly, to return to preoperative EF levels. Possible approaches for penile rehabilitation range from the use of mechanical devices to the administration of pro-erectile drugs such as phosphodiesterase type 5 inhibitors (PDE5-I). However, despite a number of investigators focused on ED after surgery, no standard universal treatment algorithm or specific guideline is available to date for penile rehabilitation after radical prostatectomy. The aim of the present chapter is to critically review the current management options for EF recovery after radical prostatectomy with a special focus on the use of PDE5-I.

Pathophysiology of Erectile Dysfunction After Radical Prostatectomy

In healthy individuals, the erection of the penis is achieved by a complex interaction of neurovascular factors, which include neurogenic stimuli,

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_39

increased blood flow from the pudendal arteries and reduced outflow through the veno-occlusive mechanism. Endothelial integrity plays a major role in the physiology of penile erections. Erections indeed depend on sexual stimulation, which causes the release of nitric oxide (NO) and other factors that determine the relaxation of the smooth muscle in the arteries supplying erectile tissues and an increase in blood flow to the penis while occluding the venous outflow. This leads to a trapping of blood within the corpora cavernosa with a consequent significant increase of the intracavernous pressure, eventually resulting in erections [5, 6]. This also leads to increased penile oxygenation, which helps preserving the endothelial structure and prevents muscle structural changes [5]. The interaction between neurogenic, vasculogenic and structural integrity of the penis translates into a multifactorial pathophysiology of post-surgical ED, where a vicious cycle that includes a combination of mechanical, inflammatory and ischemic injuries can be hypothesized [7]. Specifically, the complex interaction between the anatomical structures responsible for the erection is disrupted during radical prostatectomy.

Several factors might contribute to the onset of ED after radical prostatectomy. First, a direct trauma or indirect damage to the neurovascular bundles, and, specifically, to the cavernous nerves can occur, even when the neurovascular bundles are correctly preserved during a nerve sparing surgical approach [8]. The functional impairment of the local nervous function, the so called neuropraxia, translates into a persistent state of flaccidity [9]. This prolonged interval of absence of frequent and rigid erections may be associated with cavernous hypoxia, eventually leading to damage to the cavernous tissue and ED [10].

Another important pathophysiologic factor is related to a reduced arterial blood flow to the penis as a consequence of direct excision of accessory pudendal arteries during surgery. Specifically, the pudendal arteries are formally responsible for a correct blood supply to the corpora cavernosa. However, in a significant proportion of individuals (4–75%), a number of accessory or aberrant arteries that originate from the obturator, external iliac or internal iliac vessels can be identified [11, 12]. As a consequence, preservation of these arteries during radical prostatectomy should be commended in order to avoid penile arterial insufficiency.

Finally, a dysfunction in the veno-occlusive mechanism is also frequently observed among individuals with ED after radical prostatectomy. For example, Mulhall et al. [13] demonstrated that the prevalence of venous leakage was higher than 25% among patients complaining ED. While the pathophysiology of this phenomenon is unknown, it is possible that neuropraxia, as well as reduced arterial flow, might be responsible for penile fibrosis and subsequent reduced smooth muscle stretch capacity. As a consequence, the veno-occlusive mechanism is compromised, ultimately leading to a venous leakage.

A successful penile rehabilitation should aim at improving penile blood flow and at incrementing cavernosal oxygenation in order to prevent the microstructural changes that lead to penile fibrosis. This would break the vicious cycle between reduced penile oxygenation, muscle atrophy and penile fibrosis that further limits oxygenation [7]. For this reason, a number of different rehabilitation protocols have been developed in the form of mechanical rehabilitation (vacuum erection devices) or pharmacological approaches. These options are designed to improve long-term erectile function after surgery.

Mechanical Devices: The Role of Vacuum Erection Devices

Vacuum erection devices (VED) were the first ED treatment introduced in the clinical practice. Although nowadays they are almost exclusively used in the second-line setting, VED retain several advantages, such as being drug free and characterized by relatively low costs. VED are cylindrical devices that can be placed over the penis. They generate a negative pressure that facilitates the trapping of blood flow into the corpora cavernosa, ultimately increasing oxygen supply to the erectile tissues. Additionally, the increased blood flow facilitates penile engorgement and subsequent erection. Early case-series, such as the one reported by Colombo et al. [14] demonstrated that the use of VED, even unrelated to sexual intercourse, significantly improved the return of spontaneous erections.

The main advantage of VED is in its own nature as it is the only non-pharmacological and non-invasive treatment available for ED. A number of studies addressed the role of VED for the purpose of EF recovery after RP. The first randomized controlled trial was published in 2006 by Raina et al. [15]. Specifically, a total of 74 individuals were treated with VED and 18% discontinuation rate at 3 months was observed. In the remaining 60 individuals, 32% reported the return of natural erections after 9 months of treatment, although only 17% achieved an erection sufficient for vaginal intercourse. Nonetheless, the use of VED was associated with a significant increase in the abridged International Index of the Erectile Function (IIEF)-5 score, and early use of VED after RP was associated with an early return to natural erections, with subsequent early sexual intercourses and sexual satisfaction [15].

The timing of VED use was better evaluated in another randomized controlled trial performed by Köhler et al. in 2007 [16]. Specifically, a total of 28 patients treated with RP were randomized to early VED treatment (1 month after RP) vs. delayed treatment (6 months after RP). At the study end, patients treated 1 month after RP exhibited significantly higher IIEF scores and better preservation of the stretched penile length as compared to individuals treated 6 months after RP. Therefore, the authors suggested that VED could be used early after surgery in addition to other penile rehabilitation approaches in order to improve EF recovery rates [16]. In this regard, in another study performed by Basal et al. [17] 203 patients treated with bilateral nerve sparing robot-assisted RP were evaluated. Rehabilitation regimens included VED alone, VED in addition to PDE5-Is, PDE5-Is alone or none of them. Treatments that included PDE5-Is, and especially a combination of PDE5-Is and VED had a beneficial effect on EF recovery across all levels of baseline EF.

In conclusion, the results of these studies suggest that VED, alone or in combination with other treatments, such as PDE5-Is, might represent a viable option for penile rehabilitation after RP. The efficacy of VED is higher whenever treatment is started as soon as possible. That being said, currently available studies are not yet able to properly evaluate the effects of this approach in the long-term. Moreover, a relatively high rate of treatment discontinuation (approximately 20%) has been reported by several authors [15, 18]. Therefore, low patient compliance with VED might limit its applicability in the clinical setting. Large well-designed randomized studies formally assessing the efficacy of VED compared to PDE5-Is and other possible combinations are not available yet. As a consequence, further studies are needed in order to evaluate which individuals might represent the best candidates for this approach.

Phosphodiesterase Type-5 Inhibitors

From a chemical perspective, PDE5-Is are analogues of cyclic guanosine monophosphate (cGMP). By promoting smooth muscle relaxation in the blood vessels that supply the corpora cavernosa, they promote an increased blood flow into the penis and increased penile oxygenation, with subsequent promotion of erection. PDE5-Is usually represent the first treatment of choice for any type of ED. The importance of these drugs in clinical practice has been widely recognized by the most recent international guidelines [19, 20] and a recent meta-analysis confirmed that PDE5-Is are well tolerated and more effective compared to placebo [21].

Currently PDE5-Is available worldwide are sildenafil, tadalafil, vardenafil and avanafil. All of them are able to significantly improve the IIEF-EF score, Global Assessment Questionnaire (GAQ), Sexual Encounter Profile question 2 (SEP-2) and SEP-3 [21]. Additionally, the safety profile of these drugs has been demonstrated in different studies [22–24], with some that suggest PDE5-Is might be associated with cardiovascular benefits [25, 26].

Sildenafil

Sildenafil was initially tested in a randomized controlled trial performed by Padma-Nathan et al. [27]. Specifically, 76 individuals treated with nerve-sparing RP were randomized to nightly sildenafil vs. placebo for a total of 36 weeks, followed by an 8-week washout period. Although the trial enrolment was ended prematurely because of suspected lack of effect at an interim analysis, the final results demonstrated that patients receiving sildenafil showed higher rates of return to baseline EF and higher IIEF-EF scores as compared to their counterparts included in the placebo arm. Despite the lack of a group of individuals receiving on-demand dosing, this study formally introduced the concept of chronic penile rehabilitation using PDE-Is. The role of on-demand sildenafil was subsequently evaluated by a more recent randomized controlled trial that included 100 preoperatively potent men randomized to nightly sildenafil plus on-demand placebo vs. on-demand sildenafil plus nightly placebo for 12 months [28]. Despite the small cohort size, the authors suggested the lack of significant benefit in EF recovery rates in individuals receiving nightly vs. on-demand sildenafil.

Tadalafil

In 2004, Montorsi et al. [29] evaluated the efficacy and safety of tadalafil 20 mg on-demand in individuals with ED after bilateral nerve-sparing RP. Specifically, a total of 303 individuals were randomized to tadalafil vs. placebo. The authors demonstrated that the use of tadalafil was associated with a significant improvement in the IIEF-EF and GAQ compared to placebo. Overall, 62% of all individuals treated with tadalafil reported an improvement in the erections vs. 23% among patients treated with placebo. Additionally, 24% of individuals treated with tadalafil achieved IIEF-EF score of 26 or higher vs. 4% among individuals treated with placebo. The mean proportion of successful penetration attempts was 54% among individuals who received tadalafil vs. 32% among patients included in the placebo arm of the study. Tadalafil proved to be well tolerated, with the most common side effects being headache (21%), dyspepsia (13%) and myalgia (7%).

This analysis was repeated more recently in another study [30] that evaluated the effect of tadalafil 5 mg daily vs. tadalafil 20 mg on-demand vs. placebo. Specifically, 423 individuals were randomized to each of the three arms in a 1:1:1 ratio. Patients were randomized to receive 5 mg tadalafil once daily vs. 20 mg tadalafil on-demand vs. or placebo. At the 9 months (end of the double-blind period), the IIEF- EF score improvement exceeded the minimally clinically important difference in both treatment groups (i.e., patients receiving tadalafil either on-demand or daily). However, only patients treated with tadalafil once daily had a significant difference in the change in IIEF-EF compared to placebo. Although the IIEF-EF and Sexual Encounter Profile question 3 (SEP3; “Did your erection last long enough for you to have successful intercourse?”) improved also during the open-label phase of the study exceeding the minimal clinically important difference for all the groups, no differences were observed between patients treated with tadalafil and placebo after open-label treatment. Less shrinkage of penile length was observed in the tadalafil once daily group as compared to placebo at the end of the double-blind period. The study demonstrated the superiority of daily tadalafil administration over on-demand treatment and suggested a role for daily low-dose therapy for promoting EF recovery after surgery and better protection towards penile structural changes after radical prostatectomy [30]. Of note, a recent sub-analysis of the same cohort performed by Moncada et al. showed that tadalafil once daily significantly reduced time to EF recovery during the double-blind treatment period.

Vardenafil

In a randomized controlled trial, Brock et al. [31], evaluated the efficacy and safety of vardenafil for penile rehabilitation in patients with post surgical ED. A total of 440 patients with ED after nerve-sparing RP were randomized to 10 mg vs.

20 mg vardenafil vs. placebo. After 3 months of treatment, the use of vardenafil was significantly associated with improved erections and higher IIEF-EF scores. A follow-up study on the same population corroborated this observation [32]. In the REINVENT study, Montorsi et al. [33] randomized a total of 628 patients with localized prostate cancer undergoing radical prostatectomy to nightly vardenafil (10 mg) vs. on-demand vardenafil (10 or 20 mg) vs. placebo. The authors demonstrated that individuals randomized to on-demand therapy achieved significantly better IIEF scores compared to both individuals treated with nightly vardenafil or placebo. This study effectively was the first to formally support the effect of on-demand dosing of PDE5-Is as compared to administration in a daily fashion. Several explanations may be given supporting the role of on-demand drug administration. In the case of vardenafil, the peculiar pharmacokinetic and half-life of this drug as well as its onset of action should be taken into account [34]. As a consequence, patients who received on-demand vardenafil did benefit from better drug distribution and better drug efficacy compared to individuals who were treated with nightly vardenafil. Of note, whether a true rehabilitation was achieved is still debated. Specifically, all the patients underwent a 2-month pharmacologic washout period after the initial 36-week treatment, regardless of the randomization arm. Interestingly, no difference was observed in the rates of spontaneous erections after washout [33].

Avanafil

In a recent study, Mulhall et al. [35] evaluated the effect of avanafil on EF recovery rates after RP. Specifically, a total of 298 patients with ED after radical prostatectomy diagnosed after at least 6 months from surgery were randomized to receive on-demand 100 mg or 200 mg avanafil vs. placebo for a total of 3 months. At the end of the study, the proportion of individuals who reported improved EF were 41% vs. 31% vs. 10% for 200 mg vs. 100 mg avanafil vs. placebo, respectively. Although the high rates of treatment discontinuation recorded among patients treated with placebo should be considered, this study demonstrated significant improvements in IIEF-EF score, as well as the rates of successful vaginal insertion and successful intercourse, at both dose levels. It is noteworthy that avanafil has been introduced in clinical practice only in the most recent years [36]. In consequence, direct comparisons with other PDE5-Is are still lacking.

In conclusion, the literature suggests that administration of PDE5-Is after radical prostatectomy might be associated with improved functional outcome recovery and, in particular, higher rates of EF recovery. However, current debates are still ongoing regarding daily vs. on-demand administration. Additionally, it has been suggested that PDE5-I treatment may require very long treatment period in order to achieve satisfactory EF recovery in an acceptable proportion of individuals. Moreover, the effects of PDE5-Is might not be maintained after a washout period. As a consequence, only future well-designed studies, possibly in randomized settings, will properly address these questions.

Intracavernosal Injections

The first form of pharmacological rehabilitation therapy reported in the literature consists of administration of prostaglandins in the corpora cavernosa. Although in a different way compared to PDE5-Is, drugs such as prostaglandin E1 (PGE1), as well as papaverine and phenoxybenzamine, induce vasodilation and expansion of the corpora cavernosa by directly inducing relaxation of the cavernosal smooth muscle. This vasodilation causes rapid arterial inflow inside the penis, promoting penile engorgement. Differently from PGE5-Is, the action of prostaglandins bypasses nerve signalling, thus inducing erection regardless of erectogenic neural stimuli, even in patients in which the neurovascular bundles have not been preserved during surgery. In consequence, this treatment can be effective also in patients with ED refractory to PDE5-Is [37].

The first report in the form of a randomized controlled trial for intracavernosal injections is the one from Montorsi et al. [4]. Specifically, a total of 30 patients treated with nerve-sparing radical prostatectomy were randomized to PGE1 injections 3 times per week for a total of 12 weeks (15 patients) versus observation without any treatment (15 patients). Of the total 12 individuals who were assessable at follow-up, 67% of the treated patients achieved EF recovery to the point of satisfactory sexual intercourse vs. 20% among untreated patients.

Albeit limited by the extremely small patient sample, the study from Montorsi et al. [4] was the first to hypothesize a relationship between better tissue oxygenation through the use of ICIs and better EF recovery rates. A number of other studies, such as the work from Mulhall et al. [37] and Raina et al. [38] confirmed the effectiveness of ICI in penile rehabilitation regimens.

Intracavernosal injections are not devoid of complications. Specifically, the risk of priapism, ecchymosis and haematoma must be carefully evaluated every time this treatment option is considered. For this reason, ICIs are not usually considered as a first line treatment in penile rehabilitation. However, this option can be considered in patients who cannot be candidate for or failed first line treatment with PDE5-Is [19, 20]. This is supported by international guidelines [20, 39]. Additionally, early administration of this treatment in a first line setting has been showed to be associated with a high risk of complications and poor patient compliance [40].

Conclusions

A number of studies analysed the effect of several treatment modalities aimed at improving EF recovery after radical prostatectomy. Many alternative strategies are currently available, with the use of PDE5-Is currently representing the first-line treatment. The role of VED and ICI is more limited. It is noteworthy that, despite guidelines are available for the management of ED, clear management strategies for post-radical prostatectomy settings are not defined yet. Future studies will better compare different strategies, eventually helping into defining an optimal program for penile rehabilitation.

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Part VII

Reconstructive Urology

Robot-Assisted Pyeloplasty

40

Giuliana Lista, Nicolò Maria Buffi, Davide Maffei, and Giovanni Lughezzani

Introduction

Although many surgical and endoscopic techniques have been described for treating uretero-pelvic junction obstruction (UPJO), Anderson Hynes dismembered pyeloplasty remains the preferred option in most cases. This kind of technique is well suitable also for laparoscopic minimally invasive approach.

Since its introduction in 1993 by Schuessler et al. [1], laparosopic dismembered pyeloplasy has rapidly become a valid alternative to the more invasive traditional open approach. The long-term results are comparable with those of open surgery with success rates ranging from 90 to >95% [2–5].

However, laparoscopic pyeloplasty, both transperitoneal and retroperitoneal approach, remains a challenging procedure and it requires high proficiency in laparoscopic skills especially considering the reconstructive part such as suturing.

Even in large series from experienced centers, the operative duration has remained long, usually due to prolonged anastomotic times.

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Robotic technology overcomes limits of conventional laparoscopy with the three dimensional vision, increased dexterity and greater precision. Therefore, taking into account that reconstructive surgery needs precise intracorporeal suturing, dismembered pyeloplasty is one of the procedures which most likely benefits from robotic assistance.

Robotic pyeloplasty using the Da Vinci (Intuitive Surgical, Inc., Sunnyvale, CA, USA) system has been firstly described by Gettman et al. in 2002 [6]. Authors reported perioperative outcomes of nine patients treated with robotic transperitoneal pyeloplasty for ureteropelvic junction obstruction.

Since then several series of robotic pyeloplasty have been published, most of which replicate the conventional laparoscopic technique.

The indications for robotic pyeloplasty are the same as those for laparoscopic or open pyeloplasty. Therefore, all patients with symptomatic UPJ obstruction, or with decreasing renal function in the presence of UPJ obstruction, can be considered for RP. Patients in whom primary treatment for UPJ obstruction has failed might also be considered for robotic pyeloplasty.

Also the pre-operative diagnostic workout is the same as for open or laparoscopic approach. Prior to surgery, patients usually undergo diuretic MAG4 renogram and CT scan in order to evaluate the presence of renal stones and or crossing vessels and plan the surgery accordingly.

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_40

Surgical Technique

Transperitoneal Robot Assisted Pyeloplasty

Patient Positioning and Operating Theatre Layout

The patient is positioned in a 60° lateral flank position with the affected side facing superiorly. The lowermost arm is placed on an arm-board. The uppermost arm is placed in a gutter-type rest or alongside the flank. The lowermost leg is flexed at the knee and the uppermost leg is straightened with one or two pillows placed between the legs. The table is then flexed with the break positioned between the patient's iliac crest and costal margin in order to obtain a wider operating field (Fig. 40.1).

The operating theatre layout is showed in Fig. 40.2. The anaesthetic equipment is placed at the patient's head. The robot cart is coming from behind the patient's shoulders.

Port Placement

The camera port is usually placed at the umbilicus level or on the pararectal line for obese patients. A 12 mm or a 8 mm trocar is used for the Si and for the Xi DaVinci equipment respectively. A 30° or a 0° laparoscope can be used, choice based on surgeon's preference. The two operative robotic ports are positioned one at the midpoint between the anterior superior iliac spine and the umbilicus and the other on the pararectal line 1 cm beyond the costal arch. The 5-mm assistant port is positioned on the midline at the midpoint between the umbilicus and the xiphoid process (Fig. 40.3).

Fig. 40.2 Operating theatre setup for transperitoneal robotic pyeloplasty

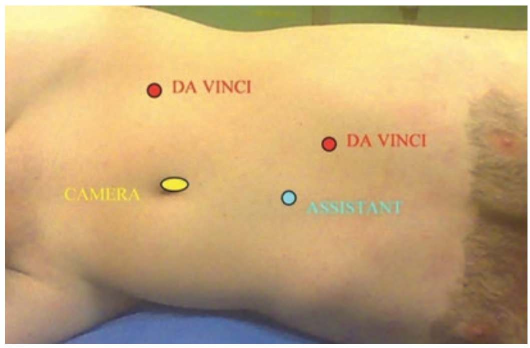

Fig. 40.3 Port placement for transperitoneal robotic pyeloplasty

Fig. 40.1 Patient's position for transperitoneal robotic pyeloplasty

The right side of the peritoneum, overlying Gerota's fascia, is incised, and the target structures (the ureter, the dilated renal pelvis, and eventually the aberrant crossing vessels) are exposed. On the left side, the white line of Toldt is incised and the left colon is mobilized medially to expose Gerota's fascia, which is incised isolating the target structures. The ureter can usually be found by tracing the psoas medially from the lower pole of the kidney. Any crossing vessels are identified and preserved. The UPJ is fully mobilized using blunt and sharp dissection. Usually, bipolar fenestrated forceps and monopolar scissors are used during this phase.

The stenotic UPJ is identified and excised. Redundant renal pelvis is reduced by excising the excess tissue. Any stone within the collecting system can also be removed at this time. The ureter is then spatulated longitudinally and the pyeloplasty performed according to the Anderson-Hynes technique. The remodelling is usually performed using two 4-0 Vicryl running sutures, one for the posterior and for the anterior aspect of the anastomosis using a robotic needle driver.

In the case of a crossing vessel, a dismembered pyeloplasty with transposition of the re-anastomosed ureter ventral to the vessels is performed.

Retroperitoneal Robotic Pyeloplasty

Patient Positioning and Operating Theatre Layout

In this case, the patient is positioned in a full flank position. The bed is flexed to maximise the space between the iliac crest and the costal arch.

The da Vinci robotic system is positioned with the arms entering 25–30° anteriorly to the head of the patient (Fig. 40.4).

Fig. 40.4 Patient's position for retroperitoneal robotic pyeloplasty

Port Placement

A retroperitoneal access is made at the level of the tip of the 12th rib. In this case it is necessary to create a working space within the retroperitoneal fat. To this purpose, balloon expanders or other cost effective alternatives (such as finger of sterile gloves tied to a trocar and filled with saline water) [7] can be used.

Once the retroperitoneal cavity is created, the other trocars can be positioned. The two operative robotic trocars can be placed at the conjunction of the 12th rib with the "erector spinae" muscle and at the level of the anterior axillary line 6–8 cm cranially to the iliac crest, respectively. The assistant 5-mm port can be positioned along the erector spinae muscle, cranially to the iliac crest (Fig. 40.5).

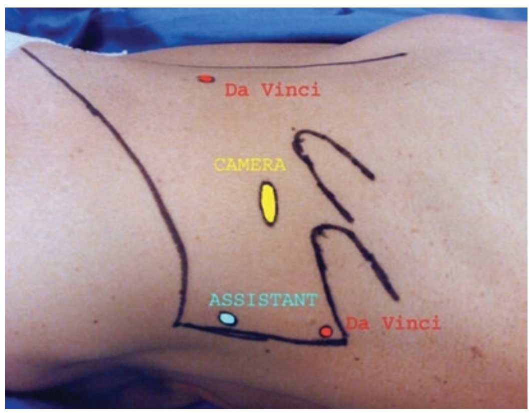

Fig. 40.5 Port placement for retroperitoneal robotic pyeloplasty

Gerota's fascia is then incised and the UPJ exposed. The plasty is performed exactly as for a transperitoneal approach.

The retroperitoneal approach allows a direct access to the UPJ with no exposure of intraperitoneal organs. However, the lack of familiar anatomical landmarks and a relatively restricted working space are some of the limitations, requiring more delicate manoeuvring.

Cestari et al. [5] reported outcomes of 36 and 19 patients who underwent retroperitoneal and transperitoneal robotic pyeloplasty respectively for UPJ obstruction.

The authors concluded that both approaches are feasible and safe, they were comparable in terms of operative time, estimated blood loss and post-operative morbidity. Also there were no cases of conversion to either laparoscopic or open approach.

On the other hand, given the wider working space provided by the transperitoneal approach, it is the preferred access in the presence of wide pelvis (>6 cm), concomitant renal stones, crossing vessels, horseshoe or pelvic kidney. In patients who previously underwent renal surgery, a retroperitoneal access may be challenging, thus a transperitoneal approach should be preferred.

On the contrary, the advantages of the retroperitoneal approach are a direct access to the UPJ, minimized risk of intraperitoneal organs injuries and the possibility to manage conservatively urinary fistul, since urine won't come into contact with the intraperitoneal cavity.

Trans-mesocolic Access for Left Robotic Pyeloplasty

The trans-mesocolic approach for left robotic pyeloplasty has been firstly reported by Gupta et al. in 2009 [8]. By creating an operating window through an incision of the mesocolon, this technique allows the surgeon to access directly the left renal pelvis and UPJ without mobilising the descending colon.

The best candidates for this approach are young thin patients, with a large renal pelvis, who undergo primary repair of UPJO. In the presence of renal stones or history of complicated UPJ obstruction (e.g. previous infections, pyelonephritis, pre-operative stenting) a classical transperitoneal access might be preferable.

The advantages of the transmesocolic approach are certainly faster operative time, shorter hospital stay and faster bowel peristalsis recovery as reported by comparative studies [9, 10].

Ureteral Stenting

When performing a uretero-pelvic junction plasty, it is required to put an ureteral stent in order to avoid high renal intra-pelvic pressure and protect the anastomosis. This kind of procedure can be done in two different ways, both retrogradely and anterogradely.

Cystoscopic retrograde stent insertion is usually performed immediately before the pyeloplasty procedure. The patient is initially in a lithotomy position and a cystoscope is used to insert the double-J stent. This approach allows to perform a retrograde pyelogram to exclude any other ureteric abnormality. However, it is more time consuming since it requires repositioning of the patient before proceeding with the pyeloplasty. Moreover, stenting results in the collapse of the renal pelvis, making indentification of the UPJ stricture more difficult. Lastly, the proximal coil of the stent can interfere with intracorporeal suturing.

Anterograde stenting consists in putting the ureteral double-J stent while performing the plasty to avoid renal pelvis collapsing. Usually an hydrophilic guidewire and an ureteral catheter is positioned through the 5 mm assistant trocar after completing the posterior part of the anastomosis. The guidewire and the catheter are pushed with a robotic grasper or needle driver into the ureter down to the bladder. The ureteral catheter is removed and the double-J stent is inserted onto the guidewire through the 5 mm trocar. The proximal coil of the stent is positioned in the pelvis and the anterior aspect of the anastomosis is completed. This technique is safe, rapid and simple [11], however it is done blindly, therefore the surgeon cannot be sure of the correct position of the stent.

Many methods to overcome this issue have been described. Rodrigues et al. [12] used methylene blue to fill the bladder and its appearance through the stent holes as an indication of proper positioning.

Gaitonde et al. [13] used a cystoscopically placed UPJ occlusion catheter placed alongside a Foley urethral catheter that was marked to show the distance needed to advance the pusher and accurately place the lower coil of the stent in the bladder. The Foley catheter and the occlusion balloon were prepared in the operatory field. After pyelotomy, the balloon was deflated, and the occlusion catheter was withdrawn into the proximal ureter. After completion of the posterior suture line of the dismembered pyeloplasty, a guidewire was inserted through the OC and grasped within the renal pelvis. The occlusion catheter was then removed and the stent advanced along the guidewire up to the renal pelvis. The distal end of the stent pusher was advanced until the calibrated mark of the Foley catheter appears to ensure the correct placement of the distal coil in the bladder.

Fiori et al. reported feasibility and safety of flexible pneumocystoscopy to place the ureteral stent retrogradely during laparoscopic pyeloplasty. This way the patient can be positioned directly on the flank position and the pyeloplasty can be carried out [14].

Few comparative studies for retrograde vs. anterograde stenting have been carried out. The studies published are all about laparoscopic pyeloplasty. According to these datas, anterograde stenting is faster; however retrograde stenting appears to assure a higher successful stent placement rate compared to anterograde technique [15–18].

Robotic stentless pyeloplasty has also been reported, however few and conflicting datas are available in order to evaluate the safety and the efficacy of a stentless approach [19–21].

Postoperative Care

Patients are mobilized and fed on postoperative day 1. The bladder catheter is usually removed on postoperative day 2 and the drain the following day if the output is less than 50–70 mL. Patients are discharged from the hospital on post-operative day 2 or 3.

Patients are usually seen by the urologist after 4 weeks and assessed with urynalysis, urine culture and abdominal ultrasound. Ureteral stent is usually removed after 5 or 6 weeks from the operation.

Patients are evaluated at 6–12 months with urinalysis, urine culture, MAG3 renal scintigraphy and URO-CT scan.

Outcomes of Robotic Pyeloplasty

Since its introduction in urological practice, robotically-assisted laparoscopic pyeloplasty has been reported as having excellent success rates for relief of obstruction and very low perioperative morbidity. The robotic surgical technique not only maintains the benefits of laparoscopic surgery but also provides enhanced manipulation and visualization as well as a shorter learning curve.

Multiple case series including a consistent number of patients have been reported in the literature for paediatric patients; data for the adult population are also becoming increasingly available.

The definition of optimal outcomes of robotic pyeloplasty in the current literature is still highly heterogenous, since several methods and variable cut-offs may be adopted to define functional, anatomical and symptomatic resolution. These include radiographic exams (renal scintigraphy, intravenous pyelogram or US), symptom resolution (pain relief) and laboratory tests.

Ultrasound and urography scan can lead to incorrect interpretation of obstruction resolution due to the presence of residual hydronephrosis which can persist for months or longer after pyeloplasty. Renal scintigraphy is widely recognised as the best noninvasive technique to assess obstruction of the upper urinary tract objectively and it should be always adopted to evaluate postoperative outcomes.

The first experience with robot-assisted Anderson Hynes pyeloplasty was published by Getmann et al. in 2002 [6]. The authors reported outcomes of nine consecutive patients treated with transperitoneal robotic pyeloplasty. All surgeries were completed robotically, one patient was re-operated with an open surgery approach because of urinary fistula. At a 4 months follow up, all cases had favourable outcomes.

Patel reported the first large series (50 cases), with a success rate of 100%. This outcome was defined as the absence of obstruction at the MAG3 renography. The authors concluded that the technique offers optimal short-term efficacy and minimal morbidity, with an easier and quicker learning curve [22].

Mufarrij et al. published a multi-institutional experience, describing the outcomes in 140 patients, with a 29 months follow up, including primary and secondary UPJO with or without concomitant stone extraction, and also patients with a solitary kidney. The authors reported a success rate of 96%, recurrency was described in six cases. Complication rate was 7.1%, double-J stent migration was described as the most common post-operative complication. As for minor complications, hyperpyrexia was the most frequent. There was no difference in terms of operative time and perioperative outcomes between patients treated for a primary stenosis and secondary UPJO cases [23].

An other large series was published by Schwentner et al. in 2007. Outcomes of 92 cases, 80 of these with primary UPJO and 12 with secondary UPJO, were reported. The follow up was about 40 months and success rate was up to 96%. In the secondary UPJO group the failure rate after robotic pyeloplasty was slightly higher [24].

The excellent outcomes of the robotic procedure were confirmed in an other large multi-institutional serie of 169 cases, both primary and secondary UPJO. In this serie, success rate was 97.6% with a 39 months follow up. The estimated blood loss was less than 50 mL and complication rate was 6.6% [25].

Cestari et al. concluded that both the transperitoneal and the retroperitoneal robotic pyeloplasty were safe and feasible procedures with a low morbidity rate with an overall success rate of 96%. However the cases were differently selected for the two approaches [5].

Overall, the outcomes of the procedure have been defined as excellent and reproducible [22, 25, 26], with durable results [24]. Robotic pyeloplasty has also been recognised as being easer and quicker to learn than its laparoscopic counterpart [22].

The success rate reported in the literature [27] is very high (81–100%), with reintervention rates reported to be 0–13.1%. Operative times are quite variable, ranging from 105 to 335 min. It is a safe operation with reproducible outcomes, low conversion rates (0–4.8%), modest complication rates (2–17.9%) and little estimated blood loss.

Outcomes of robotic pyeloplasty in the pediatric population have been extensively reported in the latest literature.

The largest single institution study, published by Minnillo et al., assessed 155 pediatric patients undergoing RP and found a success rate of 96% with a 3% of failure rate [28].

A recently published meta-analysis of comparative studies in the pediatric population found no difference in success rate between robotic, conventional laparoscopic and open pyeloplasty [29].

The overall success rate for robotic and laparoscopic pyeloplasty was 99.3 and 96.9% respectively with no significant difference between the two approaches. The overall re-operation rate was low for robotic pyeloplasty (2.8%) and the cumulative complication rate was 8.3% with no differences compared to the other approaches. Length of hospitalization was significantly shorter for robotic approach compared to open and laparoscopic pyeloplasty.

A recent multicenter study [30] included 407 pediatric patients treated with RP and found an overall complication rate of 13.8%. The majority of these compilations were low grade (Clavien Dindo ≤ II). There were no Clavien grade IV or V complications.

Comparative Studies

Few studies have so far evaluated the outcomes of minimally invasive pyeloplasty with open pyeloplasty, mostly focused on the laparoscopic approach. A meta-analysis, published by Autorino et al., of currently available studies shows no difference in terms of success rate and complication rate between minimally invasive and open approach in the adult population. Minimally invasive pyeloplasty provides a shorter hospitalisation time and less analgesic requirements compared to open surgery [27].

In the adult population, only two analytical studies have included patients undergoing robotic pyeloplasty, but only one clearly differentiates between those undergoing laparoscopy and robotic-assisted surgery.

Basatac et al. [31] shows significant decrease in length of hospital stay, estimated blood loss, earlier time to drainage removal and lesser need for narcotics. In terms of success rates, intra-operative complications and conversions, no significant differences were found.

Regarding operative time, satisfactory data comparing the two approaches are lacking. Basatac shows a shorter time for robotic surgery although only taking into account console time; the difference is not statistically significant. Hanske et al. [32], when evaluating a large number of pts undergoing MI vs. open, reports a statistically significant difference in the percentage of pts requiring prolonged operation time (<236 min): 29.6% for MIP vs. 15.3% for OP. Hanske also report a statistically significant decrease of overall complication rates for the MI approach, as well as for individual classes of complications (pulmonary, thromboembolic, sepsis/shock, renal failure, wound).

LAP vs. ROB

Although being a successful procedure available within the urologist's armamentarium since the 90s, laparoscopic pyeloplasty has stepped back to leave robotic pyeloplasty as the most used MI approach for UPJO.

As noted previously, several benefits of the robotic platform allow to reduce the learning curve and time dedicated to the reconstruction of UPJ, as well as being less physically demanding on the surgeon. On the other hand, laparoscopy maintains tactile feedback and, above all, is still considered to be the more cost-effective.

In terms of analytical studies, a general equivalence among the two procedures has been reported for their safety and efficacy, given the very high success rates for both. Complications rates are shown to be similar in most studies, while the largest multicenter series of LP and RP in the paediatric population reports a reduced incidence of postoperative complications for RP (3.2% for RP vs. 7.7% for LP, P = 0.02) [33].

Although not always statistically significant, a definite trend towards shorter operative time for robotic vs. laparoscopic pyeloplasty is suggested by most comparative studies. In the most recent meta-analysis by Autorino et al. [27], a OT time reduction of −27.9 min (p = 0.03) favouring RALP was noted. The same meta-analysis failed to demonstrate a significant reduction in length of hospital stay, which was indeed shown by most of the recent literature, especially in the paediatric population [22].

Role of Robotic Approach in the Management of Recurrent Ureteropelvic Junction Obstruction

The robotic approach is feasible, safe and effective for treating recurrent UPJ obstruction. Secondary mini-invasive pyeloplasty is obviously recognized as a challenging procedure due to the fibrosis and the adhesions in the area of the previously operated UPJ. The fine movements of the robotic instruments and the magnified vision contribute to a more precise and bloodless dissection and to a better quality of the anastomosis in complicated cases.

Secondary robotic pyelopasty has been mostly described in the pediatric population with data from small series (less than 10 patients). No comparative prospective studies between several approaches (endoscopic vs. laparoscopic vs. robotic approaches) have been reported.

Thom et al. found that nine secondary robotic procedures done at their center required longer operative time, with more blood loss and a lower success rate (failure rate was 22%) [34]. Atug et al. reported data of seven adult patients who underwent redo dismembered robotic pyeloplasty. The authors compared these outcomes with data from 37 patients treated for primary UPJ obstruction. Mean operative time was 60 min longer in the secondary pyeloplasty group. However, blood loss, hospital stay, and success rates were similar [35].

Hemal et al. reported outcomes of nine patients (mean age: 16.4 year) treated for secondary UPJ obstruction after failed open pyeloplasty and additional failed retrograde endopyelotomy.

All patients were treated robotically and showed clinical resolution of symptoms and no sign of obstruction at post-operative renal scan [36].

Niver et al. published data from 20 adult patients treated with robotic redo pyeloplasty for secondary UPJ obstruction; authors reported a success rate of 94% concluding that robotic-pyeloplasty for secondary UPJO repair is a safe and durable option [37].

Lindgren et al. [33] reported data from 16 children with recurrent or persistent UPJO obstruction following prior pyeloplasty (12 open, four robotically-assisted) plus additional interventions in 12 of them. Re-do RAP and re-do robotically-assisted laparoscopic ureterocalycostomy were performed in 13 and 3 patients, respectively. All children improved symptomatically, 88% showed radiographic improvement and none required further surgical intervention at a short-term and intermediate follow-up.

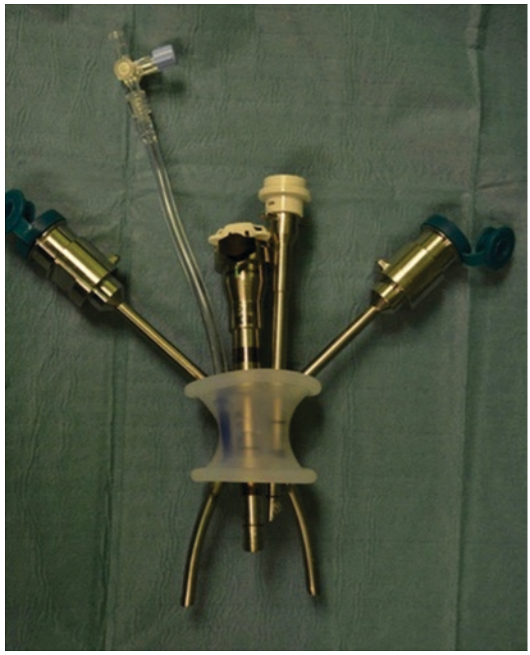

Fig. 40.6 Da Vinci single site

Single-Site Robot-Assisted Pyeloplasty

The treatment of UPJO is often required in young patients. Consequently, besides the resolution of the obstruction, a good cosmetic result represents an important goal of this kind of surgery. Laparoendoscopic single site (LESS) pyeloplasty has been introduced with this purpose [33, 38]. However LESS is a very challenging procedure, especially the suturing part, even for experienced laparoscopic surgeons. This is due to the loss of instrument triangulation, instrument clashing and to the reduced visibility and maneuverability associated with the coaxial orientation of instruments and of the laparoscope. The robotic technology partially minimize these limitations associated with LESS.

Robotic LESS pyeloplasty (R-LESS) technique is performed with the use of a 2.5 cm umbilical incision. Through this the single site port is inserted and the robot arms connected (Fig. 40.6). A transperitoneal approach is performed and the pyeloplasty is carried out according to the Anderson Hynes technique as for the standard robotic procedure [39]. The GelPort system, introduced by a 3–5 cm umbilical incision, has also been used to perform robotic LESS pyeloplasty [40] (Fig. 40.7).

Fig. 40.7 GelPort system

Data from a multi-institutional series of 30 consecutive patients showed that RLESS pyeloplasty is a feasible and safe technique in highly selected patients. Among these cases, only two patients required conversion to laparoscopic and robotic procedures. In three cases an additional 3 mm trocar was needed. Success rate, at a

13 months follow up, was comparable to rates reported in conventional robotic series (93.3%).

Esclusion criteria for RLESS pyeloplasty technique are a body mass index (BMI) >30 kg/m^2, previous abdominal and renal surgery, an extremely large renal pelvis (i.e., pelvis diameter > 6 cm), complicated UPJO with stones, pelvic kidney, and horseshoe kidney [41].

Robotic LESS pyeloplasty is feasible and reproducible in selected cases offering short hospitalizazion time and optimal aesthetic results. However real benefits compared to standard robotic pyeloplasty still need to be proven.

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41 Robot-Assisted Laparoscopic Ureteral Reimplantation

Jens Rassweiler

Clinical indications for ureteral reconstruction include strictures, trauma (often iatrogenic), vesicoureteral reflux (VUR), fistulas and malignancy. Traditional open surgery remains the gold standard for ureteral reimplantation with good long-term results (success rates over 90%) [1–3]. Short ureteral defects can be managed by uretero-ureterostomy or ureteroneocystostomy. Longer defects require complex procedures such as psoas hitch ureteral reimplantation often combined with a Boari flap.

Laparoscopy provides patients the advantages of less blood loss, low postoperative morbidity, less postoperative pain, quicker recovery and better cosmetic results [4–7]. Successful results using laparoscopic ureteral reimplantation have been reported in the literature to treat both benign and malign diseases [7–13].

However, with the advent of robotic surgery, these procedures began to be performed with robotic assistance. Conventional laparoscopic surgery has some limitations like lack of three-dimension (3D) vision, poor manoeuvrability and ergonomic movement of instruments which lead to a difficulty in intracorporeal suturing. Due to clutch function and the sitting position of the surgeon, robotic assistance offers beside significant technical advantages ergonomic working position for the surgeon. The da Vinci® surgical robotic system (Intuitive Surgical Inc., Sunnyvale, CA) is being increasingly used to perform complex reconstructive urologic surgeries. The feasibility of robotic-assisted laparoscopic (RAL) Cohen cross-trigonal ureter reimplantation in VUR procedure was investigated in animal model by Olsen et al. in 2003 [13]. After Yohannes et al. published the first case of robot assisted laparoscopic ureter reimplantation (RALUR) for a left distal ureteral stricture [14], an increased number of cases were reported with using robotic technology in direct ureter reimplantation or Boari flap, with or without psoas hitch [15–33]. The advantages of robotic surgery like three-dimensional visualisation, increased degree of freedom in movement and avoiding physiologic tremor, especially in the dissection and suturing of the anastomosis in the narrow small pelvis, can overcome limitations of conventional laparoscopy.

Indications

Clinical indications for RALUR are ureteral strictures, iatrogenic injuries, VUR, ureterovaginal fistulas, endometriosis and low-grade distal urinary tract transitional cell carcinoma.

Surgical Technique

Our technique for robotic ureter reimplantation is based on the transperitoneal approach. We are using compression socks to lower extremities and

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_41

prophylactic antibiotics (second generation cephalosporin) before the operation.

Under general anaesthesia, a 16-F Foley catheter is inserted in the bladder with the patient placed in supine position in a vacuum mattress, the legs are slightly abducted (lithotomy position) and all pressure points padded. The skin is incised over 15 mm transversely just below the umbilicus, and the approach is performed by using either a Veress needle or Hasson technique (Fig. 41.1a, b). We prefer a supraumblical incision for the ureter strictures above the iliac crest. After creation of a pneumoperitoneum (15 mmHg, maximum flow: 15 L/min), a 12-mm optic port is placed below the umbilicus. The trocars are placed using the 30° binocular lens and under direct vision, as shown in Fig. 41.1. The 8-mm Da Vinci trocars are placed along the lateral border of the rectus muscle 2–3 cm below the level of the infraumbilical camera access.

Two (5-mm left and 10-mm right) accessory ports are placed in upper abdomen a few centimetres above the medial Da Vinci trocars under endoscopic vision. The patient is than placed in a Trendelenburg position, and the robot is docked like in robotic prostatectomy.

In case of sufficient ureteral length, the modified Lich–Gregoir technique as used by transplant surgeons offers the advantage of minimal bladder opening. Another alternative represents

Fig. 41.1 (**a**, **b**) Trocars and patient positioning for robotic ureteral reimplantation

the Politano–Leadbetter type of ureteral implantation with mucosal flap or the classical submucosal tunnel. In case of a short ureter, a Boari flap may become necessary. In all these modifications, we emphasise a vesico-psoas hitch to stabilise the anastomosis.

Ureteral Dissection

The console surgeon operating with a bipolar forceps on the left arm and a monopolar scissors on the right. The peritoneum is incised on the psoas, above the level of the iliac vessels and the ureter is isolated stepwise until the stricture site could be identified (Figs. 41.2 and 41.3). In tumour cases, the distal part is ligated with Hem-o-lock clips, excised completely down to the bladder and sent for a frozen section, confirming the absence of residual tumour. The ureter is spatulated using the right-curved scissors (Fig. 41.4).

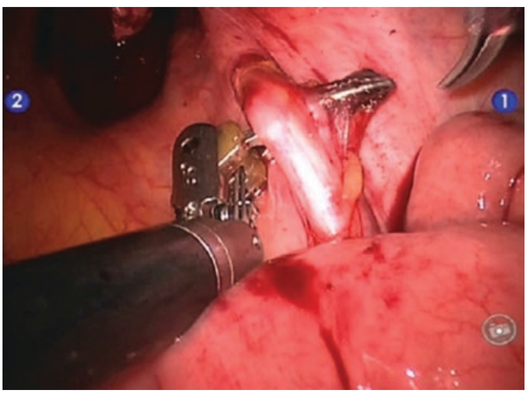

Fig. 41.2 Robotic preparation of the left ureter

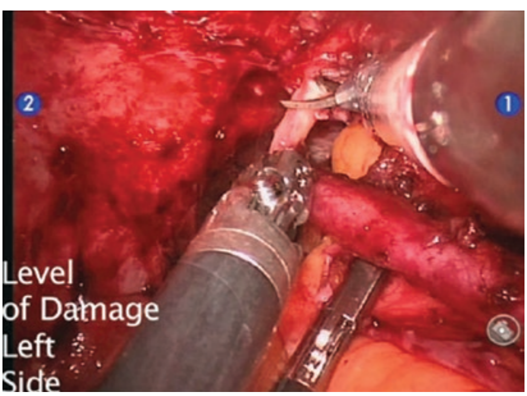

Fig. 41.3 The ureter is isolated stepwise until the stricture site could be identified

Mobilisation of the Bladder

The anterior peritoneum is incised anteriorly and the retropubic space of Retzius entered. The bladder is filled with 250 mL normal saline and the Retzius space improved by blunt dissection, followed by division of both lateral umbilical ligaments.

Vesico-Psoas Hitch With/Without Boari Flap

A tension free anastomosis is one of the most important point of the surgery. If the is a concern about a tension-free anastomosis, a psoas hitch with or without Boari Flap should be considered. The fixation of the bladder on the psoas tendon is performed using the needle holder on the right side. We used 3–4 interrupted sutures (Vicryl 3–0, SH needle, 15 cm) for hitching the bladder with a slide-knot technique (Fig. 41.5). Care must be taken to avoid the genitofemoral nerve in doing so, as with open procedures. If necessary, a Boari flap is created starting about 3 cm from the bladder neck and extending to the dome. The flap is also fixed to the psoas muscle with the antero-lateral surface of the bladder serosa.

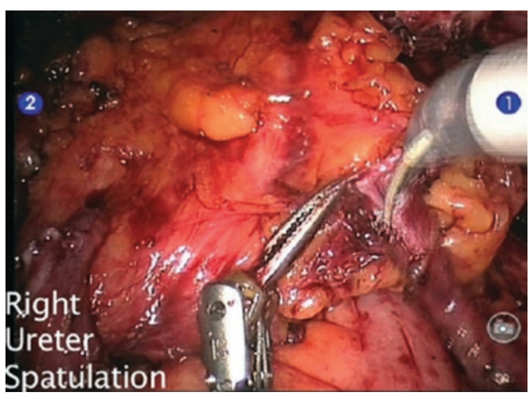

Fig. 41.4 Spatulation of right ureter using Maryland grasper and curved scissors

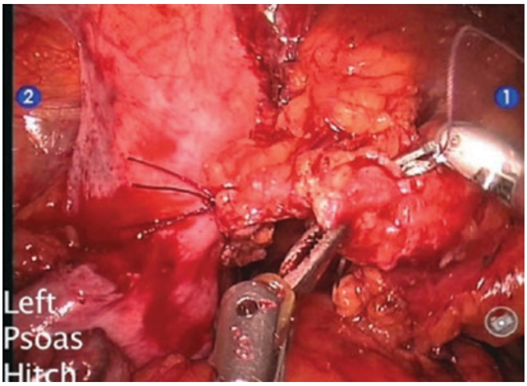

Fig. 41.5 Performing the psoas hitch on the left side

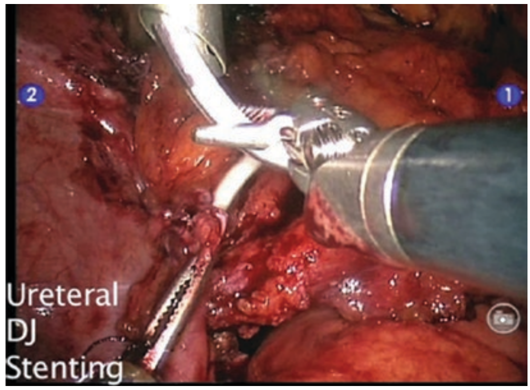

Fig. 41.6 Intraoperative stenting the left ureter using right needle holder and left grasper

Creation of a Submucosal Tunnel and Ureteral Anastomosis

To create a nonrefluxing ureteroneocystostomy, a submucosal tunnel of 3-cm mucosa flap is formed starting at the medial rim of the hitched bladder using robotic-assisted scissors. Thereafter, the ureter is spatulated and anchored to the detrusor muscle at the caudal end of the flap by using interrupted sutures (Vicryl 3–0, RB needle, 15 cm) and then covered by the flap, thereby creating a submucosal tunnel. In some cases, the ureter can be anastomosed to the bladder (i.e. Boari flap) with interrupted sutures. A guide wire is passed retrogradely in the ureter followed by placement of 6 F open-end pigtail catheter (Figs. 41.6 and 41.7). In some cases to placing the pigtail catheter pre-operatively can facilitate this step. Another technique is delivering the ureter through a port incision and extracorporeal tailoring. This technique can be applied in obstructive mega ureter cases combined with extracorporeal forming an anti reflux nipple.

Modified Lich–Gregoir Technique

Incision of detrusor fibres is carried out with a round tip scissors in order to create a 2–2.5-cm detrusor incision. Haemostasis is achieved with fine application of bipolar cautery (Maryland grasper) and care is taken to identify and avoid any injury to the bladder mucosa (Fig. 41.8).The mucosa to mucosa anastomosis is performed after minimal opening of prepared bladder mucosa on the cranial end using 4/0 single PDSII sutures. The detrusor muscle is approximated over the underlying ureter anastomosis. Simple interrupted sutures of 3/0 Vicryl are used approximate the detrusor muscle (Fig. 41.9).

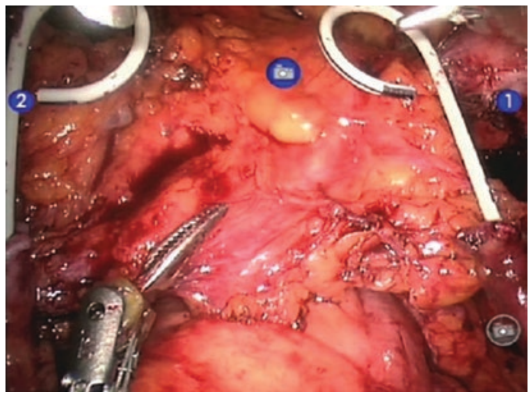

Fig. 41.7 Bilateral ureter stenting before the reimplantation

Closure of the Bladder

Tubularisation of the Boari flap is accomplished with interrupted (Vicryl 3–0, SH needle) sutures. Closure of the bladder performed in continuous fashion using barbed polyglyconate sutures (V-Loc 180TM; Covidien, Tyco Healthcare Group, Norwalk, Connecticut, USA). The bladder peritoneum is wrapped around the anasto-

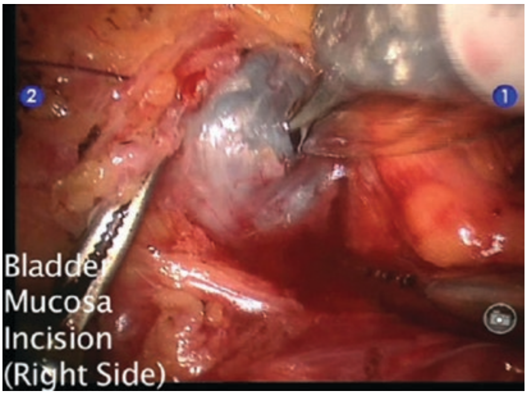

Fig. 41.8 Incising the bladder mucosa for the reimplantation (Lich-Gregoir)

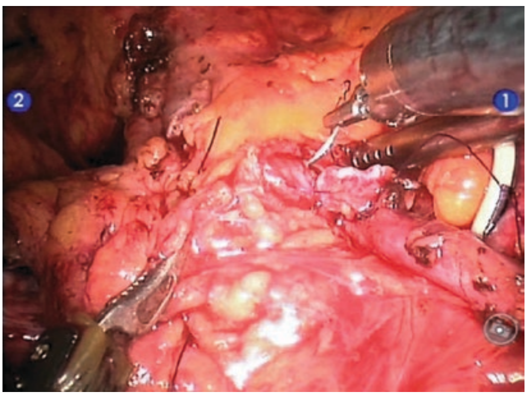

Fig. 41.9 The detrusor muscle is approximated over the underlying ureter anastomosis. Using simple interrupted 3/0 Vicryl sutures

motic site to prevent extravasation (Fig. 41.10). Water tightness is confirmed by filling the bladder with 300-mL saline via the indwelling Foley urethral catheter. A drain is placed at the site of the anastomosis.

Procedures and Outcomes

Vesicoureteral Reflux: Management

The standard surgical treatment of VUR is ureteral reimplantation either transvesical or extravesical. Peters et al. first published his experience in bilateral VUR repair with intravesical reimplantation using robotic assistance. Ports are placed in the dome of the bladder, and the procedure is performed in a fashion identical to that used for open transtrigonal (Cohen) reimplantation [16]; the newly developed voiding dysfunction, which can be up to 10%, is an annoying complication of extravesical reimplantation. Casale et al. published a nerve-sparing robotic extravesical ureter reimplantation of 41 patients having bilateral VUR with a success rate of 97.6% and observed no postoperative urinary retention [11]. In another series of 16 extravesical RALUR in children, there were three reflux failures or reflux downgrades, with one mild urinary retention and one urinary leakage [17]. In a comparative study with 19 intravesical and 20 extravesical RALUR compared with 22 intravesical and 17 extravesical open ureter implantation, there were no difference between success rates of RALUR and open ureteral implantation. Although patients undergone intravesical robotic-assisted reimplantation had a shorter duration of urinary catheter drainage, fewer bladder spasms and a shorter hospital stay compared to those who undergone the intravesical open technique, there were no difference in these parameters between the extravesical techniques [27]. The most recent paper by Boysen et al. reviewed about 260 children who underwent extravesical RALUR between 2005 and 2014. They demonstrated complete resolution of VUR in 87.9% of the ureters. There was a 9.6% overall complication rate, with no grade 4 or 5 complication [33].

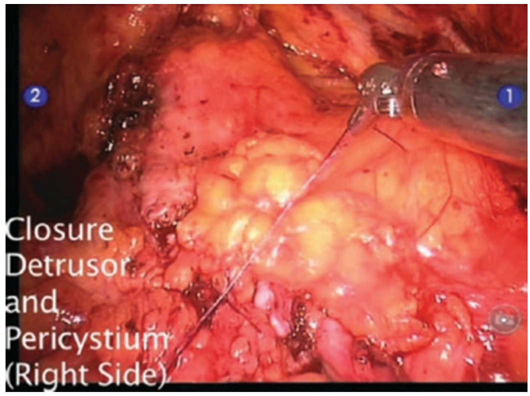

Fig. 41.10 Closing the bladder and confirming the water tightness by filling the bladder with saline

Cost and complication comparison between RALUR and open ureteral reimplantation in VUR surgery was studied by Kurtz et al. from 70 hospitals in a national wide database. RALUR was associated with higher cost in comparison with open surgery [32].

Boari Flap Procedure

Laparoscopic creation of Boari flap was first described in 2001 by Fugita et al. After using robotic assistance in reconstructive operations, Schimpfet al. published a case of robotic-assisted laparoscopic Boari flap ureteral reimplantation. In 2009, they also published a series of 11 patients who underwent RAL distal ureteral surgery for different aetiologies. They used Boari flap in two cases; one for recurrent ureteral stricture and the other for ureteral cancer. In ureteral stricture case, they had an external iliac vein injury during the sharp dissection due to inflammation adhering the ureter to the vein and repaired it robotically [23]. Another single institutional pilot experience was published by Allaparthi et al. for distal ureteral low-grade urothelial cancers. They had no operative or postoperative complications and good oncological results in a median follow-up of 6 months [24]. These limited cases show RAL Boari flap reconstruction is safe and feasible with the advantages over conventional laparoscopy like facilitation of intracorporeal suturing, three-dimensional visualisation, improved ergonomics and freedom of movement.

Psoas Hitch Ureteral Reimplantation

Ureter reimplantation can be combined with a psoas hitch or Boari flap to gain additional length when ureteral length is insufficient for direct reimplantation. Psoas hitch elevates the ipsilateral part of the bladder which is important for a tension-free anastomosis to prevent an anastomotic stricture in open and laparoscopic procedures. Uberoi et al. first described the technique for RAL distal ureterectomy and reimplantation with psoas hitch for a distal ureteral carcinoma [19]. Glinianski et al. Reported distal ureterectomy and ureteral reconstruction with psoas hitch in nine patients with ureteral carcinoma. In this series, only six patients needed a psoas hitch; three had a reimplantation into the bladder dome without psoas hitch. The mean overall follow up was 23 months. One patient presented a partial stricture at the ureteral anastomosis, and one patient presented recurrence involving the liver, retroperitoneal nodes and omentum 28 months after the operation. There is a concern of tumour seeding in minimal invasive surgeries, and care should be taken to avoid spillage of tumour by at least clipping the distal and proximal edges of the tumour [20]. Patil et al. published the largest series of RALUR with psoas hitch in 2008. It was a multi-institutional and multinational series including ten ureteral strictures and two uretero-vaginal fistula indications for ureteral reimplantation. The results were successful after a mean follow-up of 15.5 months [21].

Tapered Ureteral Reimplantation for Megaureter

Hemal et al. firstly described the robotic repair of obstructive megaureter in a series of seven patients. They performed all the cases robotic assisted and in transperitoneal fashion, except the two who had needed an extracorporeal ureteral tapering. The total mean console time was 127.5 min (100–210 min). They had only one perioperative urinary tract infection and good functional results with an average follow-up time of 16 months. The tapering was done only in the terminal 5–7 cm of the distal ureter over a 10-F feeding tube or ureteric catheter inserted through one of the 5-mm assistant port [25]. Recently, Goh and Link presented a case with a total operative time of 262 min and used an additional third robotic arm for upward traction of ureter dissection [26].

Complications and Management

Intraoperative complications include urinary extravasation/bladder injury, excessive bleeding, ureteral injury and pelvic or abdominal organ injury. Vessel (external iliac vein injury) and intestinal injuries can be managed with robotic suturing [23]. Postoperative bladder urine extravasation and also voiding dysfunction, especially after bilateral extravesical reflux surgery, should be treated with indwelling urethral Foley catheter or with a percutaneous suprapubic tube [17, 27]. The most common complications after the operation are ureteral leakage. These patients were treated with placement of a Double-J stent for 2–4 weeks [27]. Stricture formation is another complication resulting from either ischemia or excessive tension the anastomosis. Ureteral stricture after RALUR with psoas hitch was reported in one case with ureteral cancer. The stricture was managed with balloon dilatation, but after the stricture recurrence, periodic stent changes were performed considering of advanced age and comorbidities [20]. Phillips and Wang reviewed case reports and series in the literature and found a low complication rate of 10%. The most common complication was stricture recurrence at the surgical site (5%) [28].

Complications in the literature are summarised in Table 41.1. In our opinion, the magnification and easy suturing in robotic assisted surgery may decrease the complications, but large and long follow-up needed to evaluate these advantages.

Table 41.1 Summary of robot-assisted laparoscopic ureteral reimplantation (RALUR) series in literature

References	Number of cases	Diagnosis	Surgery type	Success rate (%)	Complications
Peters and Woo [16]	6	Vesicoureteral reflux	Intravesical bilateral RALUR	83.3	Urine leakage (*n*:1)
Cascale et al. [11]	41	Vesicoureteral reflux	Nerve sparing extravesical RALUR	97.6	None
Patil et al. [21]	12	Ureteral stricture (10) Ureterovaginal fistula (2)	RALUR with psoas hitch	100	None
Lendvay [17]	16	Vesicoureteral reflux	Extravesical RALUR	81.2	Urinary retention (*n*:1) Urine leakage (*n*:1)
Glinianski et al. [20]	9	Ureter cancer	RAL distal ureterectomy, UR (*n*:1) RALUR with psoas hitch (*n*:6)	100	Ureteral stricture (*n*:1) Aspiration pneumonia (*n*:1 with large hiatal hernia)
Hemal et al. [25]	7	Primary symptomatic obstructive megaureter	RAL ureteric tapering and ureteroneocystostomy	100	Perioperative urinary tract infection with fever (*n*:1)
Schimpf and Wagner [23]	11	Ureter cancer (6) Bladder diverticulum (2) Ureter obstruction (2) Ureter injury (1)	RAL distal ureterectomy and UR (*n*:4) RAL diverticulectomy and UR (*n*:2) RALUR with Boari flap (*n*:2) RALUR with psoas hitch (*n*:3)	100	External iliac vein injury (*n*:1) (repaired robotically) Ileus (no intervention) (*n*:1) Haematuria (fulguration) (*n*:1)
Marchini et al. [27]	39	Vesicoureteral reflux	Intravesical RALUR (*n*:19) Extravesical RALUR (*n*:20)	92.2 100	Bladder leak (*n*:4) Urinary retention (*n*:2) Ureteral leakage (*n*:2)

(continued)

Table 41.1 (continued)

References	Number of cases	Diagnosis	Surgery type	Success rate (%)	Complications
Baldie et al. [29]	13	Iatrogenic ureteral trauma (9) Crohn's disease (1)	RALUR with Boari flap (*n*:1) RALUR with psoas hitch (*n*:1)	100	Symptomatic bowel injury (Clavien grade IIIb) (*n*:1)
Musch et al. [30]	16	Benign distal ureteric stricture (10) Ureter cancer (4) Vesicoureteral reflux (1) Ectopic ureters (1) Prostate cancer (1)	RALUR with psoas hitch ± Boari flap (*n*:12) Extravesical RALUR (*n*:3)	94	urinary leakage and peritonitis (Clavien grade IIIb) (*n*:1) Silent myocardial infarction (*n*:1)
Buffi et al. [31]	21	Primary obstructed megaureter (11) Ureteric stricture after ureteral surgery (9) Post-hysterectomy ureteric stricture(1)	Extravesical RALUR	93.3	Haematoma (1) Urinary fistula (1)

Conclusion

Laparoscopic ureteral reimplantation is technically demanding even for experienced surgeons, and each case represents a different challenge based on aetiology and location of the stricture. Despite the difficulties of the procedure, magnification and high-definition visualisation allow a clear identification of ureter and bladder, of the surrounding tissues and the ureter pathology.

RALUR is safe and feasible with the clear advantages over conventional laparoscopy like three-dimensional visualisation and increased degree of freedom, especially during dissection and suturing. Due to clutch function and sitting position of the surgeon, robotic assistance offers significant technical and ergonomic advantages particularly in bilateral cases.

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42 Robot Assisted Laparoscopy for Genito-Urinary Prolapse

Dirk Kusche

Introduction

Pelvic organ Prolapse (POP) is a quite common condition amongst women, especially elderly women seem to show a growing incidence, since obesity, rising age and other risk factors get more and more common; for minor prolapses, physical therapy and pelvic floor muscle exercises can be a sufficient form of therapy. In greater degrees of prolapse, a vaginal pessary can be inserted; in case of insufficient non-invasive strategies, surgical repair can be advised.

Different techniques of surgical repair have been discussed for quite a while. All of them are dealing with the support of the anterior or posterior vaginal wall. Nevertheless this support is depending on the support of the vaginal apex to reconstruct the genital axis. This is usually best achieved with the sacrocolpopexy in combination with a mesh and was first described in 1958 [1].

Initially done as an open procedure this operation was later performed in a conventional laparoscopic manner, combining the very good long term results of the open procedure with the advantages of minimally invasive surgery. The disadvantages with laparoscopy in complex procedures are the difficult learning curves and the long operation time. To ease the use of minimal invasive surgery is the domain of the da vinci system. Robotic surgery can bridge the gap between the advantages of laparoscopy and the difficulties in suturing etc. By doing so this kind of robotic surgery can play a key role in prolapse therapy.

Different Methods of Sacrocolpopexy

The sacrocolpopexy can be performed in an open, laparoscopic or robotic way. For the longer used open technique the excellent long term results are well known: around 4% recurrence for the sacrocolpopexy vs. 15% for the sacrospinous ligament suspension [2, 3].

Between the open approach and the conventional laparoscopy are no significant differences recorded. Ganatra et al. found in their analysis for laparoscopic sacrocolpopexy, at a mean follow up of almost 25 months, a reoperation rate of 6.5% and a satisfaction rate of almost 95% [4].

Due to the relatively new technology there is not much data for robotic surgery available [5].

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_42

Techniques of the Robotic Assisted Sacrocolpopexy (Single and Multiport Accesses, etc.)

A step-by-step description of the surgical technique.

The robotic assisted sacrocolpopexy can be divided into 11 steps [6].

1. Operation Room setup, Patient positioning and port placement
2. Preparing the mesh for implantation
3. Anatomical overview and dissection of the anterior vaginal wall
4. Dissection of the posterior vaginal wall
5. Demonstration of the mobilized anterior and posterior vagina
6. Dissection of sacral promontory
7. Fixation of the ventral part of the mesh
8. Fixation of the dorsal part of the mesh
9. Mesh adjustment and fixation on the promontory
10. Closure of the peritoneum
11. Postoperative care

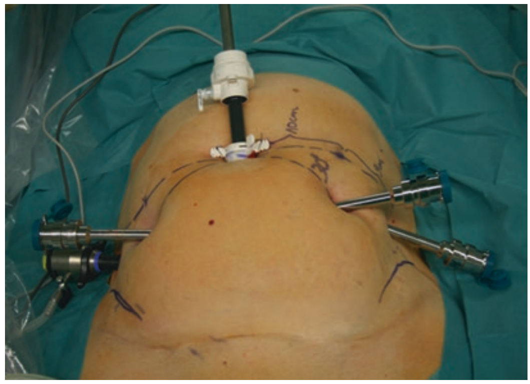

Fig. 42.1 The ports are placed in a "W-shape configuration"

1. The patient is placed in a supine position on a padded vacuum mattress, both legs slightly spread.

   The ports are placed in a "W"-shaped configuration (see Fig. 42.1). The table is put into a moderate Trendelenburg position. Four robotic arms are used, utilizing the camera (with a 0° or a 30°down scope), one Maryland bipolar forceps, a fenestrated Grasper (Pro Grasp), robotic scissors (Hot Shears) and one large needle driver, respectively. Furthermore a vaginal retractor is inserted into the vagina simultaneously.
2. It is advisable to have the mesh prepared beforehand, (see Fig. 42.2). We usually use a semi-absorbable VYPRO ® mesh (Ethicon, Somerville, NJ, USA), 15x10cm size. The mesh is cut into two pieces, both 4 cm of width, one of which is again cut to 4 cm length and is being used as the short wing of the Y-shaped form; this short part is attached to the remaining longer part of the mesh with non- absorbable sutures. The anterior wing usually is slightly shorter than the posterior wing (which is 6 cm of size), because the posterior dissection usually can reach more distally. The total length from basis of the "Y" to the tip of the wings should be approximately 15 cm, if there is surplus mesh at the longer portion, it is of no importance, since it can be cut off later (see Fig. 42.3).
3. After port placement and docking of the robot, the abdominal cavity is examined; often peritoneal adhesions from prior surgeries have to be divided first. The iliac vessels, the vaginal stump, the Douglas pouch and the rectum have to be identified as the most important landmarks.

   The overlying peritoneum is then incised at the line between bladder and vagina, to mobilize the anterior vaginal wall from the bladder, using careful blunt and sharp dissection. It is important to gain a good length of freed vaginal wall to be able to attach the mesh to the most distal part of the vagina. The vaginal wall usually has more than one layer of surrounding tissue, for durable fixation it is important to reach to a layer with a relatively rough surface.
4. Now, in analogue fashion, the dorsal vaginal wall is mobilized and dissected off the rectum by opening the recto- vaginal space. An additional rectal retractor can be used but is

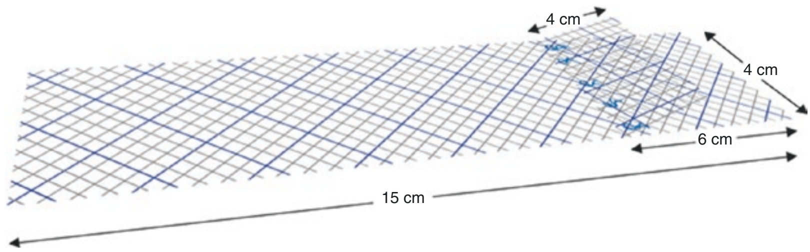

Fig. 42.2 The mesh is preoperatively modified in a "Y-shape configuration"

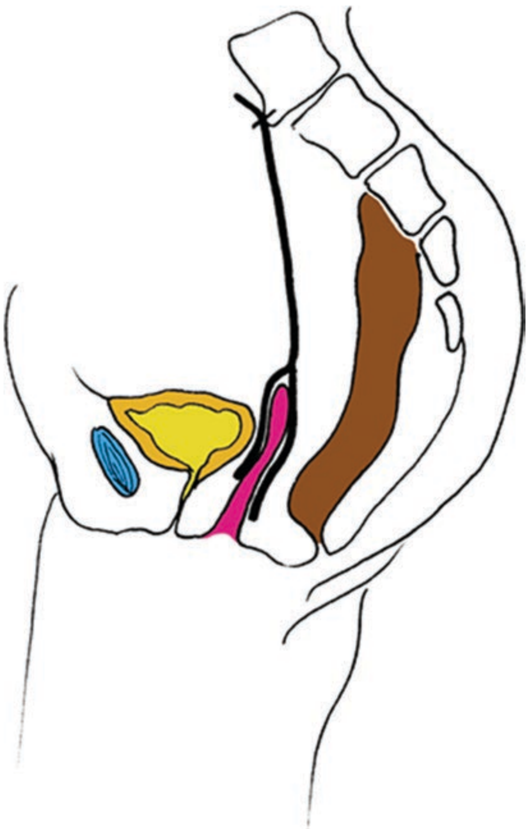

Fig. 42.3 The mesh is sutured to the anterior and posterior wall of the vagina and the middle part to the promontory

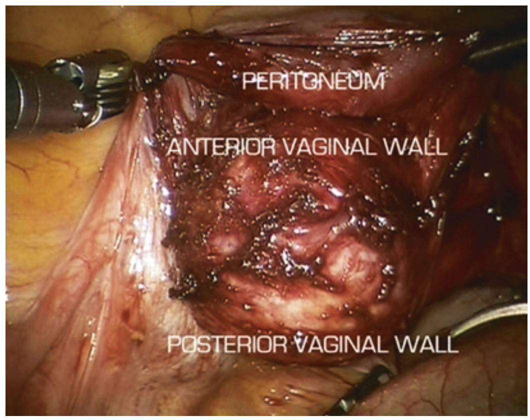

Fig. 42.4 The vaginal stump is fully mobilized facilitating the mesh to reach the most distal portion of the anterior and posterior vaginal wall

not necessary in our experience. The intra-abdominal gas usually creates an emphysematous tissue, reminiscent of spider webs that can be easily pushed away with blunt movements of the robotic instruments.

5. The now freed vaginal walls are moved in all directions with the help of the vaginal retractor, to ensure good mobility of the vaginal stump (see Fig. 42.4).
6. The sigmoid colon is retracted using the fourth robotic arm, and the peritoneal overlay of the promontory is incised on the right side of the sigmoid colon, care is taken not to injure the vessels or the ureter laterally. A switch to a 30°down lens can sometimes be helpful do gain better view of the presacral area. The anterior longitudinal ligament can be identified as a bright and shiny white structure. Care has to be taken to avoid lesions to the common iliac veins that run in close proximity to the promontory laterally, as well as the presacral vessels, that both could lead to significant haemorrhage.

   The peritoneal incision is then extended towards the primary incision site lateral to the vagina on the right side, always staying medial and in sufficient distance to the ureter and rectum.
7. Then, the pre-fashioned Y-shaped VYPRO II mesh is inserted, and suture-fixation with 2/0

vicryl sutures on a UR-6 needle is begun at the ventral, most distal part of the mobilized vagina. We recommend 3 rows with at least 2 sutures to avoid torsion of the mesh. This anterior wing is approximately 4 cm long. Care is taken to take good bites but only penetrate the vaginal wall without perforation into the vaginal lumen, in order to avoid perforation with consecutive risk of inflammation. Also, the sutures are knotted slightly loose to keep pressure of the net as low as possible, in order to avoid mesh erosions (see Fig. 42.5).

After ventral fixation, the middle part of the mesh is rolled up and held ventrally, using the fourth arm of the robot, to keep it out of the way for the following steps of the surgery.

In case of a still existing Uterus, we typically use the same mesh, but cut it into two single stripes of 15/4 cm size length/width, which are not attached to each other. One mesh is fixed anterior; it is then brought through a tunnelled perforation of the broad ligament on the right side, to bring it to the dorsal side of the uterus in order to enable it to reach the promontory. The other mesh is sutured to the posterior vaginal wall, respectively.

8. Now, likewise fixation of the dorsal vagina and the rear wing of the mesh respectively, is conducted. Facultative, in order to avoid future possible enteroceles, a Moschcowitz culdoplasty can be performed, closing the posterior cul-du-sac with a circumferential suture, which however in our experience is not necessary.
9. The sigmoid colon is then again retracted laterally utilizing the fourth arm of the robot, and the free part of the mesh is unrolled and put under only slight tension. The mesh should be anchored to the promontory without tension which can be examined by gentle movements of the vaginal retractor. The mesh is then fixated with interrupted, non-absorbable 0 sutures through the longitudinal ligament of the promontory bone. Excess mesh can be first used for better cranial retraction, e.g. by the assistant, then later be cut and removed.
10. Finally, the mesh is totally reperitonealized by closing the peritoneal incisions with V-loc TM 180 3/0 on a CV 23 needle (Covidien, Mansfield, MA, USA) running sutures, the braided thread allows for fast closure of the peritoneum. It is very important to reach a complete peritoneal cover over the mesh in order to avoid future bowel herniation, obstruction, adhesions or inflammatory responses (see Fig. 42.6). Once the peritoneum is closed again, a drain can be put in.

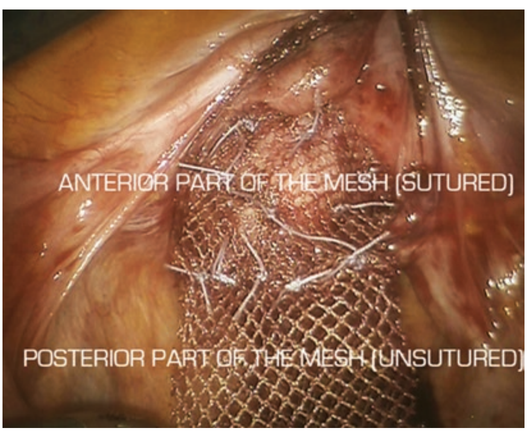

Fig. 42.5 The anterior wing of the mesh is already attached to the anterior vaginal wall

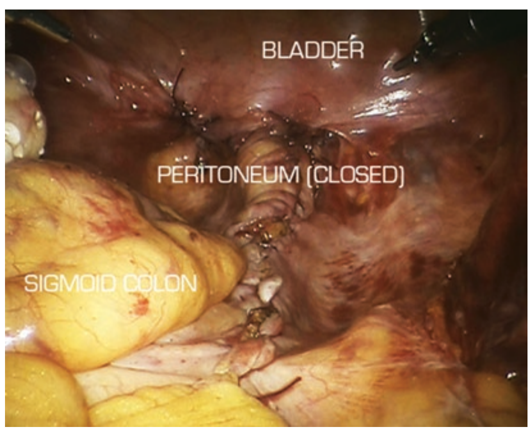

Fig. 42.6 The peritoneum is entirely closed over the mesh to prevent later complications

11. The patients are mobilized on the day of surgery. For pain medication Metamizol is given if needed. The transurethral Foley Catheter can be removed the next morning, followed by voiding and residual urine control. Heavy lifting of more than approximately 7 kg should be avoided for 3 months. A vaginal oestrogen ointment that is given twice weekly starting 6 weeks prior to surgery can be further administered for another 3 months at least.

    After restoring the correct anatomical situation it is possible that a hidden stress urinary incontinence becomes evident. In this case we would implant a tension free tape after six weeks.

    An instructional video for this technique is available from our working group [7].

Surgical Outcome and Complications

The use of robotic assisted pelvic organ prolapse (POP) repair is still not very common and of course not done for a long time. The first description of a robotic assisted sacrocolpopexy was done in 2004 by Di Marco and coworkers [8].

Due to this the literature dealing with robotic sacrocolpopexy is scarce and often lacking a long follow up. Which is understandable but especially for POP repair the follow up is crucial to determine whether the quality of life for the individual patient has improved or not [9].

Remarkable is that most authors found a recurrence rate around 5% [2, 10, 11].

Which is promising in comparison to an recurrence rate between 0–18% for open procedures, but here a longer follow up is available [3, 12].

This was confirmed by Geller and coworkers. They found similar reconstructive results for the open and robotic procedures but again for a short follow up [13].

The same kind of complications like bowel, bladder and ureter injury, laceration of the vagina, infection, mesh erosion and even osteomyelitis are reported for open, laparoscopic and robotic procedures. The range in the literature is around 0–8% and is not really different for the three different approaches [14].

For other POP operations which can be done also with the robot i.e.: the lateral repair after Richardson, the hysteropexy or an anterior rectopexy only few data exist.

An interesting new development is the transformation of robotic surgery into a single port approach. This is done already for the pyeloplasty, radical prostatectomy and for radical nephrectomy [15, 16].

But as in conventional laparoscopic single port surgery there are some technical problems which one has to overcome. Due to the limited working space it can be necessary to invent a new robotic design in which the instruments are not longer driven by wires [17].

This is by far not a frequent technique but something with a great potential and worth to investigate further.

Conclusion and Future Perspectives

To repair a POP the abdominal sacrocolpopexy is still considered as the gold standard. But due to the severe access trauma other minimal invasive operations were introduced to reduce the trauma without having more recurrences or complications. So far we can say laparoscopy as well as robotic operations can definitely reduce trauma, hospital stay and pain. The results are similar or sometimes better than in open series. The problem of suturing and tissue handling in laparoscopy that we find often in complex reconstructive procedures can be eased by use of the robotic device. Exactly this combination of minimally invasive surgery with good results and a shorter learning curve has opened a gap for robotic surgery. The biggest disadvantage is obviously the costs this type of surgery has. Being the most expensive way to perform POP repair it can end in a cul- du- sac but otherwise with a more standardized and evolving technique the device has the potential to become the future gold standard for POP repair.

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43 Robot-Assisted Laparoscopic Repair of Supratrigonal Vesicovaginal Fistulae with Peritoneal Flap Inlay

Michael Kurz and Hubert John

Introduction

Vesicovaginal fistulae have always been a highly problematic complication. Nowadays, most cases are complications after hysterectomy or obstetric surgery, whereas obstructed labour is the main aetiology in underdeveloped countries. The localisations and dimensions of the fistulae are very different dependent on their aetiology. Obstructed labour leads to necrosis of the anterior vaginal wall and consequently to a lower, urethrovaginal, vesicovaginal or combined fistula. After hysterectomy, we know that fistulae occur in about 1/1800 cases [1]. At a rate of 600,000 hysterectomies in the United States in 2003 [2], we can assume approximately 330 fistulae had to be treated in that year. This makes it not only a social but also an economic issue. These fistulae are usually found to be supratrigonal and sometimes located high on the bladder dome. This fact makes it very demanding or even impossible to operate transvaginally. They occur after inadvertent lesion of the bladder or ureters, operation-site infection or tumourous diseases. The success rate of either repair is between 75 and 97% [3–5] depending on the method and complexity. Smaller fistulae can be treated by transurethral drainage and sometimes by transurethral coagulation of the bladder wall, depending on their aetiology. However, the long-term results are not very impressive (7–12.5%) [6, 7]. A valuable alternative to conservative treatment is the use of fibrin glue [8]. In case of failure, the operative access is still available.

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Materials and Methods

Patients

From July 2006 until February 2011, we treated three cases aged 40–64 year. All were diagnosed with a supratrigonal fistula as a complication of abdominal hysterectomy with no malignancy. In all cases, a conservative treatment was not an option since the fistulae were too large and the symptoms were almost devastating for the patients.

The fistulae could be diagnosed and localised by cystoscopy and conventional cystography.

They all suffered from continuous incontinence 3 months following the hysterectomy. One patient showed large adhesions after an old uterus fixation operation in 1971 and a sigma diverticulitis. These adhesions were also in the spatium vesicovaginale including an omentum attached to the bladder dome. Altogether, there were no postoperative complications besides the occurrence of the fistulae. The patients had no significant concomitant diseases that could be responsible for wound healing disorders. One patient suf-

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_43

fered from acute intermittent porphyria. During the hospitalisation, we did not see any problems as she did not suffer any acute episode. The fistula repair was done immediately after being diagnosed, 3 months after primary operation on average.

Operative Technique

The patients received 2 g (Cefazolin) Kefzol® when anaesthesia was begun. We started with the vaginoscopy in lithotomy position. First, we inserted a 5 F Fogarty catheter through the fistula into the bladder using a vaginal speculum. Then, a cystoscopy was performed to verify the position of the Fogarty and to insert DJ catheters to protect the ureters and the ureteric orifices. For easier identification of the vagina intraoperatively, a sponge stick was inserted. Thereafter, we continued in a low lithotomy position with a Trendelenburg tilt. The complete abdomen and the genitals were disinfected using povidone-iodine. After establishing the pneumoperitoneum via the 12-mm camera port, all ports could be installed according to the scheme of the radical prostatectomy. One 8-mm da Vinci port left and right to the umbilicus, one 12-mm Versaport™ in the right lower quadrant (ca 3-cm craniomedial of the anterior iliac spine) and one 5-mm port was installed right of the camera port, ca. 3 cm proximally.

Initially we had to perform adhesiolysis due to postoperative, intra-abdominal scarring. We continued sharp and blunt dissection using the PK bipolar forceps and monopolar curved scissors to expose the abdominal surface of the bladder and the vaginal stump. After getting a good exposition, we opened the vagina and localised the Fogarty catheter and thereafter searched for the fistula (Fig. 43.1). We subsequently opened the bladder and prepared it towards the fistula to finally resect it completely including peri-fistular scar and inflammation tissue. Sharp dissection is used in order to protect the ureteric orifices and to prevent wide excisions (Fig. 43.2). The next and very important step was to mobilise the bladder dorsally to get a tension-free suture. The closure of the vagina was performed using 2–0 Vicryl®. Before the closure of the bladder, we mobilised the adjacent peritoneum to use it as a vital layer between the vaginal and bladder sutures (Fig. 43.3). The bladder was finally closed using 4–0 Biosyn® (Fig. 43.4). After performing a leakage test of the bladder, we removed all the ports.

The mean operation time was 240 min including DJ insertion and transfers. There was no significant blood loss.

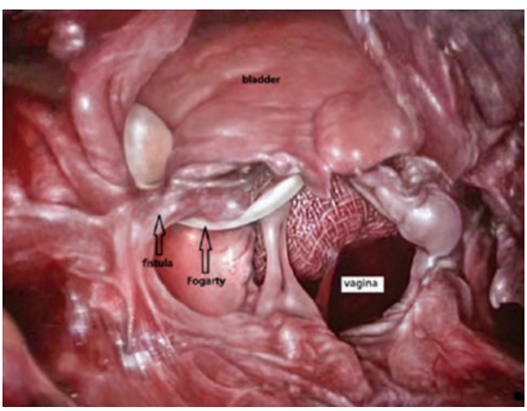

Fig. 43.1 View into the bladder and the opened vagina. The Fogarty catheter is seen with its balloon on the left side. It was inserted into the fistula and is still in situ. The excision of the fistula will follow next

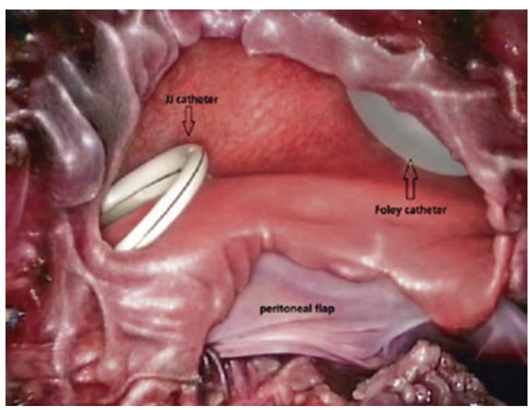

Fig. 43.3 The vagina is now closed and the peritoneal flap lies above its suture. A DJ catheter was inserted into both ureters before the operation. Here, the left one is seen in the picture

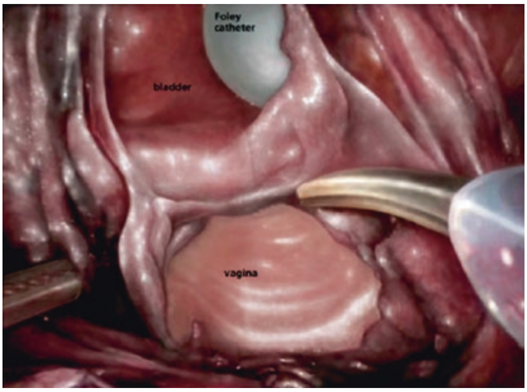

Fig. 43.2 After complete resection of the fistula and adherent scar tissue, the next step will be the bladder mobilisation

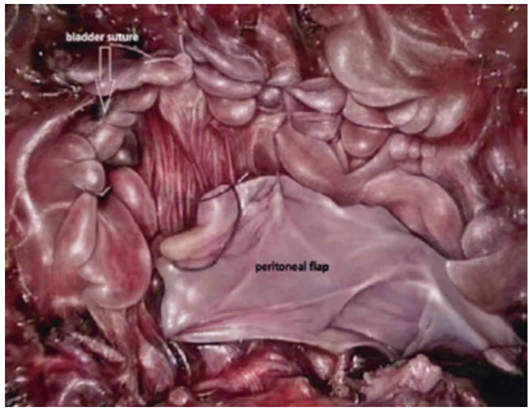

Fig. 43.4 View at the end of the operation. The bladder is now closed and watertight. The peritoneal flap is in situ and covers the vaginal suture

Postoperative Management

The wound drain was removed after 24–48 h as there was no evidence of bleeding or leakage. The patients were discharged after 5 days with the indwelling Foley catheter. After 14 days, cystography was performed prior to the catheter removal. 100% of the patients showed no leakage of the bladder suture. Sexual intercourse was prohibited for 4 weeks. The DJ catheters were cystoscopically removed after 4 weeks.

Follow-Up and Results

After a follow-up period of 4–42 months, all the patients stayed continent, and we saw no evidence of a recurrent fistula. One patient was hospitalised and treated with antibiotics due to a left-sided pyelonephritis 3.5 weeks following the operation. The DJ catheter could be removed under successful antibiotic therapy. We did not have to change the DJs. No patient complained about pollakisuria, low bladder volume or discomfort during sexual intercourse.

Discussion

In fistula surgery, the effort should always be to heal at the first attempt. Therefore, a meticulous operative plan has to be established. In all cases, we should strive to operate effectively, safely and with the lowest morbidity possible. There are no consequent guidelines which way of access should be taken while the surgeons experience is mainly what counts. Gynaecologists often choose the transvaginal way wherever possible. The advantage is the possible outpatient setting, low patient morbidity, low blood loss, minimal postoperative pain and low postoperative bladder irritability [4, 9, 10]. Some authors report that an equal success can be observed compared to abdominal approaches using a peritoneal flap when a Martius flap was not recommended [4, 11]. Exclusion criteria of the transvaginal access can be a circumferential induration at the fistula site thicker than 2 cm, a high fistula location where the transvaginal approach gives too little exposure, fistulae involving ureters, or when patients wish the transabdominal operation [10, 12]. Combined transabdominal and transvaginal operations have been reported [13].

Where a safe transvaginal fistula repair cannot be granted, there remains only the transabdominal pathway. The transabdominal transvesical technique provides most space for exact and wide preparation of the bladder and vaginal wall, easier identification of scar and fistula tissue, and thus provides a good basis for the complete excision. More recent techniques have become less morbid than the historical O'Connor procedure even though there are “mini” variations [14, 15].

In recent years, laparoscopy could also establish itself in fistula surgery as an equivalent option to the open operation.

Nezhat was the first to perform and document this operation in 1994 [16], and it was developed continuously in the following years, and several case reports appeared [9, 17–26]. The technical advantages of laparoscopic surgery are the easier access to the deep pelvis with high illumination, magnification and easy coagulation. The patient suffers less pain, and mobilisation and release from hospital is faster. Unfortunately, many surgeons avoid this technique due to its technical demands (training curve, difficult fistula resection), and it is mainly performed in special centres [27]. Especially the closure of the bladder and vagina is time consuming but very efficient and safe [9]. Here, the da Vinci Surgical System can be a very helpful assistance.

The use of the da Vinci facilitates the most important steps in this procedure and helps the surgeon to lower operation time. This may also lead to a better outcome and lower complication and recurrence rates.

It gives a 3-dimensional magnification up to 15× with a superior view of all different structures including small vessels. It also filters the surgeon's tremor and gives up to seven degrees of freedom. Yet so far, only few reports can be found about robot-assisted fistula repair [28–32]. The first one was described in 2005 by Melamud et al. at the University of California [28].

The aim of this series is to show the feasibility of peritoneal flap inlays and the effectiveness of the da Vinci Surgical System as an advancement in the laparoscopic approach to treat this embarrassing and compromising complication after hysterectomies where a transvaginal procedure, i.e. after Latzko or a Martius flap is not the preferred choice.

The surgical advantages by the use of the da Vinci Surgical system are well known and need not be mentioned. In the case of fistula surgery, we observed that patients recovered almost immediately after surgery by using the laparoscopic access which is less morbid compared to the open operation. The most difficult steps during the procedures are likely the ones that keep urologic surgeons away from the laparoscopic approach. It is the tricky preparation of previously damaged tissue and the suturing. This is where the da Vinci Surgical System gives you the utmost assistance. Accessing through the vagina as a natural orifice gives you less space to work and to prepare precisely, not to mention that many high fistulae are out of reach.

In a few cases, ureters can be affected by the fistula or have to be partially resected. In such cases, the operation can also be performed laparoscopically while a transvaginal access is futile.

Besides small differences such as suture material or ports, there was no difference between our procedures compared to prior case reports besides the fact that we performed peritoneal flaps in all patients.

Colleagues used epiploic appendix of the sigmoid colon [31]; omentum, epiploic appendix of the sigmoid colon or a peritoneal flap [30]; omentum [29]; or fibrine glue [28]. We estimate a similar functional result in all these different ways. However, of major importance is the separation of the suture lines.

One disadvantage of the da Vinci System is its inflexibility when preparation of the omentum would be necessary. Therefore, we wanted to encourage the use of a regional flap as interposition graft with no need of omental preparation or even colon mobilisation.

Despite the small number of treated patients, we can assume that the da Vinci-assisted laparoscopic method in operating high fistulae is safe and highly effective. Three out of three patients are still satisfied with the postoperative results after regaining full quality of life. Recurrences after repair are usually seen within 3 months [6], so we can consider these patients to be healed.

Vesicovaginal fistulae are a rare but a devastating complication mainly after gynaecological operations, especially hysterectomy which is very often performed. Its repair can sometimes be even more demanding. By using the given technology, we believe that the da Vinci robot-assisted, laparoscopic approach is the most auspicious in most cases of high supratrigonal fistulae.

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Robot-Assisted Ventral Inverted YV-Plasty for Recurrent Bladder Neck Stenosis

44

J. Brachlow and H. John

Introduction

After surgical treatment of benign and malignant diseases of the prostate, bladder neck contracture, also known as vesicourethral stenosis, is a well-known and well-described complication after radical prostatectomy (RRP), pelvic radiation or transurethral resection of the prostate (TURP). The correct term, according to the International Consultation on Urological Diseases (ICUD) 2014 [1], is "bladder neck stenosis" (BNS) when the prostate is in situ or "vesicourethral anastomotic stenosis" (VUAS) after radical/total prostatectomy. Therefore we use the term bladder neck stenosis according the ICUD definition.

Bladder neck stenosis ranges from a simple contracture to recurrent stenoses, which are refractory to repeated surgical treatments. The treatment options should be individualized for each patient, because they can range from a simple dilatation to repetitive endourological treatments and complex surgical reconstruction.

In this chapter we review the causes of BNS after TURP and RRP, the treatment options and focus on the technique of robot assisted ventral inverted YV-plasty for recurrent BNS after TURP.

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Etiology

While several factors have been associated with the development of a bladder neck stenosis, the exact pathophysiological mechanisms still remain unclear. The primary surgical technique, including the necessity of the application of thermal, cryo or radiation energy, the occurrence of urinary infections and/or delayed woundhealing—all may play an important role in the development of VUAS. Primary therapy of prostate cancer with pelvic radiation induces microvascular effects and progressive obliterative endarteritis, which leads to tissue necrosis of the bladder neck and consecutively to BNS [2, 3]. BNS development might follow many years after the initial treatment [4]. Patients undergoing multimodal salvage therapy (salvage prostatectomy or brachytherapy with external beam radiotherapy) have an even higher risk (between 20 and 30%) to develop BNS [5].

Controversially the development of VUAS after treatment with RRP seems to be associated with a variety of factors, in which technical factors play an essential role. These factors increasing VUAS include: low volume of surgical experience, absence of mucosal eversion, poor vesico-urethral mucosal apposition, urinary extravasation and increased blood loss. Ischemia of the bladder neck/membranous urethra and excessive narrowing of the urethral anastomosis at the time of the procedure [6–11] are further reasons for VUAS.

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_44

During surgical development it was shown, that a mucosa to mucosa apposition [12] at the time of bladder neck reconstruction combined with a tension-free, water-tight vesico-urethral anastomosis is the key to decrease the incidence of VUAS [13]. For this an enhanced vision in the pelvis and of the apex is necessary, which is provided by the robotic-assisted laparoscopic approach [7, 14].

So after introduction of laparoscopic and robotic-assisted laparoscopic prostatectomy (RALP) the incidence of VUAS has significantly decreased to 0–3.3% [11, 15, 16], compared with older results of classic open RRP [12] ranging from 0.48 to 17.5% [17, 18] in one study even reaching 32% [19].

Additionally there are possible patient-related risk factors facilitating a BNS/VUAS.

Barboglu et al. showed that smoking is the largest risk factor for VUAS. Hypertension, coronary artery disease, and diabetes also contribute to VUAS [6]. Elliott et al. reviewed the Cancer of the Prostate Strategic Urological Research Endeavor (CaPSURE) database. They reported in this population-based disease registry that body mass index, Caucasian race and age were also factors associated with VUAS [4].

BNS may also occur as a complication of TUR-P [20]. An incidence between 0.14 and 20% was reported [20]. With rise of surgical experience and technical developments in surgical instruments leading to less invasive procedures, the complications have decreased [21]. However, the incidence today is still between 0.3 and 9.2% [20, 22, 23].

Pansadoro and colleagues [24] described three types of strictures in the prostatic fossa after surgical management of LUTS/BPH. Type I, where the fibrous tissue involves only the bladder neck, reducing outflow, which is for most urologists the true BNS. Type II, where the stricture is localised to the middle part of the prostatic fossa, and type III, where the stricture involves the whole prostatic urethra.

Potential risk factors for BNS after TUR-P are a low adenoma volume, severe storage phase symptoms, extensive resection of the bladder neck and the use of a large loop, which generates excessive heat with consequent production of a hypertrophic scar [25, 26]. But the above-mentioned patient-related factors must also be kept in mind.

Endourological Treatment Options

For BNS after TUR-P and even VUAS after RRP endoscopic treatment is the first line option in the literature [24]. It ranges from simple dilatation, bladder neck incision with a cold-knife, transurethral resection of the bladder neck, stent placement, bipolar plasma vaporisation, injection of mitomycin C to various kinds of laser type incision [27].

Often, patients have to undergo multiple endoscopic procedures to be cured. Yet, if two endoscopic treatment attempts have failed, we talk about highly recurrent BNS/VUAS. BNS/VUAS is a rare, but troublesome condition and there is no standard treatment so far published in any guidelines. Therapeutic options are intermittent dilatation, intermittent transurethral bladder neck incision or resection, a permanent suprapubic drainage, urinary diversion or an open reconstruction. Different authors advocate an urethrovesical anastomosis after failure of endoscopic treatments [28–30].

Surgical Technique

Access

Ambulatory preoperative cystoscopy confirms BNS. We prefer an extraperitoneal laparoscopic approach to the anterior surface of the prostate. A single antibiotic dose is given. An indwelling bladder catheter is placed if possible, alternatively a single use catheter. Patients are placed in a supine 15° Trendelenburg position with abducted legs. After setting the pneumopreperitoneum with 12 mmHg over the 12 mm paraumbilical camera port, a total of four further ports are inserted: one left lateral 8 mm work-site port, which is placed 10 cm laterally from the camera port slightly lower than the umbilicus. Another working port is placed in a similar position on the right side. Furthermore, a 5 mm trocar is inserted between the camera and the right working port. A 12 mm Versaport is introduced at the cranial edge of the right anterior superior iliac spine (Fig. 44.1).

Extraperitoneal Robotic Procedure

First, the prevesical fat is removed and the perivesical space cleaned. The bladder neck is located, and the ventral part of the prostate is exposed. The pelvic floor around the prostate is carefully exposed. We like to ligate the anterior prostatic venous plexus in BNS as retrograde blood flow might decrease vision in this reconstructive procedure. An anterior longitudinal incision in hot and cold scissor technique is performed starting from the bladder neck and ventral vesico-prostatic junction down through the stenotic area to the external sphincter (Figs. 44.2 and 44.3). As the dorsal bladder base and ureteral ridges are not touched, ureteral stents are not usually necessary.

Then the cut is enlarged to an inverted Y-shaped incision (Fig. 44.4). Now, a well-vascularized and tension-free flap is created, which offers the possibility of reconstructing a wide bladder neck and prostatic urethra with fresh vital tissue. The tip of

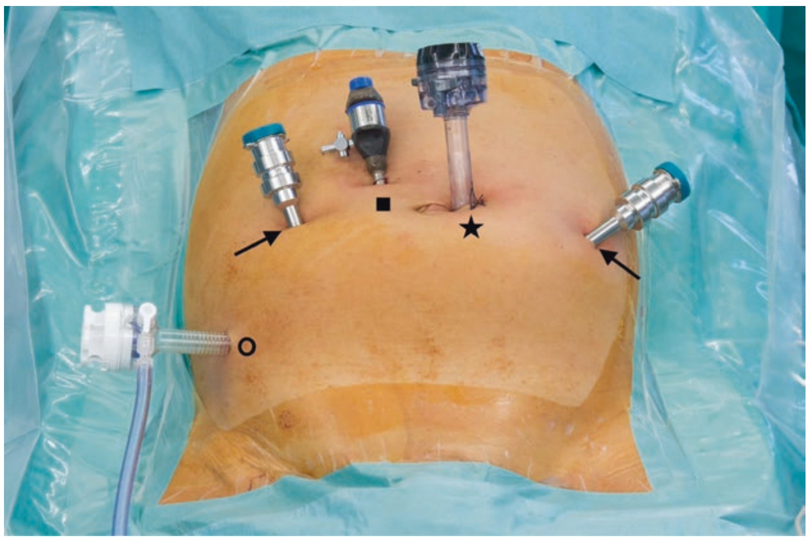

Fig. 44.1 Extraperitoneal robotic approach for YV-plasty of bladder neck stenosis. ★ camera port, → 8 mm work-site port, ■ 5 mm trocar, **O** 12 mm Versaport

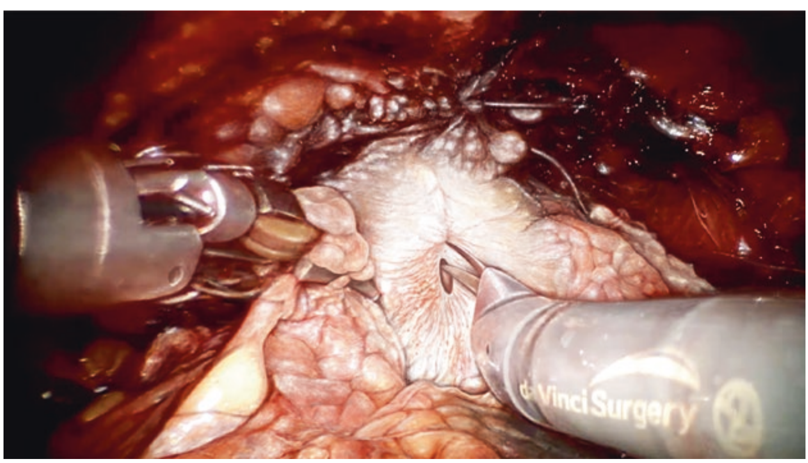

Fig. 44.2 The vesico-prostatic stenosis is incised

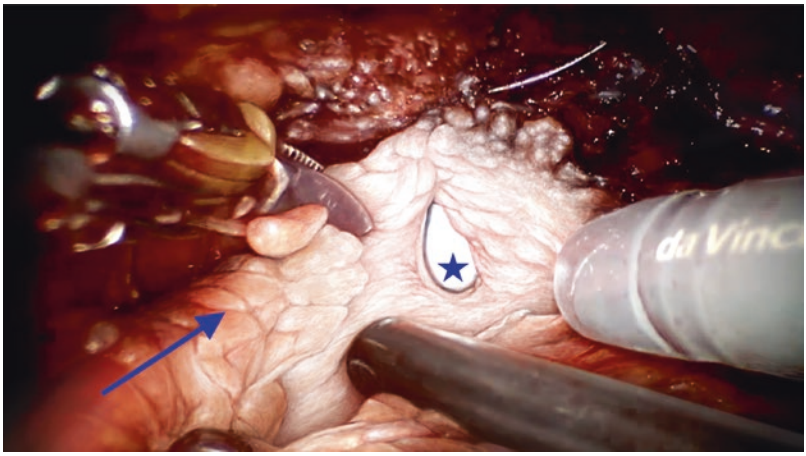

Fig. 44.3 The stenotic area of the bladder neck and intraprostatic urethra is widely open. ★ tip of indwelling catheter, → bladder wall

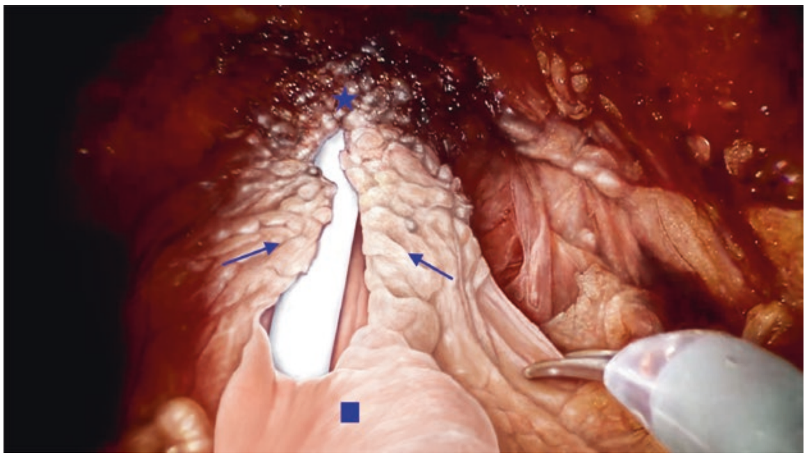

Fig. 44.4 The incision is prolonged into the bladder as an inverted Y in order to create a flap. ★ prostatic capsule, → bladder wall, ■ flap

the inverted V-flap is brought to the base of the inverted Y incision and fixed at the nadir of the original Y incision, distal to the stricture area (Fig. 44.5). To prove the intact vascularisation of the flap we conducted an intraoperative Indocyanine-green (ICG) fluorescence sequence (Fig. 44.6). A wide bladder neck can be fashioned. This is an essential step to keep a symmetrical reconstruction and interposition of vital tissue. Both legs of the inverted Y are closed with a continuous V-loc 3-0 suture (Figs. 44.7 and 44.8). Thereafter, a new Foley indwelling catheter Ch20 is placed without irrigation or drainage.

Postoperative Management

Patients have full diet and mobilisation day 1 postoperatively. Day 5 after surgery we perform a voiding cystourethrogram. In the absence of urinary extravasation, the indwelling catheter is removed. Spontaneous micturition is observed with urinary diary and the residual volume is controlled by ultrasound.

Discussion

Historically, the YV-plasty for vesical neck obstruction was first described by Young in 1953 in children [31]. Later in 1969, Colabawalla [32] published a larger study, finding satisfying results for the YV-plasty. However, in their open surgical techniques, they performed a challenging dorsal bladder neck approach with bladder YV-plasty, which cannot be compared to our present approach and discussion.

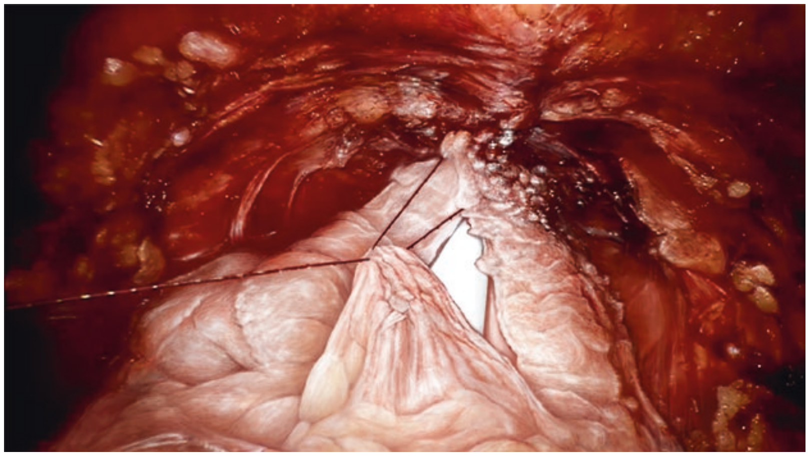

Fig. 44.5 The tip of the flap is fixed at the pelvic floor with a 3-0 barbed suture

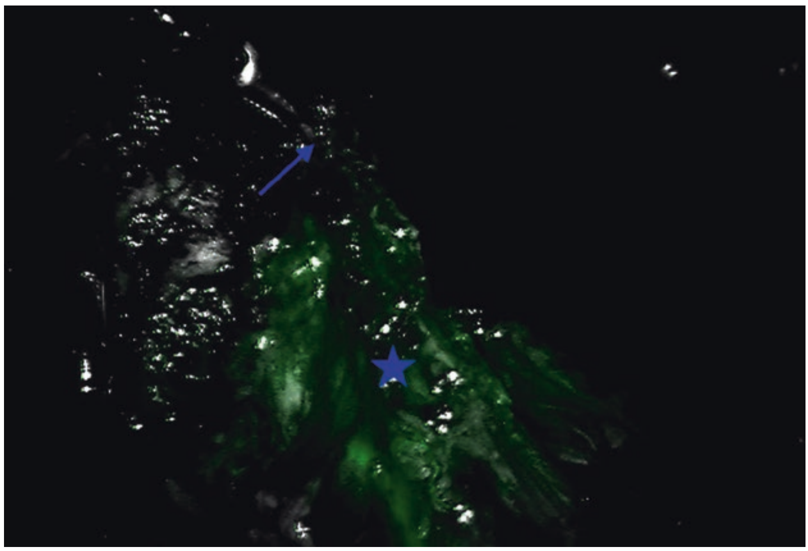

Fig. 44.6 ICG showing the good vascularisation of the v-shaped flap ★, → tip of the flap, fixed by the fenestrated bipolar forceps

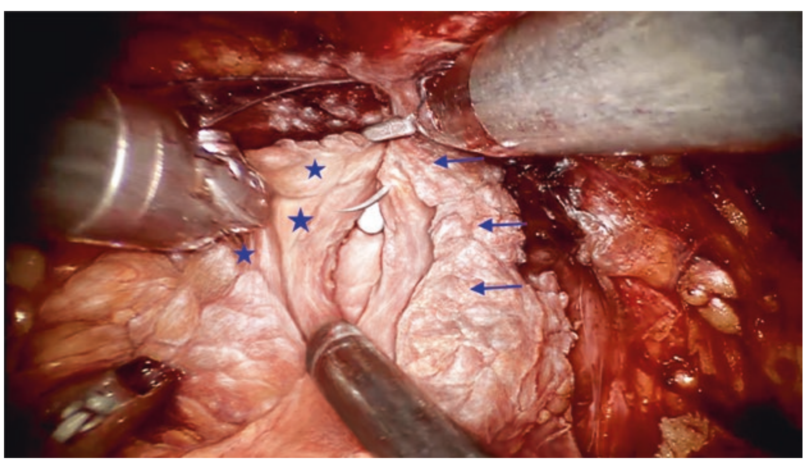

Fig. 44.7 Closure of the right inverted Y-leg of the bladder flap. ★ right leg of the bladder flap, → prostatic capsule

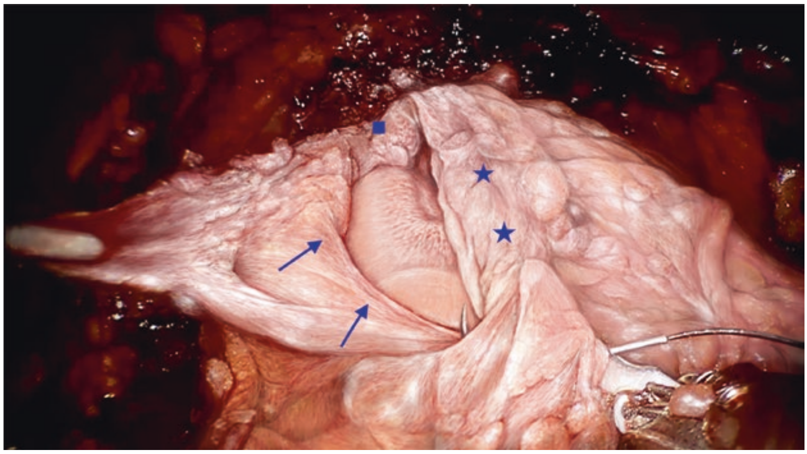

Fig. 44.8 Closure of the left side of the bladder flap by an ascending continuous 3-0 barbed suture ★ left leg of the bladder flap, → bladder wall, ■ prostatic capsule

Today, there exists a variety of surgical possibilities to treat BNS/VUAS such as dilatation, transurethral resection, cold knife incision, diversion, open reconstruction, adjuvant agents during transurethral surgery and more. A method of choice to treat recurrent BNS/VUAS remains controversial and no gold standard exists in the current guidelines. The Trauma and Urologic Reconstruction Network of Surgeons (TURNS) group showed that the efficacy of intralesional mitomycin C injection at the same time as transurethral incision of the BNS was lower than initially reported. They are the first who reported major adverse events in 4 (7%) patients of their population. They even think that lateral deep incision into the fat as Ramirez et al. reported, has a larger benefit in treating BNS than adjuvant agents [33, 34] A recent publication from Cindolo et al. confirmed that there is a lack of designed studies for the treatment of BNS after LUTS/BHP surgery. They recommend leaving the decision to the surgeon's own judgement [35].

It seems, that most groups chose their surgical technique (i.e. transurethral or radical) independently from BNS etiology [30]. However, etiology has to be considered in each patient planning surgery for bladder neck stenosis or vesicourethral anastomotic stenosis, especially in regard to the external sphincter mechanism.

Reiss et al. and Pfalzgraf et al. recommend recently a transperitoneal reanastomosis as therapy of choice for recurrent vesicourethral anastomotic stenosis after RRP in open surgical technique [36]. In patients with BNS they propose the so-called T-plasty, which is basically a modified YV-plasty for recurrent BNS with a reported success rate of 100% in ten patients [28].

Theodorou and colleagues [29] propose an abdomino-perineal repair. They excise the stenotic area and perform an end-to-end anastomosis. At the same time, an artificial urinary sphincter is implanted. Very rarely, urinary diversion must be considered as a last option for a permanent solution [37].

Most recently the robotic approach was proposed to treat BNS. However, there is a lack of postoperative long-time results. A group from Kliniken Essen-Mitte, around M. Musch et al. in Germany showed a feasibility study including 12 patients with a median follow-up of 23.2 months in transperitoneal technique. They reported no intraoperative or major postoperative problems [38]. There are some distinct technical differences to our proposed approach. First, we prefer an extraperitoneal access as there is no need for a large dissection area in the intraperitoneal cavity, preventing any intraperitoneal complications and drawbacks. We always incise the prostatic capsule and full thickness bladder wall with hot and cold scissors, which is at least as efficient as a blade fixed in a needle holder. Finally, we suture the inverted V-flap in continuous suture technique with a barbed suture, which allows a stable flap position. Whilst an extraperitoneal approach in BNS procedure is very suitable, we recommend a transperitoneal access in patients with vesicourethral anastomotic stenosis and previous abdominal interventions .

In patients with long stricture zones including the external sphincter and consecutive possible stress urinary incontinence, an artificial sphincter system can still be placed in the future if necessary.

Conclusion

The robot assisted extra- or transperitoneal laparoscopic approach to perform a YV- or T-plasty is new. After repetitive endourological attempts to cure BNS/VUAS, a new procedure must be offered to the patient. A well-vascularized bladderflap seems to be a promising concept with increased probability of good long-term results. Long-term observations will confirm, if a YV- or T-reconstruction of the bladder neck affords sustainable outcomes.

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Part VIII

Male Genital Tract

45 Robot Assisted Vaso-Vasostomy and Inguinal Varicocele Repair

Georges A. de Boccard

The initial mistake before starting a robot assisted microsurgery program was to expect a haptic feedback from the instruments. This didn't take into account the adaptation capacity of the human brain. The visual perception of the tension of the suture is in fact "felt" as tactile and replaces any need for a haptic feedback in the hands or fingers. This visual tactile feedback is already mastered by conventional microsurgeons. Even robot assisted macroscopic surgeons are now able to describe the hardness of a tissue while operating on tumors. Our microsurgical reconstruction program started in 2003 after we discovered the lack of tremor and the precise vision brought by the robot. The procedures were initially directly adapted from classical microsurgery. We first used 7/0 sutures, then shifted progressively down to 11/0 [1]. In our opinion, the best suture sizes are 9/0 or 10/0. Many surgeons use nylon sutures, but we prefer polyglycolic acid ones since it does not induce reactions and does not leave any foreign material. The choice of the needle is very important according to the structure of the tissue but is left to the appreciation of the surgeon.

Robot Assisted Vaso-Vasostomy (RAVV)

Introduction

The first vasectomies were performed for eugenic reasons at the end of the nineteenth century, then gained popularity as a male contraception even after female oral contraception appeared. It is a widespread method among married men with one or more children, especially among couples where the wife doesn't tolerate chemical or mechanical contraception. Vasectomy reversal was first performed in 1919, much later the first microsurgical operation in 1971 changed the outcome [2]. In the United States approximately 0.5 million of men undergo a vasectomy per year, followed by a 6% vasectomy reversal rate. These figures do not apply to Europe where the number of vasectomies per year is significantly lower with an even lower percentage of reversals. This is mainly due to cultural reasons with a great variation among countries including personal reasons and the age at the time of vasectomy. In Europe, men have a vasectomy when they consider that their reproductive mission has been fulfilled and not for pure contraceptive reasons. Other parts of the world like China, India or Brazil have their own figures.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_45

Microsurgical Vaso-Vasostomy (MSVV)

The result of a vasectomy reversal (VR) is related with the delay after the vasectomy, but also the technique used and the skill of the surgeon [3, 4]. Presence of cells in the perioperative fluid is not absolutely mandatory. Since the advent of the operative microscope and its use for VR in the 1970s, there have been minor changes in the instrumentation used for this procedure, but none in the way of an alternative magnification source or truly different technologies [5, 6]. Recently, the robotic platform was applied to VR in humans and seems to offer many advantages [7, 8].

Robot Assisted Microsurgical Vaso-Vasostomy (RAVV)

The patient is placed supine under general anesthesia. The scrotum is shaved and scrubbed; a single dose of antibiotic is given.

A 5 cm incision is made on the midline of the scrotum, under the penoscrotal angle, the ends of the vas are identified and bluntly dissected, avoiding devascularization. Both sides are prepared and a lace is placed under the dissected ends. Bipolar coagulation is used if necessary to ensure a dry operating field.

The first vas is transected and the scary ends are resected until a nice lumen can be seen. The prostatic end is flushed with saline in order to check its patency. The testicular end is checked for fluid. The extemporaneous microscopic examination will give an estimation of the future patency rate, but even if no sperm cells can be found, the patency rate remains high since the pregnancy rate without finding any sperm cell is still 31% [3] compared to 40% after vaso-epididymostomy [9].

Both ends are placed on the approximator (Goldstein's micro spike approximator) and a white Flexi-Drain[R] with 4–6 tubes is placed as a background allowing a better sight and draining of fluids (Fig. 45.1).

The robot is installed perpendicularly on the left side of the patient. The arms of the robots are placed along an imaginative abdominal wall, with three 8 mm metallic trocars maintaining the instruments with their black marks at about 15 cm of the operating field in order to avoid collision among the instruments. A plastic 12 mm trocar is used for the camera. We use two black diamond forceps in arms #1 and #2, and a Potts scissors placed perpendicularly on arm #3 (Fig. 45.2). No assistant is needed and the scrub nurse will regularly flush the field with saline. There is no heating problem due to the light during the procedure.

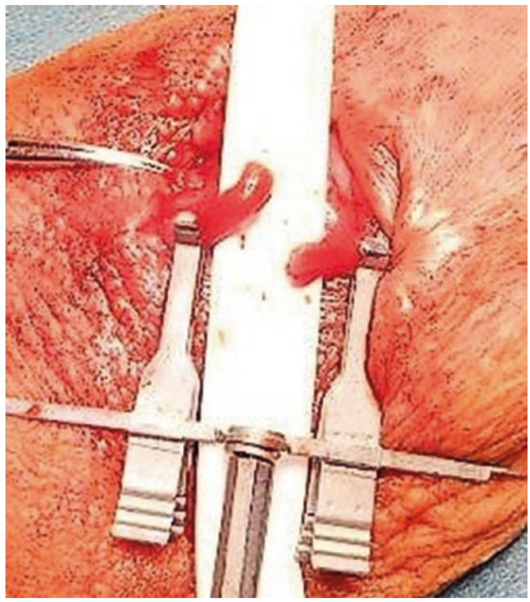

Fig. 45.1 Goldstein's approximator and Flexi-Drain

Fig. 45.2 Extracorporeal installation

Two Layer Technique

Two 9/0 polyglycolic sutures are placed on the posterior muscularis to ensure stability, then six 10/0 polyglycolic sutures are adapting the mucosa (Fig. 45.3). It is necessary to slide the double knots flat in order to ensure a good adaptation without deforming the tissues (Fig. 45.4). Since the jaws of the forceps may be traumatic to the tissues, the vas or its mucosa shall never be grasped or pinched. The anastomosis is completed with four to six more 9/0 polyglycolic sutures to ensure solidity and tightness. We sometimes complete the procedure with two 7/0 PDS sutures to ensure a tension free anastomoses.

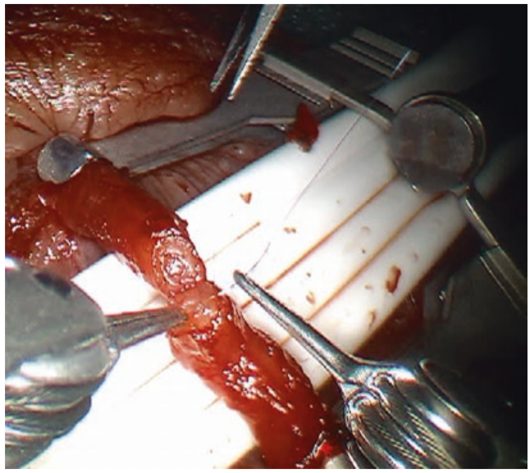

Fig. 45.3 10/0 suture of the mucosa

Modified Two Layer Technique

The anastomosis is first made with four to six 9/0 polyglycolic sutures through both the muscularis and the mucosa, then completed with the same number of stiches through the muscularis only, between the former ones, in order to ensure tightness.

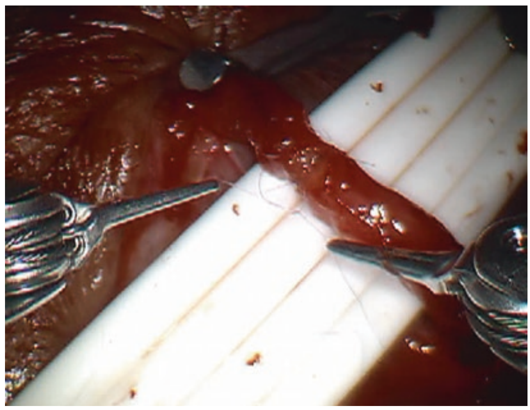

Fig. 45.4 Sliding of flat knots

Robot Assisted Vaso-Epididymostomy (RAVE)

If a proximal vasal obstruction has been demonstrated, many years after a vasectomy or an epididymal infection, the patency can still be restored with a vaso-epididymostomy [9, 10].

The installation of the operating field is the same as for a vasectomy reversal, as is the preparation of the distal part of the vas. The testis is exposed and the epididymis prepared. When the distal (prostatic) end of the vas has been opened and checked for patency, it is then brought close to the epididymal body. At this level, a single epididymal tubule shall be identified for its swelling, as distal as possible, and fluid will be checked for spermatozoa (at this stage of the procedure MESA and freezing are recommended). The posterior wall of the vas is sutured with two 9/0 polyglycolic sutures to the adventitia of the epididymis. The epididymal tubule is then pulled inside the vasal lumen with two 10/0 polyglycolic sutures after being opened using the intussusception technique [9, 10], then the anastomoses is completed with about 4 more 9/0 polyglycolic sutures assuring the tightness of the anastomosis. Here again two 7/0 PDS stitches will ensure a tension free anastomosis if necessary.

An alternative option would be the “end to end” anastomosis [4] which consists in transecting the epididymis, finding the efferent tubule from which spermatic liquid pours out and suture it with three 10/0 stitches to the mucosa of the vas, then securing the adventitia with six 9/0 sutures to the epididymis. Two additional 7/0 PDS sutures will assure the absence of traction.

Table 45.1 Outcome robotic assisted (RAVV) vs. microscopic vasectomy reversal (MSVV)

Patency rate < 8 years post vasectomy	MSVV	RAVV
Kavoussi	89%	100%
Overall patency rate post vasectomy	MSVV	RAVV
Parekattil et al.	80%	96%
Kavoussi	89%	92%
De Boccard	83%	92%

Outcome

The operating time with the assistance of a robot is slightly shorter than with conventional microscopy, probably because of the permanent focusing, even during the changing of tools for cutting the threads. The very comfortable position of the surgeon may also play a role. The results of the robot assisted vasectomy reversal or vaso-vasostomy (RAVV) seems to be slightly better in matter of patency and pregnancy rate (Table 45.1).

Robot Assisted Microsurgical Ligation of the Spermatic Veins

Introduction

Varicocele is an anatomical condition in the vascularization of the testis combining the lack of anti-reflux valves in one of the longest vein of the body with an overheating of the testis by the impairment of the temperature exchange in the pampiniform plexus [11]. It is a recognized cause of poor semen quality and can induce invalidating pain. Its influence increases with time. The latest studies have demonstrated the negative effect of varicocele on sperm production and hormone level [12] as well as the positive effect of the surgical treatment on these parameters [13].

Varicocele was recognized as a pathological condition in the early nineteenth century but the effect of the surgery on fertility was discovered only years after the procedure was indicated for pain. The first procedures were described as dangerous and life threatening. In 1838, the French surgeon Vidal describes a "standing" technique, with no serious complication. Many other techniques followed, from open scrotal to inguinal microscopic, the most popular being the retroperitoneal high ligation which led to the laparoscopic trans peritoneal approach.

Varicocelectomy

The Divergence

Trans peritoneal laparoscopic varicocele cure was described by Matsuda [14] and widely adopted but at the same time Goldstein [15] described the Inguinal microsurgical approach with an apparently better outcome and less side effects for the patient.

The Convergence

For years the two techniques cohabited until laparoscopic surgeons started using robots as a microscope. Robot assisted microsurgical ligation was first demonstrated by Shu in 2006 [16] and adopted by an increasing number of surgeons.

The purpose of the procedure is to ligate all veins that are draining in the spermatic veins, thus potentially causing a blood reflux disrupting the homeostasis of the testicles, without causing any harm to the arteries with the risk of infarction or the lymphatic vessels which would cause the development of a hydrocele.

The use of a robot, together with an excellent vision, brings stability, no tremor and more precise movements. It allows the use of different tools without losing focus and opens the way to even better outcome.

Robot-Assisted Varicocelectomy

The patient is lying supine, generally under general anesthesia. The genitals and pubis are scrubbed, disinfected and a draping leaves only the side of the insertion of the penis apparent (both sides if bilateral). An about 3 cm horizontal incision is made at the level of the external inguinal ring and the underlying tissue is bluntly dissected until the spermatic chord appears. The cord is exposed with a 13 mm Penrose drain in which the metallic handle of a scalpel has been inserted (Fig. 45.5). In bilateral cases, the contralateral chord is prepared with a normal Penrose drain, waiting for the second side of the procedure.

Once the spermatic chord has been exposed, the robot is docked with a 45° oblique approach from the head side of the patient in order to give more space to the arm #3.

When installing the robot for an extracorporeal procedure, the 8 mm metallic trocars are still necessary, with a plastic 12 mm trocar for the camera. One must pay attention to their positioning with an imaginary abdominal wall line; the black marks on the trocars must be placed approximately 15 cm away from the chord. All cables and electric lines must be placed over the arms in order not to interfere with the vision of the operative field.

The arm #1 is equipped with the bipolar micro forceps, the arm #2 with Black Diamond micro forceps, and the arm #3 with the Potts Scissors. The VTI Drop-in^{R} 20 MHz micro Doppler is prepared. 6/0 Vicryl sutures are precut at a length of 5 cm.

The arm #3 with the Potts scissors is placed horizontally in order to avoid any conflict with the arm #2. In this case also there is no heating problem due to the light during the procedure.

The surgeon may go to the console and, before starting the procedure, will check the amplitude of the movement of the tools and if necessary, do some adjustments.

The cremaster fascia is held between the Micro Bipolar and the Black Diamond forceps and incised with the Potts scissors in order to expose the structures of the chord. The fatty tissue is repelled from the vessels by a gentle movement of the opened Black Diamonds, avoiding causing any damage to the lymphatics which will appear like numerous transparent structures distributed all over the field. Generally two major veins appear, one accompanied by the testicular artery. If the pulse cannot be properly seen, the micro Doppler will help localizing it (Fig. 45.6). When the artery and the lymphatics have been securely pulled aside, the vein is lifted with the closed Potts scissors and exposed. A 6/0 braided polyglycolic ligature is placed on each sides of the exposed vein (Fig. 45.7). It is then lifted by pulling on the ligature's ends and cut (Fig. 45.8). This ensures that no other structure can be damaged.

The procedure is repeated according to the exploration of the content of the spermatic chord. Another pair of pathological veins is very often found as well as solitary ones. A second artery can also be found. The exploration will also reveal the vas which is easily identified. Its intimate blood vessels shall be respected but any other varicosal vein will be ligated and cut.

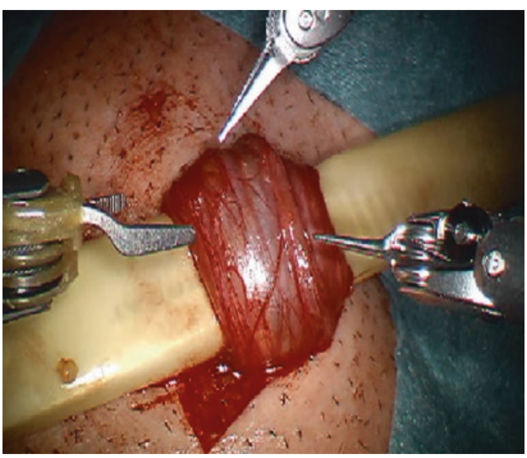

Fig. 45.5 Chord exposure

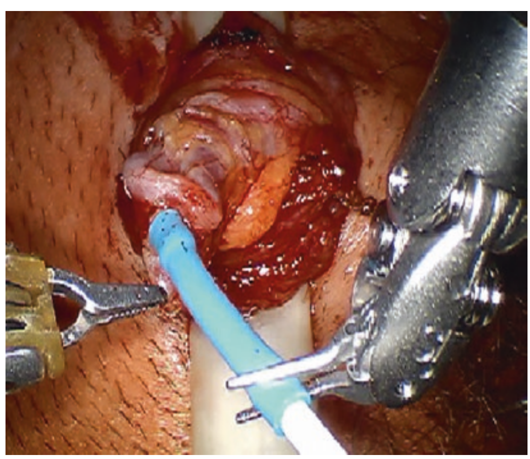

Fig. 45.6 Micro Doppler arterial flow detection

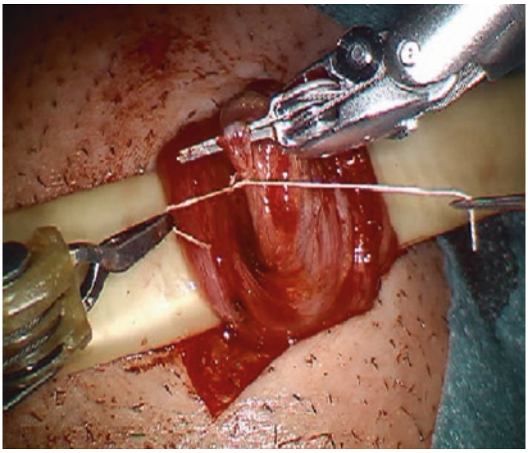

Fig. 45.7 Ligation of a vein

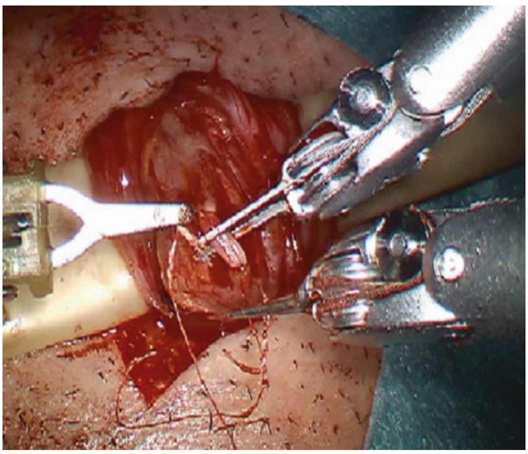

Fig. 45.8 Section of a vein

When all pathological vessels have been treated and the Doppler control confirms the patency of the arteries, the chord can be replaced under the skin.

In case of bilateral procedure, during the installation of the robot, the arms will be placed in order to allow access both sides without having to move the stand of the robot. The assistant will simply move the camera and the arms to the other side keeping the same angulation to the different tools. The console surgeon will check the amplitude of the movement before starting. The table can also be moved on the side since the trocars do not touch the patient.

Table 45.2 Results after robot assisted varicocelectomy (Parekattil)

Indication	n	Result
Oligospermia	116	70% improvement
Azoospermia	36	3 oligospermia
Pain	16	95% complete cure

On the right side fewer vessels are present with a smaller diameter but the procedure is the same.

At the end of the microsurgical procedure the robot is pulled back and the wound closed.

Outcome

The advantage of the microscopic approach is confirmed with the use of the robot in comparison with the laparoscopic or open procedures with a similar operating time and more precision considering the absence of tremor and precision of the ligations (Table 45.2) [17]. Here again the comfort of the surgeon plays an important role together with a permanent focus while alternating the different tools.

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Part IX

Complications

46 Complications of Robotic Surgical Access

Alexis Sanchez, Luis Medina, Fatima Z. Husain, and Rene Sotelo

Introduction

A fundamental key in the performance of a safe and efficient minimally invasive surgery, both laparoscopic and robotic, lies in optimal port placement and proper entry into the abdominal cavity, while ensuring proper docking to avoid external clashing of the robotic arms. The creation of the pneumoperitoneum and initial trocar placement, part of obtaining initial access, not only are important steps for successful completion of a procedure, but are significant because most complications occur during this initial step of the operation. Although serious complications rarely occur during laparoscopic surgery, 50% of these complications ensue during the initial access. However, it should be noted that access related complications occur in 1% of patients who undergo minimally invasive procedures [1–3].

It is important to note that the risk of injury when inserting traditional 8 millimeter (mm) sized robotic ports does not differ from standard laparoscopic sized ports. Although complications associated with port placement are uncommon, when these injuries do occur, the associated morbidity is high, vascular or bowel injuries related to obtaining initial access are the leading causes of mortality after laparoscopic surgery and are also responsible for 15% of cases which are converted from laparoscopic to open [4, 5].

Surgeons performing minimally invasive surgery must have the knowledge and skills to prevent, recognize, and manage complications related to obtaining initial access and port placement.

Risk Factors Associated with Complications During Robotic Port Placement

Previous abdominal surgery is associated with an increased risk of access-site complications [6]. The rate of adhesions is up to 15% in patients with a history of previous laparoscopic surgery, 20–28% in those with a prior laparotomy through a low transverse incision, and 50–60% in patients who have had a previous midline laparotomy [7]. Adhesions may be directly beneath the previous surgical scar or may be further away.

Consequently, previous abdominal surgery can be considered a relative contraindication for blind Veress needle access and should preferably be avoided, especially at the beginning of the learning curve. In this situation, access can be obtained by direct open access or by visual opti-

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_46

cal trocar insertion (with or without previous insufflation) at a point far from prior surgical scars.

It is important to not compromise the proper placement and location of ports, as this can cause difficulties in docking the robot and performing the surgery, such as robotic arm and instrument clashing [8, 9].

Once the abdomen is insufflated and the primary port is placed, the abdominal cavity should be inspected to determine whether adhesiolysis is needed before placement of additional ports. In some cases, it may be possible to safely place additional ports and dock the robot, so that the adhesions can be taken down robotically. If this is not possible, the adhesiolysis should be performed by conventional laparoscopy, and after this is completed, the robot is docked.

Obesity is an increasing problem around the world; in some cases, it constitutes a real public health dilemma. Worldwide, more than 30% of adults are obese or overweight, and from this group, the United States of America is the country with the greatest percent of obese patients (13% of all cases) [10]. There is an association of obesity with diseases such as renal and prostate cancer, and as a result, there is a growing need to treat patients with higher body mass indices [11, 12].

A thick layer of subcutaneous adipose tissue limits the depth of access, especially with insertion of the Veress needle and primary trocar. Due to the thickness of the abdominal wall and the preperitoneal fat, accurate assessment of the location of the Veress needle tip can be compromised.

The open Hasson technique is an alternative method for access for this group of patients. This technique consists of making an incision through the skin, subcutaneous layers, and then fascia until the peritoneum is reached, followed by insertion of the port [8]. Some surgeons believe that a larger skin incision is necessary for the Hasson trocar technique in obese patients, leading to leakage of CO_2 gas from around the port, resulting in lower pneumoperitoneum pressures, which can make completion of the operation challenging [13]. This is especially important when the Xi Da Vinci robotic system is being used, in which case all ports, including the camera port, are 8 mm size. Other studies suggest that the use of direct visual optical trocar placement is an excellent choice for these patients, which also has a lower reported rate of intestinal and vascular injuries [14].

The restricted mobility of conventional laparoscopic instruments during surgery on obese patients is one of the limitations that has been overcome with the use of robotic surgery. This is because using the robot eliminates the resistance of a large abdominal wall produces with movement of laparoscopic instruments to achieve the desired movement. Additionally, on the robotic console, the surgeon is in an optimal ergonomic position, adding to surgeon comfort during the operation. The use of longer (bariatric) robotic ports is highly recommended for these patients to keep the remote center in proper position and to prevent the port from accidentally slipping out of the abdominal wall, which will result in the robotic arm not functioning properly and loss of pneumoperitoneum.

On the other side of the spectrum, very thin patients are also susceptible to injury due to the proximity of the skin to intra-abdominal and retroperitoneal structures. In robotic surgery, patients with very low body mass indices can present a challenge for proper port placement as a smaller working surface area can decrease the optimal distance between ports, in addition to an appropriate working space for the assistant.

Pregnancy or large abdominal masses may cause challenges when entering the abdominal cavity as they may displace the abdominal viscera and reduce the space within the abdominal cavity [15].

In patients with ***portal hypertension*** or inferior vena cava obstruction, the presence of a collateral venous network on the abdominal wall increases the risk of bleeding during the placement of ports, and the rising pressures within the portal system makes the patient more susceptible to bleeding at the level of the mesentery and the omentum.

Furthermore, intraabdominal or pelvic conditions, including inflammatory disorders such as diverticulitis or pelvic inflammatory disease, place patients at a higher risk for developing complications associated with the development of intraabdominal adhesions [2, 16].

Lack of training or experience of the surgeon is intimately related to the occurrence of complications in minimally invasive, and robotic surgery is not an exception to this. Surgical errors represent a significant percentage of the morbidity and mortality in the health care system, which highlights how critical and important simulation and training are for prevention and early identification.

Previous studies in non-robotic laparoscopic surgery have shown that the incidence of complications in the first 100 cases for a surgeon is considerably higher than in subsequent cases (13.3% vs. 3.6%) [17].

Most importantly, in every case, the surgeon must have the ability to identify and manage complications that may occur.

Preventive Measures

The best way to manage port placement complications is prevention (Table 46.1). Before obtaining initial access, a ***nasogastric tube*** should be placed to decompress the stomach, which reduces the likelihood of gastrointestinal injuries. In

Table 46.1 Methods to prevent complications during port placement and management of potential injuries

Complication	Prevention	Management
Vascular injuries		
Abdominal wall	• Trans-illumination • Visualization of the epigastric vessels • Secondary trocar introduction under direct vision • Removal trocars under direct vision to verify hemostasis	• Direct pressure rotating the tip of the trocar • Insert foley catheter • Place “U” stitches with the suture passer • Extend the skin incision • Use of monopolar, bipolar, or ultrasonic energy for hemostasis control
Intraabdominal	• Trocar introduction under direct vision • Proper technique • Open access	• If serious vascular injury is suspected, conversion to an open procedure must be considered • Direct compression of the bleeding site • Increase insufflation pressure • Repair with precise intima to intima apposition without tension • If ligation of a vessel does not lead to ischemia, definitive repair may be postponed until the patient is stable
Visceral injuries		
Solid organ		• Apply pressure on the injury using an instrument or with sterile gauze • Increase the pressure of the pneumoperitoneum • Use of monopolar, bipolar, or ultrasonic energy • Application of dry hemostatic agents
Small bowel		• Primary closure • Resection and anastomosis
Colon		• Consider colostomy depending on the patient condition and procedure
Bladder	• Use Foley catheter in lower abdominal and pelvic surgery	• Less than 5 mm—Foley catheter placement • Major injuries—primary closure and foley catheter placement

operations involving port placement in the lower abdomen, using a ***foley catheter*** to empty the bladder is recommended. This also allows for early detection of injuries, for example, with the presence of air or hematuria in the urine collection bag, consideration should be given to a suspected bladder injury [18].

There are *3 methods to obtain initial access and create pneumoperitoneum for a minimally invasive surgery*, and a surgeon should be familiar and comfortable with each of the techniques: closed, open, and optical trocar.

The Veress needle is used in the closed technique. It is a blunt tipped spring loaded inner stylet with sharp outer needle. The stylet retracts during passage through the abdominal layers to allow penetration. Once the peritoneal cavity is entered, the lack of resistance allows the blunt stylet to protrude. Theoretically, this should prevent perforation of intra-abdominal structures. Caution is still needed since the blunt tip does not stay locked in place once inside the peritoneal cavity, and it is possible for it to retract again, exposing the needle if it comes into contact with an intra-abdominal structures.

An **initial insufflation gas pressure of < 10 mmHg after placement of the Veress needle, confirms intraperitoneal placement** in most cases. Other techniques, such as the double click test, aspiration test, and the saline drop test, are not useful in confirming proper placement because their sensitivity is less than 40% [19] (Fig. 46.1).

Another strategy that can be used for placement of the first trocar is using ***Palmer's point,*** which is located in the midclavicular line, 3 cm below the subcostal margin, in left upper quadrant. This is a point where, in theory, the probability of abdominal adhesions is considerably lower than the rest of the abdomen, making this a good access point in patients with a history of previous abdominal surgery [20] (Fig. 46.2).

If Palmer's point is used, it is critical to empty the stomach using a nasogastric tube prior to obtaining access. This location should not be used in patients with a history of splenectomy, gastric surgery, or in the presence of hepatosplenomegaly, as these are risk factors for potential intraabdominal and visceral injuries [7].

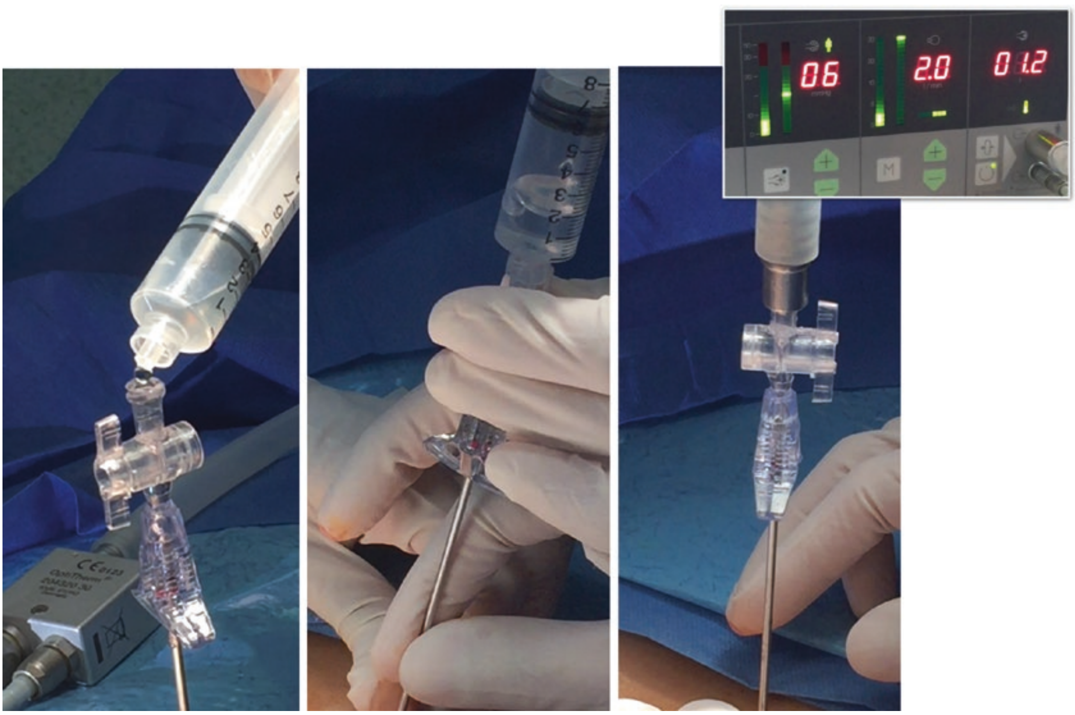

Fig. 46.1 Technique for intraperitoneal Veress needle confirmation

Once the pneumoperitoneum is created using the Veress needle, the entry of the primary trocar is carried out using the following recommendations: oblique direction (45°) and introduce with the valve open, since the escape of pneumoperitoneum through this is a sign of intraperitoneal location. The pressure of the pneumoperitoneum can be temporarily increased during the first port placement, decreasing the pulmonary compliance and increasing the mean arterial pressure. Nonetheless, this temporary pneumoperitoneum increase does not have a significant hemodynamic impact in most patients [7].

In the open technique, the abdominal cavity is approached under direct vision passing through each of the individual layers of the abdominal wall using a scalpel or electrocautery until the peritoneal cavity is reached. No step is completed blindly; therefore, theoretically, it offers advantages such as: certainty of establishing peritoneum, anatomic repair of the facial incision, and elimination of the risk of gas embolus [21]. Some studies suggest that the open technique eliminates the risk of major vascular injury and reduces the rate of major visceral injuries, however, a Cochrane database review concluded that there is no significant difference in the incidence of injury between the open and closed techniques [21, 22].

The direct visual entry technique accesses the abdominal cavity with a specialized optical port that has a conical non-bladed transparent tip, allowing each layer of the abdominal wall to be seen with a 5 mm 0-degree laparoscope as both the port and laparoscope are being advanced toward the peritoneal cavity. (Fig. 46.3) A firm, steady, and constant alternating clockwise-anticlockwise motion is used. However, Thomas et al. reported, despite the fact that each layer of the abdominal wall is visualized and identified with this technique, the use of the direct visual

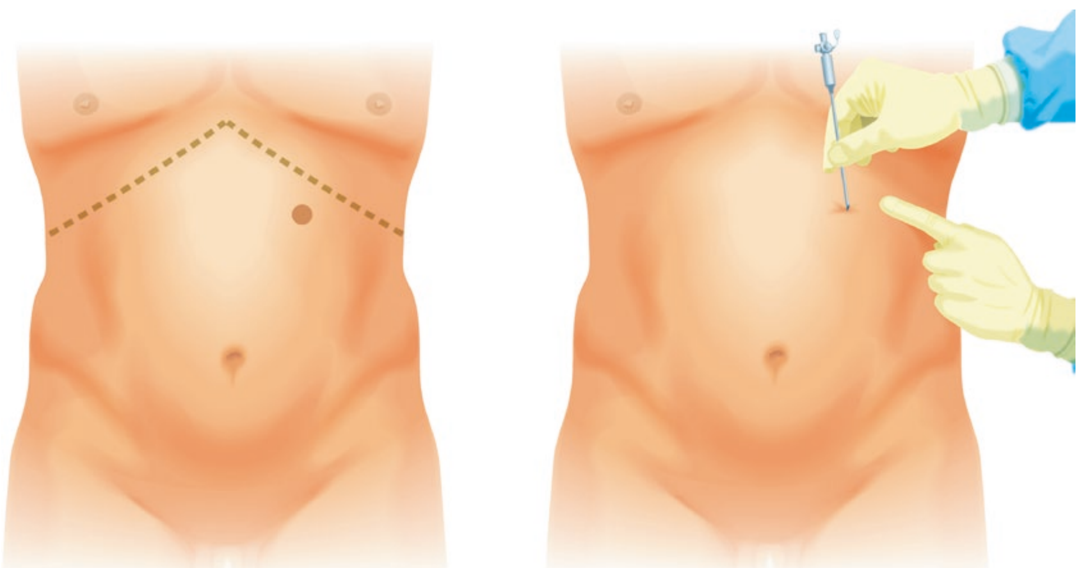

Fig. 46.2 Palmer's point location

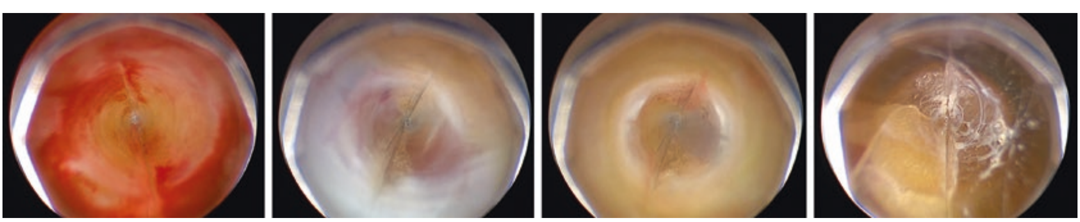

Fig. 46.3 Abdominal wall layers identified during optic trocar introduction

trocar does not entirely remove the risk of intra-abdominal injuries (i.e., when excessive force is used with port insertion, the trocar can slip, causing vascular or visceral damage [23].

Surgeons should be familiar with all techniques to obtain initial access and port placement, but should choose the access method that they feel most comfortable performing and have the most experience with.

Once the primary port is placed, the camera is introduced to confirm proper location and examine the abdominal cavity. If the open technique has been used, the trocar is already within the intraperitoneal cavity. Again, the advantage to this approach is avoiding the blind needle placement.

A maneuver that can be performed to reduce the chance for intra-abdominal trauma is to ***lift the abdominal wall with towel clamps***. In obese patients, this maneuver is not effective because the towel clamps will only lift the skin and subcutaneous fat, instead of the desired parietal peritoneum. Therefore, caution must be taken by the surgeon in this situation. Alternatively, a stitch can be placed to elevate the abdominal wall in an effective and safe manner [24].

It is important to ***avoid any amount of Trendelenburg position when the initial access is performed***. This position will displace the aortic bifurcation closer to the level of the umbilicus, increasing the chance of jeopardizing the procedure with a vascular injury [25].

Robotic access injuries can also occur while placing secondary trocars. The number and size of these trocars are dictated by the type of operation being performed. The ***trans-illumination*** technique, in which once inside the abdominal cavity the laparoscope is used as light source helps avoid abdominal wall vessel injuries when the placement of secondary ports is undertaken. Larger epigastric vessels, which are inferior to the rectus muscle, are not visualized easily using this technique, and therefore special attention should always be given while introducing ports under direct vision to identify and avoid the epigastric vessels [24].

There are different types of robotic trocar obturators: sharp, bladeless, and blunt (Fig. 46.4). The use of non-cutting trocars has proven advantages with a lower incidence of bleeding in the abdominal wall, postoperative pain, and patient satisfaction. However, these trocars require more application of force for insertion, which can potentially increase the rate of injuries [26]. Special mention should also be made to avoid excessively small incisions in an effort to improve aesthetics, because they will require unnecessary force for the insertion of the trocars, again potentially leading to accidental insertion of the trocar deep into the abdomen, leading to injuries [24]. Also, it has been found that cutting trocars are more likely to cause injury when compared the ones with conical tip trocars; this is because the later displaces the vessels instead of transecting them [27].

In robotic surgery, special care has to be taken to the ***trocar location along the remote center, which is a point in the trocar around which the arms within the trocar should move. This provides the best balance between maneuverability along with a decreasing in the force exerted to the abdominal***, which is particularly important to reduce postoperative pain [28].

Once the robotic arms are connected and docked, it is important to release the tension on the abdominal wall by "burping" the arms and instruments to prevent injuries and reduce postoperative pain.

Movement of the robotic arms must be verified before and during the procedure to ***avoid external conflict*** and clashing of the robotic arms extracorporeally and instruments intracor-

Fig. 46.4 Robotic trocar obturators

poreally. Also, it is very important to be ensure that robotic arms do not put pressure on the patient's limbs or costal arches to avoid injuries.

Some of the most critical portions of robotic surgeries are performed by the bedside surgeon and scrub nurse, who play important roles during the operation. Instrument movement injuries can occur when instruments are exchanged, for example if they are accidentally advanced further than the desired location or if the memory of the original clutched position was erased inadvertently during manipulation by the bedside assistant [29, 30]. The console surgeon is responsible for the safety of the procedure, and should ensure that ***no actions are carried out without direct visualization***.

Management

Although, the incidence of bowel and vascular injuries is low for minimally invasive surgery, there is a significant increase in morbidity and mortality associated with a major vascular injury or an unrecognized bowel injury.

Vascular Injuries

The incidence of vascular injuries during laparoscopic surgical procedures is estimated to be 0.05–0.26%, although actual number of these injuries is likely underreported [18].

Vascular injuries may involve retroperitoneal, intraabdominal, or abdominal wall vessels. The most common vascular injury site is the abdominal wall, specifically epigastric vessel injuries. Most vascular injuries occur during Veress needle introduction or initial trocar placement [24]. The aorta and common iliac vessels are the most commonly injured vessels [32]. Vascular injuries have potentially have lethal complications. Furthermore, air embolism can be caused by placement of the Veress needle inside veins or parenchymal organs [31].

Options for management of abdominal wall bleeding include: using a trocar to apply direct pressure rotating the tip against the bleeding site; foley catheter placement, inflation of the balloon, and use of gentle traction to tamponade the site; placement of "U" stitches under direct vision using a suture passer (Fig 46.5). In some cases, it is necessary to lengthen the skin incision for exposure to adequately achieve hemostasis.

It is important to note that sometimes bleeding after partial lacerations of the inferior epigastric arteries may not stop spontaneously because these vessels are fixed under the rectus muscle, and as a result, they cannot contract or retract themselves if an injury does occur [2].

Major vascular injuries are preventable, therefore, caution should be taken to reduce these types of injuries.

The most common sites of intraabdominal vascular injuries include iliac vein, greater omental vessels, inferior vena cava, aorta, pelvic and superior mesenteric veins, and lumbar veins [11].

Suarez et al. [32] has described basic principles of repair for intraabdominal vascular injuries as follows:

- First, once a potentially serious vascular injury is suspected, immediate conversion to an open procedure must be considered.
- Direct compression of the bleeding site is the quickest and safest way to gain initial control of blood loss, especially with a venous injury.
- If the patient exhibits unstable vital signs, adequate volume replacement, while controlling the blood loss, must take place prior to attempting repair of the injury.
- If the bleeding site is difficult to see, early and wide exposure of the site and the surrounding structures must be obtained.
- The vessel wall must be repaired with precise intima to intima apposition without tension; venous injuries may be best handled by ligation rather than suture repair if the patient is unstable.
- If ligation of a vessel does not lead to ischemia, definitive repair may be postponed until the patient is stable.
- If a retroperitoneal hematoma is found at the time of the examination of the abdominal cav-

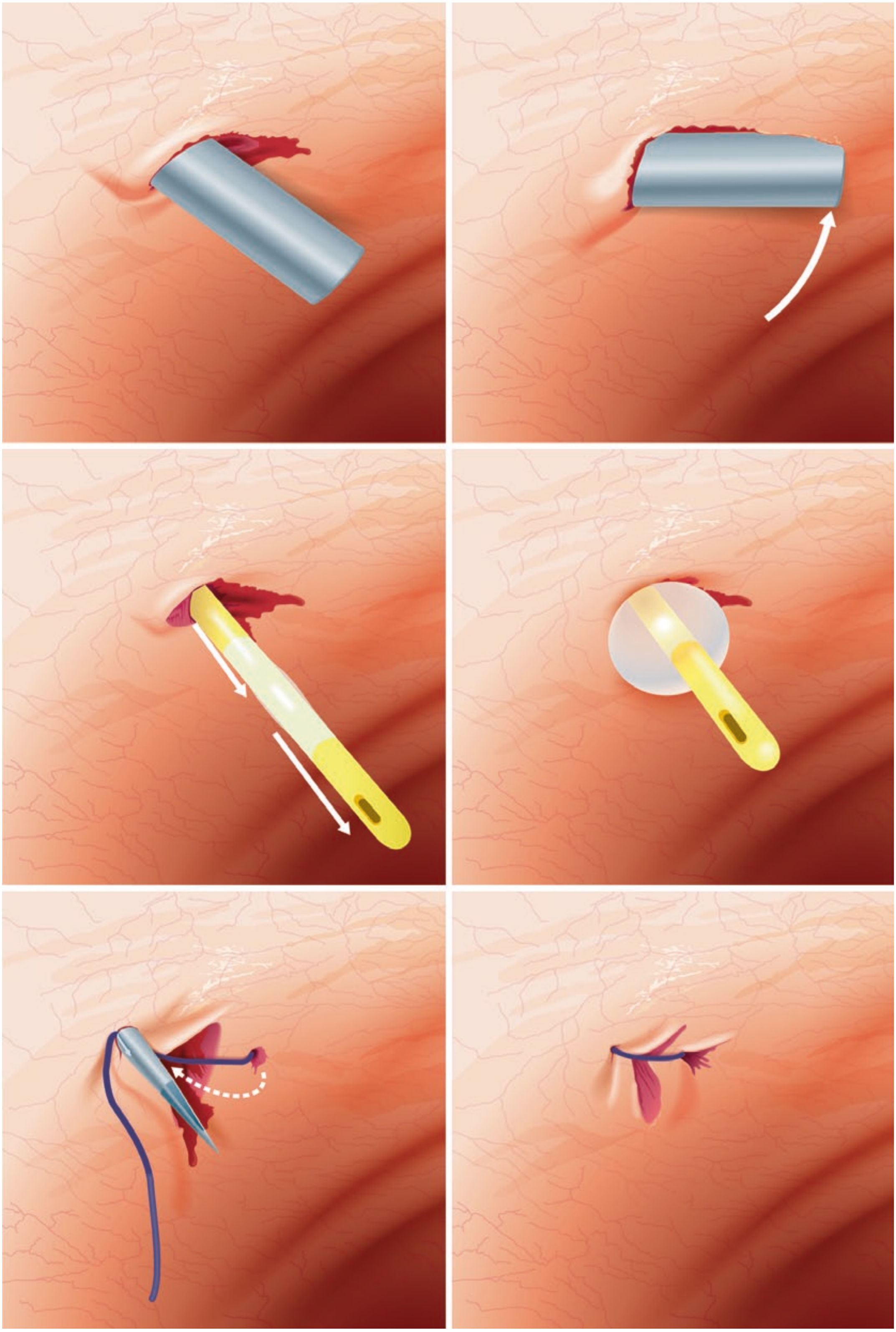

Fig. 46.5 Hemostatic maneuvers for abdominal wall bleeding control

ity with the optical trocar, it may indicate that it should be explored and the injury should be repaired immediately according to the findings.

Delayed bleeding can ensue in a time frame of 1 h and up to 3 days after surgery. The clinical setting can var. Patients can be asymptomatic with no clinical signs until the development of an abdominal wall hematoma, which may then lead to abdominal wall pain or ecchymosis. If there is quick expansion of a hematoma or bleeding, the patient can be unstable from the hemodynamic standpoint. If there are no signs of rapid expansion, bleeding can be treated with close observation and follow-up, however, if there are signs of instability, exploration is recommended with drainage. In some cases, embolization can be used for management as well [2].

At the conclusion of the operation, all ports should be removed under direct vision to ensure that there is no bleeding that may have been tamponaded by the trocar. If there is bleeding identified, it can be stopped using cautery, pressure, or any of the measures mentioned above.

Gastrointestinal Tract Injuries

After vascular injuries and anesthesia related complications, bowel injuries are the third major cause of morbidity and mortality for minimally invasive surgeries [29]. Port placement bowel injuries account for 30–50% of these cases, while other causes can be attributed to electrocautery from surgery devices (The most common section of the bowel injured is the small bowel) [2]. Delays in diagnosis can result in major consequences such as peritonitis, sepsis, and even death [2].

The incidence of bowel injuries is between 0.04 and 0.5% [33]. Of these, 30–50% are not diagnosed intraoperatively, leading to a mortality rate of up to 30% [7]. However, when the injury is recognized and repaired immediately, adverse events and consequences rarely occur [34].

If a bowel injury occurs during trocar insertion, the recommendation is leave the trocar in place, and then place another trocar to explore and evaluate the injury. Depending on the situation, the injury can be repaired in situ or the bowel can be externalized through a small incision, and subsequently repaired. Significant or complex tears may require laparotomy. Similarly, if other abdominal viscera are injured during trocar insertion, the trocar should be left with its sheath in place, and another trocar should be inserted to explore the extent of the injury [35, 36]. Depending on surgical expertise, repairs can be accomplished with intracorporeal suturing.

Injuries to the gastrointestinal tract must be repaired immediately at the time of detection. Repair should not be delayed until the end of the operation because identifying the area of injury later on in the surgery can be challenging. First, the extent of the injury must be determined. Small bowel injuries may be controlled by primary closure using intracorporeal suturing, which is greatly facilitated by the da Vinci system. Major injuries requiring bowel resection can be managed by excision and anastamosis, using a stapler or manually using the robot.

Colonic injuries pose a larger problem. Depending on their severity, injuries to the colon can be treated by primary repair, in which case, drainage is always recommended. Major injuries often require a segmental resection. The decision to perform primary anastomosis or colostomy should be individualized taking into account the patient's condition and the primary procedure to be performed.

Injuries to the bowel which are delayed in diagnoses, require laparotomy, bowel resection with diversion, washout and drainage of the abdominal cavity.

Solid Organ Injuries

The management of injuries to the liver or spleen includes initial application of pressure to the site of injury using an instrument or by introducing sterile gauze into the abdominal cavity. Increasing the pressure of the pneumoperitoneum may also help control bleeding. In addition, the use of dry hemostatic agents (Surgicel, Gelfoam) or thrombin sealants should be considered if the bleeding does not stop. The use of suture to achieve hemostasis should be used with caution, as this may cause larger tears and continued bleeding.

Other Visceral Injuries

Bladder injuries may occur during procedures in lower abdomen and pelvis. As previously discussed, if placement of ports will be below the level of the umbilicus or there is previous history of pelvic surgery, placing a foley catheter prior to obtaining access and initial port placement, may reduce the risk of injury to the bladder and allows for early diagnosis of a potential injury if the collection bag fills with air or with the presence of hematuria [37].

Instilling dye, such as indigo carmine or methylene blue, into the bladder also allows for an accurate diagnosis of potential bladder injury. If the injury was caused by a Veress needle or is less than 5 mm in size, it can be managed with bladder decompression using a Foley catheter for 7–10 days. Major and large injuries require closure with absorbable suture, which can be performed easily in most cases using the robot, with Foley catheter drainage during the postoperative period.

Port-Site Hernia

Hernias at port sites are less common in minimally invasive procedures when compared with open surgeries, with the rates of port site hernias at 2 years are 1.9% and 7.8%, for minimally invasive and open surgeries, respectively [38]. However, minimally invasive surgeries are not exempt of risk. Several risk factors have been identified such as: obesity, malnutrition, infections, and incomplete preventive closure of larger port sites [39]. There is also a higher chance of port site hernias when a single port site surgery approach is used or when devices that diminish the air leakage are used (9% more than in multi-port procedures; p:0.24) [40]. The lowest risk of hernias is with bladeless trocars and those less than 12 mm [2].

Additionally, there is a lower hernia incidence in patients in whom a transversal incision rather than with the vertical or midline incision is used for ports or extraction [41].

Another important aspect to take into consideration is which port sites fascia should be closed at the end of the surgery. The reported literature states that 86.3% of port site hernias occur when ports equal or larger than 10 mm are used, incisional hernias in port less than 8 mm are uncommon (less than 3% of the cases) [39]. As a result, all ports 10 mm or larger should be closed at the end of the operation, to avoid port site hernias.

When the fascial closure of the ports is carried out, it is best carried out with non-absorbable suture, with closure in a continuous fashion preferably over a non-continuous one. The amount of tissue and travel between stitches should be small, rather than large (more than 10% decrease on incidence when compared; $p < 0.001$) [41].

Final Consideration

Obtaining safe abdominal access, pneumoperitoneum, and proper port placement, without complications, are key to a successful robotic surgery. With the appropriate training and experience, potential complications can be avoided, and if they do occur, can be identified and managed immediately with little morbidity for the patient.

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47 Complications of Robotic Instrument Malfunctions

Ziho Lee and Daniel D. Eun

Introduction

A robotic instrument malfunction refers to a defect in a robotic instrument that limits its normal function. Fortunately, robotic instrument malfunctions are rare, and occur in 0.25–1.1% of urologic robotic surgeries [1, 2]. However, it is critical for the surgeon to be knowledgeable about robotic instrument malfunctions as they may compromise the surgeon's ability to safely complete an operation and adversely affect clinical outcomes. For example, robotic instrument malfunctions may increase operating room times, cause operating room delays, and lead to iatrogenic injuries. Despite this, the literature regarding robotic instrument malfunctions is unfortunately limited.

A review of every possible robotic instrument malfunction and their potential complications is beyond the scope of this chapter. Rather, our approach to discussing robotic instrument malfunctions involves categorizing them into two major types and reviewing their risk factors, prevention, diagnosis and treatment. Herein, we categorize robotic instrument malfunctions as mechanical or electrical. A mechanical instrument malfunction refers to a physical defect that inhibits normal range of motion and/or function. An electrical instrument malfunction refers to arching, when an electrical current deviates from its intended course.

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EndoWrist® Instrument Overview

Currently, the da Vinci® (Intuitive Surgical, Inc., Sunnyvale, USA) surgical system is the only surgical system that is readily available and utilized in urologic robotic surgery. Consequentially, our discussion of robotic instrument malfunctions focuses on EndoWrist® (Intuitive Surgical, Inc., Sunnyvale, USA) instruments, which are the only instruments compatible with the da Vinci® surgical system.

The major components of EndoWrist® instruments are shown in Figs. 47.1 and 47.2. The instrument housing (Figs. 47.1a and 47.2a) is the portion of the instrument that interfaces with the robotic arm, and it allows the bedside assistant to engage and disengage the instrument from the robotic arm. Instruments capable of delivering monopolar or bipolar energy will have connectors located on the instrument housing. On the instrument housing portion of each robotic instrument, there are a series of discs that interface with the robotic arms (Figs. 47.1b and 47.2b). These discs connect to cables that run from the instrument housing to the instrument shaft, wrist and end effector. This intricate pulley system allows the surgeon to transmit movements to the

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_47

instrument from the master controls at the surgeon console. The shaft (Figs. 47.1a and 47.2a) is the portion of the instrument that allows the instrument to be introduced into the body through a port. It acts as a rotating arm that connects the instrument housing to the wrist. The wrist (Figs. 47.1a and 47.2a) is the portion of the instrument that enhances surgical dexterity compared to traditional laparoscopic instruments. The end effector (Figs. 47.1a and 47.2a) is the portion of the instrument that provides its specific function. For example, depending on its desired function, the end effector may be used to grasp, dissect, cut and suture tissue; and apply electrocautery, clips and staples.

Mechanical Instrument Malfunctions

Mechanical instrument malfunctions result in restrictions in range of motion and limitations in the intended function of an instrument. The wrist and end effector are the most commonly reported sites of mechanical instrument malfunctions. Friedman et al. retrospectively reviewed all reported robotic instrument malfunctions in the Manufacturer and User Facility Device Experience (MAUDE) database, a publically accessible directory of medical device-related adverse events that is maintained by the United States Food and Drug Administration, between January 2009 and December 2010. The investigators found that 285/565 (50.4%) of all reports were mechanical malfunctions at the wrist and end effector [1].

Mechanical defects at the end effector will limit the intended function of the instrument. End effectors with articulating jaws, such as grasping retractors, scissors, and needle drivers, are particularly susceptible to mechanical malfunctions. For example, the tool tips may bend or break, the articulating jaw may become difficult to open or close, and various pieces of the end effector may fall off into the surgical field. When bending of the tool tips occurs, the articulating jaws may become misaligned and inhibit the surgeon's ability to hold sutures, retract tissue, and cut with precision. Bending of the tool tips most often occurs as a result of improper instrument handling during the perioperative period, such as during sterile processing, storage, and aggressive intraoperative use. Although bent instrument tips are not commonly reported in the literature and were only noted in 2% of the wrist or tool tip complications in the aforementioned report by Friedman et al. [1] it is one of the most common instrument malfunctions that we encounter at our institution. As bent instrument tips are easily identified and corrected by replacing the instrument, we suspect that the majority of these instrument malfunctions are not reported.

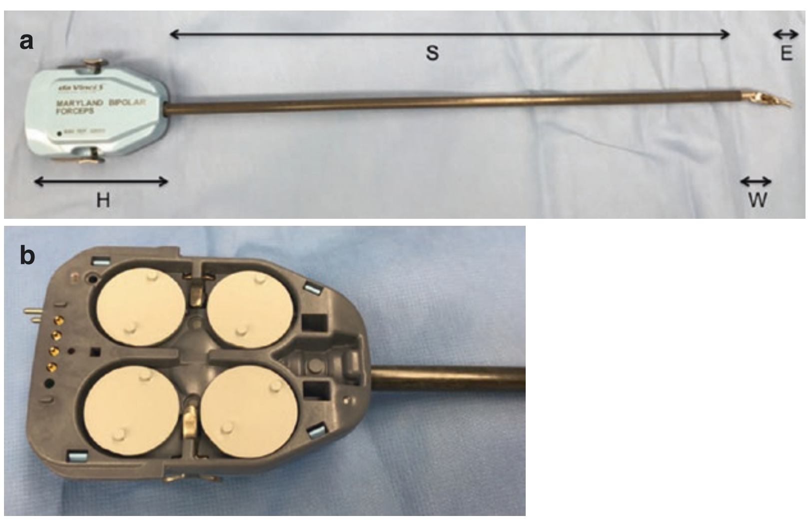

Fig. 47.1 Representative instrument used for da Vinci® S and Si. (**a**) *H* housing, *S* shaft, *W* wrist, *E* end effector. (**b**) Discs on back of instrument housing that transmit motions to wrist and end effectors via cables that run through the shaft

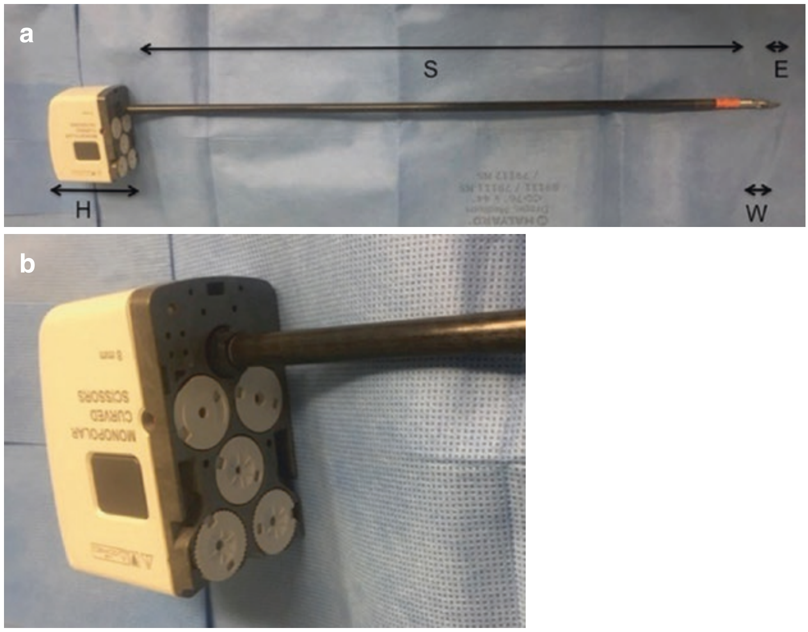

Fig. 47.2 Representative instrument used for da Vinci® Xi. (**a**) *H* housing, *S* shaft, *W* wrist, *E* end effector. (**b**) Discs on bottom of instrument housing that transmit motions to wrist and end effectors via cables that run through the shaft

When the articulating jaw becomes difficult to open or close, it can not only prevent the surgeon from adequately grasping or releasing tissue, but it can also make it difficult for the bedside assistant to remove the instrument from the patient's body. Park et al. described an instance during a robotic prostatectomy in which the bolt at the joint of a Prograsp™ (Intuitive Surgical, Inc., Sunnyvale, California, USA) forceps became loose and began to slide out. This resulted in diminished functionality of the Prograsp™ forceps, and the bedside assistant was unable to remove the instrument through the port. The bedside assistant was eventually able to remove the Prograsp™ forceps from the patient's body by removing the instrument and port together [2].

When a piece of an end effector breaks off into the surgical field, the surgeon must find the foreign object and remove it from the patient's body. In a separate report, Park et al. described an instance during a robotic prostatectomy in which one of the jaws of a needle driver broke off into the surgical field. The surgical team was able to find the fragmented instrument and remove it from the patient's body [3].

Mechanical malfunctions also occur at the shaft. In the aforementioned study by Friedman et al., the authors found that shaft malfunctions accounted for 76/565 (13.5%) of all reported instrument malfunctions [1]. Instrument shaft defects may be caused by instrument collisions with robotic ports and arms. While collisions with robotic ports generally cause trauma along the vertical axis of the shaft, collisions with robotic arms generally cause trauma along the perpendicular axis of the shaft. These collisions may cause peeling, bending, cracking, or breaking of the instrument shaft.

Mechanical defects may also occur at the cables that run from the instrument housing to the wrist and end effectors. When cables become frayed, broken, or displaced from pulleys, the instrument's range of motion becomes limited. In the aforementioned report by Friedman et al., cable malfunctions accounted for 29/565 (5.1%) of all reported instrument malfunctions, and most commonly occurred at the wrist and end effector [1]. Collisions are an important cause of cable malfunctions. Collisions between robotic instruments and robotic arms or ports outside of the patient's body can cause damage to the cables within the instrument shaft, while collisions between robotic instruments inside the patient's body can cause damage to the cables within the wrist and end effector. Also, applying excessive force on the robotic instrument is another important cause of cable malfunctions.

Risk Factors

As previously mentioned, instruments with articulating jaws are at greater risk for mechanical malfunctions compared to those without jaws. In a retrospective review of all instrument malfunctions that occurred during robotic surgeries performed at a single institution across six departments between July 2005 to December 2008, Kim et al. noted that 16/19 (84.2%) instrument malfunctions occurred in instruments with jaws [4]. One potential contributing factor to this is that the surgeon lacks tactile sensation and force-feedback during robotic surgery. As such, the surgeon may inadvertently apply excessive force onto the jaws or move the jaws beyond their range of motion, causing the instrument to break [3].

Reusing instruments increases the cumulative "wear and tear" of an instrument, which may increase the likelihood of mechanical malfunctions. In the previously cited case reports by Park et al., both mechanical instrument malfunctions occurred after repetitive use of the instrument. In the report in which the joint bolt of a Prograsp™ forceps became loose, the instrument had been used in three prior cases [2]. In the report in which one of the jaws of a needle driver broke off, the instrument had been used in two prior cases [3]. In order to maintain instrument quality control and minimize the risk of mechanical instrument malfunctions with cumulative uses, Intuitive Surgical pre-programs each instrument to a limited number of uses.

Technological advancements in robotic surgical systems and instruments have decreased the rate of mechanical instrument malfunctions. In a review of all robotic instrument malfunctions in the MAUDE database from 2003 to 2009, Lucas et al. examined whether robotic experience or technologic improvements decreased the frequency of reported instrument fragmentation. The year in which surgery was performed (2003–2006 vs. 2007–2009) was used as an indicator of robotic experience, while the robotic system (da Vinci® S versus da Vinci) used was used as an indicator of technologic improvement. As the incidence of instrument fragmentation when utilizing the da Vinci® was two times greater than that observed for the da Vinci® S, the authors concluded that technologic improvements resulted in a decreased incidence of instrument fragmentation [5]. This makes intuitive sense as newer robotic surgical systems and instruments were presumably developed by making improvements on the limitations noted in previous robotic surgical systems and instruments.

Prevention

Proper intraoperative set-up and handling of robotic instruments can prevent mechanical instrument malfunctions. Placing robotic ports with appropriate spacing can minimize both intra-corporeal and extra-corporeal instrument collisions. For the da Vinci® S and Si, ports should be placed at least 8 cm apart, and for the da Vinci® Xi, ports should be placed at least 6 cm apart. When engaging and disengaging instruments from a robotic arm, it is critical to make sure that the instrument wrists are straight to avoid unnecessary collisions between the instrument wrist and the robotic port. Prior to engaging a robotic instrument, the bedside assistant should straighten the instrument wrist by rotating the discs located on the instrument housing rather than manipulating the wrist directly. Prior to disengaging a robotic instrument, the surgeon should straighten the wrist using the master controls at the surgeon console.

Diagnosis

The importance of diagnosing mechanical instrument malfunctions as soon as they occur cannot be overemphasized. The reason for this is because prompt identification of a mechanical instrument malfunction can minimize the risk of operative complications that may be harmful to the patient. All members of the surgical team, including surgeons, trainees, bedside assistants, nurses and technicians, are responsible for diagnosing mechanical instrument malfunctions.

As mechanical instrument malfunctions can occur at any point during the perioperative period, maintaining a high index of suspicion is critical. In the preoperative and postoperative setting, the surgical team should inspect all instruments to identify any defective components. If a damaged instrument is found, it should be immediately replaced. Having a dedicated robotic surgical team that is trained in proper instrument handling and knowledgeable about normal instrument function may assist in the identification of mechanical instrument malfunctions in the preoperative and postoperative setting [6].

In the operative setting, as previously mentioned, the most commonly reported mechanical instrument malfunctions are at the wrist and end-effector [1]. It is unclear, however, whether mechanical defects at the wrist and end effector are actually more common than those at other locations, or if mechanical defects at the wrist and end effector are more readily identified as the surgeon is looking at the instrument tips for the majority of the operation. Regardless, the surgical team should remain vigilant in diagnosing mechanical malfunctions at all components of a robotic instrument.

Treatment

When a mechanical instrument malfunction is diagnosed, the surgeon should immediately stop surgery and manage the mechanical malfunction prior to progressing with the remainder of the operation. This will not only minimize the likelihood of intraoperative complications related to the mechanical instrument malfunction, but it will also allow for the remainder of the procedure to be performed in a safe manner.

In general, most mechanical instrument malfunctions may be managed by replacing the defective instrument. All instruments with a mechanical defect should be promptly replaced, regardless of how minor or inconsequential the mechanical malfunction may seem. Attempts at manually repairing a robotic instrument should be avoided as they can cause further deterioration of the instrument. Also, an instrument with a mechanical defect should not be used as it forces the surgeon to operate under sub-optimal conditions. In the aforementioned report by Kim et al. all instrument malfunctions were managed by replacing the instrument. Subsequently, all cases were successfully completed with no major complications attributable to instrument malfunctions [4]. As such, it is imperative that an extra set of robotic instruments be made available for each robotic procedure so that defective instruments can be readily exchanged for functional instruments without significant delays.

One potentially anxiety-provoking mechanical instrument malfunction is when a piece of the instrument breaks off into the surgical field (Fig. 47.3a, b). In such instances, the surgeon should immediately stop surgery to look for the broken piece, as further tissue manipulation may

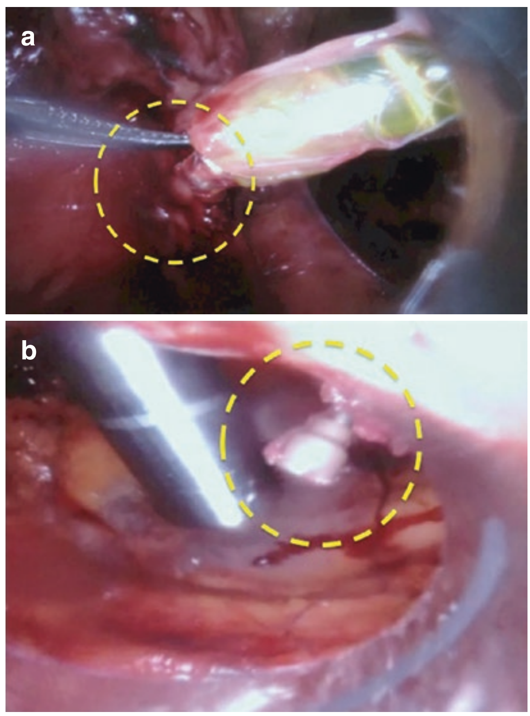

Fig. 47.3 (**a**) *Circle* highlights missing end effector on Permanent Cautery Hook. (**b**) *Circle* highlights missing end effector of Permanent Cautery Hook found on abdominal wall

push the broken piece deeper into the surgical field [7]. Although a broken instrument piece may be found by surveying the surgical field in most cases, [3] fluoroscopy may be utilized to assist with finding a broken instrument piece. When using fluoroscopy, images should be taken in the anterior-posterior and lateral planes to identify the precise location of the broken instrument piece. If fluoroscopy is not available or the surgeon is unable to find the broken instrument piece using fluoroscopic guidance, the surgeon must consider converting to an open procedure to find the broken instrument piece.

Electrical Instrument Malfunctions

An electrical instrument malfunction refers to arcing, when an electrical current deviates from its intended course. In the aforementioned report by Friedman et al., electrical instrument malfunctions occurred in 156/565 (27.6%) of all reported instrument malfunctions [1]. Arcing may result in unintended thermal damage to nearby tissues, as stray electrical currents have been shown to reach temperatures between 700 and 1000° C [8]. Although arcing is a potential complication in any instrument that utilizes electrocautery, it occurs more commonly in monopolar compared to bipolar instruments. In particular, hollow structures such as blood vessels, bowel, and ureter, are especially susceptible to stray electrical currents as thermal injuries may cause immediate or delayed perforation.

Electrical instrument malfunctions primarily occur due to insulation defects at the Tip Cover Accessory (TCA), an insulating sleeve that covers the metallic wrist of Monopolar Curved Scissors [9, 10]. The TCA prevents an electrical current from escaping from the instrument wrist, and allows the electrical current to be transmitted from the working tips of the Monopolar Curved Scissors. Mues et al. reviewed all TCA failures that occurred during robotic surgical procedures across six departments at a single institution from July 2008 to January 2009, and noted that arcing occurred in 12/454 (2.6%) cases and 3/12 (25%) of arcing incidents caused significant patient injuries. Iatrogenic injuries resulting from electrical instrument malfunctions included damage to the external iliac vein, small bowel, and ureter [10]. In a case report of a robotic radical prostatectomy by Lorenzo et al., arcing from TCA failure resulted in perforations to the right obturator and external iliac veins. On inspection of the TCA, the authors noted two 1 mm holes [9].

Electrical instrument malfunctions may also occur due to insulation defects along the instrument shaft. Mendez-Probst et al. evaluated instrument insulation defects in an *in vitro* study of 37 robotic instruments that had reached the end of their lifecycle The investigators noted that all 37/37(100.0%) instruments leaked electrical energy from a location other than the end effector. Furthermore, as there were no visible insulation defects in any of the studied instruments, microscopic insulation defects may be an important cause of electrical malfunctions [8]. This is consistent with reports evaluating electrical instrument malfunctions in traditional laparoscopic surgery that have suggested that visually screening instruments for insulation failure is limited [11, 12] and associated with only 10% sensitivity [12].

Risk Factors

Prolonged intraoperative use of monopolar instruments may increase the risk of insulation defects in the TCA. In the previously mentioned report by Mues et al., all TCA failures occurred after 2 h of intraoperative use and the majority of macroscopic insulation defects occurred at the junction of the TCA and the instrument shaft. Given this finding, the authors now regularly change TCAs from Monopolar Curved Scissors after 2 h of intraoperative use [10].

Similar to mechanical malfunctions, increasing instrument usage may make an instrument more susceptible to electrical malfunctions. In the aforementioned study by Mendez-Probst et al., all robotic instruments that had reached the end of their lifecycle demonstrated leaking of electrical energy. As the authors only evaluated the robotic instruments at the end of their lifecycle and there were no intraoperative complications related to instrument insulation failures during the active portion of their lifecycle, the precise timing of the insulation defect was not able to be determined. Nevertheless, the results of this study suggest that all instruments will have microscopic insulation defects at the end of their lifecycle [8].

Older, first-generation TCAs are associated with a higher risk for arcing compared to newer, second-generation TCAs. Second-generation TCAs have been available since July 2012, and have largely replaced first-generation TCAs. Engebretsen et al. compared insulation defects between 36 first-generation TCAs and 40 second-generation TCAs that had previously been used in a single urologic or gynecologic robotic surgery. Under light microscopy, defects ranging in size from 0.5 to 2.75 mm were noted in 14/36 (39%) first-generation TCAs, while only superficial scratches were noted in 10/40 (25%) of second-generation TCAs. Furthermore, using an *ex vivo* porcine model, arcing occurred in 12/36 (25%) first-generation TCAs and 0/40 (0%) second-generation TCAs ($p < 0.001$). During assessment of arcing in first-generation TCAs, the investigators noted that extreme wrist angulation and higher power settings were associated with shorter time to insulation failure [13].

Prevention

Similar to the prevention of mechanical instrument malfunctions, proper intraoperative set-up and handling of robotic instruments can minimize the risk of electrical instrument malfunctions. As such, instrument wrists should be straightened prior to engaging and disengaging instruments with robotic arms, and the ports should be placed with adequate spacing between the ports. Given the importance of TCA in preventing arcing, proper intraoperative handling of the TCA is critical. TCAs should be appropriately applied to a Monopolar Curved Scissors using the prepackaged TCA applicator. In all cases, the TCA should cover the entirety of the instrument wrist while leaving the tips of the end-effector uncovered. Also, it is important to maintain the electrocautery power settings below the insulating capacity of the TCAs. In this regard, Intuitive Surgical has recommended that the power settings be maintained below 3 kV. Despite this, as TCA failures may still occur while adhering to the manufacturer recommended power settings, [10] surgeons should use the lowest power setting possible for the short amount of time necessary in order to achieve the desired effect.

Diagnosis

The previously discussed principles regarding the prompt diagnosis of mechanical instrument malfunctions are also pertinent to the diagnosis of electrical instrument malfunctions. However, diagnosing electrical instrument malfunctions, may present a unique challenge as they may be difficult to identify. Although arcing may result in instantaneous thermal injury, it may also result in delayed necrosis with no immediately noticeable tissue injury. This is particularly true in hollow structures such as blood vessels, bowel, and ureter where a single stray current can lead to perforation 3–15 days postoperatively [8, 14]. Furthermore, in the previously mentioned report by Engebretsen et al. in which 12/36 (33.3%) of first-generation TCAs demonstrated arcing on ex vivo testing, there were no arcing incidents noted intraoperatively during clinical use [13]. One possible explanation for this is that the insulation defects in the first-generation TCAs could have been out of the field of view during surgery and caused arcing that was not noticeable. For example, TCA insulation defects could have been on the surface that faced away from the surgeon, making arcing incidents harder to identify (Fig. 47.4).

Treatment

Just as with mechanical instrument malfunctions, when an electrical instrument malfunction is diagnosed, the surgeon should immediately pause surgery and manage the electrical malfunction prior to progressing with the remainder of the

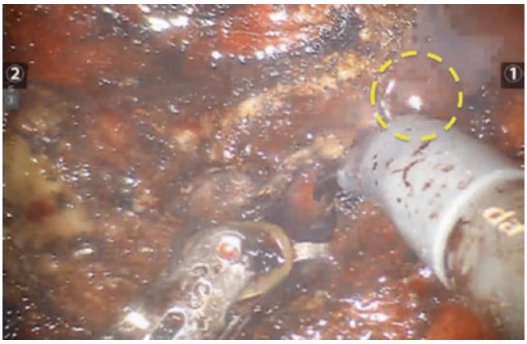

Fig. 47.4 *Circle* highlights arcing secondary to insulation defect on surface of TCAs facing away from surgeon

operation. For instruments that do not utilize a TCA, the instrument should be removed from the robotic arm and replaced. For instruments that utilize a TCA, the surgical team should attempt to differentiate insulation defects at the TCA from those at the instrument itself. This involves removing the robotic instrument from the robotic arm and carefully inspecting the TCA and instrument shaft. Insulation defects at the TCA may be treated by replacing the TCA, while insulation defects at the instrument may be treated by replacing the instrument. When the precise location of the insulation defect is unclear, which occurs when there are no macroscopic defects in the TCA and instrument shaft, both the TCA and the instrument should be replaced. Microscopic defects are especially concerning because stray currents emanating from microscopic defects have a higher current density than those emanating from macroscopic defects [11].

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48 Complications of Robotic Oncologic Renal Surgery

Andre Luis de Castro Abreu, Tania Gill, and Giovanni Cacciamani

Radical (RN) or partial nephrectomy (PN) are standard treatment for renal masses, with partial nephrectomy pursued whenever feasible for small renal masses. Most recently, robotic partial nephrectomy (RPN) and robotic radical nephrectomy (RRN) have gained favor as they offer oncologic outcomes similar to their open surgical counter-part, but with benefits of less blood loss, quick recovery, less complications and similar functional outcomes [1–3]. In fact, RPN is the most common PN approach since 2012 and, currently, it is estimated that about 60% of PN in the USA are performed robotically. Nowadays, in centers with adequate expertise, indications for RPN are the same as for OPN; furthermore, contraindications for RPN are more surgeon- and patient-related, rather than tumor-related. As such, given adequate robotic expertise, in 2017, if a patient is deemed to be a candidate for OPN, he/she is also typically a candidate for RPN, thus delivering the considerable benefits of minimally invasive surgery. The number of RRN has also consistently increased and most recently, reports have shown safety and feasibility for RRN and robotic inferior vena cava (IVC) thrombectomy (RIVCT), as such, expanding the indications of the robotic approach [4].

RN, PN and IVCT are major operations and, as such, are associated with complications (Tables 48.1, 48.2, and 48.3). Herein, we present, specific complications related to RRN, RPN and RRN-RIVCT surgery and tips for prevention and management. Complications not specific to RRN, RPN and RRN-RIVCT surgery, such as those deriving from patient positioning, port-placement, instrument insertion, or non-surgical issues are not a subject of this chapter and have been described elsewhere in this book. We divide complications into intra- and post-operative categories and address the practical aspects of RRN, RPN and RRN-RIVCT surgery.

Overall, the prevention of complications begins with a detailed understanding of important landmarks and meticulous surgical planning. This is best achieved by a CT scan-based evaluation of the kidney, tumor and renovascular anatomy by the surgeon. In this context, we believe that the image quality afforded by a renal protocol CT scan is superior to MRI scan. At our institution, we use 0.5–1 mm slice-thickness CT scan images, with oral and intra-

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_48

venous contrast. Arterial, parenchymal, venous and excretory (delay) phases are generated for evaluation. Close collaboration with a specialized uro-radiologist is advisable for detailed imaging interpretation. If available, a 3D reconstruction of the tumor, intra-renal arterial tree and kidney in case of RPN, IVC thrombus detailed in case of RRN-RIVCT and 3D–printed models can facilitate better 3D understanding of the anatomy [5, 6].

Important information for RN are as follows:

- Understanding the relationship of the kidney and its vasculature with: duodenum, vena cava, hepatoduodenal ligament and liver for right-sided nephrectomy; aorta, lumbar veins, renal vein tributaries (adrenal and gonadal veins), superior mesenteric artery, splenic vessels, spleen, pancreas and stomach for left-sided nephrectomy
- Important implications for RPN are as follows:
  - Patient characteristics: body habitus; body mass index, perinephric fat measurements and adhesiveness.
  - Renal vessels: number of arteries and veins, arterial tree branching, tumor-feeding arteries, relation between the tumor, renal artery and renal vein.
  - Tumor: size, clinical stage, location (anterior, posterior, lateral), relation to polar lines (upper, mid or lower pole), endophytic/exophytic ratio, proximity to the hilum, closeness to collecting system, tumor contact surface area (CSA).
  - Collecting system: ureteral course, endophytic/exophytic ratio of the renal pelvis.
  - Nephrometry scoring systems such as R.E.N.A.L [7], PADUA [8], Renal Tumor Contact Surface Area (CSA) [9], C-Index [10], Adhesive Probability Score [11], Renal Pelvic Score [12] are useful tools for precise anatomic understanding and sophisticated surgical pre-planning for PN based on individualized, patient-specific radiologic data. This helps to predict and minimize complications related to PN surgery (Table 48.4). Nomograms are also available: http://lbs.fccc.edu/nomograms/main.php?nav=3&audience=1
- Important implications for RRN and RRN-RIVCT are as follows:
  - Perirenal hilar lymph node involvement, peri-IVC inflammation and cancer invasion.
  - Collateral vessels.
  - Extension of the tumor thrombus (thrombus level), thrombus diameter and IVC flow.
  - Occurrence of bland thrombus

Table 48.1 Literature review: complications on robotic partial nephrectomy

Author	Year	Cases	Complication rate (%)	Bleeding (%)	Urine leak (%)	Other
Gettman [33]	2004	13	2 (8%)	0 (%)	0 (0%)	1
Caruso [34]	2006	10	3 (30%)	2 (20%)	0 (0%)	2
Kaul [35]	2007	10	2 (20%)	1 (10%)	1 (10%)	0
Aron [36]	2008	12	4 (33%)	0 (0%)	0 (0%)	4
Deane [37]	2008	11	1 (9%)	1 (9%)	0 (0%)	0
Rogers [38]	2008	11	2 (18%)	0 (0%)	2 (18%)	0
Rogers [39]	2008	148	9 (6.1%)	1 (0.6%)	2 (1.2%)	6
Wang [40]	2009	40	8 (20%)	3 (7.5%)	1 (2.5%)	4
Michli [41]	2009	20	3 (15%)	0 (0%)	0 (0%)	0
Ho [42]	2009	20	0 (0%)	0 (0%)	0 (0%)	0
Benway [43]	2009	129	11 (8.5%)	4 (3%)	3 (2.3%)	4
Patel [44]	2010	71	10 (14%)	4 (5.6%)	2 (3%)	4
Scoll [45]	2010	100	5 (5%)	0 (0%)	2 (2%)	3
Petros [46]	2010	83	5 (8%)	1 (1.2%)	2 (2.4%)	2
Ficarra [47]	2012	49	15 (26%)	n/a	n/a	n/a
Gupta [48]	2013	17	1 (6%)	0	1	0

Table 48.2 Literature review: complications on robotic radical nephrectomy

Author	Year	Cases	Tumor size, cm	Conversion to open	Overall complication rate	Overall intraoperative complication rate	Overall postoperative complication rate	Clavien-Dindo <3	Clavien-Dindo ≥3
Rogers [49]	2008	35	–	n/a	–	–	0%	–	–
Hemal [50]	2008	15	6.7	6%	5 (33%)	2 (13%)	3 (20%)	3 (20%)	–
Boger [51]	2010	13	4.8	n/a	4 (30%)	2 (15%)	2 (15%)	0%	2 (15%)
Lorenzo [52]	2011	38	–	n/a	–	–	–	–	–
White [53]	2011	20	7.6	n/a	2 (10%)	–	2 (10%)	2 (10%)	0%
Dogra [54]	2012	23	6.3	13%	8 (34%)	3 (23%)	5 (21%)	5 (21%)	0%
Khanna [55]	2012	11	5.2	0%	3 (27%)	0%	3 (27%)	3 (27%)	0%
Wang [56]	2015	17	5.8	0%	2 (11%)	1 (6%)	1 (6%)	–	–
Gill [57]	2015	16	9.1	0%	2 (15%)	2 (6%)	1 (6%)	1 (6%)	0%
Petros [58]	2015	101	8.2	0%	5 (5%)		5 (5%)	0%	5 (5%)
Abaza [59]	2016	32	9.5	0%	8 (25%)	1 (3%)	7 (22%)	7 (22%)	0%
Davila [60]	2016	15	–	6%	–	–	–	–	–
Homlers [61]	2016	76	5.1	9%	5 (6%)	4 (5%)	1 (1%)	–	–

Published series between 2000 and 2016 (Pubmed, Scopus, Web of Science) reporting Robotic Radical Nephrectomy with 10 or more patients

Table 48.3 Literature review: complications on robotic radical nephrectomy and *Inferior Vena Cava Thrombectomy*

Author	Year	Cases	Tumor size, cm	Conversion to open	Overall complication rate, n	Intraoperative complication rate, n	Overall postoperative complication rate, n	Clavien dindo <3	Clavien dindo ≥3
Abaza [62]	2010	5	10.4	0	0	0	0	–	–
Wang [56]	2015	17	5.8	0	2	1	0	–	–
Ball [63]	2015	2	8	0	0	0	–	–	–
Gill [57]	2015	16	9.1	0	2	1	1	1	0
Abaza [59]	2016	32	9.5	0	8	1	7	7	0
Kundavaram [26]	2016	4	9.5	0	3	0	3	2	1

Published Series between 2000 and 2016 (Pubmed, Scopus, Web of Science) reporting Robotic Radical Nephrectomy with Inferior Vena Cava Thrombectomy

Table 48.4 Nephrometric scores and complication for robotic partial nephrectomy

Nephreometric score	Parameter analyzed	Grade	Overall complications (%)
R.E.N.A.L. [7, 64]	Radius (max diameter in cm), Exophytic/endophytic properties, Nearness to the collecting system, Anterior/posterior, Location relative to the polar line	Low complexity	3.4%
		Moderate complexity	5.4%
		High complexity	15.9%
P.A.D.U.A [8]	Radius (max diameter in cm)	Anterior low (6–7)	2.0%
	Exophytic/endophytic	Anterior moderate (8–9)	40.0%
	Location, sinus line	Anterior ≥ high (≥ 10)	50.0%
	Renal rim	Posterior low (6–7)	5.6%
	Renal sinus	Posterior moderate (8–9)	32.0%
	Collecting system	Posterior ≥ high (≥ 10)	61.5%
C-index [10, 65]	Tumor centrality	Low (score 2.5 or greater)	14.7%
		High (score less than 2.5)	29.0%
Contact surface area [9]	Tumor-parenchyma contact surface area	< 20 cm^2	19.2%
		≥ 20 cm^2	34.5%
Adhesive Perinephric fat (APF) score [11]	Presence of APF	None stranding (0 pt)	n/a
		Mild/Moderate stranding (2 pt)	n/a
		Severe stranding (3 pt)	n/a
Renal pelvic score [12]	Morphology of renal pelvis	Intraparenchimal	75% (urine leak)
		Extraparenchimal	6.5% (urine leak)

Intraoperative Bleeding and Vascular Injury

Intraoperative bleeding during PN can originate from the PN resection bed, renal hilar vessels, lumbar veins, or less likely, from vena cava or aorta. However, for larger tumors being managed by RRN and RIVCT, major bleeding may also occur from collateral vessels, IVC, short-hepatic veins, adrenal vein and the vena cava or aorta.

Preventing Intraoperative Reno-Vascular Bleeding

Understanding the inter-relationships of the tumor vis-à-vis reno-vascular anatomy is crucial for uneventful nephrectomy. Firstly, wide medial mobilization of the colon (and duodenum for right-sided tumors) to completely expose the kidney and IVC, and identification of the renal artery and vein and their tributaries is mandatory. The ureter should be identified and retracted laterally by the robotic fourth arm, and the psoas muscle is identified posteriorly. Renal vein and artery are dissected and vessel loops applied. Careful dissection of the tissue in layers is advised.

Managing Intraoperative Reno-Vascular Bleeding

In case of intra-operative vascular bleeding, it is important to keep calm, communicate with the operative team and anesthesiologist, call for any needed assistance, and ensure blood is available for transfusions if necessary. The surgeon needs to expeditiously make a decision whether he/she has the necessary skill-level and experience to control the bleeding robotically, or whether open conversion is necessary. Remember: open conversion is NEVER a surgical "defeat", rather it is the smart and responsible decision to ensure patient safety, which must always be the paramount consideration.

Important measures to control bleeding are as follows: Increase the pneumo-peritoneum to 20 mmHg. Insert a mini-lap sponge (4″ × 18″

dimension) to compress the bleeding site. Suctioning should be judicious to clear the field, and also to compress the site. Change instruments for graspers and/or needle-drivers, as soon as possible, if necessary. Place additional ports if needed. After identification of the bleeding site, it should be controlled by applying weck clips or suturing. A critical maneuver in this regard is having a "rescue stitch" always ready on the back-table for prompt management of hemorrhage. The "rescue stitch" is a 15 cm long (6″), 2.0 Vicryl® suture on a CT 1 needle, with a Hem-0-lock® clip tied to its end [13]. This stitch is easy to handle, as it is malleable (does not have "memory"), and the weck clip tied to the end allows for knotless bleeding control by merely pulling on the stitch.

Preventing PN Resection Bed Bleeding

Different factors impact PN resection bed bleeding, such as: mass diameter, depth of penetration in the renal parenchyma and tumor contact surface area [14]. To prevent this complication, it is important to:

- Have an excellent 3-D understanding of renal mass characteristics pre-operatively.
- Have renal vessels isolated with vessel loops, for (re)clamping
- Mobilize the kidney properly. During PN surgery, "always mobilize the kidney more than you think it would be necessary", especially for posterior or upper pole tumors.
- First clamp the renal artery, then the renal vein.
- In case of selective/super-selective clamping, consider using infra-red "Firefly" technology to ensure appropriate arterial control of the area of interest prior to tumor resection [15].
- If larger intra-renal vessels in the renal sinus are encountered during tumor resection, they can be pre-clipped (Weck clip) prior to transecting.
- Keep the field clean to allow for good visualization during tumor resection.
- Start suturing the inner layer of the PN defect during the reconstruction/hemostasis. This step is very import to prevent bleeding from deep, difficult-to-reassess, resection sites after the clamp is released. There are many ways to suture the PN resection bed. We prefer the horizontal mattress suture technique, which hemostatically compress the PN bed, without closing it over, thereby still allowing excellent visualization of the entire PN bed at all times. Usually 1–2 mattress sutures are used for hemostasis prior to unclamping.
- "Early-unclamping" technique: Besides the advantage of reducing warm ischemia time (WIT), the early-unclamping technique (first unclamp renal vein, then renal artery) provides direct visualization of any residual bleeding, which can then be pin-point suture-controlled.
- To physically clear the PN resection bed of any overlying blood clots and to identify any residual parenchymal bleeders, we recommend strong irrigation rather than suctioning; the latter can cause parenchymal abrasions leading to additional oozing.
- Apply hemostatic matrix sealants (Floasel®, Surgicel®) if necessary [16].
- Complete the renorraphy using the sliding-clip technique, which provides superior closing tension.
- Decrease the pneumo-peritoneum and evaluate for bleeding.
- Place a drain.

Managing PN Resection Bed Bleeding

If during tumor resection, the bleeding is persistent:

- Irrigation could be more appropriate than suctioning, as mentioned.
- Check if the bulldog clamps are well applied or add an additional clamp on the artery.
- Clamp the vein if the vein was not clamped upfront; conversely, take off the renal vein clamp if it has been clamped, so as to allow unimpeded venous drainage.

- Perform further dissection and look for accessory renal arteries that may have been missed.
- If there is persistent bleeding after a meticulous renorraphy as described above, re-clamp the hilum and apply additional stitches and hemostatic matrix to close the parenchymal defect. A completion nephrectomy due to continued parenchymal hemorrhage after renorrhaphy is a very rare event.
- Bottom line: do not conclude the operation until you have absolutely perfect hemostasis. Even a little bit of renal parenchymal oozing is unacceptable.

Minimizing Chances of Post-PN Bleeding

Inspection of the renal fossa, renal hilum, adrenal vein and adrenal fossa should be meticulously performed. Decreasing pneumoperitoneum can be a valuable maneuver. Most often, the bleeding post PN is from the kidney tumor resection bed.

Superior Mesenteric Artery Injury

Due to its anatomic location in close proximity to the left renal artery, injury to the superior mesenteric artery (SMA) during the left renal surgery is a rare, but potentially catastrophic, complication. SMA injury can rarely occur with large tumors or bulky hilar lymphadenopathy, wherein the SMA may be mistakenly ligated instead of the left renal artery. Failure to recognize and immediately repair the SMA results in ischemic bowel and mortality. Immediate evaluation of signs or symptoms of intestinal ischemia is mandatory [17].

Managing Superior Mesenteric Artery Injury

To avoid SMA injury, it is important to keep in mind that the left renal artery is directly posterior to the renal vein. Therefore, during transperitoneal left RRN or RPN, any artery identified anterior to the renal vein during hilar dissection, might possibly be the SMA. In this case, before progressing with the operation, ensure that the artery is indeed directly supplying the left kidney. If SMA injury is recognized intraoperatively, it should be repaired immediately. A vascular surgeon must be consulted.

Post-Operative Bleeding

The same precautions and proper surgical technique used to prevent intra-operative bleeding are applicable to post-operative bleeding as well.

Preventing Post-PN Bleeding

Particularly important is to avoid "deep" passages of the needle which can traumatize the deeper (and larger) intra-renal vessels, and to always "follow the curve" of the needle during renorraphy suturing. This maneuver is critically important to avoid laceration of unseen, deeply-located, intra-parenchymal vessels and causing parenchymal fracture lines, with subsequent bleeding into the renal parenchyma. This could also lead to renal artery pseudo-aneurysm formation and delayed postoperative bleeding [18].

Managing Early Postoperative Bleeding

Immediate or early postoperative bleeding has been reported in up to 4.3% of RRN and 8.1% of RPN (Tables 48.1, 48.2, and 48.3). Hemorrhage post robotic kidney surgery can be a life-threatening event, as such, should be promptly recognized and treated. Hemodynamic instability, decreasing hematocrit, low urine output and abdominal distention represent signs of post-operative hemorrhage. High and bloody drain output makes hemorrhage evident. Usually the source of bleeding is the resection bed, however, it can be from other areas including renal hilum, adrenal gland, lumbar veins, epigastric vessels and others.

Following RRN, if hemorrhage is suspected, hemodynamic stabilization and fluid resuscitation, if necessary, are the priorities. Transferring the patient to the Intensive Care Unit (ICU) for monitoring and stat blood transfusion(s) should be considered. If the patient responds to initial maneuvers, and vitals signs and hematocrit stabilize and urine output is reestablished, continue monitoring in the ICU. In case hemodynamic instability persists, surgical exploration is required. Usually open exploratory laparotomy is needed for clot evacuation and bleeding control. For selected cases, and depending on surgeon experience, robotic or laparoscopic re-exploration can be attempted.

Following RPN, we recommend renal angiography with selective angioembolization of the bleeding site(s) as the critical initial step in management after fluid resuscitation. Typically angio-infarction allows definitive diagnosis, and control, of the renal bleeding. If the bleeding is from the PN resection bed and cannot be properly controlled, repeat angio-embolization may be considered. Rarely, completion nephrectomy may be necessary.

Managing Delayed Post-PN Bleeding

In case bleeding occurs a few days or weeks post PN, it likely represents a renal artery pseudoaneurysm. In fact, renal artery pseudoaneurysm is an uncommon complication and is reported in 1.7% of patients following LPN. Usually the patient presents 15 days or more post-PN with gross hematuria, flank pain and decreased hematocrit. CT scan is diagnostic and percutaneous angioembolization is successful in most cases [19].

Intraoperative Tumor Violation

Preventing Tumor Violation During RPN

- Proper kidney mobilization and de-fatting the adjacent normal kidney are essential. On occasion, de-fatting the kidney can be challenging and demanding [11]. It is essential to maintain fat over the tumor and only defat the non-tumor part of the kidney. This is important not only for en bloc excision for achieving negative oncologic margins in patients with unsuspected pT3a disease, but the overlying peri-tumoral fat also provides a nice handle for retracting the tumor away from the PN bed, thus technically facilitating the actual tumor resection.
- Intraoperative laparoscopic ultrasound (US) probe is necessary to obtain important real-time information on the renal mass, such as: size, intra-renal depth, margins, blood supply and relationship with surrounding structures.
- The tumor should be scored, under US guidance and robotic visualization, with adequate margins.
- Handle the renal mass minimally and carefully, grasping only the fat maintained on top of the tumor. Carefully incise the renal parenchyma maintaining a rim of normal parenchyma around the tumor to reduce risk of positive margins (PMs).
- Keep the field clean using judicious suction/irrigation. Use sterile water for irrigation.
- Continuously assess and re-assess the tumor margin as you are carefully excising the tumor; tumor excision should be performed slowly and meticulously, always looking for any possible tumor violation.
- Infrared intraoperative optical imaging with Firefly® may, on occasion, provide some information differentiating renal tumors from surrounding normal parenchyma [20].

Managing Tumor Violation During PN

If a small tumor violation is identified during tumor excision, immediately reassess the margins robotically, back-up, and perform a 1 cm deeper, wider resection. If gross tumor violation has occurred and spread grossly in the PN bed, radical nephrectomy and complete resection of the renal fossa contents, including all perinephric fat and adjacent parietal fat, psoas fascia and peritoneum, may be necessary. If the PN is being done for imperative or absolute indication, consider open conversion to save the kidney. The renal fossa should be irrigated with distilled water; sterilization of the area using a small sponge dipped in dilute povidone-iodine and applied directly and strictly to the renal fossa only may be considered; however, beware that this can cause chemical peritonism if it comes in contact with bowel serosa, so be extremely careful. If positive margins are found on frozen section or on intraoperative pathologist's assessment, deeper and or wider resection should be considered. Overall, tumor violation during PN should be, and is, a rare event.

Postoperative Urine Leak

Urine leak is a not uncommon complication of RPN, with an incidence ranging from 1.2% to 18 (Table 48.1). Urine leak may be defined as drainage greater than 50 mL per day, for longer than 1 week, with fluid consistent with urine [21]. Violation and an incomplete repair of the renal collecting system could lead to postoperative urine leak.

Preventing Urine Leak Post-PN

Understanding the renal mass relationship with the pelvi-caliceal system, and evaluating renal pelvis anatomy and the nephrometry scores help to pre-operatively identify patients at increased risk for post-operative urine leak [12, 22]. For those patients, an open-ended 5F ureteral catheter is placed cystoscopically just prior to the RPN. This catheter is secured to the urethral Foley catheter.

In case of urinary collecting system entry, it should be specifically repaired using 4–0 Vicryl® on a SH needle. A retrograde injection of highly dilute methylene blue through the ureteral catheter facilitates identifying the collecting system injury, and also confirming water tightness post-repair [23]. The ureteral catheter is kept in place along with the Foley catheter to ensure low pressure urinary drainage from the collecting system, and is usually removed on post-operative day 2.

A 19F Blake drain is placed next to the PN area and secured to the skin. This drain is usually removed when the output is low and the measurement of creatinine level on the fluid is compatible with serum. It is important avoid thermal energy during the dissection close to the collecting system and the ureters. If ureteral injury is recognized intraoperatively, it should be repaired (4–0 Vicryl® on a SH needle) and a double J stent should be placed.

Managing Urine Leak Post PN

- Post-operatively, when the drain is in place, the urine leak can be managed by:
  - Leaving the drain under gravity, without suction, and carefully shortening the drain by a few centimeters. These maneuvers would be efficient in case the drain is propagating the leak.
  - Placing "double J" ureteral catheter and a urethral Foley to facilitate drainage of urine from the collecting system to create a low-pressure system may, although not always, promote healing of the defect.
- If the drain was not placed and there is a symptomatic collection on postoperative image, a 'pig tail' catheter should be percutaneously placed in the collection by interventional radiology. If the urine leak persists, then a "double J" ureteral catheter and a urethral Foley should be considered in addition to the 'pig tail'.

Robotic Inferior Vena Cava Tumor Thrombectomy (RIVCT): Minimizing Intraoperative Bleeding

In case of RRN-RIVCT, complete exposure of the IVC and its tributaries is imperative. In fact, in case of IVC thrombus the operation should be performed as a sequence: "IVC first, kidney last". For left-sided renal tumors with IVC thrombus, the operation should also follow the same sequence, as such; the patient is always positioned initially with left side decubitus to approach the

IVC. In case of level III or IV IVC thrombus, dissection and isolation of the hepato-duodenal ligament for subsequent Pringle maneuver should be considered. The IVC should be isolated and vessel-looped in a sequence as follows: infra-renal IVC, left renal vein, supra-renal IVC. Significant mobilization of the liver may be necessary for proper proximal IVC control and ligation of the short-hepatic veins and adrenal vein. Trans-esophageal echocardiogram, as well as laparoscopic ultrasound, provide valuable information on intra-operative thrombus level. The lumbar veins are ligated as necessary to isolate the IVC. Usually one or two lumbar veins are ligated. In around 30% of the cases there is one lumbar vein from the supra-renal IVC [24]. If the thrombus extends up to the diaphragm or into the superior vena cava/right atrium, thoracoscopy or mini-thoracotomy should be performed upfront for proximal control of the IVC [25].

Pre-operative renal artery embolization should be considered to pre-emptively minimize blood flow through collateral veins, to decrease IVC flow and enhance feasibility of the RRN-RIVCT procedure itself. Angtio-infarction can also be helpful in many instances because the renal vein may need to be ligated prior to the renal artery, in case of large tumors or bulky peri-hilar lymph nodes, precluding intraoperative arterial ligation upfront. Angio-embolization is usually carried out one day prior to operation. Flank pain or low-grade fever due to angio-infarction of the kidney may occur, but are usually well tolerated by the patients. Renal function deterioration related to contrast usage might be a concern, and therefore appropriate hydration should be performed.

The use of laparoscopic vascular staplers is helpful for safe and secure sealing of large peri-renal and renal veins. **A team approach is essential for success. Cardiothoracic surgeons and experienced open urologic oncologists should be available for prompt intervention.**

Minimizing Bleeding from IVC

Appropriate IVC exposure and dissection as previous discussed is fundamental for minimizing hemorrhage. Reconstruction of the IVC should be carefully performed with a running suture. We recommend 4–0 Gore-Tex® suture for IVC reconstruction, since Gore-Tex suture has less 'memory' than Prolene suture, and therefore is easier to manipulate intra-corporeally during robotic surgery.

After suturing/reconstructing the IVC, the tourniquet on the renal vein should be carefully loosened to allow for IVC filling and flushing out the air or small particulate matter that might have remained after saline/heparin irrigation. Once the IVC suture line is confirmed to be watertight, the proximal and distal IVC tourniquets can be loosened.

Preventing Tumor Violation During RPN-RIVCT

With increasing experience, our approach on how to manage the IVC thrombus has been modified. In our initial experience, we used to perform cavotomy, deliver the thrombus and wrap it in a laparoscopic sponge as an "en block" specimen with the kidney. Currently, we first completely control the thrombus-bearing IVC segment with Rummel tourniquets, and then staple the thrombus-bearing renal vein, thereby disconnecting the thrombus within the renal vein from the thrombus in the IVC. In this manner, the thrombus remains entrapped within the renal vein, and has no contact with the peritoneal cavity. Cavotomy is performed, the IVC thrombus that is delivered along with the IVC staple line which is excised en bloc, and the tumor thrombus specimen is immediately entrapped in an Endocatch bag, again avoiding local contact or spillage. IVC reconstruction can be performed without concern of inadvertent tumor violation/manipulation. If there is any concern for cancer invasion of the IVC wall, cavoscopy can be performed using a flexible cystoscope by the bed-side assistant through one of the trocars. In case IVC wall invasion is indeed confirmed, the involved IVC wall and margins are resected and bovine pericardial patch reconstruction is completed robotically [26].

Postoperative Lymphorrhea

If concomitant retroperitoneal lymph node dissection is performed, clip ligation of the lymphatics is mandatory to avoid lymphorrhea or chylous ascites [27]. If lymphorrhea is confirmed by fluid analysis (high HDL, high Cholesterol), low fat diet is the initial management; if lymphorrhea is persistent, total parenteral nutrition might be attempted. The use of Somatostatin to treat postoperative lymphorrhoea was reported in order to reduce intestinal absorption of fat and attenuate lymph flow in major lymphatic channels [28]. However, if there is no resolution with clinical management, surgical exploration should be considered.

Thoracic Complications

Thoracic incidental gas collections, namely, pneumothorax, pneumomediastinum or pneumopericardium may occur during a robotic renal surgery, and may infrequently represent a significant issue. Thoracic complications are mainly due to congenital causes or intraoperative pleural injuries.

Congenital Defects

During trans-peritoneal robotic renal surgery, the pneumoperitoneum can escape into the thorax via diaphragmatic defects, such as previous pleura-peritoneal canal or thinner areas of the diaphragm, which allows for CO2 to leak into the pleural spaces [29, 30].

Intraoperative Pleural Injuries

Pleural injuries may occur during port placement or during the tissue dissection. Pleurotomy may occur during kidney, liver or spleen mobilization. Most often, right-sided pneumothorax happens due to the grasper used to retract the liver cephalad. This grasps the diaphragm, which can potentially create small diaphragmatic injuries that ultimately lead to CO2 leak into the thorax due to high-pressure pneumoperitoneum. On the left side, diaphragmatic injury may occur during mobilization of spleen and the upper pole of the kidney [31]. Although not directly related to robotic renal surgery, central line placement may lead to intraoperative or postoperative pneumothorax.

Preventing Thoracic Complications

- Use appropriated pneumoperitoneum pressure setting.
- Avoid rigorous retraction of the diaphragm by the grasper when retracting the liver.

Managing Thoracic Complications

If pleural or diaphragmatic injuries occur and are recognized intraoperatively, the anaesthesiologist should be notified immediately to adjust ventilatory parameters, allowing the surgeon to complete the procedure and repair the pleural or diaphragmatic defect. Strict postoperative monitoring is necessary [31]. If a large, hemodynamically symptomatic pneumothorax is identified postoperatively, the initial treatment of choice is thoracic drainage, usually with a pigtail.

Post-operative Renal Failure and Trifecta on RPN

The primary reason to perform PN is to preserve the renal function. A recent concept is the Trifecta outcomes during robotic or laparoscopic partial nephrectomy that describes negative cancer margins, minimal renal function decrease and no urological complications [21]. Overall positive margin rate is low in the various PN case series, and complication rates improve with increasing experience, even for more complex cases (including tumor characteristics and patient comorbidity). As such, renal function decrease is the main driver of

Table 48.5 Modifiable and non-modifiable factors related to renal function following robotic partial nephrectomy and robotic radical nephrectomy with inferior vena cava thrombectomy

Modifiable	Non modifiable
Robotic partial nephrectomy	
• Preserve as much vascularized kidney parenchyma as possible • Perform, when possible, a minimal-margin partial nephrectomy, which maintains a sliver of normal parenchyma over the tumor, thus distinguishing it from straight enucleation, which is performed directly along the tumor capsule surface • If possible, perform early-unclamping or clamp-less RPN • Reduce ischemia time, however not at the cost of a meticulous tumor excision and meticulous renal reconstruction; the latter 2 issues must always take priority over ischemia time • Reduce operative time, reduce intra-operative hemorrhage • Pin-point suturing in order to avoid devascularizing the renal parenchyma	• Baseline renal function • Comorbidity (hypertension, diabetes, arteriosclerosis) • Tumor size and location can affect the amount of kidney preservation
Robotic radical nephrectomy + IVC thrombectomy	
• Judicious use of contrast on pre-operative angioinfarction • Optimize IVC clamping time • For left-sided thrombus, when possible based on vascular anatomy, control infra-renal IVC cephalad to the right renal vein and caudal to the left renal vein entry into the IVC	• Baseline renal function • Comorbidity (hypertension, diabetes, arteriosclerosis)

Trifecta outcomes. In order to prevent renal failure after PN, we have to take into consideration modifiable and non-modifiable factors (Table 48.5). Within those modifiable factors, surgical technique, including clamp-less PN, may eliminate ischemia, which is a major factor impacting postoperative renal function [32]. It has been shown that in the same Institution, distinguishing between 4 different period - discovery era, conventional hilar clamping era, early unclamping era, zero ischemia era—Trifecta outcomes occurred more commonly in the zero ischemia era (45%, 44%, 62% and 68%, respectively) [21].

Renal function preservation can be attempted for RRN-RIVCT by hydration, and judicious use of contrast during preoperative angio-embolizations. Reducing IVC clamp time is also beneficial. One unique technique that can be very helpful for left-sided IVC thrombectomy is the distal dissection of the IVC being performed proximal to the right renal vein and distal to the left renal vein. If feasible, this maneuver preserves right renal function, as the right renal artery and vein are unclamped throughout the entire operation.

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49 Complications of Robot-Assisted Radical Prostatectomy

Christian Wagner and Jorn H. Witt

Introduction

While there are numerous possible side effects of prostatectomy (no matter which approach, open, perineal, laparoscopic or robot-assisted) like urinary incontinence and erectile dysfunction, there are some more or less specific complications of the surgery that need to be addressed.

The lack of an accepted standardization for reporting complications concerning robot-assisted radical prostatectomy (RARP) leads to numerous different reports about types and incidences, which makes it difficult to summarize overall complication rates. In the available literature, the most common complications were perioperative hemorrhage/bleeding, blood transfusions, lymphoceles and anastomotic leakage.

Generally speaking, complications can be divided into intraoperative, postoperative, and technical complications and errors.

Unfortunately, in contrast to more emotionally positive topics, complications is a topic which is generally talked about and especially published about less frequently; one of the reasons may be the growing fear of medico-legal implications about “confession”. However, it is of crucial importance to not only talk about the possible complications, but also to give tips and tricks how to manage them—and, perhaps even better, how to avoid them in the first place.

Some of the surgical complications may appear to be “standard surgical complication”, like hemorrhage, but there are issues to it that go a little further.

Intraoperative Complications

Intraoperative Bleeding/Hemorrhage

Usually, due to Trendelenburg position during pelvic cases and the intraabdominal insufflation pressure, venous bleeding during RARP is quite little, especially venous oozing is less intense in comparison to open surgery. Sometimes, especially in case of inflammation, an increased tendency of general bleeding can be encountered, in this case the intravenous administration of tranexamic acid (at least in our experience) can be considered. However, when opening up veins of a larger diameter, like the puboprostatic plexus or the iliac vein, repair is necessary. Arterial bleeding in case of smaller branches of the prostatic arteries can usually be avoided by ligating or clipping them beforehand. Unlike upper tract surgery, major vessel injuries fortunately occur less often. An injury of the Iliac artery is quite uncommon, maybe because of the arterial wall thickness, or the

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_49

fact that it lies to the lateral borders of the surgical field. Avoiding major vessel injury can be achieved by applying only gentle traction on the structures, and being careful with electrocautery, bearing in mind that the insulation sheath of the instruments may break and thus lead into an electric current flowing to unwanted places. Also, one has to keep in mind the assistant has to be able to locate his instruments three-dimensionally, because the typical "poking movements" of less experienced assistants in search of the scissors or other instruments may result in perforation of other structures.

In our experience the first step in case of bleeding (just like in open surgery) should always be pressure and tamponade, followed by exploration and repair if necessary. Compression with the robotic instruments should be always used with gentle force only. Especially the needle driving instruments have a strong closing force, that could potentially result in perfusion problems of the gripped tissue. A surgical sponge/bolster appears to be the most appropriate means of applying temporary pressure, and simultaneously can help to clear the field. Reduction of suction, instead using gentle irrigation, and an intraabdominal pressure above the central venous pressure (capnoperitoneum between 10 and 15 mmHg) are additional measures. In case of a major venous injury (Fig. 49.1), it is not advisable to raise the pressure, since it may result in a gas embolism, a potentially much more dangerous complication in comparison to hemorrhage. Closure of vessel injuries usually can be performed safely with a suture (Fig. 49.2), which should be always favored in comparison to clips (that may slip off). For beginners, we recommend to have a "Safety suture" at hand, a medium sized needle on a medium length thread, that has a knot at the end and is preloaded with a clip. (Fig. 49.3). This suture can be used for gaining control even in stronger bleeding sources, thereby offering a dryer field for the definitive closure of the injury. A conversion to open surgery is a possible and considerable solution—however we believe that if you are not a very beginner in the robotic console, control can be achieved in most cases much easier with robotic assistance. If the surgeon's robotic experience level is low however, conversion is always an appropriate possibility. In the inevitable case of conversion, consider leaving one robotic arm in place that applies pressure with a bolster, it could serve as the "finger on the wound" and save some units of blood during the conversion process, and may also indicated the site of the vessel injury.

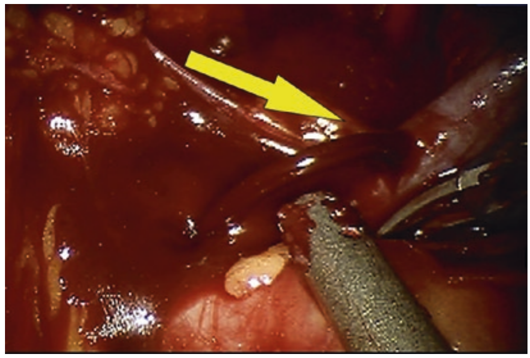

Fig. 49.1 Venous bleeding (*arrow*) from external iliac vein after puncture with the scissor tip

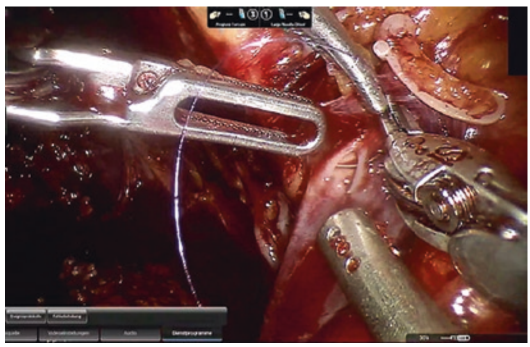

Fig. 49.2 Suturing of the venous lesion

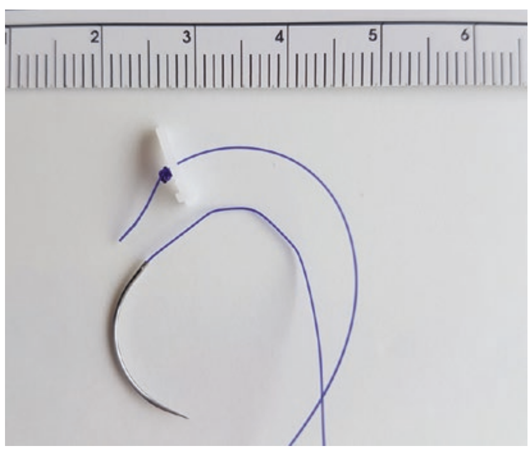

Fig. 49.3 "Safety suture" with a knot at the end and preloaded with a clip

Bowel Injury

In big contrast to retropubic prostatectomy, small bowel injury much more frequent in transperitoneal RARP. Especially in patients with prior major abdominal surgeries, and/or a history of inflammatory diseases and reactions, like peritonitis, or perforated bowels (sigmoid colon, appendices), the probability to encounter severe adhesions usually is much higher. To avoid this, extraperitoneal RARP may be a viable option, however developing the extraperitoneal space in case of major scarring sometimes is quite challenging and may result in a peritoneal tear with possible harm to the bowel, too. In the beginning of the learning curve, it is strongly advisable to make a good patient selection; in case of a high experience in laparoscopic surgery, usually adhesions can be managed laparoscopically. In our institution, we barely ever make use of a Verres needle insufflation, because entrance under vision (Hasson technique) is known to cause less bowel injuries in the first place, and since there is the need of an incision to extract the specimen anyway, we prefer using a ring wound retractor (Alexis® by Applied Medical) or a Hasson balloon trocar.

In case of expected peritoneal scarring, we use the most distant part of the abdomen for prior insufflation, one should be not afraid to make use of an additional trocar to gain access, having a better overview adds to the safety and efficiency of the adhesiolysis. One advantage of smaller cameras (like the da Vinci Xi/X System's 8 mm Scope) is the possibility to swap between trocars during adhesiolysis. Another option is switching between 0°and 30° (upward) lenses. Open Adhesiolysis also is a viable option in those cases where access is otherwise impossible. A temporary closure of the wound after completion of adhesiolysis enables to perform RARP afterwards, still offering the benefits of robotic surgery.

In case of a serosal tear in the bowel, suture repair is strongly advisable, either marking the site for later robotic repair, or primary closure. In case any bowel lesion especially with a full thickness lesion (Fig. 49.4), advice from the general surgeons should be considered, mostly because of medico-legal reasons. A primary repair without compromising the diameter of the bowl lumen (suturing transverse to the bowl direction) with a monofilament running suture (e.g. 3/0 or 4/0) is our standard technique. A partial resection of the bowel sometimes is inevitable.

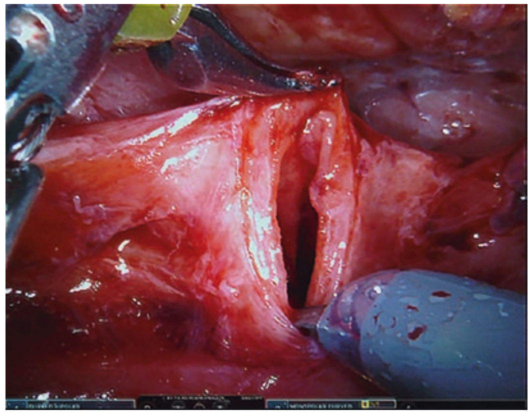

Fig. 49.4 Robotic exploration of a lesion in the small bowel after initial laparoscopic adhesiolysis

It is crucial to avoid thermal energy whenever possible because of the delayed bowel necrosis. Moreover, traction force should be reduced to a minimum, and direct grasping of the bowel should only be reserved to atraumatic graspers. When the robotic ports are placed, the remaining adhesions can usually be taken down robotically.

Rectal Injuries

In comparison with open retropubic surgery, rectal injuries appear to happen much less often, likely because of the improved vision and spatial orientation that is offered by the robotic technique, especially during the dorsal parts of the dissection. In advanced tumors, which should only be operated on by more experienced surgeons, the possible higher risk of rectal injuries should always be considered. We do not bowel prep our patients, however we advise to insert a rectal tube in advanced tumors and make use of the underwater insufflation test (bubble test) after resection of the prostate. (Fig. 49.5); furthermore, inserting a scope with a light source rectally and reducing the robotic lights (diaphanoscopy) can show a thinned-out rectal wall even if there is no complete hole yet. A rectal injury (Fig. 49.6) can usually be repaired easily and efficiently with sutures (Fig. 49.7) robotically; a colonic diversion should be reserved to major rectal injuries only. In case of a recognized rectal injury with sufficient repair, we do not alter the postoperative management or medication, and we have seen no problems with it so far. An additional single-shot dose of a broad spectrum antibiotic like Metronidazole is routine in our institution, but we would refrain from using a longer therapy course. Also, keeping the patient on non-per-os postoperatively, or leaving the rectal tube offers no advantages, and does not go in compliance with the standards and benefits of fast-track surgery. The recognition of a rectal injury is crucial, because it is typically the unrecognized injury that cause the worst effects. In order to lower the probability of a rectal fistula, an additional interposition of tissues can be performed. The easiest way is a dorsal reconstruction using the posterior prostatic fascia, other possibilities are options are: omental flap; a vesical fat flap; a modified dorsal reconstruction using the vesicoprostatic muscle; or sacrificing the neurovascular tissues for a transposition,

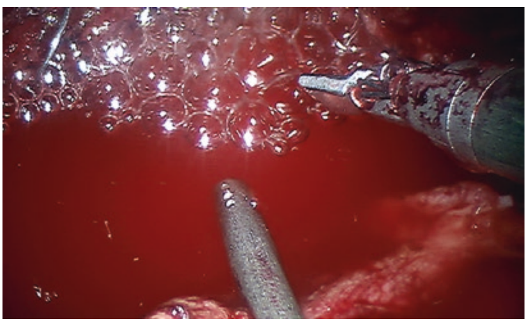

Fig. 49.5 Positive rectum insufflation test (bubble test)

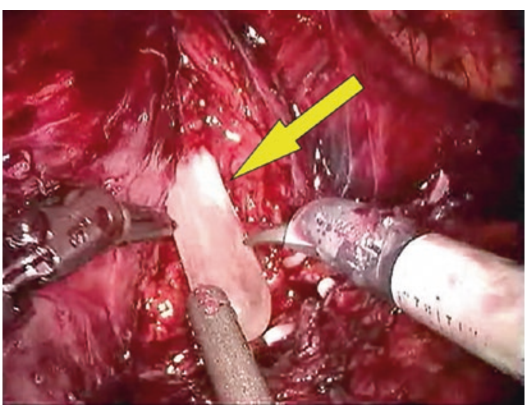

Fig. 49.6 Rectal injury, inserted rectal tube clearly visible, penetrating through the gap

Nerve Injury

The most frequent injury to adjacent nerves (apart from the nerves of the neurovascular structures) is the obturator nerve injury. This usually happens during lymphadenectomy. To avoid it, a clear identification of the nerve is mandatory before transecting or clipping the lymphatic tissues.

In case of a (partial) transections (Fig. 49.8), a suture repair can be performed (using 8–0 or smaller sutures). Sutures smaller than 6/0 has to be manipulated with a micro needle driver (Black Diamond Micro Forceps). Hemolok™ Clips that were accidentally placed on the nerve can be opened either by using the specific removal tool, or better (less manipulation and cheaper) by cutting the non-locking end of the clip with a hooked scissor (Figs. 49.9 and 49.10). If we encounter an obturator nerve injury, we recommend extended physical therapy and a course of B-Vitamins, even though this lacks evidence.

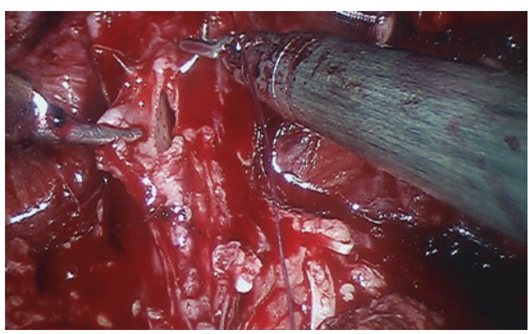

Fig. 49.7 Rectal injury, primary suture closure

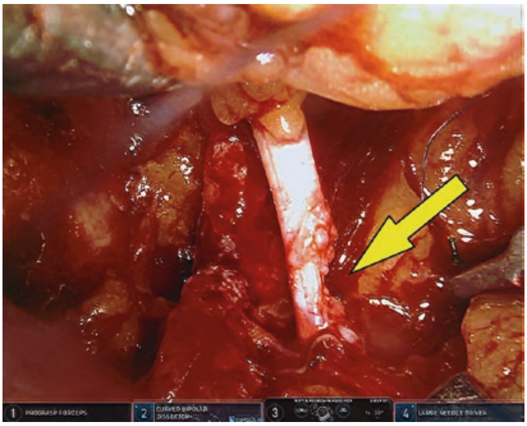

Fig. 49.8 Partial transection of the obturator nerve after accidental clipping

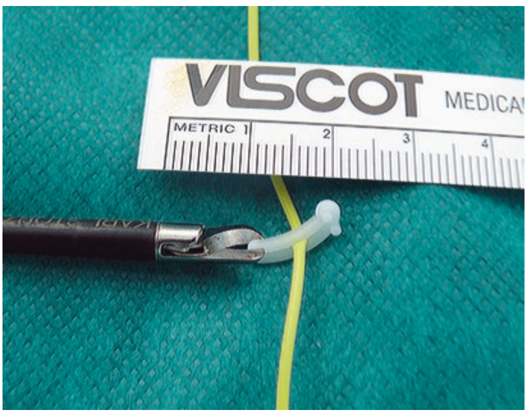

Fig. 49.9 Opening of a clip with a hooked scissor on the opposite sit of the lock

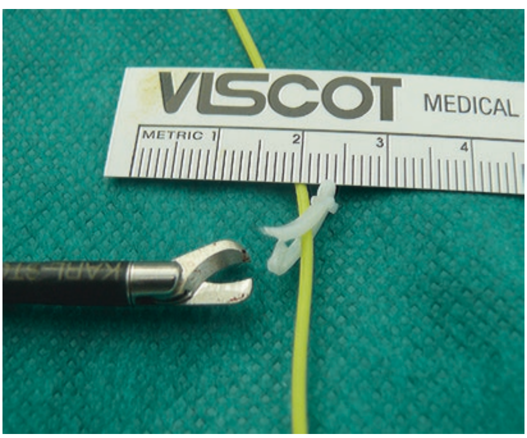

Fig. 49.10 Opening of a clip with a hooked scissor on the opposite sit of the lock

Ureteric Injuries

In general, ureteric injuries are a quite rare condition, but if they occur, they are often recognized quite late. Especially, prolonged secretion of large amounts of high-creatinine fluid from the drains and increasing abdominal symptoms like distension (because of chemical urine peritonitis) are warning signs, and should point to checking the ureters with retrograde ureteropyelogramme or IVP. One can easily be misled to consider an anastomosis insufficiency to be the cause for it, but in our experience, this usually does not cause a high-volume drain output. Usually the ureteric damage occurs during extended lymphadenectomies, so it should be considered mandatory to clearly identify the ureter before transecting or clipping of lymphatic tissues, and of course avoiding a denudation of the ureter off its surrounding tissues, too. A different danger point is during the dissection of the dorsal bladder neck and the seminal vesicles, especially in more advanced tumors, or during a dorsal approach, when the ureters are not far away from the surgical field. One trick is to avoid cautery during dissection of the tips of the seminal vesicles, not only to avoid damage for the neurovascular structures, but also for the ureters. A third possible reason for damage is an unrecognized duplex system, or a transection of the ureteric orifice during dorsal bladder neck dissection. This sometimes can be challenging in cases of one or more median lobes, care has to be taken to make sure the interureteric ridge is left in place.

Visible continuous clear urine output from the ureteric orifices (easiest to visualize with a 30° down scope during anastomosis) is the first checkpoint to assure the ureter has not been transected. However thermal damage causing long term necrosis or stenosis cannot be excluded like this. Placing DJ Stents over a hydrophilic guidewire during RARP despite the lack of haptic feedback is usually easy to perform, and in case of doubt of ureteric damage we recommend to do so. In case of suspected injury to ureteral blood supply, the use of intravenous indocyanine green (ICG) fluorescence (FireFly™) can be helpful to identify a sufficient blood supply. In case of major injury to the ureters or a complete transection, a ureteroneocystostomy, e.g. in a psoas hitch technique, can be performed.

Bone Injury

In situations with a narrow pelvis, most likely in black or small patients, the robotic instruments can cause a constant bruising to the pubic bone. Care has to be taken to avoid touching the periosteum, since contact with infected urine in case of a anastomotic leak can lead to a severe periostitis. Lowering the robotic instruments dorsally, or even repositioning the patient to a deeper Trendelenburg position may be necessary. Also, the periurethral suspension stitch can be a potential entrance point for bacteria, leading to a symphysitis ossis pubis, a rare but devastating and excruciatingly painful condition that requires long-term antibiotic and analgesic treatment.

Positioning Damage

The Trendelenburg position is an unphysiological position that requires some safety measures to assure the patients to not slip from the table, and does not suffer from pressure point damage. We use 35° Trendelenburg, measured with an inclinometer (a smartphone app can be used alternatively to standardize the tilt degree). In order to offer a safe position, we use a three compartment vacuum mattress, that is modelled onto the patient, and spread the padded legs. Specifically, for expected longer operating times, we do not recommend placing the patient in lithotomy position using spreader bars or pneumatic compression devices or stirrups, because of the even more unphysiological position of the legs and hips, which may result in a compartment syndrome after prolonged cases. It is key to try to keep operating times below approximately 4 h, which may be considered a cutoff time to decrease the risk of compartment syndrome.

Another devastating, yet rare complication (we haven't seen this in more than 11,000 robotic cases) of the Trendelenburg position has been reported only in case reports so far: posterior ischemic optic neuropathy (PION), leading to significant vision loss or even blindness after surgery. All reported cases had in common a long operating time (8–10 h), so keeping the time for the case short should be advisable in respect to this infrequent problem.

Although one might think the quite steep Trendelenburg position may result in other problems, usually after a short period of compensation (causing a short drop in blood pressure and heart rate that can be effectively managed by anesthesia), the body seems to compensate the position. Restricted fluid management during surgery is mandatory and should be standard for the anesthesiologist today. However, we recommend that patients with a high intracerebral pressure (hydrocephalus) or previously untreated glaucoma should be checked up before surgery. Furthermore, in patients with a history of cardiopulmonary problems, we recommend cardiologic preoperative checkup.

Postoperative Complication

Can be structured into early and late complications.

Early

Hemorrhage

Postoperative hemorrhage requiring intervention is an infrequent, yet considerable complication after RARP. With an estimated peak time during the first 24 h up to 3 days after surgery, patients usually present with a decrease in blood pressure and increased heart rate, and a drop in hemoglobin. In our institution, a decrease of postoperative hemoglobin for more than three points on the first morning after surgery has been a sufficient cutoff to figure out potential patients requiring reintervention. Also clinical observation of the patient is critical to identify possible bleeding situations. Due to the mostly used transperitoneal access, early reintervention is highly advisable, because unlike retropubic approach, bleeding usually does not tamponade itself. Providing adequate transfusions may result in many units of blood, leading to a potential additional risk for the recipient. Furthermore, larger amounts of blood collections are a potential source of superinfection, and can cause a secondary rupture of the urethrovesical anastomosis or inflammatory problems like peritonitis. Regular checkup of the patient is required, there are unspecific clinical warning signs that should ring a bell, such as hiccup, nausea, unusually strong pain and ongoing mobilization problems such as dizziness. Using a drain usually is not a sufficient tool to recognize bleeding, since most parts of the blood can drain to the abdominal cavity. When in doubt, we perform an ultrasound and in case of a suspected hemorrhage we bring the patient back to the OR as early as possible. An additional CT scan can be performed, but in most cases does not provide crucial information that leads to a change in the proceeding, yet only leads to a further delay or reintervention. In our experience, an open revision is usually not required, since most bleedings can be managed laparoscopically by suction of the fluid collections, and a mix of irrigation and suction using a larger diameter suction device can effectively clear the field. Inability to clear the field has been reported in the literature to be one of the main reasons for conversion to open revision—in our opinion this is an avoidable step. Some bigger blood clots can be extracted with a spoon forceps. Sometimes coagulated blood may hamper clearance by clogging the suction tube, which can easily be overcome by using a syringe to wash it free. Smaller bleedings can be take care of by cautery or placement of clips, in case of a bleeding source which is difficult or impossible to control with standard laparoscopy techniques (such as a source from the common or internal iliac vessels for example), we would rather switch to a conversion to robot-assisted revision surgery than to an open approach. Even though the cost may be higher, it offers a very effective minimally invasive treatment option that causes only little delay in the healing process for the patient with all the benefits for both the surgeon and the patient.

Typical bleeding sites we check are: the prostatic pedicles, the dorsal vascular complex, neurovascular bundles, ventral bladder surface, epigastric vessels, accessory pudendal arteries, pelvic wall, port sites and the lymphadenectomy areas. An example of a laparoscopic revision within a bleeding situation from the right lymphadenectomy region is shown in the Fig. 49.11 (initial view of the hematoma) and (Fig. 49.12) (bleeding source). In many cases, a specific bleeding source cannot be identified, which may represent a spontaneous resolving of the bleeding in the meantime.

If hemorrhage is recognized early, transfusions can be avoided in the majority of the cases, if the patient is fit and has a low cardiovascular comorbidity profile. As auxiliary measures, we recommend using intravenous tranexamic acid and the use of local hemostatic agents such as fibrin products or starch powder.

To avoid bleeding complications it is advisable to take care of the vessels during the case using clip or ligation, and a meticulous check for a dry field at the end of the case. Therefore, we lower the intraabdominal pressure to zero, using

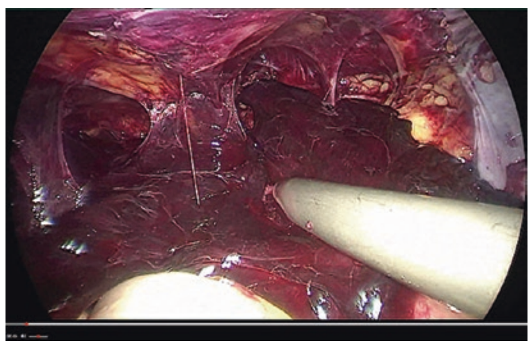

Fig. 49.11 Laparoscopic revision of a postoperative hemorrhage, initial overview shows partial clotting of the hematoma ventrally to the bladder and laterally right side

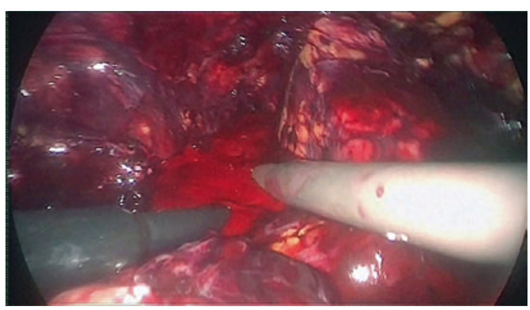

Fig. 49.12 Laparoscopic revision of a postoperative hemorrhage, bleeding source in the right lymphadenectomy region

one of the robotic arm to elevate the abdominal wall to emulate gasless laparoscopy, in order to simulate the postoperative situation, to make sure we are not missing venous bleeding that would be otherwise compressed by the capnoperitoneum. During this procedure at least one insufflation port has to be in an open position to maintain a zero capnoperitoneum. This avoids a negative pressure in the surgical cavity during suction with a resulting collapsed surgical field. This lowered pressure has to be maintained for a while, because the vessels may be still reflectively contracted, so at least a minute or two of desufflation is advisable. In addition, to check a sufficient closure of the puboprostatic venous complex, intermittent external perineal pressure is applied, so the possibly retracted veins are pushed in again, and open veins can be sewed with selective sutures. Extraction of the trocars should occur under vision, since the trocar may have injured a vessel during insertion, but during the case may have compressed the bleeding.

Incisional/Port Site Hernia

Laparoscopic trocars of more than 8 mm in diameter have been proven to be a possible site for port site hernias. Therefore, they should be closed effectively. We recommend using an all-layer suturing technique under vision, for example using dedicated trocar closure devices like the Carter-Thomason needle or Busche device. Alternatively, external suturing can be performed, too.

Patients with port site hernias present with unusual wound pain and unspecific abdominal symptoms. A bulging is sometimes not visible, especially in obese patients this can lead to a delay in diagnosis. Ultrasounds and/or CT scan confirm the diagnosis. For treatment, a primarily laparoscopic approach with extraction of the herniated bowel segment is usually sufficient enough, however in case of a prolonged herniation, sometimes a bowel resection can be required.

Ileus

Problems with bowel function are quite common problem after every lengthy transperitoneal laparoscopic procedure, usually resulting in only mild symptoms and delay in bowel movement. Measures like bowel prep and feeding restrictions have been used in the past a lot to overcome these issues. However, there is no convincing evidence to support this; it is more likely that this approaches have a negative influence. Instead, it is advisable to keep surgery times as short as possible, an also trying to keep the intraabdominal compartment as physiological as possible. One major point for this is keeping the capnoperitoneum as low as possible, since it has been shown that using a 15 or 12 mmHg pressure has significant impact on the bowel. Therefore, we advise to bring the pressure down to 8 or 10 mmHg, with high flow, and have the assistant use the suction only in short periods. Moreover, we apply a gas warming device.

An actual ileus can be caused by mechanical problems like a herniation or compression by adhesions, which require surgical treatment. A subileus can usually be treated conservatively, with auxiliary measure like chewing gum, early mobilization of the patient, early feeding, and administration of medication to stimulate bowel movement postoperatively. An upper gastrointestinal X-ray series can be performed in a situation of a delayed bowl movement, with the contrast medium also working as a very effective stimulant.

Anastomotic Leak

In contrast to retropubic prostatectomy, transperitoneal RARP shows the potential problem of urine draining into the peritoneal cavity. This can cause a significant chemical peritonitis, resulting in ileus symptoms. Therefore, a sufficient vesicourethral anastomosis should be achieved. With the versatility of the robotic technique, this is generally possible even in difficult cases. Even if bladder neck reconstruction is necessary, a sufficient closure of the anastomosis is feasible. To avoid urine spill during surgery, it can be recommended to only open the bladder neck when the bladder is empty, and to suck away remaining urine portions. If one places a suprapubic tube (which may lead to an improved postoperative patient comfort), we recommend closing the insertion site at the bladder, and attaching it to the anterior abdominal wall. We try to keep the time for the indwelling catheter on a minimum, because longer times may result in higher infection rates and a prolonged time of or urinary incontinence. If the cryptogram shows no leakage, the Foley catheter can be removed. In case of a primary insufficiency, the catheter should be kept longer. 3 weeks after surgery the catheter can be removed also in cases with a remaining insufficiency if there is no contrast medium reaching the peritoneal cavity. A sudden pain during voiding, followed by gross hematuria should be signs for a secondary anastomotic leak, and it is advisable to place a new catheter and check the urethrovesical anastomosis once again.

Only in few cases of prolonged anastomotic leak is it necessary to drain the urine through ureteric stents, here one option is the placement of extra-long mono-J stents, and fixing them together with the Foley. Alternatively, a transvesical placement with open revision surgery is also an option.

Late Complications

Lymphocele

During RARP, a pelvic lymphadenectomy in many cases is performed, and with an increasing number of lymph nodes removed, the incidence of lymphoceles is known to rise, too.

In order to avoid lymphoceles, many measures can be undertaken to try to decrease the risk, however so far, there is no convincing evidence which is the best technique to avoid lymphocele formation. Generally discussed measure are: using cautery, placement of clips, avoiding clipping of nodes but only the lymphatic strains, using hemostatic agents, peritoneal fenestration and avoiding heparin injection to the lower extremities. Even though one might think that due to the transperitoneal access, there may be a natural lymphatic drainage, the incidence of pelvic lymphoceles is lower in comparison to retropubic prostatectomy, but not zero. This may be explained for one by the earlier mobilization of the patient, resulting in higher lymphatic fluid output, and secondly to the early closure of the peritoneal incision during the healing process. One interesting technique to overcome this problem described lately is the suture-fixation of the bladder at the obturator fossa, to keep the peritoneal incision at the lymphatic region open.

In our intuition, we use meticulous clip ligation (small clips) of the lymphatic strains to the external limit of dissection, and we avoid administering heparin to the lower extremities or the lower abdominal wall.

In case a lymphocele is encountered, one has to bear in mind that many of those resolve spontaneously. Only symptomatic lymphoceles require intervention, for example if a lymphocele causes compression of the iliac veins or the bladder thus resulting in the inability of the bladder to adequately fill up or a possible formation of a deep venous thrombosis. Of course, painful or infected lymphoceles or compression of the obturator nerve require treatment, too. In uninfected lymphoceles, a laparoscopic or robot-assisted fenestration is the most effective way to provide a fast cure, with only littles chances of recurrence. Figure 49.13 shows the identification of a left side lymphocele followed by the fenestration (Fig. 49.14). In infected lymphoceles we recommend a stepwise approach with antibiotic treatment and a percutaneous ultrasound-guided drainage, followed possibly by administration of local sealing agents like gentamicin. If drainage does not lead to a sufficient and lasting collapse, laparoscopic revision is the next step. We do not advise primary laparoscopic intervention in

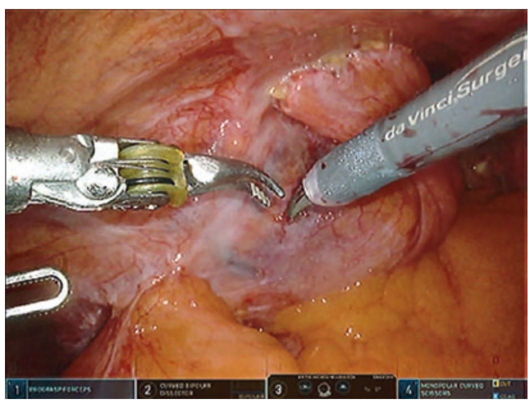

Fig. 49.13 Robotic identification of left pelvic lymphocele

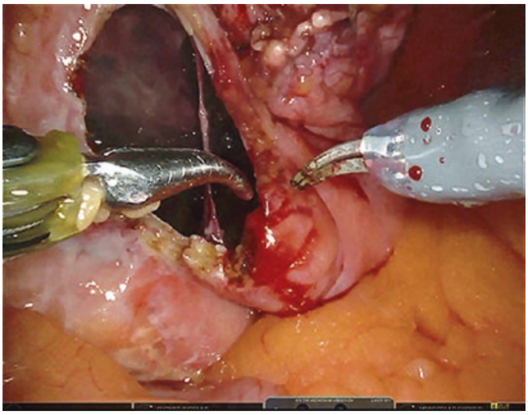

Fig. 49.14 Robotic incision of left pelvic lymphocele

infected cases, because of the possible spread of infected fluid/pus into the peritoneal cavity. In experienced laparoscopic hands, an open lymphocele resection is usually not necessary.

Anastomotic Stricture/Bladder Neck Contracture

With the benefit of improved dexterity and vision of the robotic platform, and the widespread use of the running van Velthoven anastomosis technique, the formerly (in the times of retropubic prostatectomy) not uncommon long-term complication of anastomotic stricture has virtually become a thing of the past. In our experience of more than 10, 000 RARP it only occurred in three Patients.

Venous Thrombosis

Due to the advent of enhanced recovery protocol, in combination with early patient mobilization and an improved understanding of the necessity to administer low molecular heparins, the incidence of deep venous thromboses has dramatically decreased, and hence the incidence of potentially lethal lung arterial embolism has diminished consecutively. Current guidelines recommend postoperative medical treatment with low-molecular heparins for 4 weeks postoperatively.

Lymph Edema

Generally, an infrequent long term problem, short-term mild lymphedemas of the groin region, especially in patients with pelvic lymph node dissection, are quite common. Most postoperative lymphedema resolve over time, a long term problem should always be checked for an obstruction, e.g. a lymphocele. Lymphatic drain problems of the legs are extremely rare.

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50 Complications After Robotic Bladder Surgery

Stefan Siemer

Especially with bladder surgery, surgeons have to be aware of various potential complications. Their knowledge and skills to manage them are essentially important. Complications compromise patient outcomes and prolong operative time or length of hospital stay. Robotic surgery might have the potential to reduce complications, but bladder surgery is still technically demanding including the need of urinary diversion for radical cystectomy. Complications after robotic bladder surgery may occur at different types of surgery, mainly the radical cystectomy approach. With an increasing experience with robotic procedures such as radical cystectomy and due to the positive impact of minimal invasive techniques on morbidity, robotic technology in bladder surgery is applied to a wider variety of bladder procedures such as partial bladder resection, diverticulectomy and ureteral reimplantation. Some complications are associated with the laparoscopic technique and the robotic equipment such as port positioning, robotic surgical access and malfunctioning of instruments (Chap. 48). But there are other complications, attributable to the specific procedures and seen independently form the approach with open surgery, respectively. Therefore the most common complications on patients undergoing robot assisted bladder surgery will be mentioned and some suggestions for intraoperative solutions and their prevention will be provided.

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Radical Cystectomy and Urinary Diversion

Open radical cystectomy with urinary diversion is a procedure that is well known for its significant risks for complications. Every report might be limited by reporting methods and patient selection. However, standardized reporting methodologies following the Clavien reporting system that should be used in its modified version [1], resulted in astonishingly high complication rates ranging from 28 to 64% and a mortality of up to 7% [2–5] for open radical cystectomy (ORC). Another factor that influences surgeons postoperative outcomes are the significantly high readmission rates, approaching 27% within the first 90 days [6]. The benefits of minimally invasive surgery in colorectal cancer were supported by level one evidence [7]. This still needs to be shown for robotic-assisted radical cystectomy (RARC), but current results are encouraging.

A recent meta-analysis compared pooled data from three randomized controlled trials [8–10] and showed no significance in perioperative complications between RARC vs. ORC. However, postoperative flatus was significantly shorter in the RARC group ($p = 0.002$) and time to regular diet was significantly shorter in the RARC group ($p < 0.0001$) [11]. While

H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3_50

this meta analysis could not show any difference in perioperative complications between RARC and ORC, recent studies showed a 32% reduction for the robotic approach in 90 days complications after intracorporeal urinary diversion [12]. Furthermore, the rate of major complications (Clavien grade 3–5) was significantly different from ORC to RARC (45.7 vs. 26.2 and 30.8% vs. 16.9%) [13, 14]. A comparison between two high volume centers for ORC and RARC showed no differences in high-grade complications (all P ≥ 0.06) while ORC was associated with significantly lower odds of overall complications. Interestingly, this analysis failed to detect any differences between the two approaches after the RARC group exclusively contained individuals receiving an intracorporeal diversion [15]. A systematic review with meta-analysis of 239 patients from four randomized controlled trials revealed, that RARC had significantly lower estimated blood loss and wound complication, but no significant difference in perioperative morbidity [16]. Overall studies do not provide clear benefit of RARC compared to ORC, while studies with intraoperative urinary diversion were not included. To date, only very few studies of RARC with totally intracorporeal neobladder formation have published their functional results. Therefore the list of complications for urinary diversion reported herein is a mix of intracorporal and extracorporal approaches. However one should keep in mind that urinary diversion as the reconstructive part accounts for the majority of postoperative complications [17] and the intracorporal approach has potential to further reduce perioperative morbidity. However, only about one quarter of patients receive intracorporeal diversion in contemporary robotic series [18]. On multivariable analysis, increasing age group, neoadjuvant chemotherapy, and receipt of blood transfusion are independent predictors of any and high-grade complications with the robotic approach.

Even if there is a lack of uniformity within the published literature for either the open or the robotic approach, it provides us with knowledge of different types of complications as well as the frequency of their occurrence. This might help to decrease their incidence and therefore protect patients. While risks and complications from the robotic approach are left out in this chapter, it will focus on typical complications associated with bladder surgery and urinary diversion. Table 50.1 gives an overview of potential intraoperative complications and possible solutions, while Table 50.2 lists postoperative complications with an estimated frequency of their occurrence in robotic and open series. The majority of complications can be categorized as vascular, gastrointestinal, thromboembolic, infectious and genitourinary. These will be summarized in more detail below.

Vascular Injury

During the operative procedure, rare but feared complications are vascular injuries and successive bleedings. These can occur form the port site, as well as from the abdominal vessels while mobilizing the bladder. Furthermore, the venous plexus could cause bleedings after apical dissection of the specimen. A pelvic lymphadenectomy is usually performed and a lesion of iliac vessels might occur during that part of the operation. Whenever such bleeding occurs, direct visualization is necessary to identify its localization. In case of a small vessel branch, direct coagulation might be sufficient. A port side bleeding and abdominal vessel bleedings can resolve after a large transcutaneous suture through the abdomen to compress the vessel that might then be explored further by the end of surgery. Bleedings from the venous plexus can usually be stopped sufficiently by apical sutures after raising pneumoperitoneum pressure up to 20 mmHg. Higher abdominal pressure usually slows or even stops venous bleedings from iliac vessels and in almost all cases allows to repair the defect with a vascular suture. In case of arterial bleedings, this might be possible if a small branch is involved and can be clipped or the defect is small, however, this often leads to conversion to an open approach that should not be delayed when serious bleedings take place.

Table 50.1 Intraoperative complications

Type of complication	Complication	Details	Solution	Frequency %	
				RARC[a,b,c,d]	ORC[b,e]
Gastrointestinal	Bowel injury	Unnoticed sharp incision or coagulation of small intestine or colon	Operative revision and bowel reconstruction or resection; abdominal irrigation	0.3	1–5
	Rectal injury	Injury during division of the vascular pedicles	Primary rectal closure in two layer fashion; and/or colostomy	1–5	2
Neurologic	Nerve injury	Obturator nerve injury during lymphadenectomy;	End-to-end repair with interrupted 6-0 nylon or ethibond sutures; neurosurgery consultation	2	
Vascular	Vascular injury/intraoperative bleeding	Trocar bleeding	Controlled coagulation; transcutaneous suturing	1–5	
		Abdominal wall vessels	Controlled coagulation; transcutaneous suturing		
		Lesion of iliac vessels	Raise pneumoperitoneum pressure (up to 20 mmHg); vascular suture as indicated; conversion in case of large arterial bleeding		
		Plexus santorini	Apical suture		
	Blood transfusion			0–15	
	Anastomotic leakage	Ureteral leakage	Revision of ureteral anastomosis	–	
Genitourinary		Vesiko-urethral leakage at neobladder formation	Revision of anastomosis ; mobilisation of neobladder mesentery; blocking of foley catheter and tension to neobladder neck; penrose drain	–	
Laparoscopic technique	Conversion to open laparotomy	Bleeding, difficulty to progress		0–5.7	

[a]Smith et al. (2013)
[b]Bak et al. (2016) [3]
[c]Yim et al. (2015)
[d]Xylinas et al. (2013)
[e]Lawrentschuk et al. (2010)

Table 50.2 Postoperative complications

Type of complication	Complication	Details	Solution	Frequency%	
				RARC[a, b, c, d, e]	ORC[b,e, f]
Vascular	Blood transfusion			4.3–25	1–66
Genitourinary	Urinoma	Complications of urinary diversion	Replace ureteral stent; drainage	1.2–4.3	0–7.7
		Urine leak from the neobladder	Bladder catheter; drainage	1.2–5	
	Kidney failure	Ureteral stenosis	Ureter catheter, nephrostomy, ureteral reimplantation; nephroureterectomy	2–14%	0–7
	Electrolyte and acid based problems	Hyperchloremic metabolic acidosis	Systemic alkalinization	NR	0–4
Gastrointestinal	Ileus	Mechanic	CT scan with oral contrast; surgery	3.8–21.5	0–65%
		Paralytic	Enhanced recovery program, physical therapy, chewing gum, ruel out electrolyte abnormalities, nasogastric tube		
	Bowel leak	Insifficient bowel anastomosis	Operative revision	0–1	0–8.7
Infection	Lymphocele	Asymptomatic lymphocele	Conservative treatment	<l–8.5	4
		Symptomatic sterile lymphocele	Percutaneous drainage, sclerotherapy with tetracycline oder povidone-iodine (PVP-I)		
		Symptomatic infected lymphocele	Percutaneous drainage; open surgical marsupialization		
		Recurrent lymphocele	Laparoscopic marsupialization		
	Systemic infection	Urosepsis	Intensive care management	0.3–22.7	0–12.8
		Urinary tract infection	Antibiotic and antipyretic therapy		
	Wound healing disorder	Subcutaneous infection	Local aseptic wound irrigation	1–9.6	0–15
		Wound dehiszen	Relaparotomy or secondary fascia suture		
	Bleeding	Port site bleeding	Compression; additional suture	5–6	

Wound	Hernia	Incisional hernia/inguinal hernia	Laproscopic repair with dissection of the hernia and mesh graft or open abdominal incision for icisional hernia	0–1.2	4.1–27.3
Cardiovascular	Thrombosis/emboly	Deep vein thrombosis	Immediate anticoagulation intially with heparin; angiologic control depending on pulmonary situation	1.7–3.8	0–5.3
	Cardiac	General		4.1	0–13
Respiratory		General incl. Pneumonia		3.4–5.8	0–7.8

[a]Smith et al. (2013); NR, not reported
[b]Bak et al. (2016) [3]
[c]Yim et al. (2015)
[d]Xylinas et al. (2013)
[e]Cusano et al. (2016)
[f]Lawrentschuk et al. (2010)

Postoperative Ileus

Although laparoscopic surgery benefits fast postoperative recovery by minimizing peritoneal irritation and surgical trauma, postoperative ileus is still the most common complication after RARC (Fig. 50.1). Besides urine leakage following urinary diversion, bowel leak after ileal anastomosis or mechanic obstruction, complete etiology of paralytic syndrome is not fully understood. To avoid postoperative Ileus, an emphasis should also be placed on preoperative and postoperative enhanced recovery pathways. Table 50.3 presents one fast track method to maximize outcomes and minimize patient morbidity [19]. Key features are a minimization of preoperative fasting, an elimination of preoperative bowel preparation, early mobilization to additionally prevent deep vein thrombosis, early enteralization and direct removal of nasogastric tubes at the end of surgery with a re-start of oral intake on the first day after surgery as well as an omission of intraabdominal drains as often as possible. Together these improvements have led to a more rapid return to regular diet, earlier mobilization, lower opioid consumption and overall improved patient recovery in a series of RARC [19]. However, if postoperative ileus occurs, management includes a control of electrolyte lab counts as well as exclusion of mechanical small bowel obstruction. Thereafter, a nasogastric tube might be necessary followed by mobilizing agents such as neostigmine and metoclopramide or oral gastrografin.

Fig. 50.1 Postoperative ileus in a patient after RARC and ileal conduit urinary diversion; symptoms occurred after removal of ureteral catheters with successive development of wound dehiscence and operative revision

Lymphocele

Lymphocele formation is especially associated with extended pelvic lymphadenectomy and occurs in 1–8.5% in contemporary case series. Its formation may last for a couple weeks until patients get symptomatic. This can either occur as an infection or edema of lower extremities after compression of pelvic vasculature that is unfortunately associated with deep vein thrombosis. Therefore only the asymptomatic patient without signs of infection or vascular compression should be monitored while others should be treated according to Table 50.2. Usually percutaneous drainage with recurrent instillation of sclerotic agents is sufficient (Fig. 50.2). Only very few patient will need intraperitoneal fenestration that can be performed laparoscopically or open and an omentum flap can be placed to prevent recompartimentation and recurrence. In case of bulky disease at the time of lymphadenectomy, meticulous clipping of suspected structures as well as hemostatic agents can prevent lymphocele.

Deep Venous Thrombosis

The risk of deep vein thrombosis might be reduced with the robotic approach due to the intraoperative trendelenburg position leading to increased venous reflux. As already mentioned, postoperative lymphocele can contribute to deep venous thrombosis with the risk of subsequent embolism. Therefore, every effort should be made to avoid this serious complication. Standardized care comprises early mobilization and medical compression stockings as well as perioperative heparin. The minimal invasive approach might be of particular advantage by allowing earlier ambulation.

Table 50.3 Perioperative “rast track” care plan

Day	Care plan
–1/Preoperatjve	Normal breakfast; Admission to hospital ;Liquid diet (soup) Unrestricted dear fluids: two high carbohydrate drinks 6 p.m. Fleets enema in the evening
Surgical	Two high carbohydrate drinks 5 a.m.; Intraoperative antibiotic single shot; No abdominal drainage; Removal of nasogastric tube at the end of procedure
Postoperative	Free fluids as tolerated 2 h after surgery; Magnesium citrate 300 mg; Mobilise first time 5 h after surgery; Non-narcotic analgesics (didofenac 75 mg every 12 h); Pain medication using i. v. non-opioids and opioids as required
+1	Protein drinks and light diet as tolerated; Free fluids in an amount of more than 1500 mL; Magnesium citrate 3 × 300 mg; Non-narcotic analgesics (didofenac 75 mg every 12 h); Pain medication using i. v. non-opioids and opioids as required; Mobilise and refer to physiotherapist; Shout of bed; two times walking on the corridor
+2	Light diet regular diet possible; Rectal laxative (bisacodyl suppository); Non-narcotic analgesics (didofenac 75 mg every 12 h); Pain medication using i. v. non-opioids and opioids as required; Mobilise and refer to physiotherapist; 8 h out of bed; two times walking on the corridor
+3	Regular diet after gradual return to oral feeding
+4	Mobilise and refer to physiotherapist
+5	8 h out of bed; Full mobilisation

Complications of Urinary Diversion, Urinary Leak and Ureteral Stricture

Urinary diversion as the reconstructive part of radical cystectomy accounts for the majority of severe postoperative complications. Bowel leak at the bowel anastomosis usually leads to laparotomy with revision of the anastomosis, irrigation of the abdominal cavity and drainage.

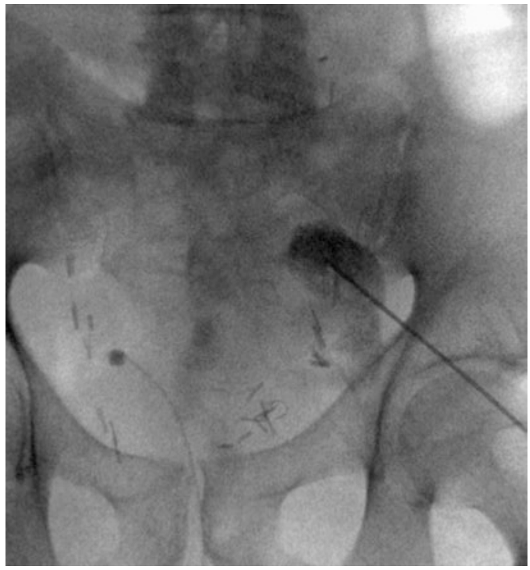

Fig. 50.2 Postoperative symptomatic lymphocele in a patient after RARC with intracorporal neobladder (indwelling neobaldder catheter); The lymphocele in the left fossa iliaca is punctured and visualized with contrast prior insertion of a percutaneous drain

Electrolyte and acid based abnormalities due to urine resorption may occur as hyperchloremic metabolic acidosis and should be controlled regularly and treated via systemic alkalization. During the reconstruction of ureteroileal anastomosis and ileourethral anastomosis of a neobladder, watertight closure of all suture lines and anastomoses should be controlled rigorously to avoid uncontrolled leakage with consecutive urinoma (Figs. 50.3 and 50.4). Techniques for the robotic approach should therefore follow the same principles to be effective for ORC.

Ureteral strictures (Fig. 50.5) represent a very severe late complication of urinary diversion. As the majority of these strictures arise from ischemia of the distal ureter, ureteral dissection is an important part of RARC and low tension to the ureter as well as avoidance of unnecessary proximal dissection above the aortic bifurcation will protect ureteral vasculature. Other reasons for postoperative strictures might be tight suturing or

Fig. 50.3 Insufficient ureteroileal anastomosis on the right side after wallace plate reconstruction involving three ureters due to a double kidney on the right side. Problems resolved after percutaneous nephrostomy and thereafter successive removal of the ureteral catheters from the right and left side

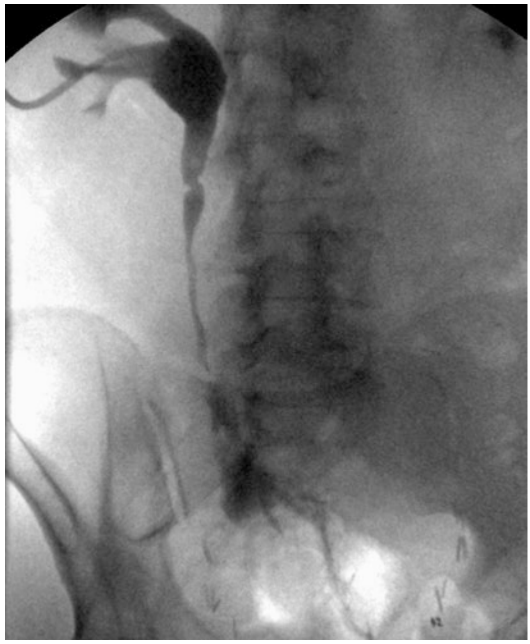

Fig. 50.5 Ureteroileal stricture on the right side 3 months after neobladder formation; even though only a short segment is structured, this led to a operative reimplantation of the right ureter

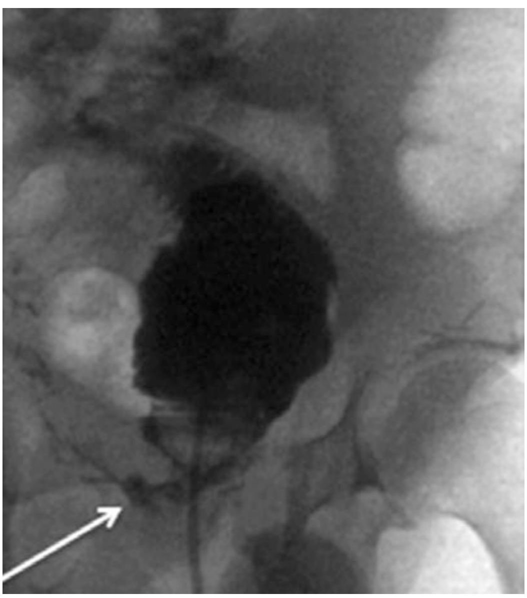

Fig. 50.4 Ileourethral insufficiency after neobladder formation on the right side (*grey arrow*); patient had secondary insufficiency after initial catheter removal; treatment was conservative with catheterization for an additional four weeks and therefrom spontaneous resolution of anastomotic leakage

postoperative infection that lead to scar formation. Possible solutions are ureteral catheters or nephrostomy followed by antegrade splinting. Finally, only ureteral reimplantation could resolve larger strictures as long as kidney function is preserved.

Robotic Diverticulectomy

Even though bladder diverticulectomy has been performed successfully with a variety of operative techniques, laparoscopy resulted in a significantly decreased blood loss, decreased analgesic use and shorter hospital stay compared to open surgery [20]. With the widespread use of robotic-assisted techniques, bladder diverticulectomy is increasingly done with the robot. Recent case series and reviews report very rare complications with no high-grade intraoperative or postoperative complications. Whenever the diverticulum is close to the ureteral orifices, it might be helpful to previously insert a JJ stent in the ureter to ovoid ureteral injuries [21]. If there is a suspicion of thermal injury to the ureter close to the bladder diverticulum, the JJ should be left indwelling for approximately 2 weeks, while direct ureteric injury must be repaired as necessary. In rare cases of ureteral insertion directly into the diverticulum, the ureter can be reimplanted directly into the bladder after diverticulectomy is performed. Operative time can be shortened using an internal dissection approach with immediate entry into the bladder diverticulum [22]. Usually patients underwent postoperative transurethral catheter removal between postoperative days 7 and 14. A cystogram can be performed to exclude an urinoma due to insufficient bladder wall sutures.

Robotic Ureteral Reimplantation

After its initial application with pyeloplasty, the robotic platform is increasingly used for distal ureteral resection and reimplantation. These procedures include ureteroneocystostomy, psoas hitch implantation and Boari flap. Initial experiences mainly comprise monocentric case series, however these techniques seem to be feasible and safe and therefore able to reproduce open surgical outcomes [23, 24]. Besides complications that are associated with the robotic approach, complication rates seem to be very low (3.2–7.9%) and comprise bleedings after sectioning the umbilical artery or hematuria, postoperative urinoma after insufficient bladder suturing, pyelonephritis and postoperative ureteral stenosis recurrence. It is recommended to insert a drain for a few days, a foley catheter for at least 1 week and a double J stent in an antegrade approach for 4–6 weeks.

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H. John, P. Wiklund (eds.), *Robotic Urology*, https://doi.org/10.1007/978-3-319-65864-3