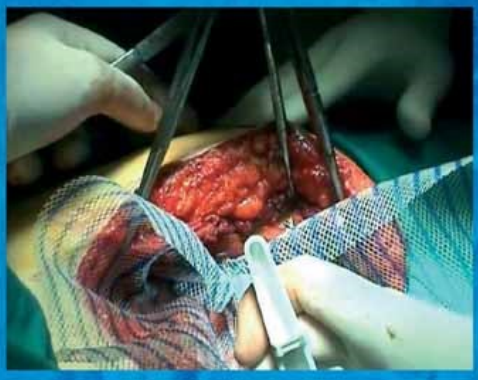
UPDATES in SURGERY

Feliciano Crovella
Giovanni Bartone
Landino Fei

Incisional Hernia



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Incisional Hernia

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Foreword

When the Steering Committee and we chose the title *Incisional Hernia* for the Biennial Report, our thought was that, although the topic had been covered in numerous conferences in Italy and abroad, this was an opportunity for a review of the most important and emerging issues.

The first commendation, then, is for the title. The second commendation goes to the authors, and in particular the editors, who have shown great dedication and ability in creating a volume whose contents list reveals a harmonious sequence of contributions which leave no aspect of this complex and interesting chapter of abdominal wall surgery untouched.

The carefully selected and varied topics include general issues such as the anatomy of the abdominal wall with all of its functional aspects (not always sufficiently represented in surgical monographs), as well as epidemiology and, above all, physiopathology, which is fundamental for regulating surgical treatment. New and emerging areas have also been covered, such as the aetiopathogenesis of alterations to collagen and its matrix—an area of great interest in terms of the rational planning of prosthetic repair.

In this age of synthetic prostheses, a publication of this kind must include a careful examination of the various types of prosthesis, their characteristics, and their indications for use, including biological prostheses. This volume is no exception.

Laparoscopic surgery, too, has revolutionised this field, and as a result the editors have paid particular attention to the intrinsic difficulties of this approach, outlining all of its advantages and limitations with respect to traditional open surgery.

It is therefore with great pride that we commend to Italian and foreign surgeons alike this meticulous and comprehensive work, in which the editors Feliciano Crovella, Giovanni Bartone and Landino Fei have assembled the contributions of highly experienced authors. We trust that this volume will be an incentive, a teaching aid, and a tool for all who wish to test their mettle with the techniques and technological revolutions of the new millennium.

Verona, October 2007

Claudio Cordiano
Past President, Italian Society of Surgery

Rome, October 2007

Roberto Tersigni
President, Italian Society of Surgery

Contents

Special Part

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General Part

The Historical Evolution of the Treatment of Incisional Hernia

Ruggiero Nigro, Feliciano Crovella

A hernia is defined as the protrusion of viscera from the abdominal cavity through a natural, preformed, anatomical route, while an incisional hernia indicates the protrusion of viscera from the abdominal cavity through a route formed after trauma induced by cutting (surgical incision, laparascopic trocar puncture wounds [1], stab wounds).

For a long time, the term "eventration" was reserved for serious abdominal-wall damage, whereas according to Quenu [2] real eventration was that due to pregnancy, and post-operative eventration was what we now call incisional hernia. This concept was expanded when modern abdominal surgery started, at the end of the nineteenth and beginning of the twentieth centuries. It was in this period that cases of post-operative eventration appeared and gradually increased in number, while at the same time surgical techniques, aimed at their correction, developed and multiplied.

The evolution of surgical techniques has followed the progress of research and the development of technology. Consequently, the possibility of prosthetic repair, initially with metal prostheses and later with synthetic ones, was considered. The positive results of these techniques were essentially the outcome of knowledge of the particular physiopathology, with particular attention given to the traction exerted on the linea alba by the large muscles of the abdomen [3].

Even though numerous case studies of surgically treated eventration were published early on, the history of specific surgical treatment of incisional hernia began in the second half of the 1800s. Before that, surgeons used "exclusively restraining methods". Surgical treatment or, to use the less elegant term coined by several authors, bloody treatment, developed along three lines: (1) simple laparoplasty, (2) organic auto or heteroplasty and (3) alloplasty.

Simple laparoplasties were carried out according to Gosselin's anatomopathological and clinical descriptions [4]. In the beginning, suturing of the wall-defect breach was carried out transcutaneously on a closed abdomen. Successively, between 1880 and 1900, aponeurotic suturing techniques on one or more planes, with or without opening of the peritoneum, were introduced and increased in number. In 1972, De Franchis [5] published a report on incisional-

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hernia surgery that was considered to be a reference point due to its abundant bibliographical data and its descriptions of the various surgical techniques used in the treatment of incisional hernia, These were based on what is considered as the cornerstone of abdominal-wall reconstruction, that is, aponeurotic suturing. Consequently, techniques based on layer suturing, according to Quenu [2], or on mass suturing, according to Le Dentu [6], were carried out.

In 1896, Quenu described the suturing of several layers adjacent to the incision of the rectus muscle sheath and along its medial margin, suturing of the posterior face of the sheath of one rectus muscle with the posterior face of the contralateral one, and suturing of the muscle edges preceded by suturing of the anterior face of the two rectus muscles. This technique was particularly recommended in cases of diastasis of the rectus abdominis muscles. In reality, this method represented an autoplasty through the use of the lamina anterior and posterior musculi recti abdominis.

During the next stage in the evolution of a surgical approach to treating incisional hernia, plasty was proposed using "U"-shaped muscle-aponeurosis suture stitches [7] or "8"-shaped stitches through the entire thickness [8]. These and other techniques were advocated with the aim of obtaining abdominal-wall reconstructions that would radically and definitively eliminate the pathology of incisional hernia. Some authors focussed their efforts on incisional hernias situated in specific areas. Schulten [9], for example, dedicated his research efforts to umbilical-pubic incisional hernias.

Regarding treatment of the peritoneal sac, while some surgeons currently recommend its resectioning, others advise its breakdown with "puckering" by means of a few catgut stitches [10]. It is obvious that these techniques cannot be carried out in a generalised manner, as some sacs of not recent formation, multilocular sacs, and those adhering to the viscera they contain must necessarily be resected, while others without any particular adherences to the herniated viscera can be suppressed.

The most common and most frequently adopted autoplasty is still the one described by Mayo, in 1901 [11], which is based on overlapping. He developed the idea on the basis of what Juvara [12] had already accomplished in 1900, making an overlap of the muscle-aponeurosis planes, the commonly defined "waistcoat" plasty, for the treatment of umbilical hernias. This procedure, further modified by Judd [13] in 1912, consists of overlapping one lip of the wall-defect breach with the opposite lip in order to double the thickness of the wall in that place. The edge of the lip that remains underneath is fixed, by several U stitches, at a certain distance from the edge of the overlapping lip. The edge of the peritoneal face of the lip that is overlapped is sutured to the underlying aponeurotic surface with a fine overcast suture. This technique is still frequently used, particularly in lateral and subumbilical incisional hernias.

In 1941, Welti [14] accomplished an autoplasty based on uncovering the right rectus major abdominis. This was stripped with two longitudinal incisions after the linea alba had been incised; the medial margin of the two incisions was then sutured to the left edge of the linea alba, leaving the rectus muscle, still uncov-

ered, to become medial and to act as a barrier, anterior to the wall-defect area, that determines the definite healing of the eventration. This technique was partly modified by the "debulking incisions" of Clotteau and Premont [15], Gibson [16] and Albanese [17]. The techniques of auto- and heterotransplant of the fascia lata [18], skin grafting [19,20], or of skin cut into small plastic-like strips [21] have also been applied in the treatment of incisional hernias of small dimension. The use of skin grafts, above or below the aponeurosis but preferably above it [22], developed from 1940 onwards along the lines proposed by Loewe [23] in 1913, even though the appearance of epidermoid cysts was reported. In order to avoid them, Grassi [24] advocated using the dermis under traction due to its greater capacity to merge with the surrounding tissues.

Besides the use of aponeurotic or cutaneous tissue for auto- and heteroplasty, cartilaginous [25], periosteal [26], muscular [27], decalcified bone [28], meningeal [29–31], as well as autologous and heterologous tissues have been proposed. In all of these cases, there is a more or less abundant production of reactive fibrous tissue that constitutes a very valid protective framework.

Some of the inconveniences and, above all, the need to repair extensive wall-defect breaches led to the use of alloplastic material. Accordingly, the age of alloplasty can be divided into two periods: (1) metals and (2) inert synthetic materials.

The first proposal to use metallic materials dates back to the beginning of 1900, when Shipley [32] used metal wires which he tied on the skin, tightening the knot around common buttons. Gold was used as well, but in order to reduce the costs other filigrees, aluminium and alloys, such as brass, were turned to [33,34]. These prostheses were badly tolerated and provoked violent tissue reactions so their use was discontinued. Just when it seemed that the period of metals was about to die out, new possibilities arose with the appearance of tantalum and stainless steel.

Tantalum, in particular, demonstrated good tolerability and solidity. Moreover, it also stimulated a favourable proliferation and invasion of connective tissue, with results that were generally considered good as long as the anatomical formations were perfectly reconstructed, the material was kept away from fatty tissue, a thorough haemostasis was carried out, fixing sutures were applied exactly and perfectly, and maximum sterility was respected in order to avoid, as far as possible, the formation of haematomas, haemorrhagic infiltrations, seromas and suppurative complications [29,35]. Relapses were rare [36]. The same cannot be said for stainless steel, whose only difference with earlier metallic meshes was its lower cost [37–39].

After 1940, the use of prostheses increased, as the development and manufacture of plastic materials progressed, leading to surgical applications of inert synthetic materials. Initially, many practitioners turned to the use of nylon. In 1949, Michaux [40] recommended sectioning nylon with a cautery knife so as to avoid fraying of the edges. However, this precaution was refuted, in 1951, by Testa [41], who demonstrated experimentally that the nylon border not only becomes rigid with this treatment, but stimulates an intense, dangerous and

excessive fibrous proliferation in the subcutis and perimysium. This occurred to an even greater degree when catgut was used, so other types of suture were recommended.

Stock [42] (1954) suggested the application of a nylon mesh between the peritoneum and the muscle layer. Bourgeon [43,44] (1955, 1956) reported that the mesh could also be applied intraperitoneally and fixed to the aponeurotic-muscle plane with single sutures, since, as early as 8 post-operative days, it became fastened to the fibrous exudate serosa and after 2 months was covered by a tissue with the same aspect as the peritoneum.

Similar effects were obtained with orlon, and very good results with the use of dacron [45], particularly in peristomal incisional hernia [46], ivalon and teflon. It is of note that the number of case histories with no relapses increased [47,48] and all authors stated that patients could be out of bed quickly, even in cases of post-operative eventration. By contrast, regarding the above-mentioned peristomal incisional hernia, the use of marlex mesh resulted in frequent relapses [49].

In recent times, due to the progress made in the chemical industries, numerous kinds of synthetic prostheses have rapidly appeared on the market and, while some of them have been short-lived, others have become progressively well-established. This succession has included nylon, dacron, teflon, ivalon, velour-lined silicone, and, above all, polytetrafluoroethylene (PTFE), the latter reducing the formation of adherences. Mersilene, introduced in France by Rives [50], is the material of choice for most French surgeons, while in the United States surgeons generally prefer marlex (polypropylene). The last three materials better respond to the needs of surgery in the repair of incisional hernias. This was stressed by Arnaud [51], who, in 1977, stated that a prosthesis must not be toxic, must last in time, must be flexible and resistant, must have the right strength and provoke minimal tissue reaction.

In recent times, with progress in surgical techniques, the number of cases of limited-sized incisional hernia treated by laparoscopy has increased. After freeing the viscera adhered to the incisional hernia sac, a Gore-Tex mesh is applied to the peritoneal surface and fixed with a few sutures or with special synthetic material clips.

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The Anatomical Structures of Abdominal-Wall Continence

Francesco Ruotolo, Massimo La Pinta, Luca Salvatore Gallinaro, Marco Di Giovan Paolo, Flavio Forte

Descriptive and Topographic Anatomy

The study of the structures involved in the maintenance of abdominal-wall continence includes not only anatomical but also functional aspects that are closely linked, since the anatomical description is the key to a functional interpretation (Fig. 1).

The abdominal cavity, situated between the diaphragm in the upper part and the pelvic strait below, is surrounded by a wall that presents an anterolateral segment and a posterior lumbo-iliac segment. The skeletal part of the wall is made up of five lumbar vertebrae and their respective disks, the upper part of the pelvic bones and the bony components of the lower thoracic wall.

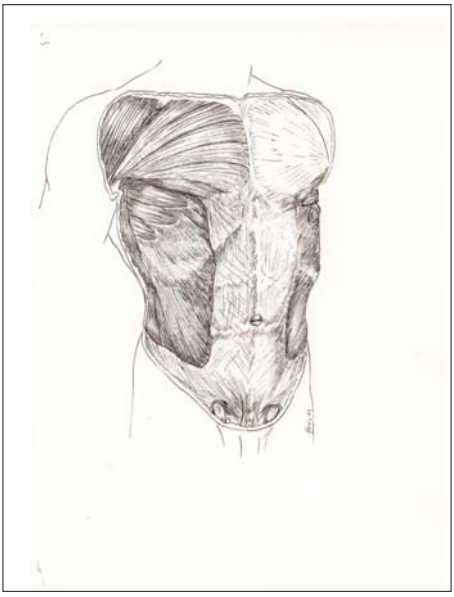

Fig. 1 The abdominal wall

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

The disposition of the muscles is as follows:

– Dorsally, the quadratus lumborum, psoas major and iliac muscles that strengthen the posterior surface of the wall
– Laterally, three muscular layers similar in orientation to the intercostal muscles: external oblique abdominal muscle (EO), internal oblique abdominal muscle (IO) and transversus abdominis muscle
– Ventrally, the rectus abdominis muscle covering the distance between the thoracic wall and the pelvis.

Structural continuity between the posterior, lateral and anterior parts of the abdominal wall is assured posteriorly by a solid sheath and anteriorly by flat tendinous laminae (aponeuroses) that derive from the muscles of the lateral side of the wall.

From a topographical point of view, the anterolateral wall of the abdomen includes an anterior region (sternal, costal and pubic, including the umbilical area) and two lateral regions (costo-iliac and inguino-abdominal). However, this subdivision cannot rule out a unitary anatomical and functional concept, as proposed by Tillaux [1] and based on:

1. A common embryological derivation due to the myotomes on either side of the vertebral column. Starting from the sixth gestational week, the myotomes colonise the somatopleure; whose ectodermic layer will form the skin of the trunk and the endodermic layer the parietal peritoneum. The myotomes give rise to the serratus muscular group dorsally, the flat muscles laterally and the rectus abdominis muscles ventrally. They proceed simultaneously towards each other from the cranial, caudal and lateral directions until the abdominal wall closes, around week 12 of gestation (Fig. 2).

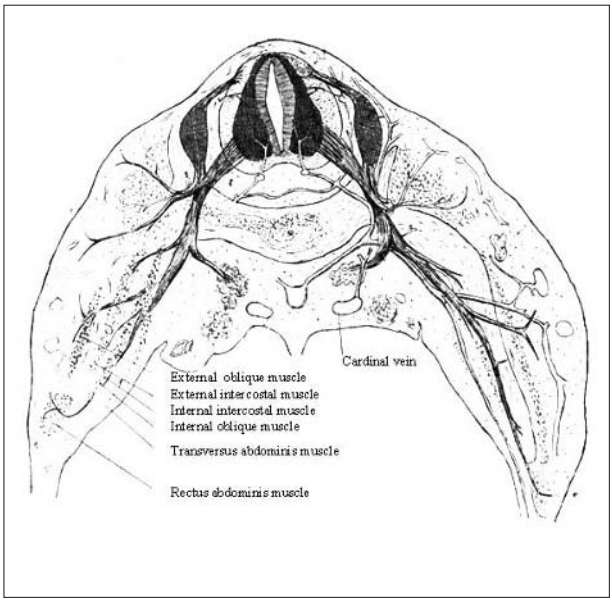

Fig. 2 Transverse section of a 5.5-week embryo. Modified from [2]

2. The existence of a myoaponeurotic system in which fascia, muscles, aponeuroses and sheaths operate synergistically.
3. Innervation and shared vascularisation.
4. The existence of connections with muscular groups and bony and fascial structures of neighbouring areas.
5. The finding of weak areas that persist in the above-mentioned regions or between them and in neighbouring areas.
6. In the presence of parietal defects, the need to reconstruct the structural components and restore wall continuity to guarantee the proper working of the musculofascial system.

The anterolateral wall is divided into three layers: superficial, middle and deep [3] (Fig. 3). In the first layer, the fascia superficialis is the essential element in adipose and cutaneous resistance and continence. This fibro-elastic structure, a vestige of the abdominal cutaneous muscle, is solid but exhibits good distension and retraction capacities and possesses a rich blood afflux. The fascia separates into two layers below the umbilicus, the fascia of Camper, which is superficial and fatty, and the fascia of Scarpa, which is deep and membranous.

In the intermediate myoaponeurotic layer, there is a lateral system made up of the EO, IO and transversus abdominis muscles (with aponeuroses of insertion linking the anterior and lateral regions) and a medial system formed by the rec-

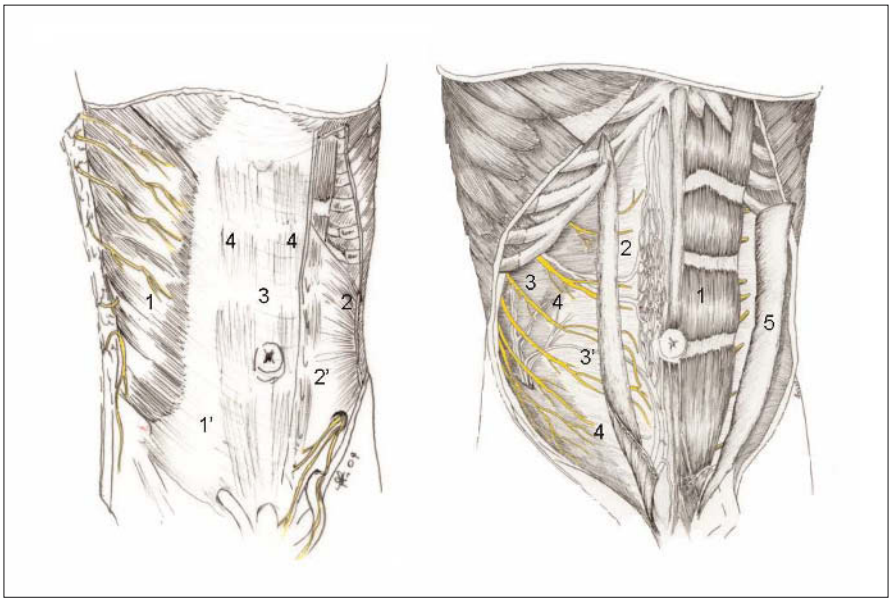

Fig. 3 Frontal view of the anterolateral wall layers, *Left 1*, External oblique muscle and *1'* its aponeurosis; *2*,internal oblique muscle and *2'* its aponeurosis; *3*, linea alba; *4*, anterior layer of the rectus sheath. *Right 1*, Rectus; *2*, posterior layer of the rectus sheath; *3*, transversus abdominis muscle and *3'* its aponeurosis; *4*, Spigelian semilunar line; *5*, aponeurosis of the internal oblique muscle

tus and pyramidalis muscles wrapped by the rectus sheath [4,5]. The lateral system is made up of the large muscles that originate at the bony framework of the abdominal wall; these extend in the mediocaudal direction and are transformed into the wide tendinous planes that form the rectus sheath and the linea alba. The EO muscle originates from the last eight ribs, with fleshy digitations that intertwine with those of the serratus anterior and latissimus dorsi muscles. The muscular tendinous boundary line descends vertically and medially to the hemiclavicular line and below the anterosuperior iliac spine the muscle becomes completely aponeurotic. The tendinous fibres follow the oblique course of the muscle fibres from top to bottom and from outward inward. At the linea alba they intertwine with the opposite fibres of the internal oblique and transversus abdominis muscles, while in the inguinal area they form Falloppia's inguinal ligament, Gimbernat's ligament and the medial, lateral and posterior pillars (Colles'reflected inguinal ligament) of the external inguinal ring (Fig. 4).

The IO muscle originates from the thoracolumbar fascia, from the iliac crest and from the anterosuperior iliac spine. The tendinous fibres follow the direction of the muscle fibres with a wide aponeurosis that contributes to the formation of the rectus sheath and the linea alba (Fig. 5).

The more distal fibres of the IO, together with the aponeurotic fibres of the transversus abdominis muscle, are involved in the composition of the conjoined tendon only in 5% of individuals. This structure is referred to as the "conjoined area" because of the contributions of other connective-tissue elements.

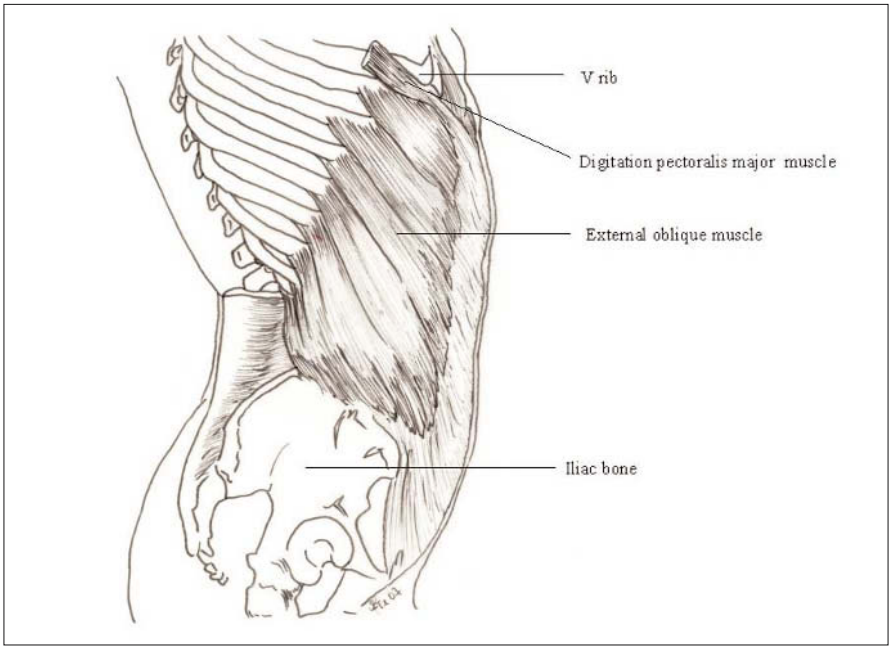

Fig. 4 External oblique muscle and its aponeurosis

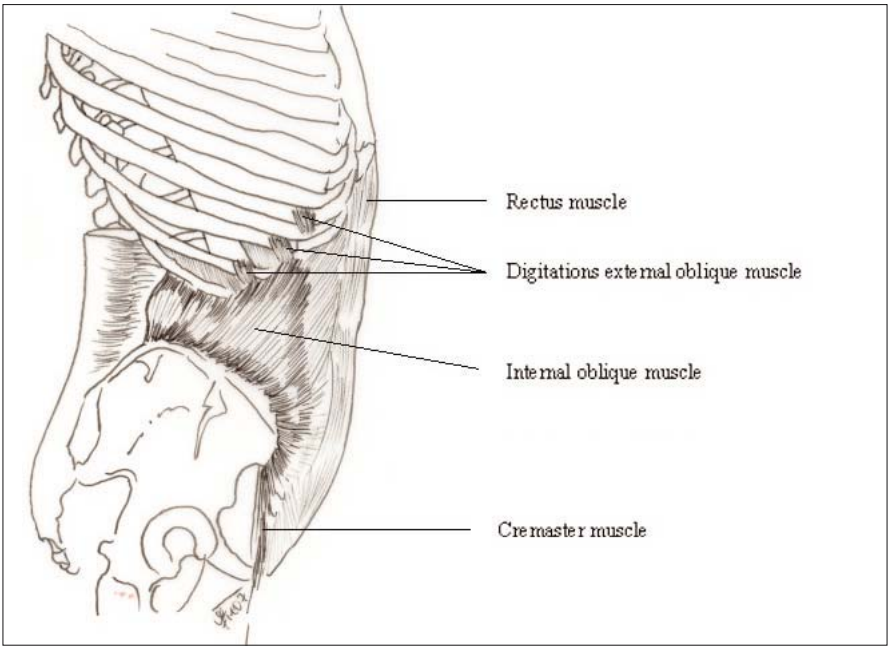

Fig. 5 Internal oblique muscle and its aponeurosis

The transversus abdominis muscle, fleshy in the middle and tendinous at the extremities, originates from the internal surface of the last six ribs, from the thoracolumbar fascia, the iliac crest and the ileopsoas fascia, but not from the inguinal ligament. From these sites, the muscle fibres move medially and become aponeurotic fibres along the Spigelian semilunar line, which extends from the IX costal cartilage to the pubic tubercle, forming a medially concave arch and crossing the muscle tendon line of the oblique abdominis muscles externally (Fig. 6)

The portion of aponeurosis situated between the semilunar line laterally and the external edge of the rectus abdominis muscle medially is known as the Spigelian fascia. It presents a weak area between the external edge of the rectus, the spinoumbilical line of Monro, the bi-spinoiliac line of Lenzmann, the semilunar line of Spiegel and the arcuate line of Douglas (Fig. 7).

At this level, the fibres of the IO and the transversus abdominis muscles run almost parallel; for this reason, even the smallest myoaponeurotic defect can provoke the formation of a ventral lateral hernia.

The aponeurosis of the transversus abdominis muscle contributes to the formation of the rectus sheath and the linea alba; in the inguinal area, it plays a primary role, as the arcus transversus abdominis and as a component of the conjoined area, in parietal resistance and in direct parietal reconstruction, which is carried out by suturing the aponeurosis itself to the inguinal ligament (Fig. 8).

The three flat muscles and their aponeuroses are separated by thin connective

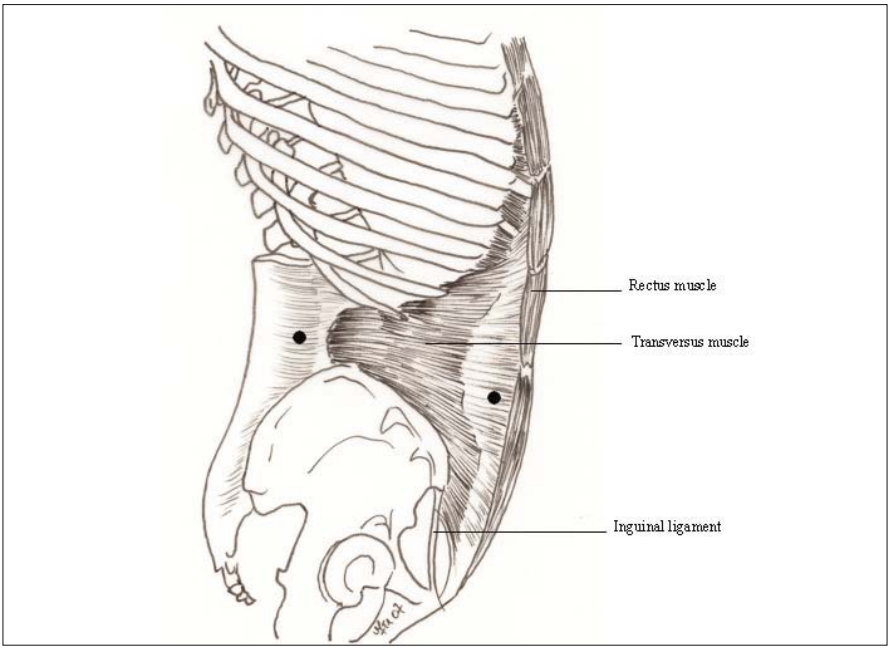

Fig. 6 Transversus abdominis muscle and its aponeuroses (●)

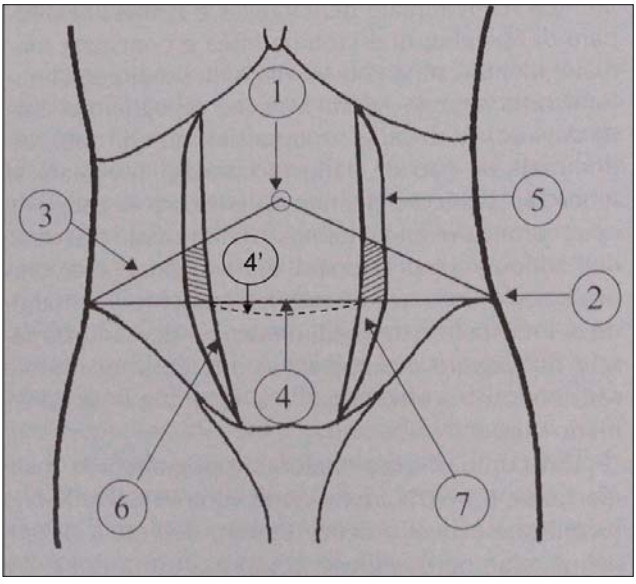

Fig. 7 The Spigelian fascia and its weak area. *1*, Umbilicus; 2, anterosuperior iliac spine; *3*, spino-umbilical line; *4*, bi-spiniliac line and *4'* the arcuate line; *5*, semilunar line; *6*, external edge of the rectus sheath; *7*, Spigelian fascia, ///, weak area. Modified from [6]

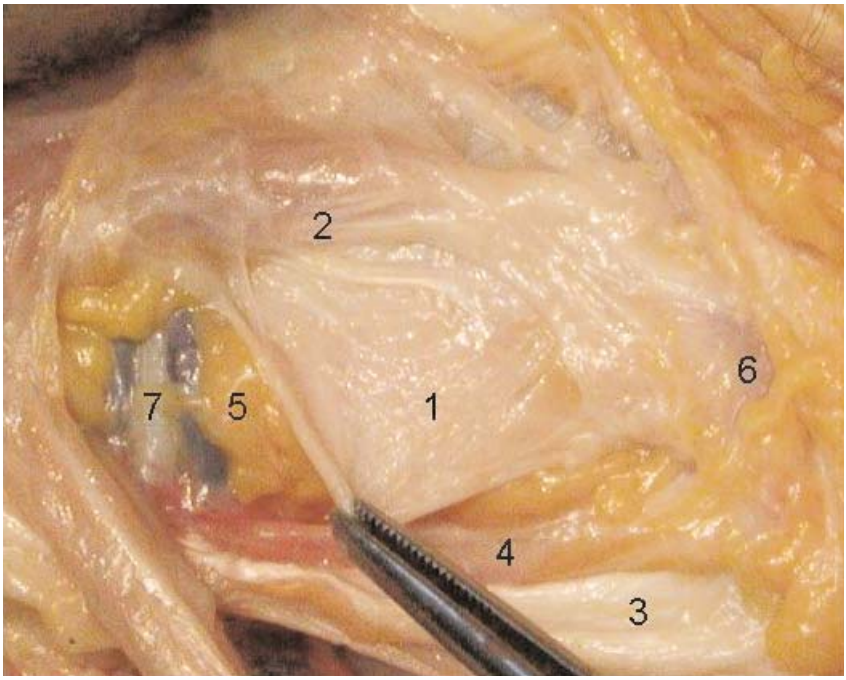

Fig. 8 Myoaponeurotic transversus arch. *1*, Cooper's transversalis fascia (FT); *2*, myoaponeurotic transversus arch; *3*, inguinal ligament; *4*, iliopubic tract; *5*, space of Bogros; *6*, conjoined area; *7*, inferior epigastric vessels

coating membranes. The most external of these is the Gallaudet or Lauth fascia (from which the intercrural fibres of the superficial inguinal ring and the external spermatic fascia originate), while the most internal is Cooper's transversalis fascia (FT) or fascia abdominis interna, which is part of the intra-abdominopelvic fascia [7].

The rectus muscle, the upper part of which inserts into the costal cartilages V–VII and into the xiphoid process and in the lower part into the pubic crest, is a metameric and polygastric muscle.

Its four muscular venters are separated by three tendinous intersections that closely adhere to the anterior layer of its sheath (vagina musculi recti), corresponding to its embryonic segmentation. This disposition explains why haematomas or abscesses of the sheath extend only to the posterior face of the muscle.

The pyramidalis muscle, which is absent in 20% of individuals, is small and triangular in shape. It extends from the pubic crest to the linea alba and is considered to have split off from the rectus abdominis muscle situated in front of it and inside the vagina musculi recti abdominis, over which it exerts tension.

The anterior and lateral abdominal walls are joined by the aponeuroses of the three flat abdominal muscles and constitute the functional unity called the

anterolateral myoaponeurotic abdominal wall. These aponeuroses contribute in a complex way to the formation of the anterior and posterior layers of the rectus sheath and, weaving in the centre, they constitute the linea alba [8]. In the past it was thought that the aponeuroses of the three flat muscles were made up of single sheaths, each of which contributed unilaterally to the formation of the anterior and posterior layers of the rectus sheath.

At the arcuate line of Douglas, there is a semicircular line corresponding to the mid-point between the umbilicus and the pubis. This line is clearly visible when the abdominal wall is examined from inside. All the aponeuroses pass in front of the rectus muscle and, consequently, the FT alone forms the posterior wall of the rectus sheath, with a varying contribution by the aponeurotic bands of the transversus muscle (Fig. 9).

The absence of the posterior layer of the sheath is probably the cause of the particular weakness in the distal tract of the linea alba, which nonetheless presents a strong, resistant reinforcement fascicle behind the rectus abdominis muscles, the so-called adminiculum lineae albae [9].

The most plausible hypothesis regarding the purpose and origin of the semicircular line—and, consequently, the absence of a real posterior fascia positioned distally to it—is the one that links this anatomical position to the presence of the bladder, which during foetal life is positioned immediately behind the rectus muscle, thus preventing formation of the aponeurosis.

The work of Askar and Rizk referred back to ancient anatomical observations (Santorini, 1739) and radically modified traditional views on the formation of

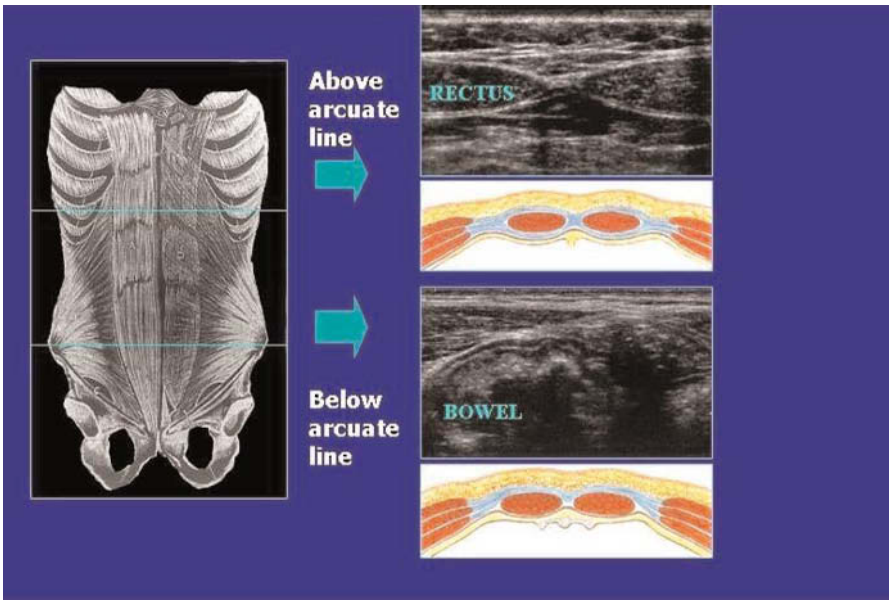

Fig. 9 Composition of the rectus sheath above and below the arcuate line

the rectus sheath and the linea alba. These authors showed the bilaminarity of the aponeuroses of the flat muscles and the manner in which they intersect the median line (Fig. 10) [10,11].

Each one of the three aponeuroses is made up of two separable anatomical layers that unite and form the two laminae of the rectus sheath above the arcuate line: a layer of the IO aponeurosis crosses the EO aponeurosis on the external surface of the outer layer of the rectus sheath or crosses the transversus abdominis muscle aponeurosis on the inner side of the rectus sheath. Both the most superficial and the deepest of the three fibrous laminae of the external layer of the rectus sheath run obliquely and parallel, while the fibres of the middle layer run perpendicular to them (fish bone).

The fibrous corpus of the linea alba cannot be reconstructed perfectly by any suturing method because the original structure derives from a complex decussation. The rectus muscle therefore is enclosed within a robust fascia formed by the bilaminar aponeuroses of the three flat muscles that pass by it from behind and frontally, above the arcuate line. In a distal position to the line, the anterior lamina is formed by six merging aponeurotic layers and the posterior one by the FT. The flat muscles act synergistically, guaranteeing the efficacy of the rectus muscle system. The rectus muscles are linked by the linea alba, the tendinous median line formed by the crossing of the bilaminar aponeuroses of the three abdominal flat muscles: the consequence of a sagging in the central tendinous plane is a deficiency of the rectus muscle, “the master muscle of the abdominal wall” [10].

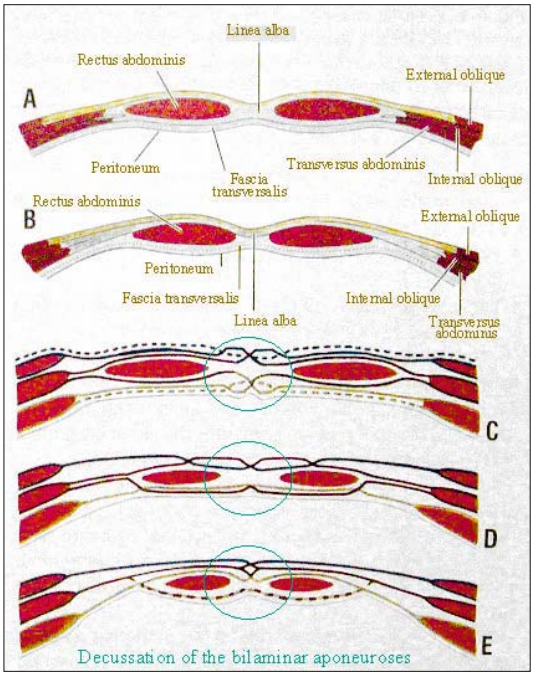

Fig. 10 Decussation of the bilaminar aponeuroses of the flat muscles (according to Askar and Rizk). Modified from [10,11]

The myoaponeurotic layer presents a physiological defect at the linea alba, the umbilical ring, which is surrounded by the fibrous fascicles of the rectus sheaths that merge around the umbilical cord around the tenth gestational week, after the herniated midgut has returned inside the abdominal cavity.

The lower two-thirds of the umbilical ring are occupied by the fibrous nucleus that derives from the fusion of the skin with the urachus and with the three umbilical blood vessels. In the upper third umbilical ring, the loose subcutaneous connective tissue continues almost directly with the subperitoneal tissue, forming a weak area that is often reinforced by a fibrous lamina derived from the rectus sheath, Richet's *fascia umbilicalis*.

The deep parietal layer is made up of the FT, the loose pro-peritoneal connective tissue, and the parietal peritoneum. The FT is a fine and resistant connective lamina that is part of the intrabdominopelvic fascia. It covers the internal surface of the transversus abdominis muscle aponeurotic plane, closely adhering to it. Below the semicircular Douglas line it forms the back layer of the rectus sheath; in the upper part it continues with the diaphragmatic inferior fascia and in the lower part with the iliac and pelvic fascia. Towards the posterior lumbar wall, it blends with the front lamina of the thoracolumbar fascia and in the inguinal area it has a bilaminar aspect with dense thickenings.

The fascia is made up of a membranous layer of rather loose connective tissue with neither aponeurotic nor muscular elements and is variable in consistency. It is more solid in the sub-umbilical site, where it plays an important role of continence, and split in the inguinal area where the front and back laminae delimit a space in which the inferior epigastric vessels run. Its inferior part, positioned between the myoaponeurotic transversus arch above and Thomson's iliopubic tract and Cooper's ligament below, forms the posterior wall of the inguinal canal, which represents a critical site of this area (Fig. 11).

Opinions are discordant on the resistance of the FT and its use as an element on which to base surgical repair of the inguinal plate. However, due to its myoaponeurotic connections and thickenings, the FT can indeed fulfil this function.

In the inguinal area, usually divided into inguino-abdominal and inguinocrural portions, the weak area of the wall is defined by Fruchaud's myopectineal orifice (MPO), a potential site for various kinds of hernias. In the upper part, it is delimited by the arches of the IO and transversus abdominis muscles, laterally by the iliopsoas muscle, medially by the lateral edge of the rectus muscle and below by Cooper's ligament [12] (Fig. 12). Covering of the MPO by means of a prosthesis inserted in the space of Bogros, situated between the FT's posterior lamina and the peritoneum, is the rationale in the preperitoneal repair of hernias, both open and laparoscopic.

From an anatomical and functional point of view, the posterior wall and the deep orifice of the inguinal canal are of particular interest. In 25% of patients, the posterior wall comprises only the FT while in the remaining 75% the anterior lamina of the FT is fused with the myoaponeurotic transversus arch, yielding Condon's transversus abdominis–transversalis fascial layer [13].

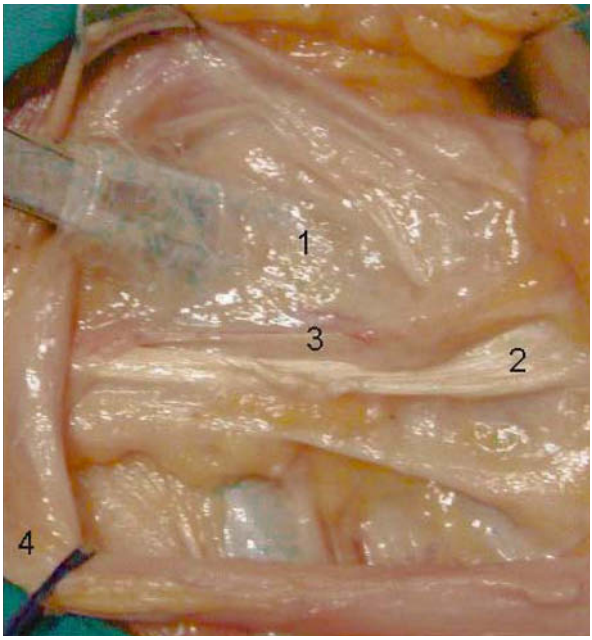

Fig. 11 Cooper's transversalis fascia (FT). *1*, FT; *2*, inguinal ligament; *3*, iliopubic tract; *4*, spermatic cord

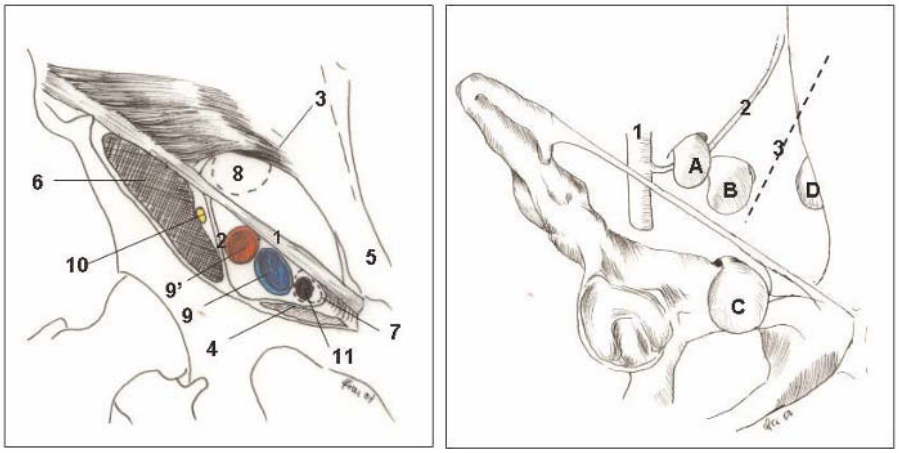

Fig. 12 *Left* Fruchaud's myopectineal orifice. *1*, Inguinal ligament; *2*, iliopectineal arch; *3*, myoaponeurotic arch IO and transversus abdominis; *4*, Cooper's ligament; *5*, rectus muscle; *6*, iliopsoas muscle; *7,* femoral ring; *8*, deep inguinal ring; *9*,*9'* femoral vessels; *10*, femoral nerve; *11*, Cloquet's lymph node. *Right* Inguinocrural hernias. *1*, External iliac artery; *2*, inferior epigastric artery; *3*, medial umbilical ligament

Proceeding towards the lateromedial direction, the posterior wall of the inguinal canal presents: a lateral area between the internal inguinal orifice and the inferior epigastric vessels that is reinforced by Hesselbach's interfoveolar ligament (a thickening of the FT); a medium area constituted only by the FT, corresponding to Hesselbach's triangle, which is delimited medially by the rectus sheath, laterally by the inferior epigastric vessels and below by the inguinal ligament or by Cooper's ligament; a medial area consisting of the FT reinforced by Henle's ligament (thickening of the FT or laterovertical expansion of the rectus sheath), by Colles' reflected inguinal ligament (crus posterior) and by the conjoined tendon (a rare anatomic configuration that derives from the fusion of the aponeurotic fibres of the IO and the transversus abdominis muscles inserted on the pubic tubercle and the upper branch of the pubis) (Fig. 13).

The concept of falx inguinalis applied to a complex of Henle's ligament and the conjoined tendon should be replaced by that of a "conjoined area" comprising Henle's ligament, the transversus abdominis muscle aponeurosis, the inferomedial fibres of the IO muscle or its aponeurosis, the lateral margin of the rectus muscle sheath and Cooper's pecten ligament. In contrast to the inguinal ligament, which is elastic and fixed only at its extremities, this ligament is a fixed and rigid structure. It is formed by a thickening of the upper branch of the pubis periosteum and of the sheath of the pectineus muscle and by aponeurotic insertion fibres of the transversus abdominis muscle system and of the iliopubic tract.

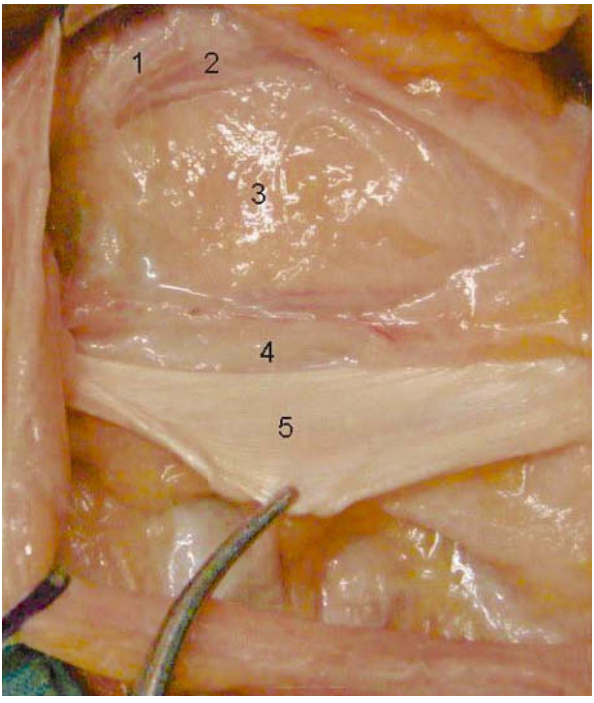

Fig. 13 Posterior wall of the inguinal canal. *1*, Internal oblique arch; 2, myoaponeurotic transversus layer; *3*, FT; *4*, iliopubic tract; *5*, inguinal ligament

The deep inguinal ring, situated half way between the anterosuperior iliac spine and pubic tubercle , is reinforced at its medial margin by Hesselbach's interfoveolar ligament, extending from the iliopubic tract to the arch of the transversus abdominis muscle. The internal ring is an opening of the FT delimited by the aponeurotic fibres of the transversus layer; its lower edge being formed by the iliopubic tract and its upper one by the transversus abdominis muscle arch (Fig. 14).

On the medial side of the ring, the FT forms a V-shaped fold (transversalis fascial sling) that is open laterally and along its the upper part and whose branches are called crura. As the sling and its crura tightly close the deep inguinal ring under the edge of the IO muscle when the transversus abdominis muscle contracts, they guarantee a "shutter" effect that strengthens the back wall of the inguinal canal at maximal intra-abdominal pressure.

With the laparoscopic technique, which does not consider the hernia as a protrusion but rather as the expulsion of a gut segment from the abdominal cavity, the anatomical topography of the inguinal area, from the peritoneum to the posterior surface of MPO, is as follows (Fig. 15):

– Layers: peritoneum, posterior FT lamina, anterior FT lamina and transversus abdominis muscle aponeurosis.
– Anatomical spaces: space of Bogros; lateral extension of the retropubic space of Retzius, situated between the peritoneum and posterior FT lamina; and vascular space in which inferior epigastric vessels run between FT laminae—of these, the anterior one, fused with the tranversus abdominis muscle aponeurosis, forms the posterior wall of the inguinal canal.

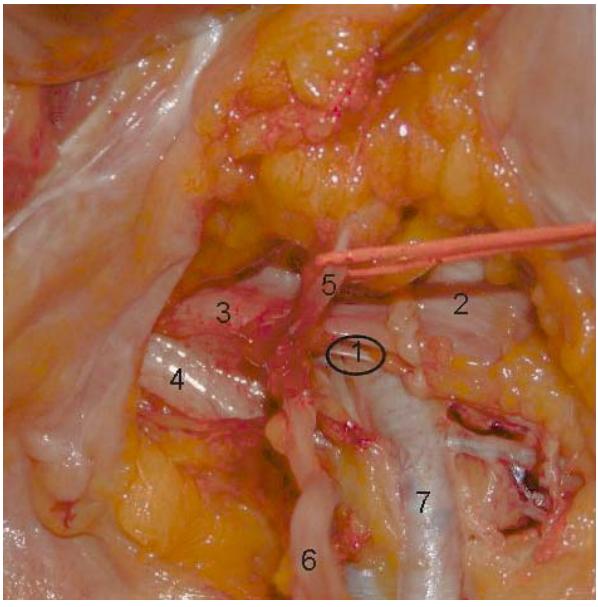

Fig. 14 Internal inguinal ring. *1*, Internal inguinal ring; *2*, aponeurotic transversus layer; *3*, iliopubic tract; *4*, Cooper's ligament; *5*, inferior epigastric artery; *6*, round ligament of the uterus; *7*, external iliac artery. From [14]

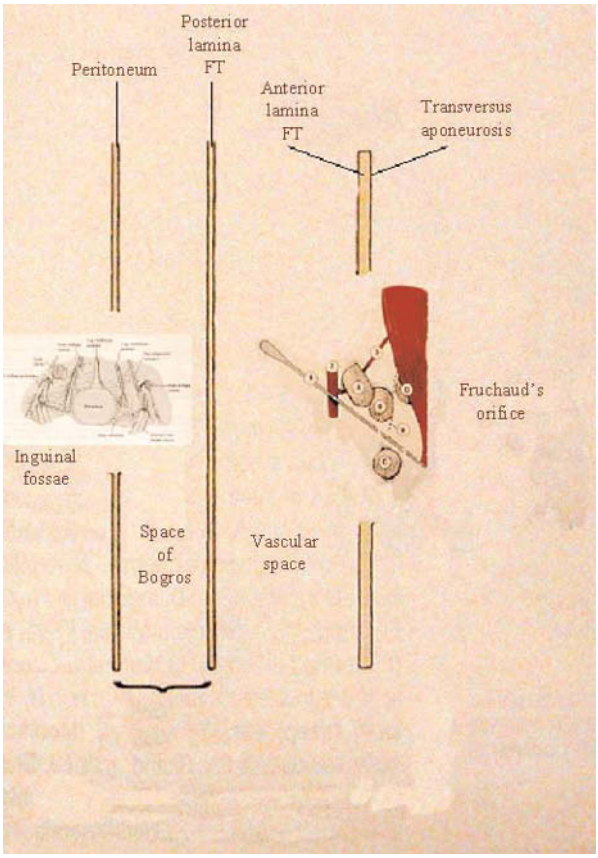

Fig. 15 Topographic layout of the inguinal region in sagittal section. Modified from [3]

– Supravesical, medial and lateral fossae; these are potential sites of hernias.

The posterior distal surface of the anterior abdominal wall is divided on each side into three fossae. These are delimited by formations running between the FT and the parietal peritoneum, which is lifted into the median umbilical fold, corresponding to the urachus (obliterate allantoic duct), into the medial one formed by umbilical ligaments (obliterated umbilical arteries), and into the lateral fold, formed by the inferior epigastric vessels.

Three dangerous areas are located in the posterior dissection of the inguinal region:

1. The "triangle of doom" ("angle of doom"), delimited by the gonadal vessels laterally and by the deferent duct medially, where the external iliac vessels (with the beginning of their collateral branches), the genital branch of the genitofemoral nerve and, deeper, the femoral nerve are located (Fig. 16).
2. The "triangle of pain", formed by the iliopubic tract superolaterally and by the gonadal vessels inferomedially. This is the site of the cutaneous femoris

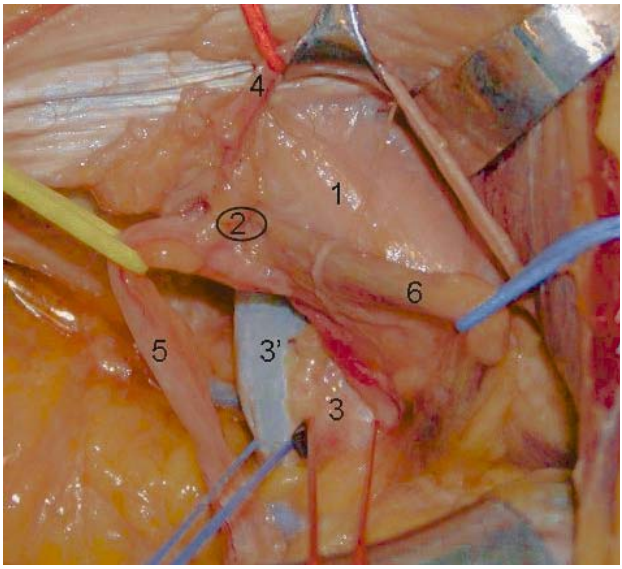

Fig. 16 The triangle of doom. *1*, Transversus aponeurotic layer; *2*, internal inguinal ring; *3-3'*, external iliac artery and vein; *4,* inferior epigastric artery; *5,* deferent duct; *6,* gonadal vessels

lateralis nerve, the femoral branch of the genitofemoral nerve and the femoral nerve; the latter straddles the two triangles protected by the iliac fascia, which is not to be dissected.

3. The corona mortis, an arterial net that forms an anastomotic ring between the external iliac and the obturator blood stream in the distal part of Bogros' space, behind the horizontal branch of the pubis and Gimbernat's ligament. Associated with this net is the deep inguinal venous system [15].

Reflecting from the deep face of the abdominal wall on to the internal iliac fossa, the peritoneum delimits, with the dihedral angle formed by the union of the FT with the iliac fascia, a triangular prismatic space, Bogros' space which straddles the inguino-crural and the internal iliac regions (Figs. 17,18).

From front to back, this region contains the following formations: the peritoneo-intestinal layer, sub-peritoneal cellulo-adipose layer (containing the external iliac vessels and their branches, the iliac and obturator lymph nodes, the gonadal vessels, the deferent duct or the round ligament of the uterus and nerve branches of the lumbar plexus), iliac fascia and crural nerve, bony plane.

From inside outward, the lumbar wall is made up of: peritoneum, extraperitoneal adipose connective tissue, transversalis fascia, deep muscular layer (quadratus lumborum and psoas muscles), middle muscle layer (sacrospinalis, internal oblique and serratus posteroinferior muscles), thoracolumbar fascia (anterior, middle and posterior), superficial muscle layer (latissimus dorsi and external oblique muscles), superficialis fascia and skin.

In the lumbar area, two weak points in which lumbar hernias may occur have been described: a deep one, Grynfelt's space, and a more superficial one, Petit's

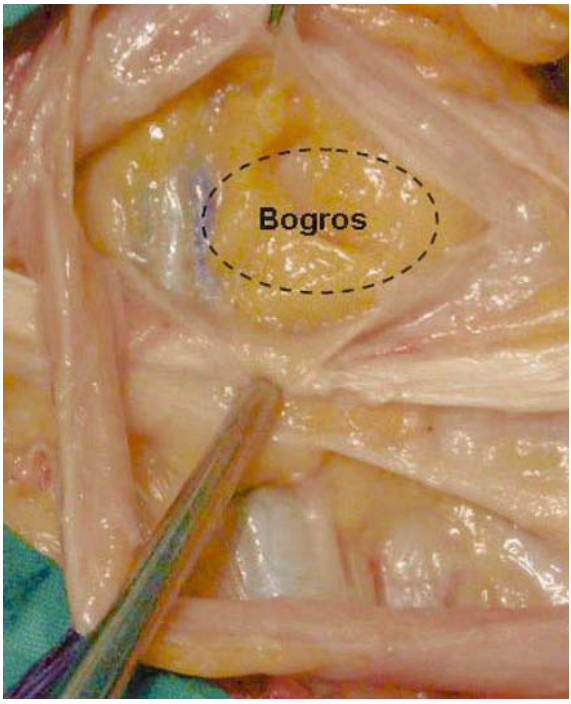

Fig. 17 Right Bogros' space

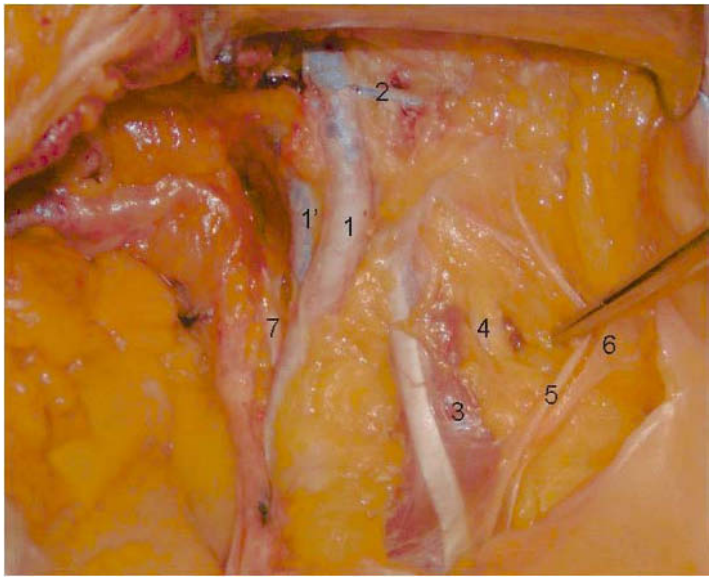

Fig. 18 Right internal iliac fossa. *1-1',* External iliac artery and vein; *2,* deep circumflex iliac artery; *3,* psoas muscle; *4,* femoral nerve; *5,* genitofemoral nerve; *6,* lateral femorocutaneous nerve; *7,* obturator nerve

triangle. Grynfelt's space is delimited posterosuperiorly by the posteroinferior serratus muscle, medially by the lateral margin of the spinalis dorsi muscles, laterally and below by the back edge of the IO muscle; laterally and above by the 12th rib. The space above is occupied by the aponeurosis originating from the transversus abdominis muscle formed by the fusion of the thoracolumbar aponeurosis layers. The trigonum lumbale, delimited by the front edge of the latissimus dorsi muscle, by the back edge of the EO muscle and by the iliac crest, contains the IO and the transversus abdominis muscles [16].

The upper abdominal region corresponds to the diaphragm which separates, like a transverse septum, the thoracic cavity from the abdominal one. It is made up of a central tendinous part and by a fleshy outer part formed by muscular fascicles that originate in the sternal, costal and vertebral regions. The posterior insertion of the diaphragm extends much further downwards than the anterior one; it is for this reason that the diaphragm is an important component of the posterior abdominal wall, to which several viscera are connected.

Vascularization of the abdominal wall is accomplished by a superficial system (epigastric, circumflex iliac and pudendal superficial arteries, branches of the femoral artery) and by a deep one, articulated along several vascular axes (Fig. 19).

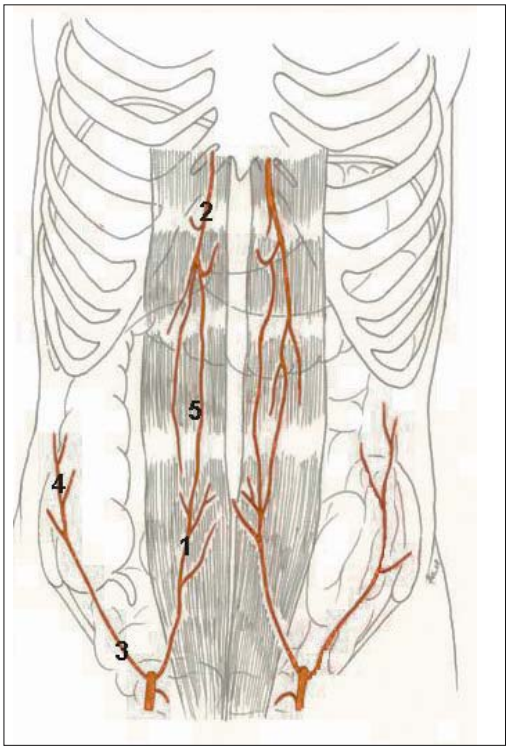

Fig. 19 Deep arterial system. *1*, Inferior epigastric artery; *2*, superior epigastric artery; *3*, deep circumflex iliac artery; *4*, lateral vascular axis; *5*, vertical vascular axis

The vertical axis is formed by the inferior epigastric artery, which is a branch of the external iliac artery, and by the superior epigastric artery, a branch of the internal mammary artery (branch of the subclavian artery), that runs in the subperitoneal areolar tissue and then perforates the posterior layer of the rectus abdominis muscle sheath to spread to the muscle, in whose thickness they anastomose.

The lateral axis is formed by the anastomotic intercostal arches and by the lumbar arches, which give origin to the branches that run through the IO and transversus abdominis muscles to supply not only the muscular structures but also the superficial planes. The inferior lateral axis corresponds to the circumflex deep iliac artery, a branch of the external iliac artery, giving origin to a branch extending to the muscles of the anterolateral wall.

A reference point defined by the inferior epigastric artery extending from the umbilicus 2 cm inside the mid-point of the Falloppian arch is particularly important for correct introduction of trocars in the inguinal area.

The anterolateral wall is innervated by the last seven intercostal nerves, the subcostal nerve, the iliohypogastric and ilioinguinal nerves, and by small ramifications of the genital branch of the genitofemoral nerve. The nerves that penetrate the abdominal wall run through the flat muscles, where they diverge greatly. These nerves can be divided into three groups: cranial (branches D5–D7), medium (branches D8 and D9) and distal (branches D10 to L1) (Fig. 20).

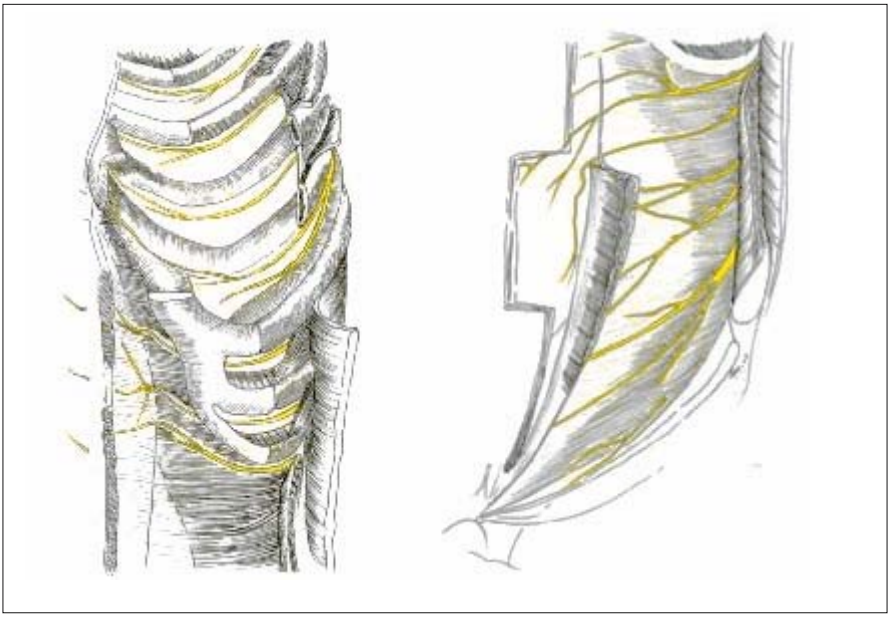

Fig. 20 Innervation

Functional Anatomy

The sheaths covering the muscles and the aponeuroses that guarantee their insertion are well-defined homogenous thickenings of connective tissue which, together with the muscular tissue, form a myofascial complex able to resist the continuous variations in intra-abdominal pressure. When a person is at rest, the sheaths play an important role in containment, whereas when tension is imposed by muscular contraction, they offer passive resistance, with the muscles taking on the barrier function. The interaction between the fascial and the muscular elements results in a clear synergism: when a person is at rest, the muscular overtension linked to the normal intra-abdominal pressure is held back by the sheath, while during stress, when there are harsh increases in pressure, the protection of the sheath is guaranteed by the muscles.

In the areas of the abdominal wall where a trait of sheath free of muscle is inserted, the neighbouring structures, which are non-deformable by a load, serve as anchorages. The fascial area can be compared to a flexible segment of a static system subject to a force that produces a flexing effect, derived from the resulting load, here represented by the intra-abdominal pressure, for half the distance between the two anchorages [17] (Fig. 21).

Under constant pressure, the load that the sheath is to bear is proportional to the surface under pressure and it increases by the squares of the distance between anchorages, with a tension that is regulated by the law of Laplace. Under equal load, the flexing effect depends not only on the distance between anchorages but also on their involution caused by the prolonged pressure. Under normal conditions, parietal contraction provokes a shrinking of the abdominal cavity and a consequent reduction in the curve range. This leads to a decrease in abdominal-wall stress which, according to Laplace's law, is proportional to the extension of the sheath area, to the distance between anchorages and to the curve range.

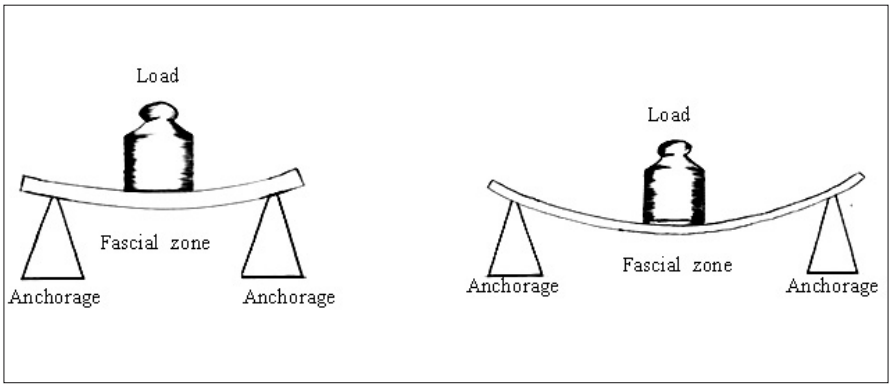

Fig. 21 Variations of the flexing effect in a static system

In a wide non-contractile (passive) area of the abdominal wall, the pressure exerted by the abdominal press produces a thrust along the anchorage line of the same area that is proportional to its surface and curve range. This is known as the "sail effect" and it can be seen, for example, in the case of a large hernia porta (Fig. 22).

The traction and pressure forces to which the wall sheath is continuously, but with variable intensity, subjected make these structures vulnerable to failure. This becomes more evident in those areas lacking muscular protection. In the second phase, deterioration of the sheath involves the muscular part which becomes atonic due to overtension. Eventually, dystrophy, fibrosis and necrosis due to compression ischaemia are the results. The muscular dynamic modifications increase the parietal damage and are involved in the myofascial failure, with a partial and therefore inefficacious contraction of the muscular fibres.

The transversalis fascia also plays a passive role and cannot resist wear unless supported by the surrounding muscles, which actively reduce and cushion straining.

The abdominal wall must be considered as a unitary functional system: "this wall of the body is made up of eight muscles by means of which it attracts, holds back, prepares, expels and accomplishes many other functions" (Andrés de Laguna, 1535) [3].

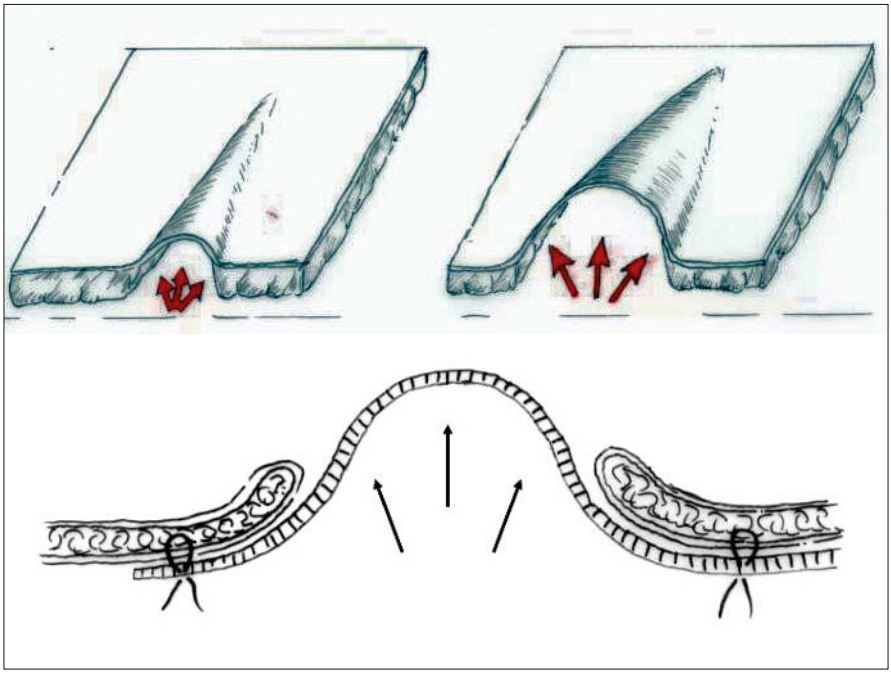

Fig. 22 Induced deformation by intrabdominal pressure on a passive parietal zone (sail effect)

The muscles of the abdominal wall work synkinetically with their aponeuroses and form a solid but flexible wall that contains and protects the viscera in the abdominal cavity, maintaining their correct anti-gravitational position. They form functional pairs that are in opposition and therefore balanced: one pair is formed by the rectus abdominis and the transversus abdominis muscles, the other by the external and internal oblique muscles. Functional balance is realised through the antagonism of the two pairs (Fig. 23).

The myoaponeurotic layer is involved in various actions including flexion, extension and rotation of the trunk and pelvis. It also takes part in defecation, micturition, the birth process and respiration through an increase in intra-abdominal pressure.

Muscular contraction pushes the viscera upwards and intervenes in expiration, both at rest and forced; the essential component is the transversus abdominis muscle, which acts as an antagonist to the diaphragm. The rib cage, diaphragm and abdominal wall comprise the respiratory wall (chest wall) (Fig. 24). Correct functioning of the chest wall is based on the transdiaphragmatic pressure: at normal intra-abdominal pressure, the fixed tendinous centre of the diaphragm supplies its muscle fibres with a valid leverage point that allows an increase in thoracic diameter [18].

The abdominal-wall muscles and the diaphragm together form a functional system in which the abdominal muscles work as stabilisers and the diaphragm as a mobiliser. Contraction of the former causes an increase in intra-abdominal pressure and immobilisation of the phrenic centre, which becomes the fulcrum of the diaphragm's muscle bundle; during contraction, the latter mobilises the

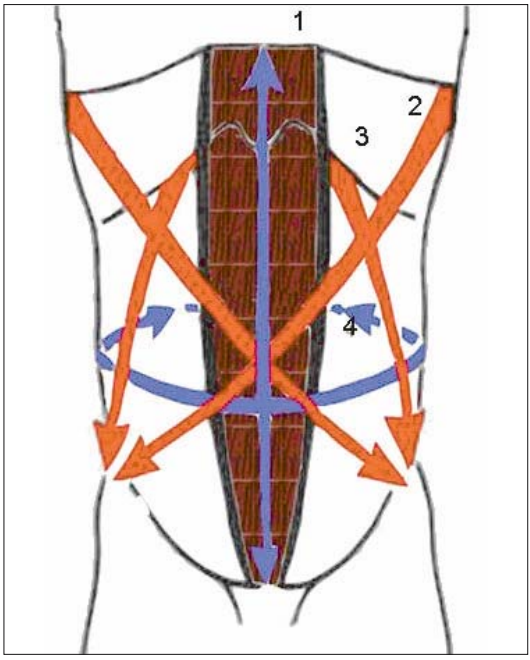

Fig. 23 Functional muscular pairs of the anterolateral abdominal wall. *1,* Rectus abdominis muscle; *2,* external oblique muscle; *3,* internal oblique muscle; *4,* transversus abdominis muscle

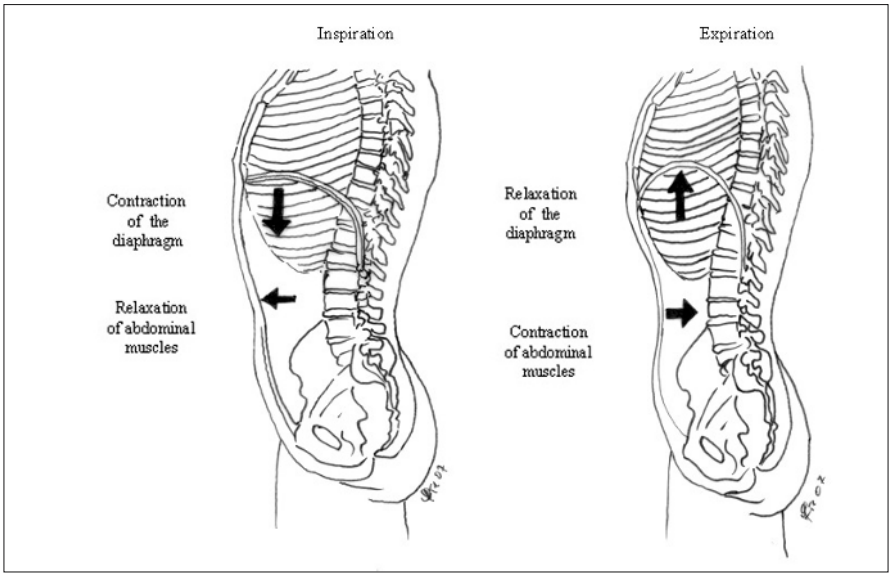

Fig. 24 The chest wall

last six ribs, producing a vertical, sagittal and transversal increase of the thoracic diameters. Accordingly, a vacuum in the chest cavity is created, which favours inspiration. The increased thoracic capacity pushes the abdominal viscera towards the front wall, which lifts up. The regular succession of these actions guarantees normal respiratory compliance.

While the diaphragm and abdominal muscles act antagonistically during respiration, during coughing and other actions that push on the abdomen, they function synergistically. The abdominal wall relaxes on inspiration and contracts on expiration. The voluntary contraction of the abdominal muscles blocks respiration; therefore, with the diaphragm in a fixed position the intrabdominal pressure increases, which allows voluntary opening of sphincters involved in micturition, defecation and childbirth (Fig. 25).

In the presence of a large parietal breach, subsequent total or partial disinsertion of the flat abdominal muscles and the formation of a hernial sac lead to a reduction of intra-abdominal pressure and the creation of a second cavity (enucleation of the content), with respiratory, visceral, vascular and vertebral sequelae (Figs. 26, 27). Synergism between the leverage point of the diaphragm and chest wall synergism is modified because of a weaker contraction of the diaphragm contraction which is due to the involvement of the latter in fixing the phrenic centre instead of increasing the thoracic diameters. The decrease in intra-abdominal pressure provokes distension of the viscera and a consequent alteration of their vascularisation and function, an altered vena caval and portal venous return, and, because of the associated muscular weakness, modification of the steadiness of the lumbar vertebral column.

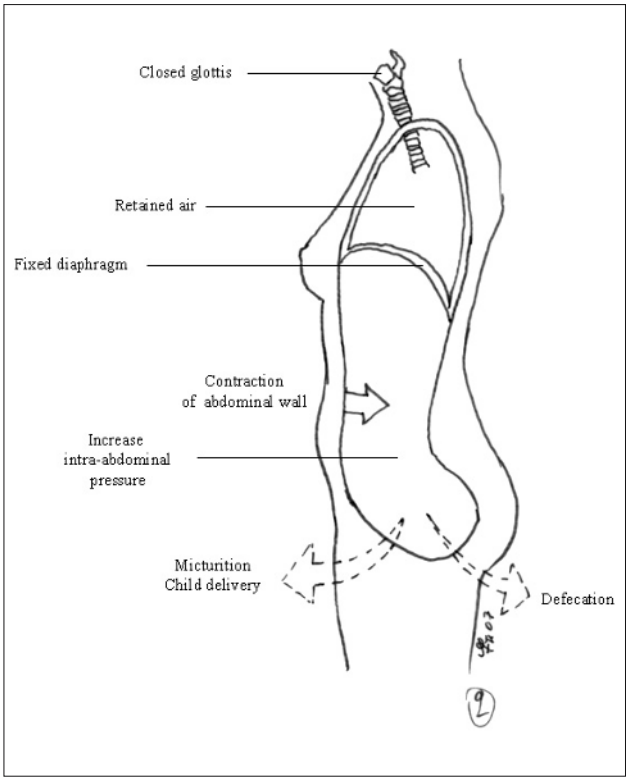

Fig. 25 Increase in intra-abdominal pressure during micturition, defecation, and childbirth

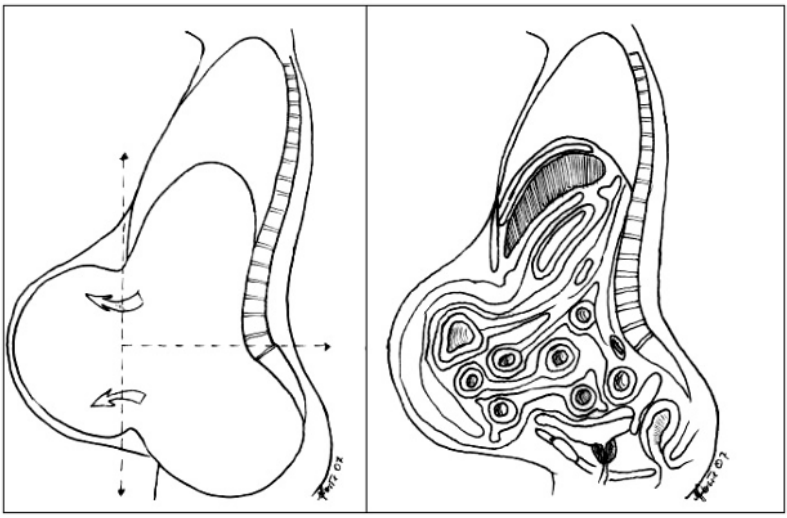

Fig. 26 Creation of a second abdominal cavity with 'enucleation' of the content due to a large incisional hernia. Modified from [19]

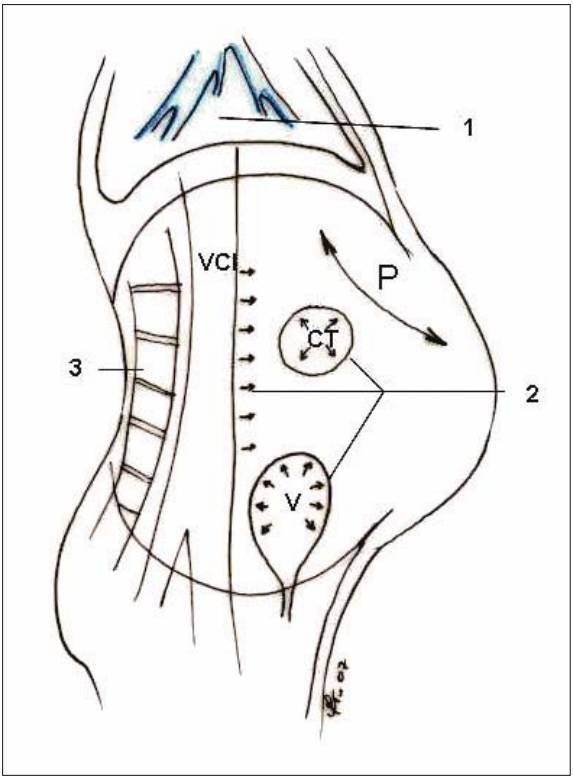

Fig. 27 Respiratory (*1*), visceral and vascular (*2*), and ventral (*3*) sequelae. Modified from [19]

In association with the dorsal superficial (latissimus dorsi, trapezius muscle) and deep (long and short spinalis muscles) muscles, the parietal muscles also contribute to the overall balance of the vertebral column and to the rotation and lateral inclination of the trunk. An important role is played by the traction exerted on the linea alba by the flat abdominal muscles through their insertional aponeuroses, which form the sheaths of the rectus abdominis muscles and the linea alba. These fascial structures confer parietal transverse resistance since the rectus abdominis muscles running longitudinally are easily deviated outwards by any transversal force that tends to separate them (Fig. 28). Also the anisotropic array of collagen fibres, which have a higher longitudinal compliance, contributes to the greater resistance of transversal parietal incisions compared to longitudinal ones [20].

Knowledge of the parietal innervation allows, at least theoretically, surgical incisions to be made that maintain its integrity and thereby assure correct muscle function. Indeed, the diverging course of the nerve fibres helps to define the limits of nerve-sparing techniques although the segmented nature of muscle innervation results in a vicarious functioning of the residual nervous branches. This is true of the rectus abdominis muscle, which becomes paralysed only by

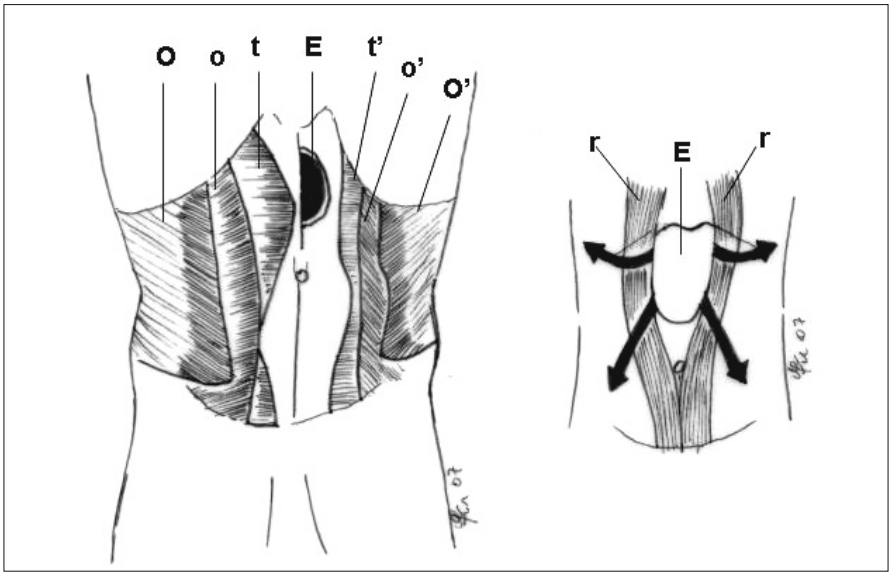

Fig. 28 Retraction of the rectus abdominis muscles induced by the flat abdominal muscles in the presence of median eventration. *O,* External oblique muscle; *o,* internal oblique muscle; *t,* transversus abdominis muscle; *r* rectus abdominis muscle; *E,* eventration. Modified from [21]

the sectioning of at least three of the last six intercostal nerves that guarantee its innervation.

As a group, the abdominal muscles, in particular the rectus abdominis muscles, are rich in pure slow-contraction tonic fibres (Burke's type 1), with few rapid and relatively resistant postural 2A fibres and even fewer rapid but poorly resistant phase 2B fibres [22].

Each of the parietal muscles makes a specific functional contribution (Table 1):

- The oblique muscles are wall tensors and costal depressors; their function is to support the abdominal viscera and assist in the flexion and rotation of the trunk.
- The transversus abdominis muscle is a tensor of the wall and a depressor of the ribs; it receives intense impulses from the central expiratory neurons.
- The rectus abdominis muscle is a tensor of the wall and a ventral flexor of the trunk; it contributes to stabilising the pelvis during walking, protects the abdominal viscera and is active during forced respiration.
- The pyramidalis muscle is a tensor of the linea alba.
- The quadratus lumborum muscle attaches to the last rib and flexes the spinal column ipsilaterally.
- The psoas major muscle flexes and turns the thigh laterally and tilts the column laterally.
- The cremaster muscle pulls the testicle downwards.
- The diaphragm muscle is the main respiratory muscle; it moves about 1.5 cm

Table 1 A synopsis of the abdominal-wall muscles

Muscle	Origin	Insertion	Innervation	Function
External oblique	External surface of the last eight ribs	Iliac crest lateral edge, linea alba	T7–T12	Compression of the abdominal contents; trunk flexion, rotation, tilt
Internal oblique	Thoracolumbar fascia, iliac crest	Lower edge of last 3–4 ribs, linea alba	T7–T12 and L1	Compression of the abdominal contents; trunk flexion, rotation, tilt
Transversus abdominis	thoracolumbar fascia,inner surface last six ribs	Linea alba, pectineal line	T7–T12 and L1	Compression of the abdominal contents
Rectus abdominis	Pubic symphysis	Lower costal cartilages, xiphoid process	T7–T12	Compression of the abdominal contents, vertebral-column flexion, abdominal-wall tension
Pyramidalis	Pubic symphysis	Linea alba	T12	Linea alba tension

during normal respiration and 6–10 cm during deep respiration.

In the inguinal region, the FT blends with the myoaponeurotic arch of the transversus abdominis muscle to form Condon's transversus abdominis-transversalis fascial layer, whose role is protection and containment.

Through its aponeurosis, the transversus abdominis muscle acts simultaneously on the deep inguinal ring and on the aponeurotic arch; when under tension, the latter becomes rigid and leans on the iliopubic tract. The IO, which contracts during sharp increases of intra-abdominal pressure, protects all of the wall planes, including the external oblique aponeurosis, from overdistension. This has a function of containment and support when at rest while, under muscle contraction, the resulting stiffening actively contributes to parietal resistance.

The degree of resistance of the posterior wall of the inguinal canal depends also on the size of the inguinal triangle, which is delimited by the lower edge of the IO, by the inguinal ligament and by the lateral edge of the rectus abdominis muscle. The inguinal triangle corresponds to a part of the wall that completely lacks IO protection.

The sphincteric action of the transversus abdominis and IO muscles is exerted on the deep inguinal ring, a critical point and possible hernial opening. The

FT forms an inverted U-shaped sling that closes the ring below the muscular edge of the IO by contraction of the transversus abdominis muscle. The ring moves and is narrowed by the contraction of the transversus abdominis muscle as its aponeurosal insertion; as a consequence, it is involved in the action of the aponeurotic fibres which, pulled by the muscle, move towards the iliopubic tract and the inguinal ligament, thus strengthening the posterior wall of the inguinal canal.

This is the mechanism behind Keith's "shutter effect", in which the posterior wall of the inguinal canal is protected from an increase in intra-abdominal pressure. This mechanism is in contrast to that suggested by other investigators, in which it is not the contraction of the transversus abdominis muscle but the shortening and lowering of the IO (so that the muscle leans on the inguinal ligament), under which the deep inguinal ring is located (Fig. 29)

Fascial structures prevail in the inguinal region while, especially in men, the muscular component is poor: this explains the considerable incidence of hernias due to weakness in the male inguinal area.

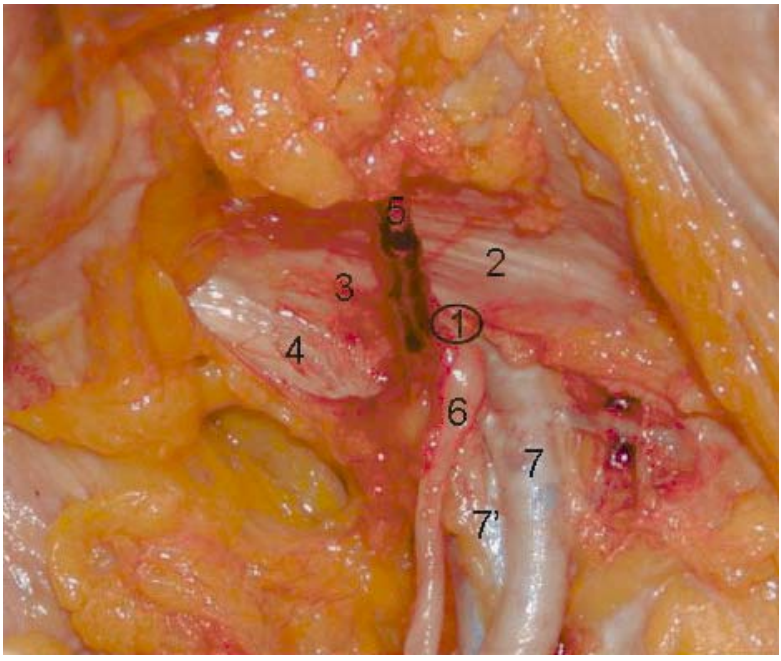

Fig. 29 Keith's shutter effect at the level of the deep inguinal ring. *1,* Internal inguinal ring, *2,* myoaponeurotic transversus arch; *3,* iliopubic tract; *4,* Cooper's ligament; *5,* inferior epigastric vessels; *6,* round ligament of uterus; *7-7',* external iliac vessels. Modified from [14]

Conclusions

In the presence of parietal defects, the recovery of abdominal-wall integrity is essential, not only for protection of the viscera, but also for stabilization, movements of the trunk and posture.

As the fascial surfaces (which are large and unprotected by muscles) are vulnerable to decompensation, it is important to compensate for the discontinuity of the abdominal muscles and to restore the appropriate function to each anatomical plane.

The ideal technique for the repair of ventral defects consists of reconstruction of the structural components of the abdominal wall, using the myofascial wall elements in continuity with their vascular and nerve pedicles [23]. Quite often, however, restoration of parietal continuity can be achieved only through prosthetic repair techniques based on the absence of suture tension. These techniques, although they do not completely restore the original anatomofunctional configuration, allow normalisation of the parietal dynamics by restoring the median central fulcrum upon which the flat muscles can again contract.

Even if the implantaion of a prosthesis creates a passive surface that, according to the laws of statics, tends to be displaced, it is also true that this effect is compensated by the uniform pressure distribution exerted on the entire area, as regulated by the fundamental laws of hydrostatics (Fig. 30):

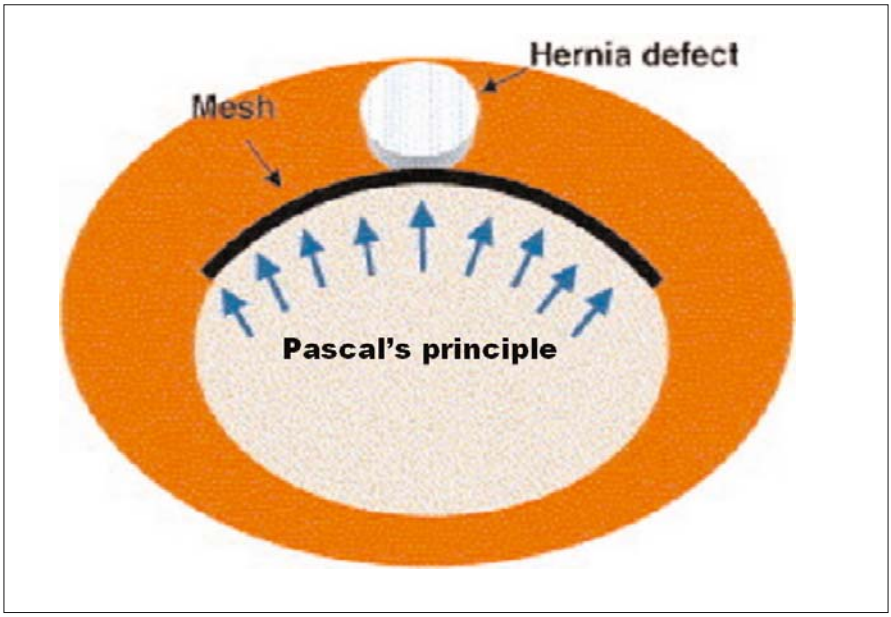

Fig. 30 Pascal's principle

1. Pascal's principle (Blaise Pascal, 1623-1662): According to the Principle of Hydrostatics, in a balanced incompressible fluid, pressure is integrally transmitted to all directions.
2. Stevino's law (Simon Stevino, 1548-1620): The Fundamental Law of Hydrostatics states that in a still liquid the hydrostatic pressure p at a generic point P is given by the distance h of this point from the free surface and is equal to the weight of a liquid cylinder of unitary section or height h.

Restoration of an adequate intra-abdominal pressure, due to a correct parietal reconstruction, resolves not only myofascial but also respiratory, vascular and visceral complications, all of which can occur in large abdominal hernias. While reconstruction of the structural components of the abdominal wall should always be favoured, it is the recovery of parietal continuity which, through adaptation and compensation, guarantees the functional and synergistic recovery of the myofascial system.

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Epidemiology

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Introduction

We carried out a survey that focused on incisional hernia and its surgical treatment based on data derived from the SDO (hospital discharge) file codes, with patient diagnoses defined by the ICD 9 CM (International Classification of Diseases–Clinical Modification) system. Data for the period 1999–2003 were obtained from the web site of the Ministry of Health, Department for Sanitary Programming [1]. To correctly interpret the data, the analysis was made with respect to calendar year, age class and sex.

Until 1994, the ISTAT (Italian Institute of Statistical Data) [2] had analysed hospital discharge information according to a survey pattern referred to the first seven days of every month of the year. Beginning in 1995, SDO [3] was introduced for every admission made by public and private institutes. Information regarding discharged patients and patients who had died was collected. The SDO thus provided an informative basis for epidemiologic studies and analyses of hospital efficiency. However, despite these efforts and the creation of different task groups aimed at improving data acquisition, complete homogeneity has not been achieved for either the collection, or the control of patient registration or the way in which the information is organised [4].

The fact that the validity of the reported information cannot be guaranteed is due to the accuracy of certification. In particular, many SDO file codes include the term "laparocele" and are therefore confusing. If this pathology was not considered to be the main one then its treatment was considered irrelevant.

The research was carried out by examining the following ICD-IX CM codes: main diagnosis of laparocele not specified with obstruction discharge (code 55220); incisional hernia with obstruction (code 55221); laparocele not specified without obstruction (code 55320); post-surgical-treatment laparocele (code 55321), and other laparoceles without obstruction (code 55329). The information was subdivided with respect to age, place of admission and average number of hospital days in bed and was verified by region for the period 1999–2003 (latest available data).

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

Data describing the surgical procedure were also collected and easily verified. The information was subdivided according to: surgical procedure of incisional hernia without mesh (code 5351) and surgical procedure of incisional hernia with mesh (code 5361). These data were recorded, analysed and subdivided according to patient age, place of admission and mean period of hospital days in bed. Again, the information was verified by region for the period 1999–2003 (latest available data).

Epidemiological Analysis

Data for the category "laparocele not specified without obstruction" (code 55320) (Fig. 1) was analysed for the 5-year period 1999–2003. In 1999, almost 10,000 cases involving women were recorded whereas in 2003 there were only 3,000 cases involving women. A similar decrease was recorded for men: 6,500 in 1999 and 2,000 in 2003. The ratio of men to women in this group did not change in the 5 years except in 2002, when less than half the patients in this group were men. It is not clear why there were 16,500 patients in 1999 whereas in the year 2003 there were only slightly more than 5,000 such patients. The data were compared with those from the group "post-surgical-treatment laparocele" (code 55321), since there are no epidemiological reasons for the disparity in patient numbers. Instead, the explanation might be that, in the hospitals included in the analysis, the medical staff responsible for designating SDO codes prefers those that are economically advantageous for the respective hospital. For the mean period in bed, a decrease during the five years was noted: for men, 7.52 days in 1999 and 6.45 in 2003; for women, the difference was less, 8.64 in 1999 and 7.15 in 2003. Regional variability was also obvious. In 1999, the mean period in bed was 6.35 days (of the 200 patients discharged) in Trentino Alto Adige but almost 19 days in Valle d'Aosta (12 patients). In 2003, in the same two regions the values were 5.6 days (71 patients) and 2.67 (only 3 patients), respectively.

For day patients admitted with a diagnosis of "laparocele not specified without obstruction", there were 720 cases in 1999, 371 in 2001 and more than 520 in 2003. So, after an initial reduction, the number of patients in this group increased. It is not known whether this trend has continued.

Data from the category "post-surgical-treatment laparocele" (code 55321) were compared with those from "laparocele not specified without obstruction" (code 55320). These results showed that a decrease in the number of patients in the latter group corresponded to an increase in the number in the former group (Fig. 2), with 891 (353 male and 538 female) patients in 1999 and almost 10,000 (4,084 male and 5,862 female) in 2003. When the data were subdivided for age we observed that, in 1999, the most cases (387: 156 males 231 females) occurred in patients 45–64 years of age, followed by those 65–74 years of age (281: 115 males, 166 females). The fewest cases were recorded in the age group

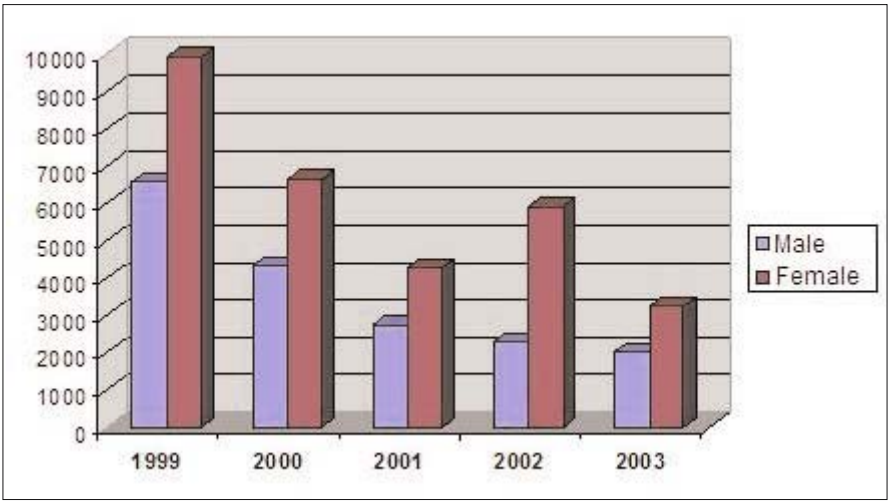

Fig. 1 Laparocele not specified without obstruction

>75 years (142: 50 males, 92 females). In 2003, patients 45–64 years of age accounted for 3,780 cases (1,573 males, 2,207 females), while in the age group 65–74 years there were 3,279 cases (1,416 males, 1,863 females), and in the group of patients >75 years there were 1,866 cases (683 males, 1,183 females). The explanation is probably not epidemiological but, more likely, economical. Also, during the study period, there was little change in the prevalence of female vs. male patients (from 1.6:1 in 1999 and 1.7:1 in 2003).

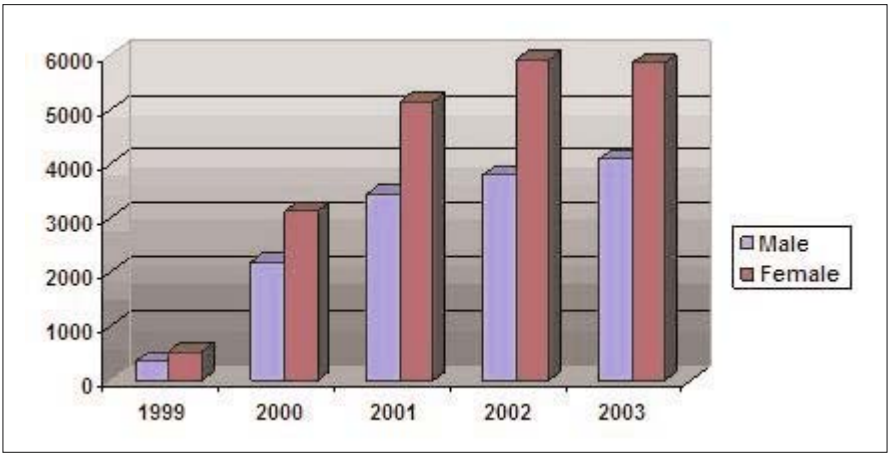

Fig. 2 Post-surgical-treatment laparocele

Even more interesting is the mean number of days in bed (Fig. 3), which decreased from 9.5 to about 7 days over the 5-year study period. This may have been due to the greater efforts of the medical staff to decrease costs by reducing the number of patient days in bed and to improvements in surgical technique and postoperative management. The number of days in bed was always longer for women (10.20 vs. 8.89 in 1999; 7.33 vs. 6.89 in 2003).

Further analysis of the category "laparocele not specified with obstruction" (code 55220) (Fig. 4). showed a progressive and clear decrease in the number of cases, from about 2,200 in 1999—with a clear prevalence of females (1,632) vs.

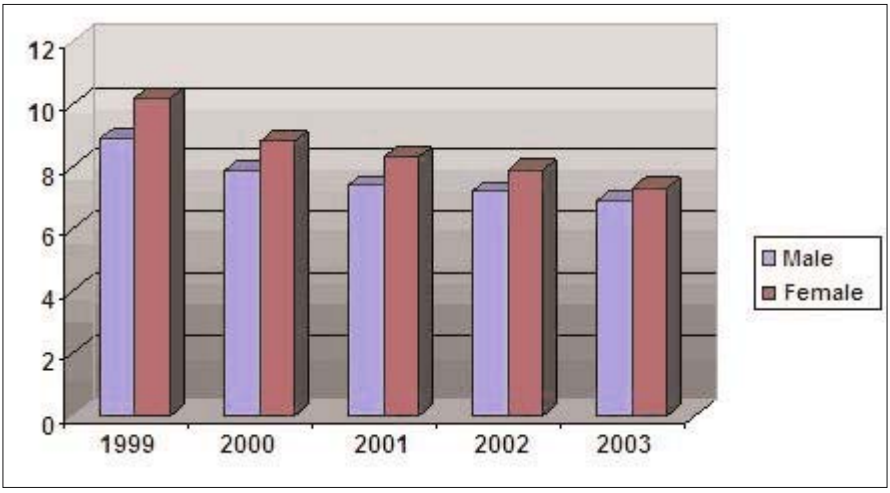

Fig. 3 Post-surgical-treatment laparocele. Mean number of days in bed

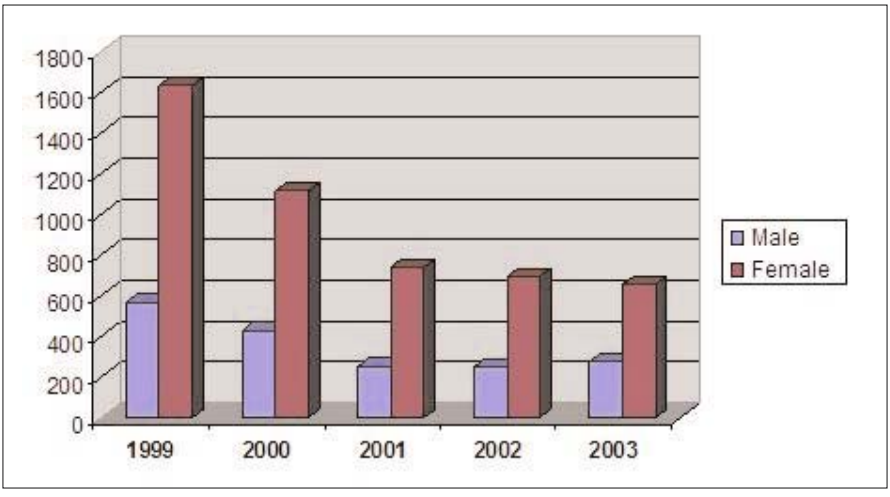

Fig. 4 Laparocele not specified with obstruction

males (565) and a female to male ratio of 2.8—to 927 cases in 2003 (653 females, 274 males; ratio 2.3). The age distribution in this category showed that from 1999 to 2003 the greatest change was in the percentage of patients >75 years of age: In 1999, there 743 such patients (152 males, 591 females) out of a total of 2,197 (33.8%) while in 2003 there were 339 patients in this age group (71 males, 268 females) out of a total of 927 (36.5%).

With respect to the mean number of days in bed, there was a progressive decrease both for males (from 8.4 days in 1999 to 7.1 in 2003) and for females (from 10.2 to 8.9). Also in this case, epidemiological reasons are not sufficient to explain the reduction during the 5-year period. Data from 1999 showed great regional variability: 7.33 days in Umbria (37 patients) but 14.75 in Alto Adige (12 patients). In 2003, if data from the Valle d'Aosta, where there were only three patients and a mean number of days in bed of 2.67, are excluded, then the range was from 6.08 days in Alto Adige (13 patients) to 9.87 days in Piemonte (12 patients).

Analysis of the category "incisional hernia with obstruction" (code 55221) showed that, in 1999, only five regions (Piemonte, Umbria, Lazio, Molise and Puglia) recorded patients with this discharge code (172 patients, 45 males, 127 females). The mean number of days in bed was 11.36 (males) and 12.0 (females). In contrast, in 2000, 12 regions recorded a total of 1,042 patients (266 males, 766 females) in this category, with a mean number of days in bed of 9.71 (males) and 10.78 (females). In 2003, the number of patients increased to 2,303 (608 males, 1,695 females) with a mean number of days in bed of 8.26 (males) and 9.33 (females). Since the initial data from the various regions were very heterogeneous the reasons for this pattern are unclear.

Data related to the type of surgery were divided in two classes, i.e. with or without implantation of a prosthetic mesh (Figs. 5,6). The number of operations performed without a mesh was 2,804 (1,760 females, 1,044 males; ratio 1.68:1) in 1999, 2,779 (1,773 females, 1,006 males; ratio 1.76:1) in 2001 and 2,658 (1,707 females, 951 males; ratio 1.79:1) in 2003. The mean number of days in bed decreased over the study period for both sexes, although it was always longer for women. For men, the number of bed days decreased from 7.9 in 1999 to 6.7 in 2003, while the decrease for women was from 9.0 to 7.5. Regional data for the mean number of days in bed were highly variable: in 1999, 11.5 days in Puglia (124 patients), around 10 in Campania (129 patients) but only about 4 in Trentino (27 discharged patients). This variability was also present at the end of the study period. In 2003, the number of bed days in Trentino was about the same period (4.1 days, 19 patients), while in Puglia and Campania it was about 20% shorter (9.3 days,159 patients; 7.8 days, 162 patients, respectively).

The number of surgical procedures that included mesh implantation was much higher, ranging from over 6,600 discharged patients (2,618 males, 4003 females) in 1999 to over 7,900 (3,235 males, 4,708 females) in 2001, to 8,566 (3,604 males, 4,962 females) in 2003. The mean number of days in bed for male patients was 8.3 for in 1999 and 7.1 in 2003; for females, it was, respectively, 9.8 and 8.1. Again, the regional data varied greatly. In 1999, the mean number

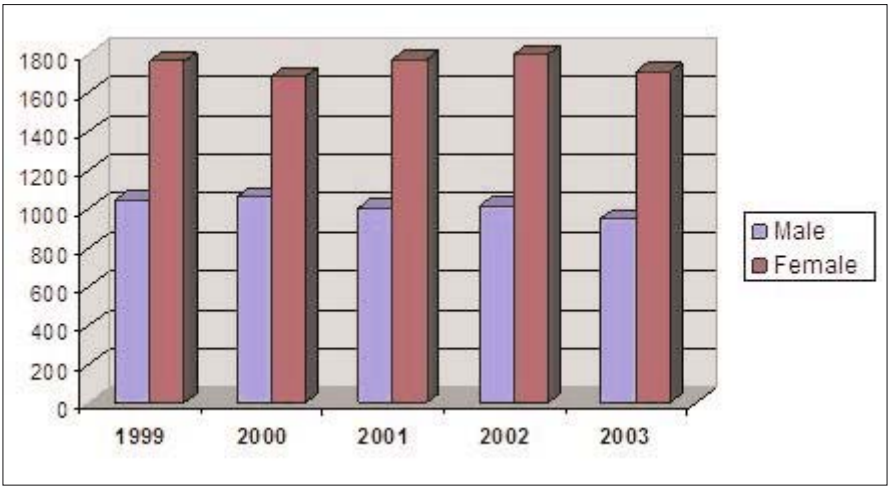

Fig. 5 Surgical procedures with mesh device, male/female

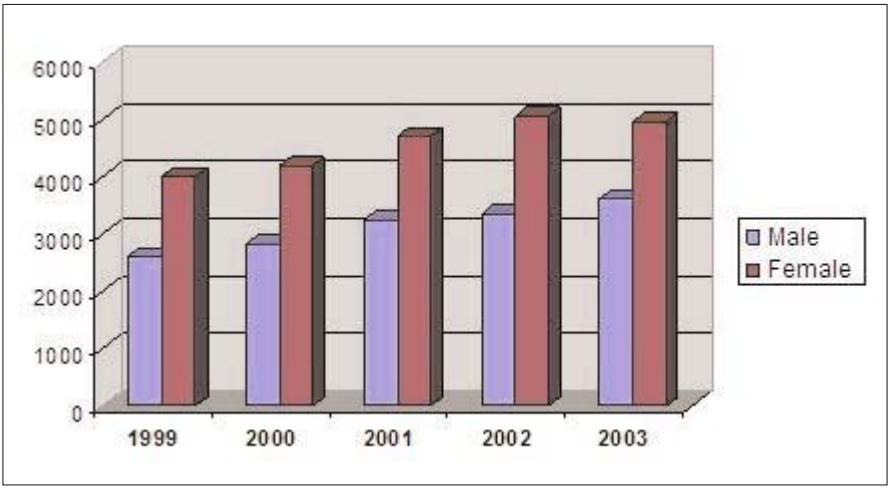

Fig. 6 Surgical procedures without mesh device, male/female

of bed days was 6.7 days (593 patients) in Emilia Romagna but over 15.5 (14 patients) in Valle d'Aosta. In Campania, for 458 discharged patients, the mean period was 10 days. For the same regions in 2003, a shorter mean period was recorded: around 9 days (26 patients) in Valle d'Aosta, 6.3 (830 patients) in Emilia Romagna and 8.8 (594 discharged patients) in Campania.

Conclusions

The analysis presented here is not a true representation of the health of the Italian population, because it concerns patients discharged from the hospital and not the general population. Furthermore, as noted in the Introduction, the validity of the reported information cannot be guaranteed since it depended on the correctness of certification. Many SDO file codes include the term "laparocele", but this was confusing because, for example, if it was not considered to be the main pathology and/or was irrelevant to the therapy administered, then the case was omitted from the SDO with the result that the incidence was underestimated.

Nonetheless, a few conclusions can be drawn from this study. The first is the female prevalence for of all the codes dealing with laparocele, complicated or not. In some years and for some codes, such as "laparocele not specified without obstruction" (code 55320) in 2002, the number of discharged female patients was twice as high as the number of males. The trend was consistent except for the group of patients age 0–24 years, in which the incidence was the same. The female prevalence may have been due to the physical changes that take during pregnancy, with subsequent weakening of the abdominal wall.

During the first three decades of life, laparocele is rare and the data did not show a gender difference in the prevalence. However, there was an age difference regarding complications associated with this pathology. Obstructive complications were more frequent in the group of patients >75 years of age and this did not change during the 5-year period, whereas non-complicated laparocele was most frequent in patients age 45–64 years, followed by those age 65–74 years, again, without variations during the 5-year period. The incidence was always higher in females, with variations in the exact numbers according to year and age group examined.

Despite the extreme regional variability, there was a trend towards fewer days in bed. This was the case regardless of the pathology (complicated or not) and surgical technique (with or without prosthetic mesh implantation). The exception was the oldest group of patients, for whom the number of bed days increased. In addition, the mean number of days in bed throughout the study period and for all of the considered pathologies was longer for females than for males.

The number of surgical procedures increased by about 20% between 1999 and 2003 (9,404 vs. 11,224). There were slightly fewer operations that did not involve a prosthetic mesh, with a progressive decrease from 2,804 (1,760 females, 1.044 males) in 1999 to 2,658 (1,707 females, 951 males) in 2003—a decrease of 5% over the 5 years. In contrast, the number of operations in which a mesh was implanted increased from over 6,600 (4,003 females, 2,618 males) in 1999 to 8,566 (4,962 females, 3,604 males) in 2003, corresponding to a 30% increase over 5 years. It is therefore clear that the increase in operations involving a mesh device more than compensated for the decrease in those performed without mesh device.

As more recent data become available, it will be of interest to continue these comparisons of hospitalised subjects and to extend these observations to the incidence of laparocele in the general population and, especially, regarding surgical technique. This evaluation will most likely confirm that laparoscopy and minimally invasive surgery are economically advantageous because they reduce the incidence of laparocele, the most frequent complication of abdominal surgery.

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Abdominal Compartment Syndrome: Clinical and Physiopathologic Implications in Giant Ventral Hernias

Vittorio Corso, Elisa Bartolucci, Massimiliano Todaro, Luigi Veneroni, Gianfranco Francioni

The surgical treatment of giant ventral hernia depends directly on knowledge of the abdominal pressure and on alterations in it.

There are many types of meshes that can be used in the surgical treatment of large incisional hernias of the abdominal wall: absorbable, nonabsorbable, and biological, which have been devised with the aims of lowering the tension, reducing the frequency of relapse and of surgical infection, and ensuring that no enterocutaneous fistulas are formed. Abdominal compartment syndrome (ACS) can arise when meshes are used that involve excessive tension on the sutures; ACS is a severe clinical condition characterised by intra-abdominal hypertension (IAH) and multiple organ dysfunction (MOF).

This chapter deals primarily with ACS and its complications, and particularly on abdominal perfusion pressure (APP) and abdominal wall compliance. We have recently published a study on definitive closure of the abdominal wall after open abdomen surgery [1,2].

Definitions

Intra-abdominal Pressure

The intra-abdominal pressure (IAP) is the pressure within the abdominal cavity; it is measured in millimeters of mercury (mmHg) or in centimeters of water (cmH_2O; 1 mmHg=1.36 cmH_2O; 1 cmH_2O=0.74 mmHg); it shifts with respiration, as evidenced by an inspiratory increase during diaphragmatic contraction and an expiratory decrease when the diaphragm expands.

Normal IAP is extremely variable [3–8] and it is influenced by the body mass index [9] and the position of the patient [10]—mean IAP being about 6.5 mmHg (minimum value 0 mmHg and maximum value 16 mmHg)—especially in morbidly obese patients and in patients who have undergone previous abdominal surgery. During general anaesthesia normal patients have an internal abdominal pressure between 0 mmHg and 16 mmHg [8].

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

The abdominal cavity is formed by:
- Rigid structures (pelvis, iliac spine and costal arch)
- An elastic structure (aponeurosis)
- Very compliant structures (abdominal wall musculature and diaphragm).

Theoretically, IAP values follow hydrostatic laws: the degree of flexibility of the abdominal wall and the specific gravity of its contents determine the pressure at a given point when the patient is in a given position (prone or supine) [10,11]. However, the movements of the diaphragm and the rib cage, the resting tone and contractions of the abdominal wall musculature, obesity, and variations in the content of the intestines (air, liquid, fecal mass) add degrees of physiological variability that limit the usefulness of a strict mathematical description of IAP. In addition, the techniques used to measure IAP [12] add a further degree of uncertainty in determination of an exact value for IAP: thus, the definition of a single value for IAP is variable. It is best to measure IAP at intervals of 4–6 h, to obtain a daily range that will allow appropriate clinical decisions to be made.

Abdominal Perfusion Pressure

Elevated pathologic IAP is an independent risk factor that is statistically associated with increased morbidity and mortality. The "critical value" for IAP that causes end-organ dysfunction varies from patient to patient and depends on preexisting comorbidities: it is therefore difficult to clearly identify a single threshold value for IAP that can be used in decision making for all critically ill patients. Abdominal perfusion pressure (APP), however, varies with the gravity of the patient's condition and with the abdominal wall perfusion.

The APP is a very important value in the patient with a giant ventral hernia: patching the abdominal wall is more efficient when the APP is appropriate. There are no controlled studies that verify this hypothesis, but a nonrandomised prospective study seems to confirm this idea.

In fact, although in the early 1990s the principal collective review claimed that the abdominal wall tolerated values of IAP of 30 or 40 mmHg, we now know that even minimal variations in IAP, of between 10 and 15 mmHg, can have extremely deleterious effects on organ perfusion and on clinical outcome.

The perfusion pressure of any anatomic compartment is dependent on three factors:
1. Arterial inflow pressure
2. Venous outflow pressure
3. Compliance of the compartment allowing it to expand in response to increases in volume.

Perhaps the example of perfusion pressure that is clinically most widely accepted is that of the traumatised brain. The cerebral perfusion pressure (CCP) can be calculated as arterial inflow minus intracranial pressure (ICP). There are correlations between ICP and: (a) brain volume, (b) cerebrospinal fluid, (c)

intracranial arterial inflow, (d) any space-occupying lesions such as a haematoma or a tumour. According to the Monro-Kellie doctrine, any increase in the volume of one or more of these four constituents of the cranium will result in a rise in ICP.

APP can be considered analogous to the perfusion pressure in the brain (Table 1). Although the abdomen is not enclosed in a rigid shell as the brain is, it is far from being compliant and expandable. The spine, the pelvis, and the costal arches are very rigid; in addition, the aponeurosis of the abdominal wall is not very compliant and depends on the patient's age, whether or not she/he is obese, and whether there is a history of previous abdominal surgery and/or pregnancy. All or any of these factors can alter abdominal wall compliance.

Table 1 The cranial and abdominal compartments (*CPP*, cranial perfusion pressure; *IAP*, intra-abdominal pressure; *ICP*, intracranial pressure; *MAP*, mean arterial pressure)

	Cranial	Abdominal
Organ	Brain	Liver, spleen kidney, stomach, bowel
Fluids	Cerebrospinal fluid	Ascites, air, fecal mass
Enclosure	Skull	Abdominal cage
Lesions	Tumour, hematoma	Blood, edema, ascites, air
Pressure	ICP	IAP
Perfusion	CPP=MAP–IAP	APP=MAP–IAP

APP is calculated as mean arterial pressure (MAP) minus IAP:

APP=MAP–IAP

Theses values are very important in the surgical treatment of giant ventral hernia, because with higher IAP the APP is lower and the plasty in the abdominal wall is less effective.

Intra-abdominal Hypertension

Currently, the definitions found for IAH in the literature vary, most commonly between 12 and 25 mmHg [3,4,6,8,11,13,14]. Recent studies have shown deleterious effects on organ function after an increase in IAP by as little as 10 or 15 mmHg [10,15,16]. Otherwise, a universally accepted definition of IAH is a value of 12 mmHg or more for IAP, recorded at a minimum of two standardised pressure measurements taken 1–6 h apart [17].

After establishing a minimum threshold for defining IAH, stratification of the pathologic IAP values is needed to calibrate and quantify the threat of insult that will produce clinically significant manifestations. There are four pathological grades of IAH (Table 2) [18].

Table 2 Grades of intra-abdominal hypertension

Grade	Intra-abdominal pressure
I	12–15 mmHg
II	16–20 mmHg
III	21–25 mmHg
IV	>25 mmHg

According to the guidelines of the World Society of Abdominal Compartment Syndrome, normal IAP is 0–5 mmHg; IAP in the intensive care patient is 5–7 mmHg; that in the patient with an open abdomen is 10–15 mmHg; IAP in septic patients is 15–20 mmHg; and finally, patients with abdominal peritonitis or bowel obstruction have IAP of 25–40 mmHg.

Abdominal Compartment Syndrome

ACS is defined as a late manifestation of abdominal hypertension that has not been correctly treated.

When a patient has an IAP of 20 mmHg or more recorded twice within 6 h in association with one or more organ dysfunctions (SOFA score >3) the patient is suffering from ACS.

To distinguish IAH from clinical ACS, Ivatury [19], in an historical scientific study, characterised ACS by the presence of a tensely distended abdomen, elevated IAP (Fig. 1) and peak airway pressure, inadequate ventilation with hypox-

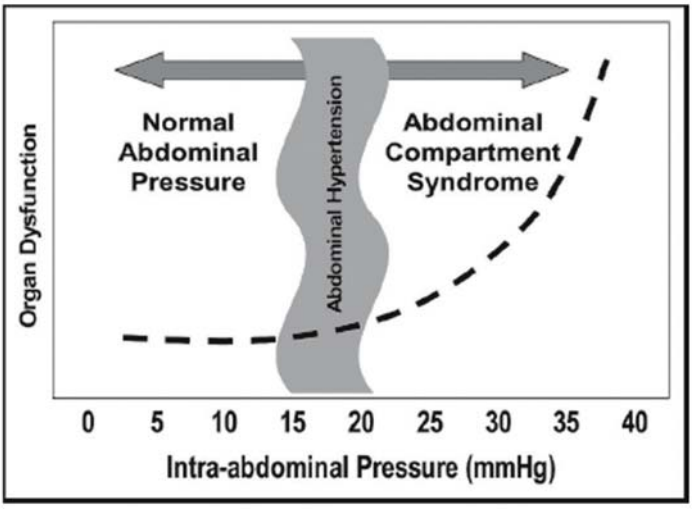

Fig. 1 Normal intra-abdominal pressure (IAP) and IAP in abdominal compartment syndrome (mmHg)

ia and hypercapnia, and impaired renal function, all of which clinical manifestations were improved by surgical decompression.

In a recent study by Malbrain [20], ACS was defined as IAH associated with failure of one or more organ systems.

Intra-abdominal Measurement Techniques

There are many direct and indirect methods of measuring the IAP. At present there is no consensus about which patients need to have their IAP measured; however, the principles are: (1) patients within the first 24–48 h after major elective abdominal surgery; (2) intensive care patients; (3) abdominally traumatised patients; (4) patients with abdominal distension associated with oliguria, hypoxia, hypotension, and metabolic acidosis; (5) patients who have received a large infusional volume of fluid or crystalloids during trauma, acute pancreatitis, or septic shock.

Direct Methods

For direct pressure measurement the peritoneal cavity is cannulated with a Veress needle or a wide-bore needle connected to a saline manometer or pressure transducer. During laparoscopic surgery an electronic insufflator is used for continuous monitoring.

Indirect Methods

Inferior vena cava pressure. A central venous line is inserted into the inferior vena cava via left or right femoral vein. The inferior vena cava pressure (IVCP) has been suggested as a basis for estimating IAP. Some authors have seen a correlation between an increase in IVCP by 40 mmHg and a reduction in IVC flow from 1,000 l/min to 500 ml/min.

The major disadvantage of this technique is the risk of bloodstream infections, septic shock, and venous thrombosis.

Intragastric Pressure. The IAP can also be measured by means of a nasogastric tube attached to a water manometer. All air is aspirated from the stomach and 100 ml of saline solution is injected. A three-way stopcock is connected to the nasogastric tube, one end of which is connected to a pressure transducer and the other, to an infusion line. The transducer is zeroed at the midaxillary line with the patient in the supine position, and IAP is read at the end of expiration. This method can be utilised in patients with bladder trauma or in patients who have undergone cystectomy.

Bladder Pressure. Measurement of pressure in the bladder has been used as the method of choice for measuring IAP: once the patient's Foley catheter is discon-

nected, we instill 50 ml of saline solution via a non-Luer lock syringe connected to the Foley catheter. Utilisation of a three-way catheter means that the Foley catheter can be connected to the manometer. The transducer is zeroed at the symphysis, which means that IAP is read after a 2-min equilibration.

This method (Fig. 2) is based on complete transmission of IAP to the bladder if the abdominal wall compliance is lowered or if it is only residual in the bladder. If the patient is mechanically ventilated, the IAP is taken at the end of expiration. In normal patients the mean IAP is considered. The results may be altered in patients with bladder trauma or abdominal adhesions. In animal studies, there is a close correlation between pressure in the bladder and IAP, so that measurement of bladder pressure can be used as a direct method.

This is currently the most commonly utilised method and is considered the gold standard owing to its simple realisation, low cost, minimal invasivity, and close correlation with IAP.

Pathophysiology Notes

Respiratory System

The occurrence of IAH progressively reduces the entire pulmonary capacity, the residual functional capacity, and the residual volume [21]. Such changes occur with IAP of about 15 mmHg [22]. The following situations arise with progres-

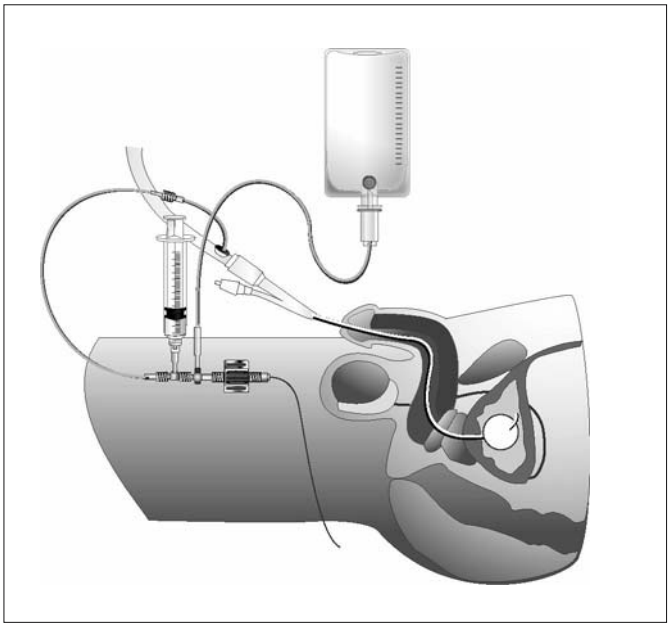

Fig. 2 Measurement of pressure inside bladder

sive increases in IAP:
- Respiratory insufficiency secondary to hypoventilation
- Hypoxic vasoconstriction reflex with an increase in pulmonary vascular resistance
- Increase in intrathoracic pressure

Clinically, pulmonary dysfunction is characterised by hypoxia, hypercapnia, and an increase in ventilatory pressure.

Cardiovascular System

With IAP levels of 20 mmHg a reduction of the ejection phase can be noted, resulting from reduced cardiac venous return; this is caused by compression of the vena cava and of the portal system [23].

The increasing intrathoracic pressure also causes direct compression of the heart, with a consequent reduction in the end-diastolic volume. This situation causes a reduction of the cardiac ejection fraction, which is only partly balanced by the increase in cardiac frequency and myocardial contractility.

In these circumstances, the Starling curve seems to be shifted towards bottom right, with progressive lowering of cardiac "output" caused by the rising IAP. Such alterations are exacerbated even further by hypovolaemia.

As a result of increased IAP, the intrathoracic pressure increase causes a rise in central venous pressure and pulmonary artery wedge pressure (PAWP). Such changes take place, as remarked above, when IAP reaches 20 mmHg [21,22].

Kidney System

High IAP levels are associated with reductions in kidney plasma flow and in glomerular filtration. In the medical literature, such a situation is characterised by the decline in urine output when the IAP level is 15–20 mmHg, deteriorating until a state of anuria occurs when the IAP is about 30 mmHg [21,24,25].

Processes leading to acute renal insufficiency—when an intra-abdominal infection is progressing at the same time as IAH—can have different reasons, and the physiopathological alterations are both prerenal and renal. Those connected to prerenal insufficiency are due mainly to altered cardiovascular function and to the reduction in the cardiac ejection fraction, which causes a reduction in renal perfusion.

Experimental studies have highlighted how correction of cardiac functional indexes does not improve renal function and therefore also does not restore diuresis in clinical terms. Indeed, compression of the renal parenchyma causes alterations in the renal venous flow, which are secondary to a rise of the vascular peripheral resistance. This is the effect of compression of the veins and the renal arteries. In an experimental study, renal vascular resistance rose to up to 500% of the normal value when IAP was 15 mmHg, and even to 1,500% of the

normal value when IAP was 40 mmHg [26].

Such a physiopathologic outcome causes alterations in the circulating levels of renin, antidiuretic hormones, and aldosterone. They increase the renal vascular resistance further, thus creating a vicious circle that cannot be corrected except by surgical abdominal decompression.

Central Nervous System

A recent prospective study has shown how an increase in IAP leads to a significant rise in ICP [27], thus confirming the transmission of pressure between two distant compartments.

Studies on animals [28,29] have shown that an increase in IAP can cause a rise in ICP by way of a rise in intrathoracic pressure, thus obstructing cerebral venous back-flow. A rise in ICP can therefore be regarded as an indirect expression of IAH.

Finally, an American retrospective study [30] has highlighted the observation that abdominal decompression by means of open surgery can be useful in correcting post-traumatic ICP.

Porto-systemic Visceral System

Reductions in blood flow caused by IAH do not only affect the kidney system, but also involve liver and bowel.

Mesenteric flow is reduced by 30% when IAP is 20 mmHg, and it decreases by almost 70% when IAP reaches 40 mmHg. We have used this knowledge, which is fundamental from a technical point of view, in a wide variety of situations. When mesenteric flow is reduced, this causes reduced perfusion of the intestinal mucosa and has the negative effect of bacterial translocation, thus increasing septic complications linked to MOF [31].

The results of other studies underline the alteration of hepatic enzymes during the progression of IAH, especially when IAH is associated with an endo-intra-abdominal infection: this is all caused by alterations in the dynamic, firstly, of portal flux and, secondly, of hepatic arterial flux [32,33].

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Respiratory Physiopathology in Surgical Repair of Large Abdominal Hernias

Gabriele Munegato, Michele Schiano di Visconte, Danilo Da Ros, Andrea Sanna

Introduction

In 1973, Rives [1] and associates emphasised the therapeutic problems and physiopathologic respiratory implications of large abdominal incisional hernias, considered to be a form of "eventration disease". He introduced the term "thoracoabdominal compartment" to describe the inseparable and the interdependent link between the chest and the abdomen and introduced the concept of "paradoxical abdominal respiration and abdominal volet".

In 1984, Trivellini et al. [2] demonstrated a clear correlation between variations in intra-abdominal pressure and thoracopulmonary compliance during the surgical repair of large incisional hernias; to avoid post-operative respiratory insufficiency, any increase in abdominal pressure must be compensated by tension-relaxing incisions in the abdominal wall. He established the need to correct any increase in abdominal pressure in order to restore respiratory compliance to its pre-operative value.

In recent years, the introduction of non-invasive methods to measure respiratory mechanics has led to a better understanding of the respiratory physiopathological aspects of incisional hernia repair [3,4]. The assessment of respiratory mechanics has permitted evaluation of the roles of the lung (Cl) and chest wall compliance (Cw) in determining the mechanical work of breathing (Wob). Intraoperative measurement of respiratory mechanics may be a useful tool in monitoring the ventilatory effects of closing large incisional hernias. In particular, in an obese patient or in a patient with chronic obstructive pulmonary disease (COPD), the surgical repair of a large ventral hernia can increase abdominal pressure and determine alterations in respiratory mechanics, with a decrease of total respiratory-system compliance and an enhanced mechanical workload of the respiratory system [5].

Similar alterations in respiratory mechanics occur in abdominal compartment syndrome and differ only quantitatively but not qualitatively from those that may accompany the repair of a large ventral hernia [6].

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

Studies of respiratory physiopathology have clearly demonstrated that in surgically closing the abdominal wall an increase in intra-abdominal pressure and changes in respiratory function must be avoided.

Classification of Incisional Hernia

The "traditional" classification of incisional hernia was based on anatomic criteria and mostly considered only the width of the parietal defect. Thus, an incisional hernia was defined as small if it was <10 cm wide, large 10–20 cm in width and giant when the opening was >20 cm [7]. However, this classification was of no use concerning either the choice of surgical treatment or the prognosis.

Chevrel et al. [8] proposed a classification of predictive value that allowed the study and/or comparison of homogenous groups and the choice of the most appropriate surgical technique depending on the different types of incisional hernia (Table 1).

Table 1 The Site-Width-Recurrence (SRW) classification for midline (*M*) and lateral (*L*) incisional hernias. Adapted from [6]

Site		Type
M	L	
Supraumbilical	Subcostal	1 A or B W <5 cm
Umbilical	Transverse	2 A or B W=5–10 cm
Subumbilical	Iliac	3 A or B W=10–15 cm
Xifopubic	Lumbar	4 A or B W >15 cm

A, Recurrence (R); *B*, R + number of recurrences; *W*, width of wall defect

According to Chevrel, three parameters were considered to have a statistically significant relationship with recurrence rate: the site of incisional hernia, its width and the presence or absence of one or more previous recurrences [6]. On the basis of this classification it is possible to investigate the relationship between the group with a high probability of recurrence and the group in which the probability is low. For example, the group W_4 R+ is more difficult to treat,

especially if the number of previous recurrences is high, so the repair results will depend on the quality of the tissues and the techniques used. Nevertheless this classification only takes into account anatomical factors and is not able to foresee important physiopathologic elements, such as variations in intra-abdominal pressure, in the treatment of large incisional hernias.

Ammaturo et al. [9] demonstrated the importance of considering not only the surface area of the wall defect (WDS) but also the total surface area of the anterior abdominal wall (SAW) and the ratio between them (SAW/WDS). If the SAW/WDS ratio is low (<15), strong wall tension may be generated after the procedure, and thus a dangerous increase of intra-abdominal pressure. The link between intra-abdominal hypertension and SAW/WDS ratio is clear; surgical techniques being equal, the lower the SAW//WDS ratio, the higher the intra-abdominal pressure. A patient with a large WDS but with a small SAW is at increased risk of developing intra-abdominal hypertension, which can cause direct mechanical impairment of respiratory, haemodynamic, renal and splanchnic functions. Moreover, obesity considerably increases this risk. The authors recommended adding a new parameter, the SAW/WDS ratio, to the Chevrel classification. This modification was important because it introduced new factors, both anatomic (not only width and type of incisional hernia but also a correlation with the patient's constitution) and physiopathologic (intra-abdominal pressure). If the SAW/WDS ratio is <15, it is important to calculate intra-abdominal pressure during surgery by measuring the pressure of the bladder. If the intra-abdominal pressure is determined to be elevated, the use of an intraperitoneal mesh or a surgical technique that enlarges the abdominal cavity is mandatory to avoid post-operative problems due to a partial abdominal compartment syndrome.

Respiratory Mechanics

Intra-operative assessment of respiratory mechanics can provide a better understanding of the pathophysiological implications during surgery of the abdominal wall especially when the patient's abdominal pressure is increased. Moreover, an assessment of respiratory mechanics is of clinical importance in order to monitor respiratory function,with the aim to avoid the undesirable effect of surgical manoeuvres, especially in those patients in whom respiratory function is altered at baseline (e.g. COPD patients) [10].

Anaesthetised paralysed patients mechanically ventilated via an endotracheal tube are ideal candidates for measurements of respiratory mechanics because they are relaxed and the superior airways are by-passed by the presence of the cuffed endotracheal tube, so that the pressure measured at the airway opening truly reflects the alveolar pressure [11]. Accordingly, the measurements are quantitative and can be easily compared with other studies published in literature.

Introduction to Respiratory Mechanics

At each ventilatory cycle, the delivery of air into the lungs is due to the pressure generated by the inspiratory muscles, Pmus(i). This pressure amounts to the sum of two components, the elastic pressure (Pel) and the resistive pressure (Pres). Pmus(i) defines the mechanical ventilatory effort and is expressed by the following equation [12]:

$$Pmus\ (i) = Pel,rs + Pres,rs \qquad \text{(Eq. 1)}$$

The greater the respiratory system's resistance and elasticity, the greater the effort that must be made by the respiratory muscles. Equation 1 can also be written as follows (Otis's 1st-degree differential equation):

$$Pmus\ (i) = Vt / Crs + Rrs\ (Vt/Ti) \qquad \text{(Eq. 2)}$$

where the muscular pressure that has to be generated to ensure tidal volume ventilation is expressed as a function of the respiratory system's compliance and of the resistance. P is the pressure that the respiratory muscles must generate in spontaneous breathing, Vt the tidal volume, Crs the respiratory system's compliance, Rrs the air-flow resistance, and Vt/Ti the mean inspiratory flow, where Ti is the inspiratory time. Wob is a function of the pressure producing a variation in volume. For a given Vt being ventilated, the amount of the Wob depends on the elastic and resistive properties of the respiratory system. The term "resistive" describes the effort required to overcome resistance to the air flow in the tracheo-bronchial tree, while the elastic effort is the sum of the work needed to overcome the elastic recoil pressure exerted by the chest wall and lung.

In an intubated patient under general anaesthesia, the effort exerted by the ventilator during inflation with a constant Vt is, at any time, the sum of the resistive and elastic forces. The mechanical respiratory effort is thus given by the following equation:

$$Wob = dP \times dV \qquad \text{(Eq. 3)}$$

or force (pressure) x displacement (tidal volume), and is expressed in J/l. The formula reveals a direct proportional relationship between the work performed and the pressure generated. Under normal circumstances, in a healthy subject with a ventilation of about 6 l/min, the pressure generated by the muscles is about 6 cmH_2O; the pressure generated during a maximum inspiratory effort is >100 cmH_2O. Therefore, the ventilatory reserve available to a normal healthy subject is clearly considerable.

It has been demonstrated, however, that the respiratory muscles are unable to tolerate a given mechanical effort indefinitely at a respiratory pressure >40% of the maximum. In this case, the muscles become fatigued and are incapable of sustaining the required task, leading to ventilatory failure [13]. The higher the proportion of effort required with respect to the maximum effort expendable, the sooner the respiratory muscles will become fatigued. Therefore, it is important to know the mechanical ventilatory effort in order to establish the ventilatory pressure expenditure, especially under conditions that can modify the required effort. In the surgical treatment of large incisional hernias, any increase in abdominal pressure induced by closing the abdominal wall increases the mechanical respiratory work-load (Wob) from elevation of the diaphragm in the presence of reduced abdominal-wall compliance.

Techniques

End-inspiratory Occlusion Technique at Constant-flow Inflation

During constant-flow inflation of the lung, if, at the end of a mechanical inflation, the airway is occluded, the ascending limb of the ramp of the applied pressure will be immediately truncated so that the peak airway pressure drops, suddenly, to an initial value (P1). If the occlusion is maintained, there will be a further decay in airway pressure until an apparent plateau pressure is reached (P2) (Fig. 1). P1 and P2 represent the elastic recoil pressure of the total respiratory system under dynamic and quasi-static conditions, respectively, after the administration of tidal volume. Dividing tidal volume by P1 and P2 yields, respectively, the dynamic and static compliances of the total respiratory system [14]. If an end-inspiratory occlusion manoeuvre is carried out, then the respiratory resistance can be determined as well (Fig. 2) [15].

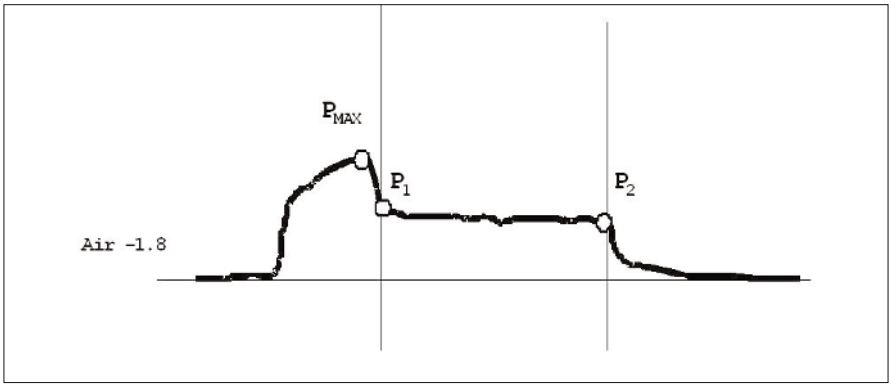

Fig. 1 End inspiratory occlusion technique at constant flow inflation: determination of Pmax, P1 and P2 in the airway curve. Adapted from [6]

$$\frac{\text{Tidal volume}}{P_1} \quad \text{Dynamic compliance of total respiratory system}$$

$$\frac{\text{Tidal volume}}{P_2} \quad \text{Static compliance of total respiratory system}$$

$$\frac{P_{max(Pao)} - P_{2(Pao)}}{V} \quad \text{Total respiratory system resistance}$$

Fig. 2 End-inspiratory occlusion technique: assessment of respiratory parameters. *Pao*, Airway-opening pressure; *V*, air flow

In fact, the difference in pressure between Pmax and P1 and Pmax and P2 represents the resistive pressure (Pres,rs) i.e. the pressure driving the inspiratory flow. By dividing Pmax minus P1 and Pmax minus P2 by the flow preceding the occlusion, respectively, the minimum and maximum respiratory resistances of the total respiratory system are obtained. Minimum respiratory resistance is an "ohmic resistance" due to the conducting airway, whereas maximum respiratory resistance represents the total respiratory resistance due to the minimum resistance plus additional resistance due to stress relaxation and the presence of different time-constant inhomogeneities within the lung (pendelluft).

Esophageal Balloon Technique: Partitioning of Respiratory Mechanics

In anaesthetised subjects, the esophageal balloon technique allows the total respiratory-system mechanics to be partitioned between lung and chest wall components [16,17]. Briefly, a nasogastric tube with a thin-walled vinyl balloon incorporated in the lower mid-portion is positioned in the third inferior tract of the esophagus to measure esophageal pressure (Pes), which, if the tube is properly positioned, reflects the pleural pressure (Ppl). During mechanical inflation of the respiratory system, the change in Pes represents the pressure that moves the chest wall, whereas the transpulmonary pressure (Ptp), which is obtained by subtracting Pes from the airway pressure (Pappl), serves to inflate the lung (Fig. 3). If the tidal volume is divided by the changes in Pes and Ptp, measured between two points of zero flow, the static compliance of the chest wall and lung, respectively, are obtained. During end-inspiratory occlusion, Pmax, P1 and P2 are easily identified on each tracing of Pappl, Ptp and Pes. By dividing Pmax-

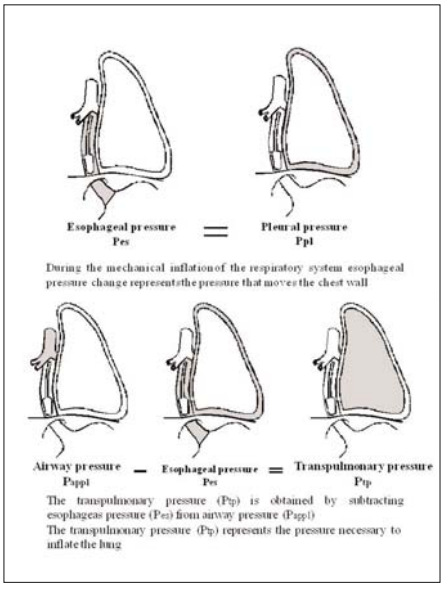

Fig. 3 Esophageal balloon technique: partitioning of respiratory mechanics. Adapted from [6]

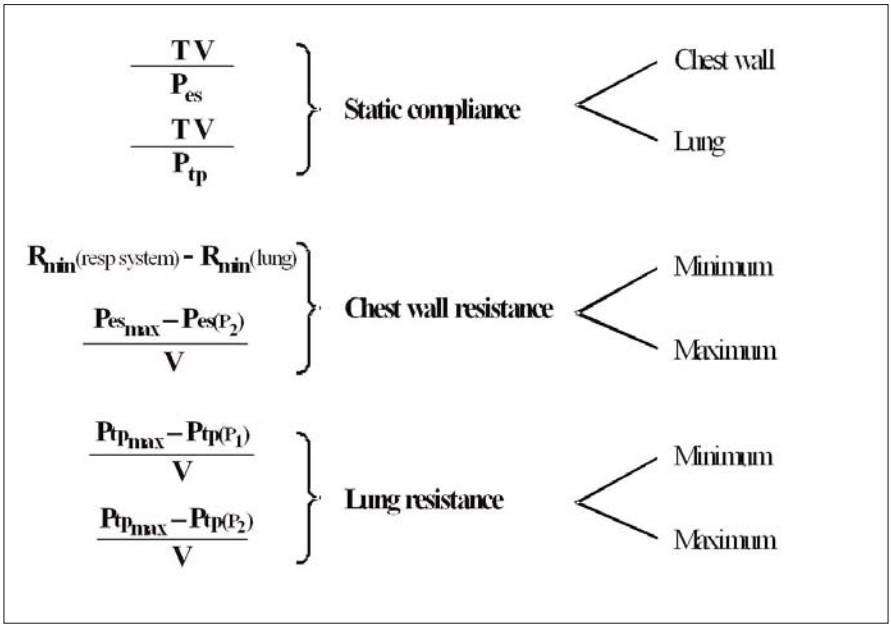

Fig. 4 Partitioning of respiratory mechanics: respiratory parameters assessment. *TV*, Tidal volume; *Pes*, esophageal pressure; *V*, air flow; *Ptp*, transpulmonary pressure; *R*, Resistances

P1 and Pmax-P2, obtained from Ptp and Pes tracings, by the flow preceding the occlusion, minimum and maximum resistances of, respectively, the lung and chest wall are computed (Fig. 4).

Work of Breathing

The Wob converts the elastic and resistive changes in the respiratory system into a number that is normalised in relation to the tidal volume ventilated at a given time. In other words, a clearly defined and consequently easily correlated quantitative element is introduced that can measure the pressure expenditure in terms of mechanical workload [15]. Wob has historically proven to be a good indicator of voluntary effort by the patient while breathing with mechanical assistance during patient-initiated breaths and spontaneous breaths. It has therefore proven useful in weaning patients from mechanical ventilation. Several researchers have found respiratory Wob to be the most sensitive indicator of ventilator dependence.

The pressure expenditure of the respirator for moving a given tidal volume under specific conditions of abdominal compliance, resistance and pressure is almost the same as the pressure that the patient would have to exert after being detached from the respirator.

The availability of a quantitative assessment of mechanical workload enables an objective prediction of the patient's respiratory behaviour in the post-operative phase. In surgery to repair large abdominal incisional hernia, when the increase in abdominal pressure is highly correlated with thoracopulmonary function, the Wob, as intra-operatively defined, can provide a post-operative predictive value [6,10].

Respiratory Physiopathology

The physiopathological respiratory aspects that are of relevance in abdominal-wall surgery were analysed by measuring the following respiratory mechanical parameters: lung compliance, chest wall compliance, total respiratory-system compliance and Wob, (expressed in J/l). We attempted to verify whether real-time knowledge of the different roles of the various respiratory parameters would allow the respiratory consequences of the surgical procedure to be checked and treated. This approach could have important consequences for the surgical method adopted, particularly in patients presenting with problems of respiratory insufficiency. The study involved ten patients who underwent surgery for large median incisional hernias (diameter >10 cm). The patients ranged in age from 63 to 72 years (mean 68±5SD); there were seven males and three females. Pre-operative spirometry revealed restrictive and obstructive chronic bronchopneumopathies. None of the patients were treated pre-operatively with pneumoperitoneum according to Goni-Moreno [18].

In all patients, incisional hernia repair was carried out according to the method of Rives [7] and Wantz [19]. A polypropylene prosthesis was inserted in the dissection space between the rectus abdominis and the posterior rectus sheath or the peritoneum below the arcuate line. Measurements of respiratory mechanics were then repeated as the following time-points:

– At the beginning of operation, before a surgical incision (baseline).
– After closure of the posterior rectus sheath-peritoneum; when it was not possible to close the abdomen, the edges of the abdominal wall were rejoined and close-coupled with forceps.
– After inserting a prosthesis to expand the peritoneal cavity if the prior measurement demonstrated an excessive rise in Wob. A PTFE peritoneal membrane, 0.1-mm thick, was fixed to the edges of the hernia orifice using short running sutures.
– After closure of the superficial aponeurotic layer (anterior rectus sheath and linea alba).

A value of $p < 0.05$ was considered statistically significant. Statistical analysis was done using Student's t-test for unpaired data. The arbitrary cut-off value was 10% of the mechanical effort of each patient, with particular attention given to patients with COPD, in which case the cut-off was set even lower on the basis of a single clinical assessment.

At the closure of the peritoneal layer (posterior rectus sheath and/or peritoneum) there was a reduction of thoracopulmonary compliance in seven patients. An example is given in Table 2.

In the remaining three patients, no change was observed. Respiratory resistances remained substantially unchanged during the entire procedure. The changes that were noted were due to decreased chest-wall compliance, while the

Table 2 Respiratory mechanics and breathing pattern in a patient who underwent widening of the peritoneal cavity with a PTFE prosthesis to avoid postoperative respiratory insufficiency: a 28.3% difference in the work of breathing (*Wob*) compared to the baseline value was recorded

	Baseline	Peritoneal closure	PTFE peritoneal widening	End of surgery
VT (l)	0.70	0.70	0.70	0.70
Crs (ml/cmH_2O)	47	42	44	44
Cl (ml/cmH_2O)	77	76	74	70
Ccw (ml/cmH_2O)	120	80	110	115
Wob (J/l)	1.8	2.31 (28.3%)	1.96	1.96

VT, Tidal volume; *Crs*, respiratory-system compliance; *Cl*, lung compliance; *Ccw*, chest-wall compliance

lung compliance tended to decrease slightly. Once the abdominal cavity was enlarged and the prosthesis inserted, the thoracopulmonary, chest wall and lung compliance normalised. At the closure of the superficial aponeurotic layer (anterior rectus sheath and linea alba), respiratory compliances (total respiratory system, lung and chest wall) showed no significant variation compared to the baseline values.

It was necessary to ventilate one patient with severe restrictive lung disease. This patient required support in an intensive care unit for 48 h, with extubation 24 h after surgery. The other patients were routinely extubated at the end of the operation and no respiratory sequelae from the surgical procedures occurred. In the seven patients with decreased compliance, as determined by the respiratory effort indicators, the peritoneum was widened by inserting a PTFE prosthesis.

In this study, respiratory mechanics could be partitioned into its two components, i.e. lung compliance and chest-wall compliance, using an esophageal balloon connected to a pressure transducer [20]. This permitted separate measurement of the elastic and resistive properties of the respiratory system for the lung and for the chest wall [15]. The results indicated that the reduction of thoracopulmonary compliance during the surgical repair of an abdominal incisional hernia is due to a decrease in chest-wall compliance, while the compliance of the lung remains substantially unchanged [5]. In addition, the Wob is a good indica-

tor of the effort required by the patient and/or the mechanical ventilator to ventilate the tidal volume. Therefore, Wob is usually used as a predictive test during weaning procedure from mechanical ventilation [11]. The assessment of Wob during surgical repair of a large abdominal incisional hernia is predictive of the Wob that the patient will perform during the postoperative period.

In our surgical procedure, particular attention was paid to ensuring that Wob remained the same, or less than 10% of the baseline value. This was done to avoid postoperative fatigue in patients with a limited inspiratory reserve. None of the patients, even those with severe chronic obstructive or restrictive pulmonary disease, suffered post-operative respiratory or ventilatory insufficiency. Therefore, our strategy represents an innovative therapeutic approach: it is possible, during surgery, to measure respiratory mechanics in order to inform the surgeon whether closure of the peritoneum has led to changes in respiratory mechanics, which increase the risk of a complicated postoperative period. In our experience, changes in respiratory mechanics during the surgical repair of incisional hernia occurred during closure of the peritoneal layer, i.e. when it was covered by the posterior lamina of the rectus sheath in the midline, while closure of the superficial fascial layer did not significantly affect Wob. This can be explained by considering the technical aspects of Rives' incisional hernioplasty. Incision of the peritoneum and posterior rectus sheath near the medial border of the rectus muscle, to prepare the dissection area for prosthetic repair, always requires excision of the hernial sac, with a large reduction of the peritoneal surface. This advantageously preserves the anterior rectus sheath and the remains of the linea alba, which facilitates closure. From a technical point of view, it is worth noting that expansion of the peritoneum was always done with a 0.1-mm PTFE prosthesis which, in our opinion, currently represents the best material for peritoneal patches because it induces fewer adhesions to the intestinal loops and because it is thin and ductile.

Similarities in Respiratory Physiopathology in Abdominal-Compartment Syndrome and Large Incisional Hernias of the Abdominal Wall

Abdominal compartment syndrome (ACS) is a clinical condition characterised by an increase in abdominal pressure that must be promptly lowered [21,22]. Surgery of large abdominal hernia can present similar problems in terms of an increase in abdominal pressure at peritoneal closure, when tension on the prosthesis during abdominal closure must be avoided to correct the increased respiratory workload [5,23]. We undertook a study that compared the changes in respiratory mechanical workload during surgery of large abdominal incisional hernias with those in ACS [6]. The static compliance of the total respiratory system (Crs), and its components, the lung(CL) and chest wall (Ccw), were measured during the acute phase of increased abdominal pressure and after decompression

treatment. The results were: ACS baseline measurements of Crs, CL, Ccw were 0.034, 0.049 and 0.115 l/cmH_2O respectively; after decompression, there was a large increase in Ccw (0.167 l/cmH_2O) whereas Cl remained the same (0.049 l/cmH_2O); Crs varied from 0.034 to 0.038 l/cmH_2O (Fig. 5).

In surgery to repair large laparoceles, Crs shifted from 0.048 to 0.046, Ccw from 0.150 to 0.180, and Cl was unchanged. Based on these results, we concluded that:

- Regarding the variations in respiratory mechanics, ACS, which is characterised by an important increase in abdominal pressure (>25 mmHg) is similar to the surgical treatment of large abdominal hernia, in which closure of the abdominal wall can result in increased abdominal pressure. The decrease in total respiratory-system compliance is determined exclusively by a decrease in chest-wall compliance with unchanged lung compliance.
- The alteration in respiratory mechanics in ACS is quantitative but not qualitative compared to the repair of large ventral hernia (45% decrease of chest wall compliance in ACS vs. 15% in surgery of large incisional hernia)
- In both situations, the decrease in chest-wall compliance induces an increase in respiratory mechanical workload and consequently an enhanced work of breathing and increased oxygen consumption by the respiratory muscles.
- Surgical management of the two clinical pictures presents the same princi-

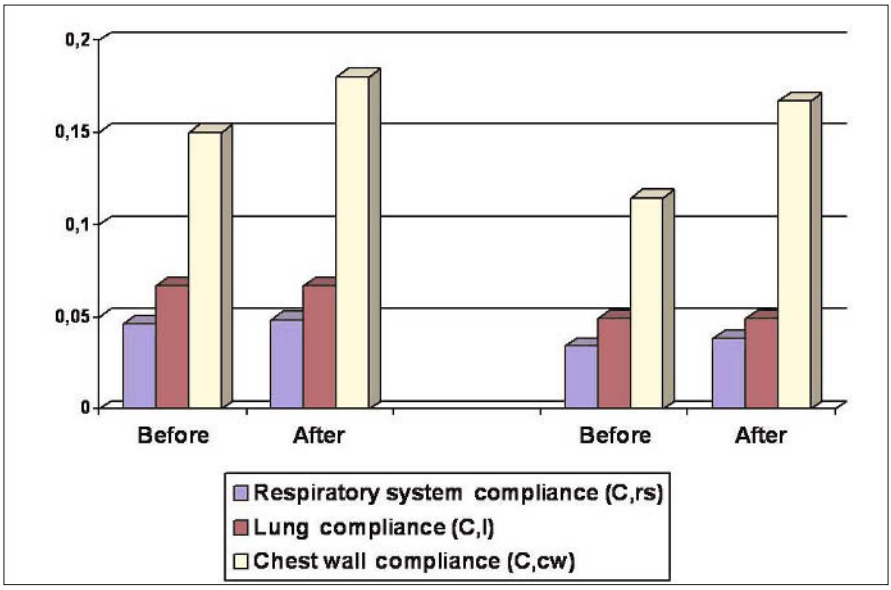

Fig. 5 Comparison between variations in respiratory system compiance, lung compiance and chest wall compliance before and after decompressive treatment of increased abdominal pressure in abdominal compartment syndrome and surgical repair of large incisional hernias of abdominal wall. Values are expressed as mean among 5 patients, respectively. Adapted from [6]

ples of widening the abdominal cavity to decrease the intra-abdominal pressure [24]. Even after decompressive surgical treatment, we observed similar changes in respiratory mechanics between ACS and surgery of large laparocele, i.e. an increase of Crs and Ccw whereas Cl remained substantially unchanged. These results confirm that surgical decompression of the abdominal cavity restores an acceptable respiratory situation, minimising the mechanical workload of respiratory muscle.

Therapeutic Surgical Considerations

In the surgery of large ventral hernias, closing the abdominal wall often presents problems related to [2]:

- The difficulty in approximating and directly suturing the margins of the defect (lack of peritoneum), thus causing the viscera to come into contact with the prosthetic material, generating the risk of adhesions.
- The closing of the defect under tension, which causes an increase in the abdominal pressure and a reduced respiratory compliance, generating postoperative respiratory complications.

The clinical importance of the above-mentioned respiratory physiopathologic aspects has been demonstrated. In the surgical repair of large abdominal hernias, particularly attention should be paid to obese patients or those with COPD. In these patients, it is important to:

- Measure variations of respiratory mechanics in real time during surgery, thus enabling the surgeon to reduce abdominal pressur, such that respiratory compliance is restored to a level compatible with a normal postoperative course.
- Measure bladder pressure at the beginning and during surgery, as this may be enough to evaluate variations in abdominal pressure. It is important to close the abdominal wall without increasing abdominal pressure.

Abdominal pressure may be decreased by enlarging the abdominal cavity. This may be achieved by either:

- Using a double-layered composite prosthesis, which can be used in direct contact with the viscera for an intra-peritoneal prosthetic repair.
- Creating a “new peritoneum” using a non-adhesive prosthesis in direct contact with the viscera, sutured to the peritoneal margins. This is followed by a prosthetic Rives repair with a polypropylene mesh.

Both methods present certain disadvantages, making them technically complex or conceptually difficult. The following objections have been raised against intra-peritoneal prosthetic repair:

a. It is always necessary to completely free visceral adhesions, which might be difficult or even dangerous, involving the risk of damaging the viscera

and thus the related risk of bacterial contamination in recurrent ventral hernias.

b. Fixation of the mesh requires numerous sutures, which do not guarantee that the mesh will be held in place properly, given that the peritoneal anchorage is superficial. Furthermore, it is technically difficult to position the last sutures fixing the mesh due to the risk of trapping the viscera; these two issues also apply when tacks are used.
c. The amount of prosthetic material positioned inside the peritoneum is considerable.
d. The response in terms of visceral adhesions is not totally predictable.

The arguments against using resorbable or ePTFE prostheses to create a "new peritoneum" are:

a. The operating time could be prolonged since a dissection has to be carried out between the rectus muscle and its posterior fascia (Rives repair).
b. It involves a double-layer repair carried out on two different anatomical planes and thus the risk of seroma formation between the two meshes.
c. The response in terms of visceral adhesions is not totally predictable.

The above-mentioned reasons have led to the proposal for a new prosthesis, one that modifies the Bard Composix E/X (Fig. 6).

The Modified Prosthesis

The prosthesis used has been realised by the author and consists of a modified Bard Composix E/X mesh in which the sealed edges have been cut off and the outer rows of PTFE stitches that keep the two layers together removed. The inner row of stitches has been retained; the edges are let free of each other, creating two different flaps: the upper one is polypropylene, the lower one ePTFE.

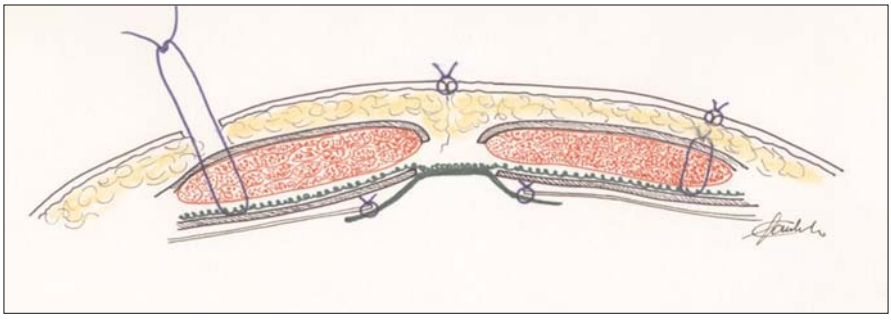

Fig. 6 Schema of modified Bard Composix E/X prosthesis positioning

Advantages

It optimizes the performance of the two prostheses: the ePTFE is used to create the "new peritoneum" with an adequate overlap of the margin of the peritoneal defect. The polypropylene, free from the lower ePTFE patch, should be placed in the retromuscular space according to Rives' technique, optimizing the rapid fibroblastic response and tissue in-growth. The mesh should be fixed in place with trans-abdominal stitches.

This technique combines the advantages of a Rives repair and an endo-abdominal repair, allowing enlargement of the abdominal cavity at the same time.

It increases the stability of the prosthesis, thus reducing migration and recurrence risks. The prosthesis (ePTFE) is fixed to the peritoneum through short running sutures and (polypropylene layer) to the rectus muscle and its posterior fascia through U-shaped sutures. At follow-up of the study patients this latter step proved not to be necessary. The clinical experience of the authors using this modified Composix E/X demonstrated that suturing of the ePTFE layer is more than enough to ensure the high stability of the prosthesis, so that the U-shaped sutures are needless. The retromuscular dissected area is large enough to accept the polypropylene layer with a minimal chance of dislocation (which could be further reduced by the use of a few resorbable stitches, avoiding postoperative pain).

Since intra-abdominal hypertension is avoided, this repair can be performed in all potentially risky clinical situations.

The author's clinical experience has shown that the method is easily performed and avoids the postoperative formation of seromas.

Technique

The first part of the operation is performed according to Rives' retromuscular repair [1,7,19]. If the peritoneum cannot be closed without creating intra-abdominal hypertension, or in patients with respiratory problems, the repair is carried out and completed as described above (Fig. 7).

The ePTFE layer, shaped according to the size of the peritoneal defect, is fixed to the peritoneum through short interrupted sutures, leaving a small free intra-abdominal overlap. The polypropylene layer must be shaped according to the dissection area between the rectus muscle and its posterior fascia, and should greatly exceed the margins of the defect.

Fig. 7 The modified Bard Composix E/X and its two overlapping prostheses: a polypropylene mesh (upper) and an ePTFE patch (lower)

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Notes Concerning Current Pathophysiological Aspects of Incisional Hernia

Aldo Bove, Laura Corradetti, Luciano Corbellini

Wound healing requires an initial haemostatic phase, an inflammatory phase lasting from minutes to hours, the migration of resident cells (fibroblasts, epidermal cells and endothelial cells) within the following 24 h and a regenerative phase during the subsequent 3 days. During the latter phase, activated fibroblasts respond to the growth factors present and initially produce type III collagen [1]. Contemporaneously, angiogenesis begins with the organisation of the collagen fibres; at this point, type I collagen and the phagocytes that remove fibrin come into play [2].

Any factor or event that compromises the normal sequence of wound healing of a surgical wound can contribute to the development of incisional hernia, and "sectoral" defects in the production of collagen appear to be determinant. An active role is also played by certain subtypes of collagen, such as fibronectin, laminin and other glycoproteins [3].

It is widely accepted that collagen is essential in guaranteeing the integrity of the organism, including the skeleton. Correct collagen synthesis is essential for efficient wound healing, both surgical and non-surgical.

A high incidence of hernias and aneurysms, especially of the aorta (suffered, for example, by Abraham Lincoln and Niccolò Paganini), are seen in genetic disorders of collagen metabolism, such as Ehlers-Danlos disease, Marfan's syndrome, Down's syndrome and osteogenesis imperfecta. Specifically, a disorder in the production of type III collagen has been reported in patients with collagenopathy and aneurysm. A mutation of the COL3A1 gene (one of numerous sequenced genes in the collagen family) has been implicated in these disorders [4,5]. In the beginning of the twentieth century, when it was believed that a hernia was the result of a simple mechanical defect, several anatomists began to ask whether a connective-tissue defect played a role in the pathogenesis of hernia.

The first author to propose a role for collagen defects was R. Read, in 1960. Read observed a high frequency of hernias in some patients who were young smokers and had collagen defects, and he subsequently showed that the aponeuroses of their abdominal muscles were thinner, with separated, less-resistant fibres [6]. In 1981, studies were published demonstrating that these individuals

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

had an increase in proteolytic activity at the expense of inhibitory anti-protease activity, a condition referred to as protease-anti-protease disequilibrium [7].

Collagen constitutes approximately one-third of the total protein content of the organism and is the predominant structural protein of the aponeurosis, where it is organized in fibres whose chemical-physical characteristics render them particularly resistant to traction (5 kg/mm^2). To date, 15 different types of collagen have been identified. Each molecule of collagen is made up of three α chains cross-linked by covalent bonds formed by lysyl-oxidase, an extracellular enzyme active in the presence of copper and ascorbic acid (Figs. 1,2).

There are basically two mechanisms, operating during two different steps of collagen synthesis, that give rise to collagen defects. The first occurs intracellularly and is congenital (immature collagen). This type of defect has been identified for only collagen types I, II, III and VII. The second occurs extracellularly, when the fibres are already formed, and is caused, as we discussed in greater detail below, by confounding factors.

Proteinases, previously thought to be exclusively involved in hydrolysis, are now known to be closely associated with collagen defects. The specific roles of these enzymes in the inflammatory phase of wound healing have been identified.

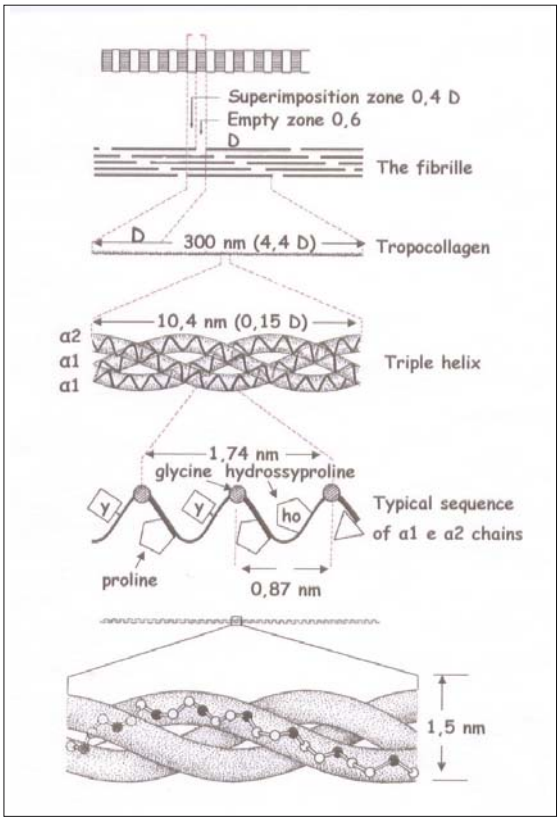

Fig. 1 The ultrastructure of collagen

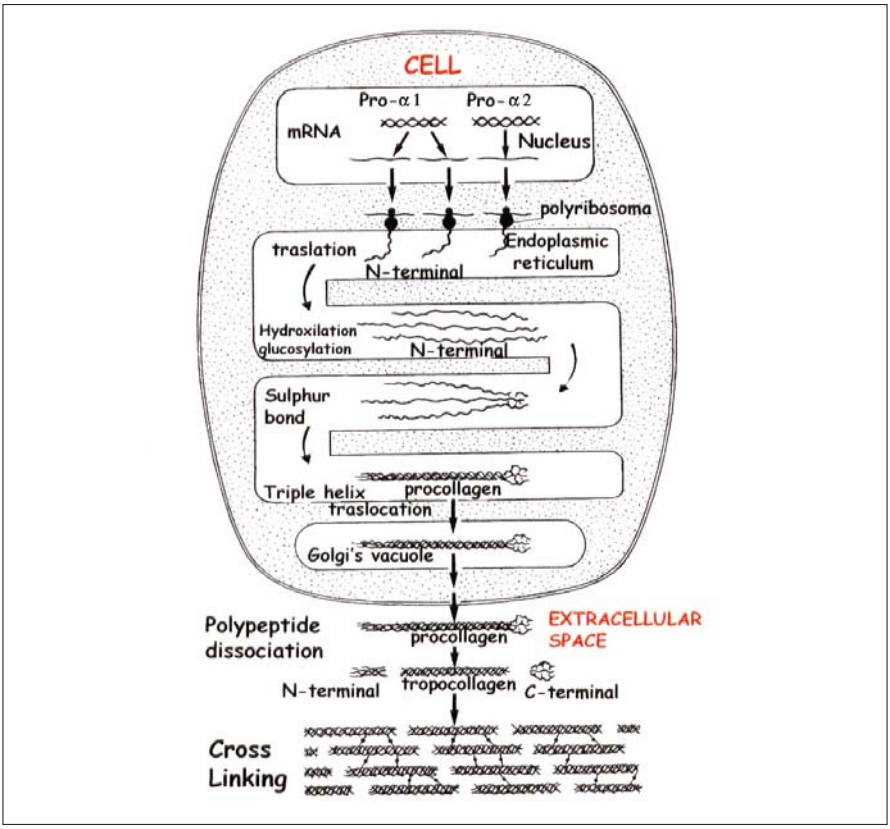

Fig. 2 The genesis of collagene fibres

Receptors activated by proteinases (proteinase-associated receptors, PARs) are expressed by many tissue types and cells involved in numerous physiological phenomena, including inflammation: for example, mitogenesis, cellular growth and development, fibrogenesis, and complex cardiovascular pathologies that involve endothelial cells and are termed "cardiovascular inflammation." PARs are also involved in inflammatory events of the skin, liver and lungs that often evolve towards fibrosis [8]. Specifically, the PAR-1 receptor participates in the repair process of tissue wounds and in repair involving endothelial cells and fibroblasts by stimulating cell proliferation, either directly or mediated by growth-factor secretion. A family of proteinases called matrix metalloproteinaes (MMPs), which include collagenases and elastases, has been identified in patients with aneurysms of the abdominal aorta. This is of particular interest because the collagen defects seen in the abdominal aorta are also present in the linea alba of patients with incisional hernias [9,10].

Within the abdominal wall, as in other tissue, damaged collagen fibres are repaired through a process of proliferation and remodelling [11]. The aim of MMP proteolytic activity is to permit the passage of macrophages and fibrob-

lasts across hydrolyzed collagen fibres, leading to tissue repair where necessary. Metalloprotease inhibitors (TIMPS) limit the excessive destruction of collagen during this process. Nonetheless, if degradation becomes too extensive, MMP inhibition is reduced, and proteolytic activity increased, biochemically pathological situations can be created. This is referred to as "the point of decreased resistance," which correspond to hernia development [12,13].

Among the various types of collagen, MMP-1 has the same function, which is to eliminate defective protocollagen during the synthesis of new fibres. MMP-8 and -9 are secreted in response to inflammation and are fundamental during wound healing [14].

Studies conducted by Anderson et al. showed that changes in the protein content of collagen, specifically, modification of the ratio of type I and type III protocollagens, play a decisive role in fibrillogenesis and in determining the final structure of the protein.

Type I collagen is found predominantly in the skin, bone and aponeurosis and is known to confer mechanical stability by providing a greater resistance to traction. Type II collagen is found predominantly in blood vessels and parenchymal organs, where the fibres are thin, typical of "immature" collagen, which is essential for the initial phases of tissue repair. Type III collagen is abundant and type I is scarce in granulation and scar tissue. Alterations in this normal equilibrium occur in the skin, aponeurosis and peritoneum of patients with incisional hernias but this disequilibrium could be the result of a local, mechanical action.

In healthy skin, type I and type III collagens are found in a 4:1 ratio. In patients with incisional hernia, type III collagen may be increased in the skin and aponeurosis. Recently, the ratio of procollagen type I and type III mRNA in fibroblasts was reported to be significantly decreased in hernia patients compared to in healthy subjects [15,16]. This suggests that a collagen disequilibrium favours the development of incisional hernias, especially in the presence of other cofactors, such as age (>60 years), sex (male), incision type, technically incorrect reduction or infection. Other, correlating or patient-dependent risk factors are atherosclerosis, metabolic disorders (obesity, renal insufficiency, protein deficiency, factor VIII coagulation deficiency, vitamin C deficiency, and smoking) [17–22].

Wound infection is one of the main, if not the most important, risk factors. It is known that the infection resistance of a wound is proportional to its blood supply and, therefore, to the presence of oxygen. In fact, leucocytes can be activated under anoxic conditions but they require oxygen in order to eliminate certain bacteria, specifically *Staphylococcus aureus* and *Escherichia coli*. No wound can be considered completely free from bacterial contamination, although there are a critical number of bacteria above which a clinically evident infection can be seen. This limit corresponds to 10^5 bacteria per gram of tissue or millilitre of liquid (serum, etc.) [23].

Other situations that affect the various steps of collagen synthesis can invalidate the wound-healing process, which normally is precisely programmed. For example, certain drugs that have a general or specific immunosuppressor effect,

e.g. glucocortisone and antiblastic drugs, delay healing by influencing the inflammatory phase. Their chronic use could thus be considered a contraindication for surgery [24]. The situation is analogous for important debilitating conditions, such as tumours or radiotherapy.

Smoking alters the natural equilibrium between the formation and degradation of collagen. Several possible mechanisms have been proposed. Knuutinen et al. noted a decrease in type I and III procollagens in the saliva and reduced collagen production in the skin of smokers [25]. Sorensen et al. observed an elevated quantity of neutrophil collagenase while MMP-8 and TIMP-1 were normal, resulting in increased collagen degradation. Another hypothesis concerns oxidative stress in smokers, which induces a greater inflammatory response due to increased chemotaxis. Under these conditions, neutrophils secrete potent tissue-destructing enzymes, such as collagenase and elastase. Also, the reduced oxygenation which follows the smoking-induced vasoconstriction (due to the adrenergic response) of small blood vessels and the persistence of the stimulus results in chronic obstructive pulmonary disease, which in turn determines a decreased pO_2 and an increased muscular and fascial mechanical stress induced by coughing.

Diabetics have a five-fold higher risk for developing incisional hernia for two reasons: first, because the inflammatory phase is inadequate and second because of alterations in the microcirculation and granulation tissue [26,27].

Malnutrition also disturbs the healing process. Vasco De Gama observed during his journey that some of the members of his crew had strange pathologies associated with wounds. George Anson, another adventurer, made similar observations: “The scars of old wounds, healed for many years, were forced open again”. They described, without knowing it, vitamin C deficiency. Vitamin C is a cofactor in the biosynthesis of collagen and an essential element for life. Vitamin C deficiency is a predisposing factor for incisional hernia [28].

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Diagnostic Imaging of Incisional Hernia

Nicola Gagliardi, Ciro Stavolo, Silvana Nicotra, Giuseppe Russo, Rosario Galasso

Incisional hernia is a post-operative complication characterised by escape of the abdominal viscera from their anatomic site through a hole developed during the cicatricial consolidation of a laparotomy. This particular pathogenic mechanism differs from other types of abdominal-wall hernias, i.e. those involving orifices or anatomic canals. In order to strengthen the abdominal wall after laparotomy, its three layers (peritoneum, muscular fascia and skin) are sutured separately. However, the muscular fascia may be rebuilt by an inadequate surgical technique or may be involved in an infection that develops post-operatively. In both cases, the consequence is weakening of the muscular structure or, even, failure of the sutures at several sites. Consequently, the support provided by the rebuilt abdominal wall gives way and one or more, initially small holes develop.

The first consequence of this particular anatomic situation is that, in the sites in which the described process has developed, wall resistance to abdominal effort is much reduced and its capacity is guaranteed exclusively by the skin externally and the peritoneum internally. Over time, as a result of pressure inside the abdominal cavity, a part of the moving viscera—generally, small-bowel loops but, more seldom, large-bowel loops—can escape into the subcutaneous space through the openings that have developed. This results in a hernia that, owing to factors determining a sudden increase of abdominal pressure (cough, vomiting and muscular efforts), eventually becomes larger.

Incisional hernia can easily become worse, above all because of the visceral-visceral and visceral-parietal adhesions that may develop or due to obstruction, incarceration and strangulation of the bowel. Owing to these fearful complications, surgical therapy of incisional hernia, even when asymptomatic, is mandatory [1].

Various imaging techniques are required to confirm the presence of incisional hernia, especially in subjects in whom particular clinical conditions, such as obesity, make clinical diagnosis of small hernias difficult or uncertain [2,3]. In addition, it is necessary to locate precisely the site of the abdominal hole, the volume of the hernial sac, its contents, the width of the muscular diastasis and the muscular thickness surrounding it [4]. Correct evaluation of these elements is prerequisite for correct surgical planning.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

The first diagnostic approach to incisional hernia remains planar abdominal X-ray in two projections. If the patient can be placed in the upright position, P-A and L-L projections are obtained. In supine patients, A-P and L-L projections are taken, the latter by horizontal X-ray. Nonetheless, in spite of the information it supplies, planar abdominal X-ray only partially answers the surgeon's questions. In fact, this technique, although easily carried out, convenient and inexpensive, is only able to determine the presence of bowel loops inside the hernial sac, pointing out both centrally and peripherally occlusive phenomena, if present, as well as the presence of free air as a sign of bowel perforation. Planar X-ray is not able to supply all the necessary morphostructural information about the abdominal wall, the site of the lesion and the possible complications that can develop inside the hernial sac due to occlusion [5].

In the presence of incisional hernia complicated by intestinal occlusion, the first clinical problem consists of differentiating those bowel loops at risk merely due to the occlusive problem from those also at vascular risk of gangrene and perforation. In the latter case, emergency surgery is required. However, planar abdominal X-ray supplies adequate answers only through a series of indirect radiographic signs that may differ between patients and which are interpreted controversially [6]. Moreover, with this imaging technique, optical problems arise that are related to the magnification of structures examined in relation to their distance from the film, such that the real volume of the incisional hernia cannot be determined accurately.

Of the first-level imaging techniques, ultrasonography has consolidated its diagnostic role in the study of the abdominal wall. This non-invasive, inexpensive, easily practicable and repeatable technique supplies diagnostic information instrumental in the evaluation of incisional hernia. In fact, ultrasonography of the abdominal wall allows the identification of small, occult incisional hernias and, in larger-sized formations, the study their contents, as both the width of the abdominal hole and the thickness of the adjacent musculature can be measured (Fig. 1a,b).

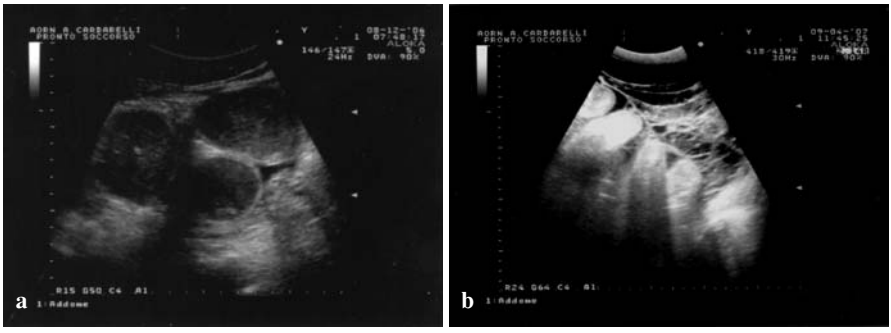


Fig. 1a,b a Incisional hernia containing decreased wall enhancement small bowel loops with endoluminal fluid. **b** Incarcerated medial incisional hernia due to multiple adhesions. The hernial sac contains small bowel loops and a small amount of fluid

The limitations of ultrasonography in uncomplicated conditions depend on the presence of adiposus panniculus, which, if too thick, prohibits correct execution of this technique. In complicated incisional hernia, in which mechanical occlusion of the herniated bowel develops, the diagnostic obstacle is sonographic obstruction, which is a consequence of meteorism of the involved bowel loops and does not allow a complete abdominal study. However, in these cases it is always possible to evaluate the parietal thickness of the bowel loops, the degree of dilatation, the presence of interposed fluid and possible associated solid lesions [7]. Moreover, if Doppler technology is also available, information can be obtained about parietal blood-flow in the hidden loops, while "real time" visualisation allows an evaluation of their peristaltic movement.

Currently, the imaging technique able to supply the very accurate information necessary for a correct surgical approach is computerised tomography (CT). The intrinsic characteristics of CT make it well-suited for examining the particular anatomic features of incisional hernia, especially in those cases involving complex structural conditions. CT is non-invasive, easily practicable and has a high diagnostic accuracy. Furthermore, the recent introduction into routine use of multidetector CT (MDCT) has further improved diagnostic confidence regarding pathologies of the abdominal wall, thus enhancing the relevance of CT in this particular diagnostic field and in resultant therapeutic choices [8].

The study technique consists of initial scans without i.v. contrast perfusion. These are acquired in order to anatomically locate the site of hernia formation, define its relations with adjacent structures and, inside the hernial sac, evaluate the presence of free air or possible spontaneously hyperdense formations that might raise interpretative doubts in subsequent contrast studies [9]. The latter almost never implies administration of oral contrast, which completely opacifies the visceral lumen, making evaluation of parietal perfusion of the bowel loops very difficult. Instead, the administration of i.v. contrast is better as it yields a series of data regarding intestinal vascularisation, particularly useful in emergency cases. By simple axial reconstruction, CT overcomes the diagnostic limits of traditional radiology and ultrasonography, above all in obese patients and in those with hidden incisional hernia (Fig. 2) [10]. Axial images allow the site of the hernia, the number of orifices and the content of the hernial sac to be determined, and accurately points out structures related to density, air or fluid content and their degree of enhancement. Consequently, incisional hernia can be differentiated from other abdominal masses, such as haematomas, abscess or tumours (Fig. 3 a,b) [11]. Based on the panoramic quality of CT and its ability to provide superior anatomic detail, abdominal and retroperitoneal parenchymatous organs, the state of the bowel at the bottom and forward hernial sites, possible anomalies, and the presence of occlusive pathologies, even in their initial phases, can be determined [12].

MDCT allow the acquisition of a wide study volume within extremely short times and, with the application of particularly advanced software, axial reconstructions with a thickness of less than 1 mm as well as multiplanar (MPR) and volumetric reconstructions are obtained (Fig. 4a–c) [13].

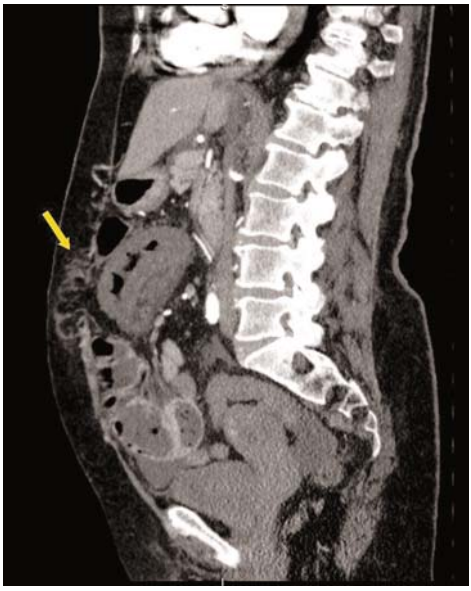
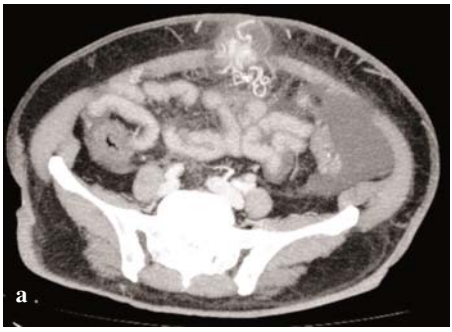


Fig. 2 Small medial paraumbilical incisional hernia that contains omental fat (*arrow*). Sagittal MPR reconstruction



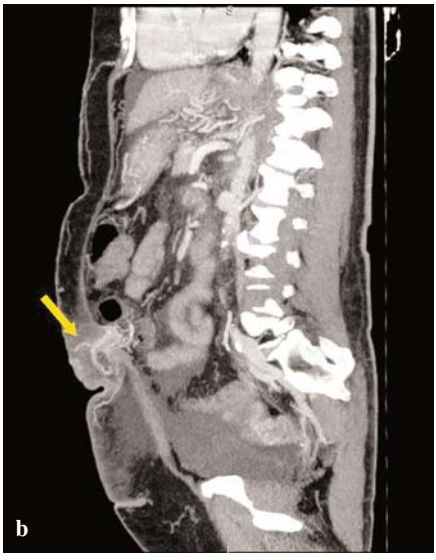


Fig. 3a,b a Small medial incisional hernia containing omental fat and vascular structures (periumbilical varices in hepatic cirrhosis). **b** Same patient; sagittal MIP reconstruction (*arrow*)

In diagnoses of incisional hernia, the advantages deriving from MDCT depend on the possibility to acquire extensive information about the size of the hernia relative to its surface extension (expressed in mm^2) and total volume (expressed in mm^3). With MPR reconstructions, it is also possible to accurately measure muscular diastasis, not only in relation to the distance between flaps,

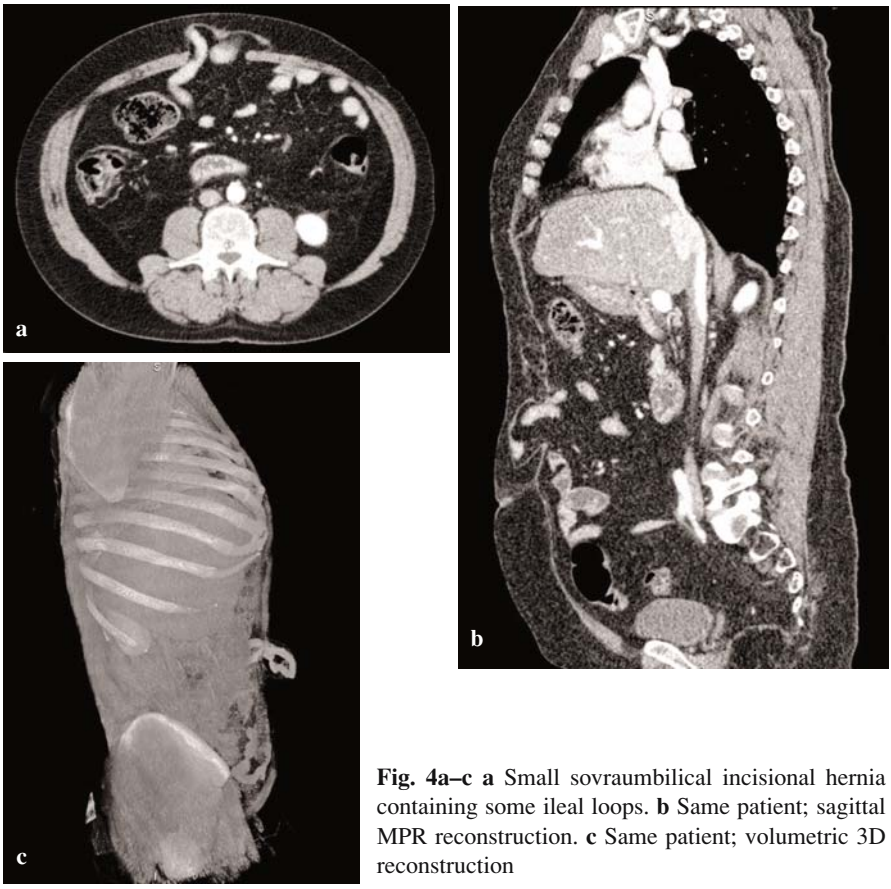


Fig. 4a–c **a** Small sovraumbilical incisional hernia containing some ileal loops. **b** Same patient; sagittal MPR reconstruction. **c** Same patient; volumetric 3D reconstruction

but also to the total surface of the hole. For the surgeon, the latter is more important than measurement of the maximum transverse diameter of the hernial sac and yields a suggestive and useful virtual reconstruction of the wall as well as an evaluation, in the planning phase, of the possibility of a plasty approach or, alternatively, the most suitable type of support yielding correct surgical reconstruction (Fig. 5a,b). In this type of evaluation, the possibility of accurately measuring the thickness of the abdominal muscle involved in diastasis, by MDCT reconstruction, is very important and it is indispensable in deciding the most favourable technique. MDCT is also an invaluable method in diagnosing the acute complications of incisional hernia, mainly occlusive and ischaemic ones. It is a frequently recurring event that bowel involved in incisional hernia is choked or forms a volvulus, with the consequent appearance of a clear occlusive symptomatology owing to excessive angulation and adhesion inside the visceral sac (Fig. 6a,b).

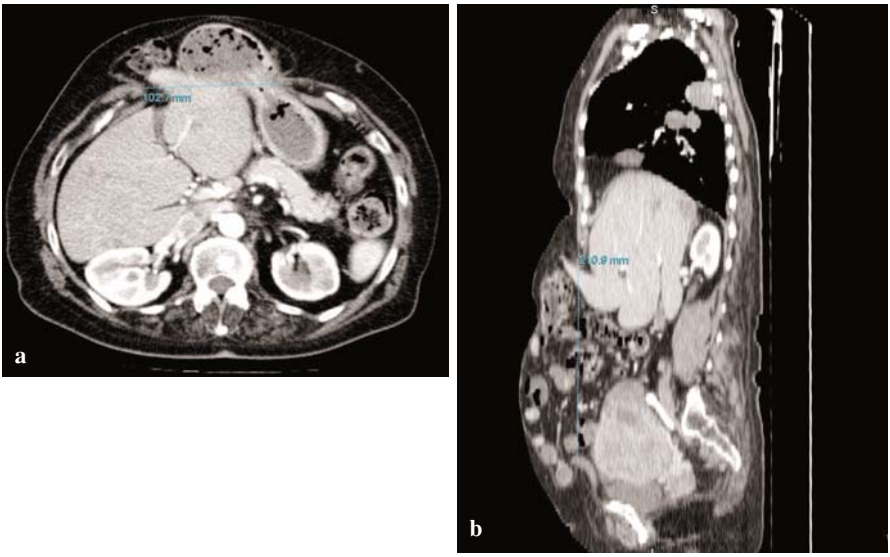


Fig. 5a,b a Large medial incisional hernia containing portion of the stomac, of the left hepatic lobe and of the transverse colon. Measurement in mm diastasis between the rectus abdominal muscles. **b** Same patient; sagittal MPR reconstruction

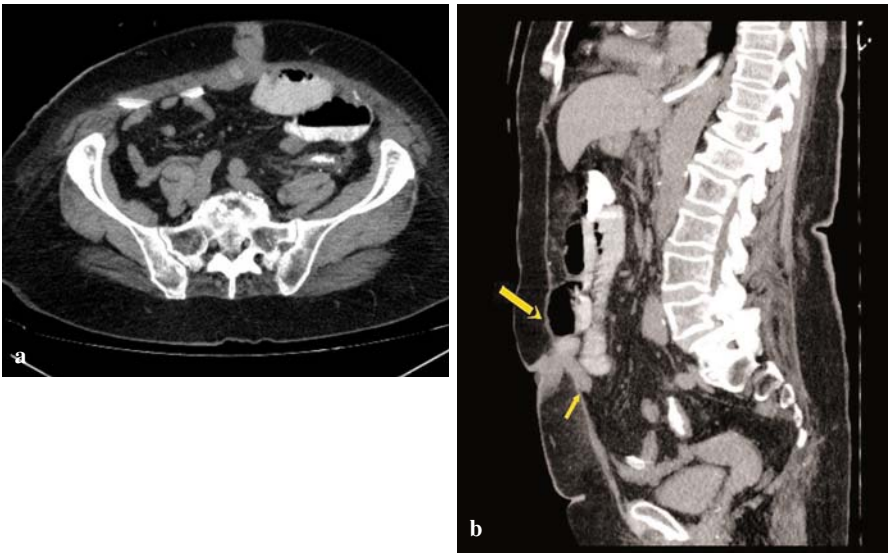


Fig. 6a,b a Incarcerated incisional hernia containing obstructed small bowel loops. Dilatated small bowel loops with gas-fluid levels are visible proximal to the obstruction; the distal bowel segment is collapsed. **b** Same patient; sagittal MPR reconstruction: proximal dilated small bowel loop (*large arrow*) and distal small bowel loop collapsed (*small arrow*)

Precise evaluation of hernial content by MDCT also allows identification of the occlusion and, in most cases, the events that generated it. Additionally, the true extent of the bowel dilatation at the bottom of the obstacle, the hernial content, abdominal-wall thickness, and possible presence of a fluid collection can be distinguished. Thus, MDCT provides a broad range of important information to the surgeon [14,15].

The technical characteristics of MDCT particularly suit evaluation of the ischaemic complications frequently occurring to the detriment of choked bowel loops. Moreover, in complicated incisional hernias, the high speed of data acquisition enabled by MDCT, with the consequent ability to examine wide body zones in very short times, allows evaluation of the contrast-enhanced bowel walls during various phases of the CT study, thus generating important information about blood flow in the involved bowel [16].

Finally, it should be noted that CT is indicated for evaluation and, in several cases, for percutaneous treatment of the complications of incisional hernia [17]. Above all, when a fluid collection forms, following suturing or prosthetic implant, CT identifies the site of collection, its volume and density; differentiates seromas from haematomas and precociously locates the appearance of overlying infective phenomena [18]. This allows the establishment of drainage by percutaneous catheters, which can be left in situ until the infective process resolves.

In summary, it is clear that current imaging techniques allow many, if not all of the diagnostic questions related to incisional hernia to be answered rapidly and accurately. The integrated use of these techniques is therefore indispensable to choosing the correct therapeutic approach.

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Special Part

Anaesthesiological Aspects in the Abdominal-Wall Surgery

Fernando Chiumiento, Maria Luisa De Prisco, Antonello Rago, Rosalia Sicilia

Appropriate perioperative protocols, correct patient evaluation, and knowledge of related, surgically induced physiopathological problems, including disturbances of cardiac and respiratory homeostasis as well as acid-base balance, are essential in abdominal-wall surgery. Moreover, both the surgical technique (laparotomic or laparoscopic) and the surgical site (above or below the navel) must be taken into consideration as these can induce important respiratory and cardiovascular modifications.

Physiopathologic Aspects

Respiratory System

The pulmonary ventilation is influenced by the position of the patient and by the surgical technique. The laparoscopic technique and/or Trendelemburg's position, moving aloft the diaphragm, compress more-sloping pulmonary areas, with consequent alteration of the ventilation/perfusion relationship. An increase in the physiological dead space has been hypothesised. This is more evident during the laparoscopy or in the treatment of large hernias above the navel; in both cases, the arterioalveolar CO_2 gradient ($D(a\text{-}A)CO_2$) is increased such that, if ventilation is not correspondingly adequate, intra-operative and postoperative hypercapnia and hypoxemia can occur.

In the absence of clinically evident alterations, it is sufficient to maintain a 35% FiO_2 and a current (Vt) volume of 7–9 ml/kg to prevent intra-operative hypoxia and hypercapnia. However, in some patients who are obese or who suffer from cardiomyopathy, chronic pulmonary diseases, etc., the above-described changes can have an important clinical aftermath, i.e. the development of atelectasis. The likelihood of this complication can be limited by adopting an I/E ratio = 1:1 or by applying an intra-operative positive end-expiration pressure (PEEP) of 5 cmH_2O.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

This approach must be adopted with caution during laparoscopic surgery due to the risk of favouring the development of up hypercapnia due to the reduction of the expiratory phase.

Further changes in the respiratory physiology, especially in relationship to the surgical site, duration of the intervention and the surgical technique (laparotomic or laparoscopic) involve a reduction of the functional residual capability (FRC), total pulmonary volume and pulmonary compliance. These events are more frequent and marked in the obese, in elderly patients and in weakened subjects, in the abdominal-wall surgery, in laparoscopic surgery, and, above all, for operations lasting more than 3 h.

Haemodynamic Modifications

The haemodynamic modifications depend partly on the modifications of abdominal pressure, as determined by the surgical repair, the surgical site and surgical technique and, partly, the volume state.

In large incisional hernias treated by laparotomic surgery, which includes exposure of the abdominal contents, volume alterations can be haemodynamically meaningful in relation to fluid loss, if the latter is not adequately compensated.

The upsurge in intra-abdominal pressure produced by abdominal-wall repair, especially for large incisional hernias, may also have significant haemodynamic consequences: a reduction of cardiac output, an upsurge in systemic blood pressure and an increase in systemic and pulmonary vascular resistances.

The combined effects of anaesthesia, patient position and increased intra-abdominal pressure (>14 mmHg) can also reduce the cardiac output to 50% of the preoperative value. Furthermore, laparoscopic surgery influences cardiac output to a greater extent than laparotomic surgery.

The increased intra-abdominal pressure (IAP) produces blood sequestration in the inferior limbs, reducing the flux in the vein cava and accordingly the venous return. The cardiac filling pressure and the intra-thoracic pressure nevertheless increase with increasing IAP, while the right atrial transmural pressure (venous return index) decreases.

The reduction of the cardiac output is also due to an upsurge in the systemic vascular resistance (SVR), which is not exclusively linked to the mechanical increase associated with IAP-related factors but also to the release of biological factors, i.e. catecholamine, prostaglandin and, especially, vasopressin. All of these factors are potential mediators of the renin-angiotensin system.

The increase in SVR explains the increase in the systemic blood pressure that occurs despite the reduction in cardiac output.

Since the abdominal organs are very vulnerable to an increase in IAP [1], when the latter is >20 mmHg, the renal vascular resistances increases by as much as 50% while the renal and splanchnic flux and glomerular filtration are

reduced to less than 25% of normal. Therefore, it is possible that the upsurge in the IAP determines a real, life-threatening "compartmental syndrome," with compromised renal function and perfusion of the abdominal organs.

Laparoscopic Surgery

In the last decade, enormous progress in laparoscopic abdominal-wall repairs has been made due to technological developments and to improved knowledge of the physiopathologic aftermath regarding the modifications of cardiac and respiratory homeostasis induced by the pneumoperitoneum.

The CO_2 gas used for the realisation of the pneumoperitoneum easily moves beyond the peritoneal membrane and is transported to the lungs through the portal and systemic circulation. Therefore, during laparoscopic surgery, there is an increase (7–30%) in the load of CO_2, which must be eliminated, and changes in ventilation are necessary to maintain a constant $PaCO_2$.

Since the organism is poorly able to vent CO_2, an excess quickly produces hypercapnic acidosis and is deposited in the tissue according to a three-compartment model:

1. Alveolar-haematic compartment, with rapid uptake, saturation and elimination abilities.
2. Musculovisceral compartment, with rapid saturation and slower elimination (20–60 min).
3. Bony compartment, with a high capacity but slow elimination (weeks or months).

Maintenance of normocarbia depends on three factors: the quantity of CO_2 to be eliminated, transport of the CO_2 (cardiac output) and its elimination (alveolar ventilation, dead space).

To the effects on acid-base balance created by the insufflation of CO_2, the haemodynamic effects of the upsurge of the IAP must be added, i.e. reduced cardiac output and the cardiac index, decreased venous return and the effects on ventilation, decreased FRC, increased peak and plateau pressures, increased the thoracopulmonary resistances, reduced compliance and an altered ventilation/perfusion ratio.

Anaesthesiologic Behaviour

These physiological mechanisms gain particular importance when the surgical procedure lasts for more than 3 h. However, as noted above, this is also the case if the patient is particularly at risk due to the presence of one or more cardiorespiratory disorders, including obesity, cardiovascular disease, respiratory insufficiency and increased dead space.

Pre-operative Evaluation

Patients selected for elective surgery must undergo a pre-operative anaesthesiology consultation because they frequently not only suffer from the above-mentioned pathologies but also other conditions, such as diabetes and hypertension, which require the attention of a specialist.

The preoperative evaluation must be able to identify coexisting respiratory, cardiovascular and metabolic pathologies in order to reduce the risk of complications. Also, based on the preoperative evaluation, the surgical site, surgical technique, anaesthesiologic technique and intra-operative and postoperative monitoring can be determined, together with the best global approach to the patient.

The surgical risk is evaluated through careful anamnesis, a complete medical examination, the performance of instrumental examinations and specialist consultations, and the standardised risk assessment.

The cardiovascular evaluation must include a 12-electrode ECG to search for signs of ischemia and left or right ventricular hypertrophy. In addition, blood pressure must be carefully measured and a chest X-ray obtained to search for cardiomegaly and pulmonary atelectasis.

In the obese patient without visible cardiomegaly or obvious left ventricular hypertrophy, as determined by ECG, it may be useful to perform preoperative echocardiography. In fact, this instrumental examination allows appraisal of the ejection fraction (EF), which, in the obese patient, even if normal at rest, in the presence of ventricular hypertrophy can be dangerously reduced due to surgical stress.

When the presence of coronary disease is suspected, an "effort test" should be administered, even if its realisation is often difficult, as it identifies patients who should undergo myocardial scintigraphy.

The respiratory evaluation must be able to identify the various pathologies noted through anamnesis, clinical examination and the standard chest X-ray. A more precise functional evaluation is obtained through tests of respiratory function and blood gas analysis.

Patients with chronic respiratory insufficiency and with a positive anamnesis for episodes of obstructive nocturnal apnoea are at greatest risk of intraoperative respiratory acidosis, despite mechanical ventilation, if laparoscopic surgery is performed.

In these patients, appropriate surgical preparation is mandatory and should include the following hygienic and therapeutic measures: abstention from smoking, simple respiratory physiotherapy, optimisation of bronchodilating therapy and correction of hydroelectrolytic and nutritional imbalances. Among these measures, optimisation of the patient's respiratory state has been shown in some clinical studies to reduce the frequency of postoperative complications.

Haematological tests permit precise evaluation of liver and renal function, haemocoagulatory and glycaemic profiles, and the potential presence of thyroid diseases. During the visit, the anaesthesiologist determine a peripheral venous

access of suitable calibre, and, in the absence of the latter, a central venous access.

The patient's pharmacologic reactions and possible interference between the anaesthetic and patient medications must be determined. Finally, the patient is informed about the type of surgical operation, the anaesthesiological technique, and the possibility of peri-operative complications.

Intra-operative Control

The principal rules to be respected during surgery are:
- Adequate prophylaxis of nausea and postoperative vomiting
- Adequate volume expansion
- Safe venous access with an adequate-calibre needle
- Mechanical ventilation in normocapnia with FiO_2>0.4%
- Adequate monitoring: ECG, NIBP, pulsoximetric, capnography, neuromuscular relaxation monitoring
- Adequate control of postoperative pain

The anaesthesiological technique depends on the surgical site and on the surgical technique. Laparotomy carried out in the inferior regions of the abdominal wall (umbilical/sub-umbilical areas) can be conducted by regional anaesthesia (subarachnoideal, epidural, continuous epidural) or by a combined approach (continuous epidural + subarachnoideal). Regional anaesthesia is associated with fewer complications, assures a more effective postoperative analgesia, and reduces hospitalisation time.

The advantages of general anaesthesia include the fact that it assures good muscular relaxation, which facilitates the surgical procedure and provides good haemodynamic stability; however, it is associated with a large number of side effects (nausea, vomiting and postoperative shiver) and postoperative complications. Patients undergoing laparoscopic surgery must be administered general anaesthesia.

Several recent studies have shown a lower postoperative inflammatory response in the patients who underwent a laparoscopic procedure than in those receiving open traditional surgery. Nevertheless, a more careful postoperative follow-up is necessary to monitor respiratory, metabolic and haemodynamic systems and to treat postoperative pain. Also in operations carried out by general anaesthesia, it is preferable to place an epidural catheter in the patient prior to surgery to assure optimal postoperative analgesia.

Intra-operative Monitoring

The type of invasive monitoring depends on the patient's condition, the presence of concomitant cardiac or pulmonary disease, the surgical site and the surgical technique used. In all patients, non-invasive blood pressure (NIBP) monitoring

and measurements of heart rate (HR) must be carried out, in addition to ECG with analysis of the S-T segment, capnography and measurement of arterial oxyhaemoglobin saturation (SpO_2). These parameters are useful for the early diagnosis of cardiac arrhythmias, hypotension or gaseous embolisms, subcutaneous CO_2 emphysema, and pneumothorax as complications of laparoscopic surgery and thus allow appropriate immediate therapeutic intervention.

In most non-elective operations with a duration greater than 3 h, monitoring of central venous pressure is useful, as it provides important information on the venous blood return and on the volemic state. In this case, a central venous access inserted in the right internal jugular vein, rather than the subclavian vein, is recommended as it yields better access. In patients with cardiac or pulmonary diseases, or in whose with pathological obesity (ASA III and IV), deeper monitoring is necessary.

Additional information is obtained with transoesophageal echo Doppler (TEE), a minimally invasive method that instantly provides information on the cardiac anatomy and thus an early diagnosis of ischaemia or possible embolic phenomena. This technique is more sensitive than measurement of the central venous and pulmonary pressures. The latter allow measurement of stroke volume (SV) and cardiac output, both of which are very useful in the course of laparoscopic surgery.

The pneumoperitoneum is accompanied, especially during the phase of large insufflation, by a meaningful reduction in cardiac output, systolic ejection volume, time of correct flux and peak velocity (PV), whereas mean arterial blood pressure (MAP) significantly increases.

The fall in cardiac output is due to a combination of two unfavourable events: (1) an abrupt reduction of the venous return and (2) an increase in peripheral resistance. The elevated MAP, coincident with an abrupt reduction in cardiac output from the left ventricle, is evidently related to an increase of the after-load. These circulatory modifications also involve a reduction in left ventricular contractility.

In studies employing invasive and non-invasive methods, haemodynamic changes in relationship to an increased IAP were described. Joris et al., using a Swan-Ganz catheter, were among the first to underline, in a group of able-bodied patients, a 50% reduction of the cardiac index and consistent increases in systemic and pulmonary vascular resistances. These changes were related to the increased IAP. Similar results were reported by other authors using non-invasive methods, such as cardiographic impedance studies and TEE [2].

The haemodynamic repercussions of increased IAP are of multifactorial origin, including a reduction of venous return, an increase in peripheral resistance, compression of the abdominal aorta and the actions of various humoral factors, such as catecholamine, prostaglandins, and renin. In fact, during laparoscopic procedures, the increased peripheral resistance (strongly tied to the increased IAP) remains after deflation of the abdomen.

The presence of CO_2 determines direct haemodynamic depressive effects on cardiac contractility and expansion of the peripheral arterioles, and, indirectly,

adrenergic activation with increased peripheral resistance. As noted above, the abdominal organs are particularly sensitive to haemodynamic variations. In fact, the decreased blood flux in the mesenteric and renal circulation is greater than the fall in cardiac parameters [3].

A non-invasive method of haemodynamic monitoring is the oesophageal Doppler probe CardioQ (Fig. 1). It is inserted through the mouth into the oesophagus in the proximity of the descending aorta.

The ultrasound bundle sent by the probe is reflected by red blood cells in the descending aorta. Variations of the frequency (Doppler effect) are picked up by the probe and transferred to the monitor, which calculates the speed of the blood (Fig. 2). From this measurement it is possible to determine the distance-minute (DM), which represents the distance crossed by the blood in 1 min. The wave flux is an indicator of linear movement of the blood in the aorta. To obtain volumetric data, the computer (Fig. 3) uses an in-house algorithm that takes into account the age, sex and weight of the patient to produce a conversion factor (K). The product of this factor and the MD is cardiac output, expressed in l/min^{-1}. Therefore, it is essential to obtain the best signal, which is normally represented by a curve with a systolic wave whose peak is the maximum speed and in which the diastolic wave is small or absent (Fig. 4). Variations of this signal are possible and are produced, for example, by the movement of the probe, which results in artificial (normally recognisable) and therefore false haemodynamic indices.

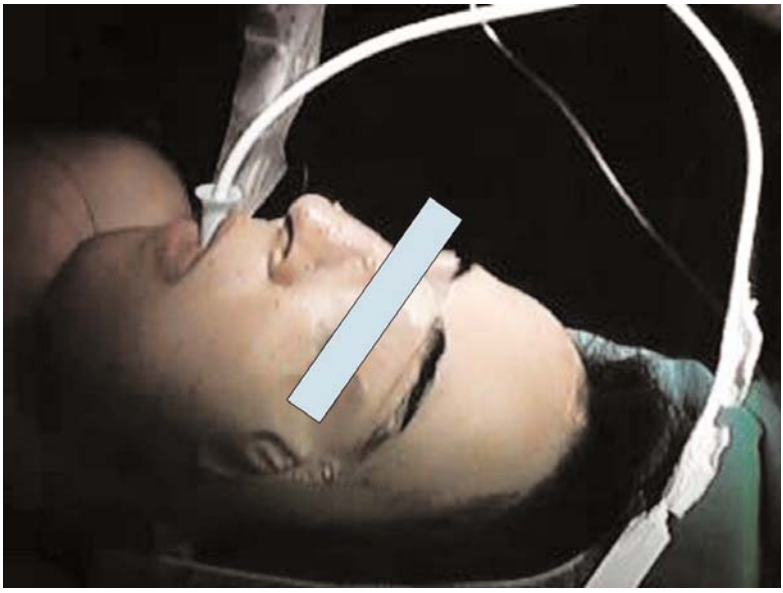

Fig. 1 The Doppler CardioQ. Courtesy of Deltex Ltd, Chichester, UK

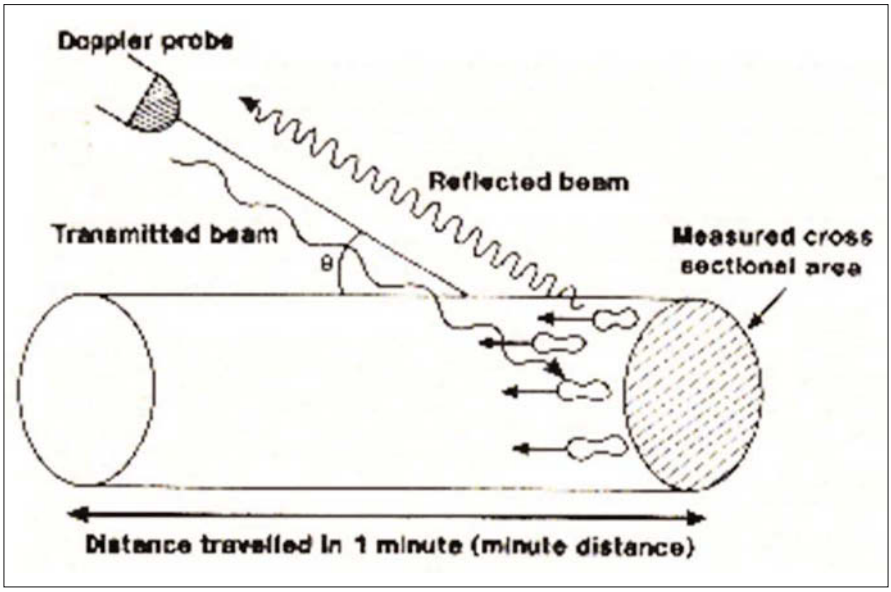

Fig. 2 The Doppler effect of CardioQ. Courtesy of Deltex Ltd, Chichester, UK

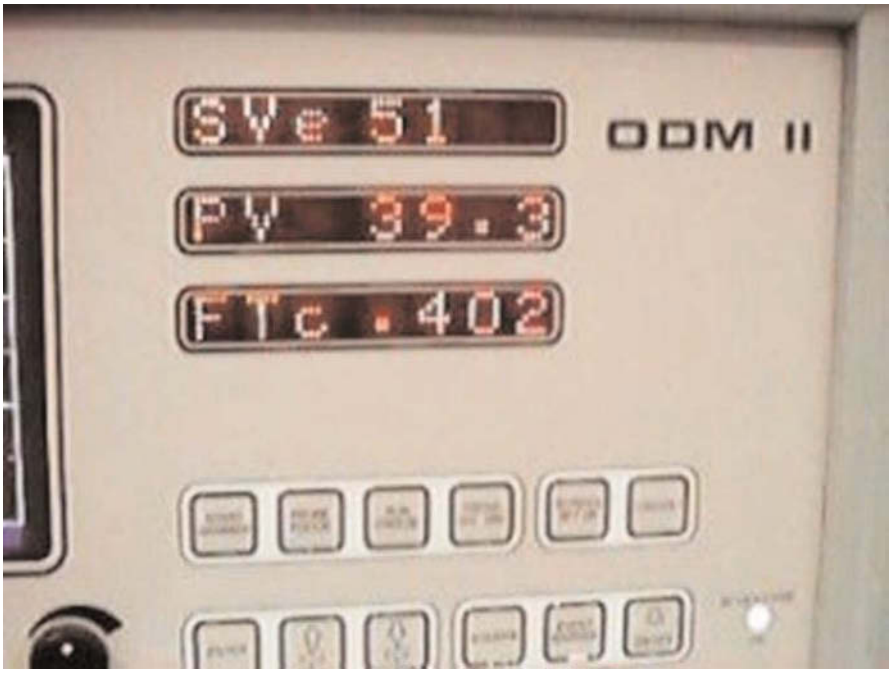

Fig. 3 CardioQ monitor. Courtesy of Deltex Ltd, Chichester, UK

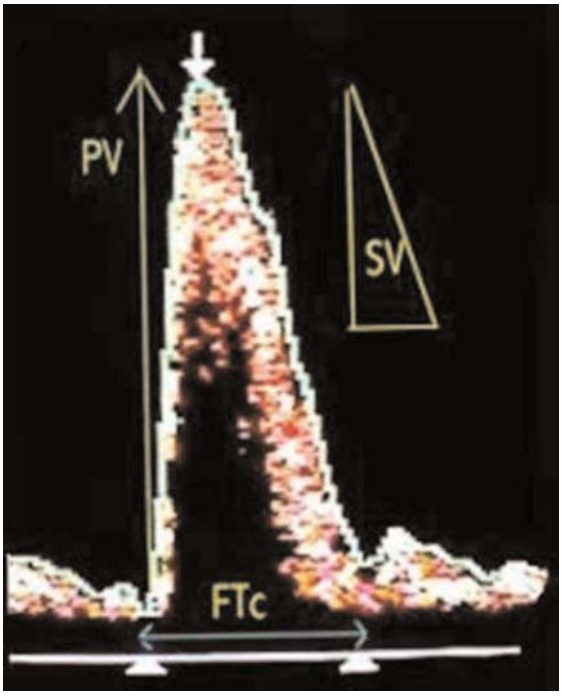

Fig. 4 Best signal of CardioQ with systolic wave. *PV*, Peak speed, an index of left ventricular contractility; *SV*, stroke volume, an index of systolic discharge derived from the stroke distance (*Sd*); *FTc*, time of correct flux, an index of left ventricular filling. Courtesy of Deltex Ltd, Chichester, UK

The haemodynamic measurements that are furnished by the CardioQ are based on several assumptions: (1) that the flux of blood in the descending aorta remains constant with respect to the left ventricular ejection volume regardless of pressure and temperature variations; (2) that the incidence of the ultrasound bundle sent by the edges of the probe is the same of that formed by the centre of the probe and (3) that the aortic diameter does not change during systole.

The probe is nonetheless easily inserted and yields excellent beat-by-beat images that reproduce the blood flux in the descending aorta. The images are readily interpreted, without the need for clinicians to receive specific training. The CardioQ can also be used to monitor the cardiac range and other haemodynamic variables in surgical patients and in those in intensive care, although the results obtained by this method do not always overlap with of invasive thermodilution through a Swan-Ganz catheter. The latter allows more precise measurements of preload, after-load and peripheral perfusion. However, invasive methods are burdened by greater patient morbidity and thus are not usually justified. While thermodilution allows estimation of the cardiac course through the right ventricle, measurements produced by the oesophageal Doppler probe, positioned approximately 1 cm in the descending aorta, derive from the left ventricle directly.

Postoperative Relapse

Compared to traditional haemodynamic monitoring (ECG, NIBP), invasive methods (PICCO, LIDCO), which require peripheral access and venous implantation, acquire data on cardiac range, cardiac index and (with PICCO) pulmonary water content, and the intrathoracic blood volume. These parameters are very important in providing early evidence of cardiac disease.

IAP monitoring, through a urinary bladder catheter, is important to precociously disclose a possible compartmental syndrome [4], which affects the abdominal organs (increased IAP and venous stasis). This condition can be clinically revealed by evidence of renal insufficiency. In this case, together with standard therapeutic measures, continuous renal replacement therapy (CRRT) may be useful, both in substituting for renal function and through the a reduction of IAP, which results from a reduction of the oedema shifting liquids to the interstitial compartment [5].

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Pathologies Associated with Incisional Hernia: Timing of Intervention

Francesco Corcione, Vincenzo Cimmino, Felice Pirozzi, Anna Settembre, Daniele Cusano

The treatment of concomitant endo-abdominal pathologies at the same time as incisional hernia repair remains a subject of controversy in surgical practice. In recent years, treatment of incisional hernias, especially very large ones, has consisted exclusively of prosthetic mesh repair. While initially mesh repair was used only in selected cases, it has since become the gold standard in treating this pathology, due to technological innovations and the increased experience of surgeons carrying out this procedure [1]. Since the early 1980s, the work of French, American and Italian surgeons has demonstrated the efficiency and feasibility of prosthetic mesh repair [2–4]. New, increasingly sophisticated prostheses are being introduced almost on a daily basis; however, rejection and infection of the mesh remain the most threatening complication that surgeons must consider. For this reason, the well-respected schools of abdominal-wall surgery of Stoppa and Rives have always issued vigorous precautions regarding the uses of prosthetic meshes for specific indications [5]. In this context, until the 1980s, the treatment of concomitant pathologies was absolutely contraindicated, as it was considered to interfere with incisional hernia repair. Nevertheless, Stoppa and Rives have allowed that certain concomitant procedures and pathologies can be managed during mesh repair without a high risk of mesh infection [6]. These are:

1. Gallbladder disease
2. Adrenalectomy
3. Oopherectomy
4. Hiatal hernia

This rule has been followed precisely by all surgeons who reject the idea of applying a mesh in a potentially septic field. To paraphrase Rives: “I prefer to repair immaculately an incisional hernia than to have mesh infection”.

However, some experienced surgeons (these authors among them) [7] with in-depth knowledge of prosthetic materials have challenged this rule and applied meshes to potentially contaminated fields. One should keep in mind that the patient should always be well-informed about the potential risks of both incisional hernia and the concomitant pathology.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

For greater clarity, the classification of surgical fields with respect to the risk of contamination has been precisely defined [8] (Table 1).

Table 1 Surgical intervention in relation to contamination risk

Clean	No contamination
Clean-contaminated	No significant contamination
Contaminated	Inflammation and free peritoneal contamination
Dirty	Pus, perforated bowel

It is well-accepted that mesh repair can be safely done during clean and clean-contaminated surgery, but controversy remains regarding contaminated and dirty fields [9]. The approach of these authors has evolved such that mesh is applied when there is no spectacular contamination or peritonitis. In terms of personal experience, three phases can be distinguished.

At first, there was agreement with the famous French school to never break the above-mentioned rule regarding the treatment of concomitant pathology. Nonetheless, during this period, and in some cases, listed in Table 2, it was necessary to apply a mesh in contaminated and dirty fields, while taking all the precautions necessary to minimise contamination, including frequent changing of gloves, towels and surgical gowns as well as the prophylactic administration of antibiotics [10,11]. The outcome of most of these cases was optimal. Consequently, with increasing experience and better knowledge of mesh properties (polypropylene vs. Dacron) the surgical approach became more aggressive, with prosthetic meshes applied in a wide variety of potentially septic fields [12].

Table 2 Concomitant pathologies treated during prosthetic incisional hernia repair (1998–2006)

Pathology	Number of cases
Complicated biliary lithiasis	11
Parastomal hernia	5
Reversal of Hartman procedure	3
Colon cancer	7
Gastric cancer	5
Distal pancreatectomy	2
Hystero-adenectomy	7
Bowel obstruction	3

To successfully accomplish these interventions, certain precautions must be respected (Table 3).

Table 3 Precautions to be taken while applying a mesh prosthesis

Skin preparation
Accurate disinfection
No touch technique
Frequent change of gloves
Immediate use of antiseptic solution during the intervention
Meticulous haemostasis
Specific antibiotic prophylaxis

To reduce contamination, frequent changing of gloves, towels and gowns is essential [7]. However, despite these precautions, this type of major surgery is seldom free of complications. In the authors' experience, a number of infections have been encountered; fortunately, none of them were serious enough to cause mesh rejection, most likely due to the type of mesh used.

In the case shown in Figs. 1–3, en-block resection of a tumour of the right colon invading the anterior abdominal wall was carried out. The abdominal wall was closed using a composite mesh (Proceed). Postoperatively, the mesh became infected but luckily this resolved by conservative management.

In addition to above-mentioned precautions; other safety measures have been instituted:

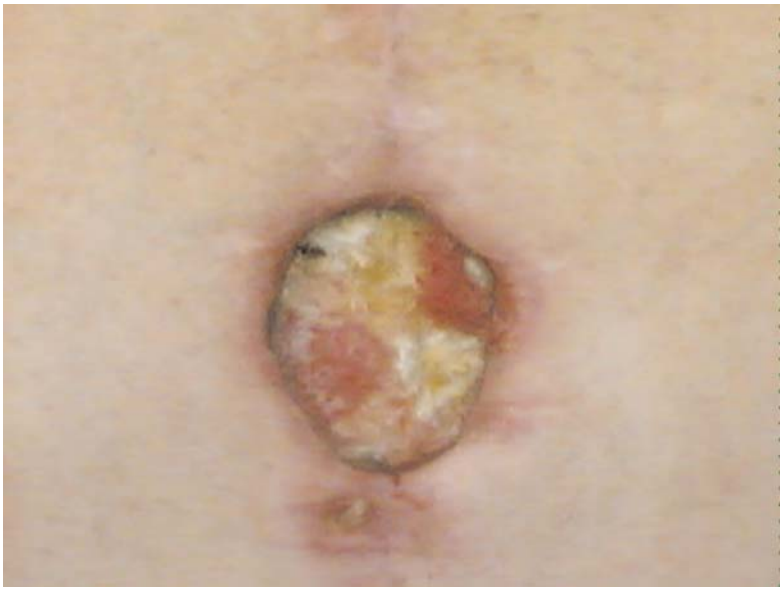

Fig. 1 Infected wound with mesh

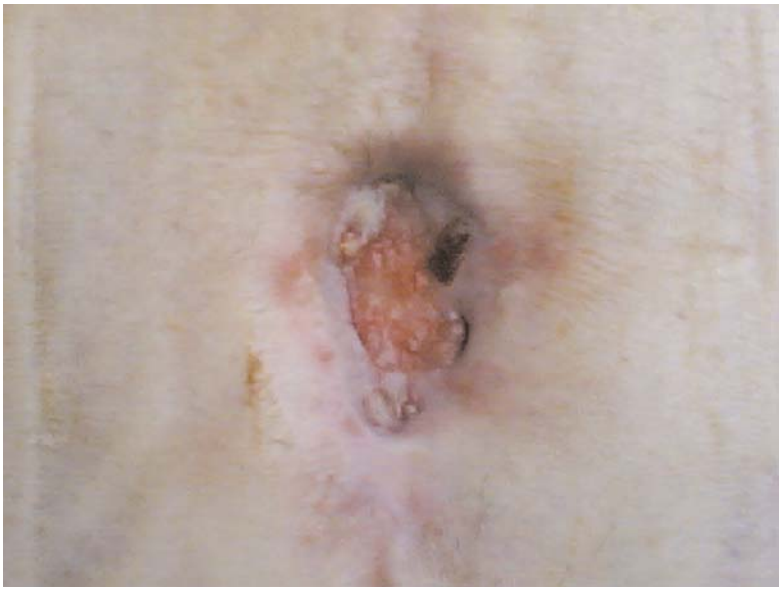

Fig. 2 Wound on the mend

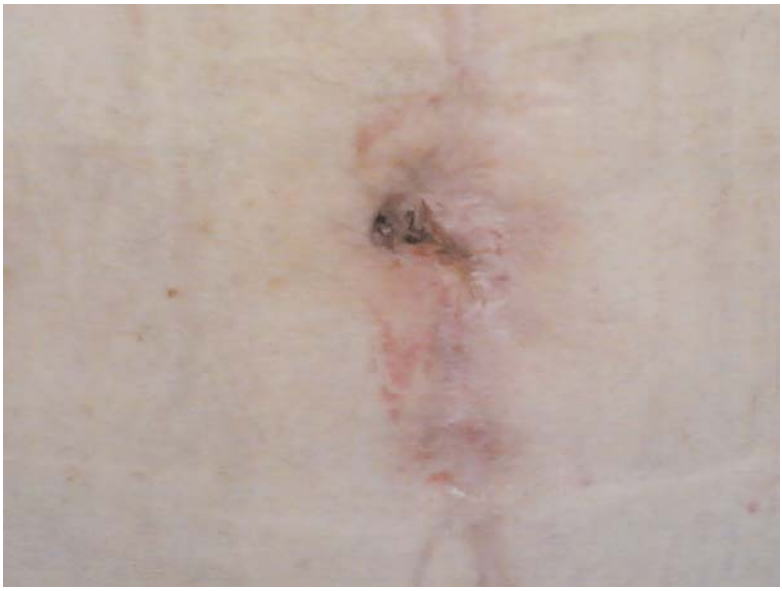

Fig. 3 Final result

1. In cases of cholecystectomy the gallbladder should not be opened and stones should not be allowed to be spill out into the surgical field.
2. Mechanical staplers should be used as much as possible to transect the bowel in order to eliminate the risk of contamination.
3. Patients should be well-informed about the risk of possible infection.

Moreover, in such cases, the mesh should be placed, whenever possible, in the extra-peritoneal space "according to concept of Rives" [5,13] when the concomitant operation has been accomplished. In some cases, however, the surgeon is forced to apply the mesh intra-peritoneally, but this option should be the last one, when it is not possible to otherwise resolve the patient's problem.

It is obvious that, from ethical and legal points of view, in cases involving a dirty surgical field (peritonitis, abdominal abscess), the surgeon must not jeopardize the health or life of his or her patients and repair only the hernia during an acute intervention. If absolutely necessary, an alternative, absorbable biologic mesh can be applied, either intra-peritoneally or subcutaneously if the abdomen can be closed.

Based on our experience and its applications, what can be said about the future? In the last month, new biological prolonged absorbable meshes have been introduced into clinical practice. Although expensive, they can most likely be used in dirty surgical fields with minimum risk of infection and proper integration within the abdominal wall. The mesh remains strong long after the surgical repair.

Although experience with this new material is currently lacking, history has shown that technological evolution advances individual knowledge. This has clear benefits for increasingly demanding patients and pathologies that have become more complex. In the next 5 years, randomised studies will be needed to clarify the role of this new generation of prostheses and their clinical applications.

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The Use of Prosthetic Mesh in Laparoscopic Ventral Hernia Repair

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Introduction

The laparoscopic technique in ventral hernia repair, first proposed by the Blanche in 1993 [1], has been progressively accepted and used because of the benefits associated with laparoscopy: shorter hospital stay, more rapid return to functional independence and reduction in the complications linked to decreased mobility. In the case of abdominal-wall surgery, and ventral hernias in particular, there are no significant benefits in terms of aesthetics and a reduction in acute postoperative pain, although these are the hallmarks of a laparoscopic approach. Even standardisation of the technique is not yet uniform, since questions and basic research are still ongoing relating to the use of different fixation media, either in addition to transfascial suturing or alone. Nor has there yet been any conclusive definition of an ideal prosthesis for intraperitoneal implantation, generally delivered by the laparoscopic route, despite anecdotal reports of procedures using extraperitoneal prostheses.

In the case of intraperitoneal implants, we already know that a prosthesis must possess two simultaneously contradictory properties: it must stimulate adequate abdominal-wall incorporation, and therefore be capable of precipitating an intense fibroblastic reaction, but that very reactivity must not extend to the visceral interface, where the prosthesis can cause fibrotic adhesions capable of developing into fistulas.

Our study is an examination of those commercially available prostheses recommended for the laparoscopic technique that have been evaluated by published scientific studies. The prostheses are described on the basis of their principal component material.

Polypropylene-Based Prostheses

Polypropylene has long been the principal material used in tension-free hernia repair because of its relatively low cost, superior capacity for abdominal-wall

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

incorporation and resistance to traction and infection. These same characteristics make polypropylene unsuitable for visceral contact, although some of the reports discussed in the literature refute any real risk of fistulisation [2–4] Experimental studies, however, demonstrate that even the new low-weight prostheses with modified structures, e.g. through insertion of polyglactin multifilaments (Vypro mesh, Ethicon, Norderstedt), induce the formation of dense adhesions that are difficult to separate, making these meshes unsuitable for intraperitoneal implantation [5]. Use of the omentum as an intestinal protective barrier and the interposition of bioresorbable polyglactin prostheses have given inconclusive results because of the development of very severe inflammatory and fibrotic reactions [6]. The stated reliability characteristics of polypropylene have encouraged experiments in search of protective materials that safely permit their intraperitoneal use.

Simple intraperitoneal instillation of protective solutions (Sepracoat or Icodrestrin) has not demonstrated any capability for reducing the formation of adhesions on prostheses [7] and therefore has not had any impact on clinical practice. Instead, greater success has been obtained by coating polypropylene or polyester prostheses with protective layers of various materials. These experiments have been the source of different meshes that are now widely used in clinical practice, and we will report on the experiences with them, as described in the literature.

Timesh (GfE Medizintchnik, Nurnberg, Germany)

This mesh, which consists of polypropylene coated with inert titanium, has not yet been widely used. The results published in the literature appear to be contradictory. A comparative study based on an animal model reported the formation of fewer adhesions compared to a DualMesh prosthesis and no cases of adhesions to hollow intestines [8]. The results were attributed to the low weight and greater porosity of the polypropylene used in the prosthesis, compared with the original polypropylene. The authors maintained that the difference between their findings and the results from other studies could be attributed to their use of a minimally invasive technique. In contrast, the comparative study published by Burger et al. [9], who used a similar animal model, reported the formation of diffuse and dense adhesions on the visceral surface of the mesh. The limited performance of a prosthesis specifically designed for intraperitoneal use suggests that coating with an inert material is less important than the macrostructure of the prosthesis itself. A rough, macroporous and thus erosive structure is considered responsible for the formation of dense adhesions.

Proceed (Ethicon, Somerville, NJ, USA)

This is a polypropylene mesh with an ultralight structure, encapsulated in a layer of bioresorbable polydioxanone and then coated with a layer of oxidized regen-

erated cellulose (ORC) intended to minimise visceral adhesion formation. The commercial launch of the Proceed mesh is rather recent. Experiments on animal models, the results of which were provided by the manufacturer, indicated that no animal implanted with this prosthesis developed dense adhesions. The mesh appears to be completely neo-peritonised within 14 days. In comparative studies, the Proceed mesh was considered equivalent to the Composix and DualMesh meshes in its degree of adhesion [10]. Less satisfactory results relating to the formation of visceral adhesions were obtained in the experimental study published by Burger et al. [9]. A very recent comparative study [11] confirmed a significant reduction in adhesion formation compared with polypropylene but not with a polyester-coated prosthesis.

Seprames (Genzyme Biosurgery Cambridge, MA, USA)

The polypropylene mesh in this case is coated with a bioresorbable membrane of hyaluronic acid and carboxymethylcellulose. The prosthesis is currently being used in abdominal-wall surgery in which contact with the intestines cannot be avoided. In comparative studies, this mesh has performed well in terms of tissue resistance and abdominal-wall incorporation, without elevated risk of infection [9]. Its use in laparoscopy is hindered by technical difficulties with insertion, due to the sticky consistency of the protective membrane [7]. More recent animal studies involving laparoscopy indicated adequate abdominal-wall incorporation with scarcely any adherence reactions. No technical problems were noted [12].

Polyester-Based Prostheses

Polyester offers optimal incorporation into the scar tissue that develops around both the fibres and the inside of the mesh, but it precipitates a pronounced adherent reaction and distorted scar development. Resistance to infection appears less marked than with polypropylene by reason of the pore size, which makes the mesh easily colonised by bacteria but not by immune cells. Its direct use in an intraperitoneal site is not feasible because of the intense fibroblastic reaction. Therefore, a composite structure has been proposed for this material that will make it capable of visceral protection.

Parietex Composit (Sofradim, Trevoux, France)

This mesh has a multifilamentous polyester structure. Its visceral surface is coated with: (1) a hydrophilic film, consisting of collagen, polyethylene glycol and glycerol, that extends 5 mm beyond the polyester margins and is bioresorbable within 3 weeks, and (2) a neomesothelial layer that covers the mesh entirely. The prosthesis has had wide clinical acceptance and has been tested in numerous

experimental studies. In particular, animal-model laparoscopic experiments with the technique [11–13] have demonstrated optimal abdominal-wall incorporation. These results correlate well with the histological evidence of colonisation with fibrotic tissue in the interstitial spaces of the prosthesis and with the full development of a neo-peritoneum. With reference to laparoscopic use, the study authors emphasised that there were no signs of damage to the prostheses (ePTFE, polypropylene, PCO) associated with their insertion through the trocar. Specifically, there was no evidence of delamination between the polyester and the collagen membrane. While still at the investigational stage, the Parietex Composite prosthesis has demonstrated greater susceptibility to infection and a heightened inflammatory response [7]. The tolerability of the mesh has been tested also in a clinical setting: Moreno-Egea [14] reported good tolerance, with less than 10% subclinical formation of adhesions on sonographic and CT scans. The aesthetic result was also noteworthy, described as the 5-year persistence of normal tension and abdominal-wall symmetry in 96% of patients.

ePTFE Prostheses

Polytetrafluoroethylene is the only material that permits uses involving direct contact with the intestines, by reason of the material's smooth microporous surface. Since this property makes it unsuitable for abdominal-wall incorporation, modification of the texture of the prosthesis was required for its use in laparoscopic surgery.

DualMesh (Plus) (Gore-Tex W. L. Gore, Flagstaff, AZ, USA)

This prosthesis has enjoyed the earliest and widest clinical acceptance [15–17]. It consists of a smooth microporous surface on one side and a corrugated surface on the opposite side. The smooth surface faces the abdominal cavity, while the corrugated part is applied to the abdominal wall, where it induces incorporation through fibroblastic activation. The commercially available configurations are numerous. Specifically, one prosthesis features impregnation with silver and chlorhexidine, which is said to specifically prevent prosthesis-induced infection in potentially infected operating fields and has been reported to be superior to other prosthesis under the same conditions [18]. Clinical use of these prostheses is very widespread, although their experimental performance has not been fully satisfactory. The comparative study of several prostheses published by Burger [9] reported the development of dense and difficult-to-separate adhesions on the smooth surface of the prosthesis. It also described extensive prosthetic retraction and surface roughening, which may very well be the cause of the adhesions. Similar studies [8–13] noted intense fibrotic reactions around the prosthesis, without penetration, and there are also reports that the DualMesh exhibits a sig-

nificantly greater degree of retraction than other prostheses tested. Fixation of the prosthesis with transparietal sutures was therefore suggested. However, experiments arriving at different conclusions are also available; these maintain that products combined with polypropylene are characterised by a greater number of adhesions, and have no better abdominal-wall incorporation [19]. These last experimental findings and the absence of clinical reports of intestinal occlusion or fistulation [20] have persuaded the supporters of this prosthesis to regard it as the prosthesis of choice [15].

Mixed-Component Prostheses

Composix (C.R. Bard, Murray Hill, NJ, USA)

This prosthesis is composed of a polypropylene layer and a sheet of ePTFE sewn together with an ePTFE monofilament. It is one of the oldest prostheses, and has been repeatedly upgraded since its original use. The meshes that compose it have been woven more solidly together and contact between the visceral surface and the polypropylene layer has been avoided, the result of sufficient overlap with the ePTFE membrane. In the most recent model, the polypropylene layer has been made lighter and more porous, considerably reducing the thickness of the prosthesis, which can be introduced via a trocar, even in the case of the larger versions (Bard Composix L/P Mesh). The prosthesis has recently been evaluated in an animal model for the purpose of verifying the solidity of its attachment to the abdominal wall, as it is retained only with titanium tacks. The published results indicated the development of very early abdominal-wall incorporation, within the space of the first 2 weeks, which greatly increased the solidity of the repaired site over time. The authors conclude that the prosthesis exhibits adequate reliability in the immediate postoperative period because of its ability to respond to increases in intra-abdominal pressure—a possible cause of failure at the initial stage of incorporation—without the help of transparietal sutures [21].

Biological Prostheses

This novel type of prosthesis is characterised by the organic origin of the tissue, usually animal tissue, and by its ability to form a support on which the tissue where the graft is placed is regenerated rather than induced to react to a foreign body. The use of this prosthesis in ventral hernia laparoscopic alloplasty is somewhat recent and therefore the relevant literature is still sparse. Nonetheless, the characteristics of the prostheses regarding minimal immune activity induction while an elevated resistance to infection is maintained are promising. The biologic materials used in clinical surgery include allografts of human dura

mater, especially in the treatment of omphalocele in neonatal surgery [22]. Four cases of transmission of Creutzfeldt-Jakob disease after treatment with allografts obtained from cadaver dura mater were reported, but the techniques practiced today in the preparation of prostheses, such as the use of sodium hydroxide and hydrogen peroxide, guarantee deactivation of the infectious agent and thereby eliminate this risk (*Tutoplast Dura Biodynamics, Erlangen, Germany*).

There is more widespread clinical use of a pure collagen prosthesis derived from the bovine pericardium (*Tutomesh, Tutogen Medical, Nurnberg*, *Germany*), certified to be free of the bovine spongiform encephalopathy virus. In a recent study on an animal model involving a non-laparoscopic technique, the prosthesis was compared with other materials (fascia lata and PTFE), and was resistant to traction and increased pressure; its adhesion-forming profile was similar to that of PTFE [23]. These results, however, have been contradicted by other research, with reports that the Tutomesh prosthesis has significant anti-adhesive properties by reason of its smooth surface and the slight foreign-body reaction it produces. Nonetheless, it virtually lacks any capacity for abdominal-wall incorporation and has low tensile resistance for the same reasons.

The *Surgisis Gold (SIS) (Cook Biotech, West Lafayette, IN, USA)* prosthesis is derived from the porcine small intestinal submucosa (SIS). The intestinal submucosa is a thin layer consisting of an extracellular collagen matrix with low cellular volume. The procedures for preparing the biomaterial help eliminate the cellular residues and thereby preserve the layer for prolonged periods of time. It was first used in an experimental vascular graft. Once implanted at the selected site, the biomaterial is incorporated and progressively replaced by new tissue virtually identical to the host tissue—a process given the name “smart remodeling”. This occurs in any of the sites in which the material has been used (vascular structures, abdominal wall, tendons, lower urinary tract, bone). The process may be explained by the scaffolding effect induced by the biomaterial while the host tissue regenerates. The implanted material also undergoes rapid intense neovascularisation, which may be the basis of its resistance to infection [24]. In clinical use, however, although the prosthesis performs well in clean sites, it is not sufficiently reliable under contaminated conditions [25].

Our Experience

We treated 142 patients with ventral hernia by laparoscopy between June 1998 and February 2007. The technique we used and our impressions progressively evolved over the course of almost 10 years. In our initial enthusiasm, we believed the laparoscopic approach was indicated for all ventral hernias independently of size. In the first 20 patients, we used a technique of approximating the fascial margins with interrupted sutures, which we believed would enable use of a prosthesis of smaller dimensions but nonetheless obtain sufficient overlap. The technique, however, was not devoid of postoperative pain or the risk of

prosthesis-induced infection associated with transcutaneous introduction of the sutures. Therefore, in pursuit of a tension-free technique, we abandoned every effort to approximate the fascial margins. In this early period, we employed the Composix bilaminar prosthesis, which we regarded as particularly solid and well-adapted for abdominal-wall incorporation. Later, while continuing to use that prosthesis, we adopted the DualMesh, which even today is the preferred prosthesis for most of our study population because of the superior flexibility of the material and the extent of the international clinical experience with it; specifically, no case of visceral fistulisation associated with the prosthesis has ever been reported. We used the Proceed mesh in 20 patients. In addition to the tolerability of the material, it has proven to be particularly ergonomic because of the ductility the mesh derives from sufficient memory, which facilitates its distension at the intraperitoneal site. Regardless of the type of prosthesis, we have never used transfascial sutures, but instead double-crown titanium tacks.

As our experience progressed, we have limited the laparoscopic indication to relatively narrow abdominal-wall defects, in which use of the prosthesis and its fixation, particularly at the edge proximal to the laparoscopic camera, are more reliable.

It is evident that an experience as rich in variables as this and not targeted toward experimental criteria would not allow us to neatly express our impressions about the various features of prosthetic materials. We would like to indicate, however, that we never encountered mesh infection in the patients we treated. Even in the two patients in whom an enterotomy with minimal spillage occurred, the intervention was completed—following suturing of the lesion and disinfection of the peritoneal cavity—with apposition of the prosthesis (DualMesh) and without postoperative complications. One patient experienced postoperative perforation, attributable to an ileal lesion secondary to penetration by a surgical anchor. At the reintervention, a month later and consisting of laparoscopic repair, the prosthesis (Proceed) seemed devoid of any relevant adherent elements. On the subject of complications, seromas were the most common event (13% in our study population) but only occasionally was it necessary to aspirate the contents and a drain was never installed.

Failure occurred in four patients: on two occasions there was inadequate fixation during the reintervention, probably associated with insufficient overlap. In one patient, the defect site was close to bony structures, which compelled us to resort to an overly loose fixation to avoid chronic pain. One patient refused reintervention for personal reasons. Two patients received a new laparoscopic intervention distant from the laparoscopic alloplasty: one patient underwent second surgery for chronic pain at 6 months and involving removal of the titanium tacks. In the other patient, the reintervention was due to a separate pathology. In both patients, the prosthesis used was a DualMesh. On laparoscopic exploration, the prosthesis appeared well-extended, completely mesothelialized, and devoid of visceral adhesions of clinical importance. Even in the cases of DualMesh prosthesis failure, in which curling of the prosthesis was evident, there were only minimal, extremely loose adhesions that were easily lysed with a blunt instrument.

Discussion

An ideal prosthesis has yet to be devised, which explains the multiplicity of commercial products and the lack of agreement among studies. In clinical practice, however, the preference for a mesh is justified not only because of its reliability, which now appears to be a common factor among all products, but also because of its technical facility regarding insertion. In laparoscopy, a prosthesis, even a large one, must be capable of being introduced via a trocar without producing lacerations or alteration in the protective film. Moreover, the operative field may sometimes be restricted such that the mesh must be equipped with sufficient memory to enable it to unfold and to make its orientation easier. A certain degree of transparency is also desirable, since it would enable objective evaluation of whether sufficient overlap has been achieved. In addition, the thickness should be appropriately set so that fixation devices in current use will adequately penetrate the abdominal wall.

One of most common complications, albeit spontaneously resolving in most cases, is seroma. The solution will probably be found not in the management of the hernial sac or the use of compressive medications, but in the use of light, large-pore meshes that permit the filtering of secretions toward the abdominal cavity, all the while maintaining the necessary resistance to traction [13].

Although the laparoscopic approach is traditionally associated with a reduction of postoperative pain, this is not always true in surgery of the abdominal wall. Instead, there have been many reports of persistent pain at some time after the intervention. Thus, what is the role of prosthesis retraction in the pathogenesis of symptomatic pain and in the development of tardive failure?

A study edited by Kockerling [26] focused on the problem of prosthetic shrinkage, an evolution linked to the physiological reaction induced by a foreign body. The body's response depends on the implantation site of the prosthesis, the material of which it is made, and its structure. This probably explains why a polypropylene mesh, fixed in an identical manner, is subject to less retraction than one of ePTFE, and such behaviour is maintained over time. Indeed, the ePTFE prosthesis cannot properly be called a mesh but rather a membrane, the structure of which does not permit complete abdominal-wall incorporation. The connective tissue fibres attach to one another to form a capsule around the mesh, referred to as the "bridging effect." Scar tissue formed in this way develops into fibrosis, facilitating the formation of folds and prosthetic retraction. In the case of large-pore meshes, single fibres are incorporated and a new mesothelium is formed that will completely coat the prosthesis and provide it with in situ stability. The study authors suggested that scar-induced retraction of the prosthesis is promoted by inadequate fixation, but it may be appropriate to consider other pathogenic factors, such as seroma formation. We support the findings of this work as a contribution to the discussion, even though in our experience the PTFE prosthesis has not demonstrated any signs of retraction, if fixed without tension and with adequate overlap.

A further aspect is suggested by the observation that many patients with a large prosthesis complain of paraesthesis at the prosthetic margins and of limited mobility of the abdominal wall [27]. It is reasonable to suppose that an elevated quantity of prosthetic material, particularly if rigid, will induce a change in the natural elasticity of the abdominal wall, to the extent that it significant impacts the patient's quality of life. In fact, the resistance capabilities of existing prostheses far exceed the maximum tensile resistance of the abdominal wall, suggesting the possibility of reducing the quantity of foreign material needed for repair and thereby improving the body's physiological performance.

With respect to biologic prostheses, clinical and experimental experience with them is still limited, but it is interesting to consider the possibility of intelligent regeneration, in which the native tissue is reconstructed with its own natural characteristics. Other studies will be needed to investigate this potential.

Conclusions

The introduction of prosthetic materials applicable to the intraperitoneal site has made it possible to use the laparoscopic approach for treating ventral hernias, with results that appear more satisfactory than conventional therapies. The more recently introduced prostheses aim at further increases in tolerability and facility of use. All of the commercially available meshes demonstrate reliability and stability, and the surgeon—while awaiting the ideal prosthesis—can choose the one that best meets his or her expectations or the specifics of the clinical situation.

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Mesh Fixation Devices

Diego Cuccurullo

Introduction

A fundamentally important step in the laparoscopic repair of incisional hernia is the fixation of the prosthesis to the abdominal wall. In fact, good results are due to the perfect rendering of this step, whereas non-adequate fixation can lead to serious postoperative complications. Dislocation of a not properly fixed prosthesis can cause, for example, a relapse of incisional hernia; a partial disconnection can also lead, in addition to a recurrence, to an interposition of an intestinal loop between the prosthetic mesh and the wall with subsequent occlusion, intestinal erosions and thus peritonitis and enteric fistula [1,2]. Also, the problem of serious chronic neuralgia can be a consequence of nerve entrapment due to the incorrect positioning of fasteners, especially transfascial sutures [1,3]. Similarly, a less than perfect adhesion of postoperative the prosthesis to the wall leaves empty spaces that increase the frequency of postoperative seromas [1–3].

Adhesion of the Prosthesis to the Wall

It is by now well-documented that the prosthesis must be of the right size to assure a 5-cm overlap of each of the margins of the defect. Moreover, retraction of the prosthesis, demonstrated by accurate scientific studies to be as much as 30% of the original size, must be considered [4,5].

In laparoscopic incisional hernia, the prosthesis is intraperitoneal, not located between two layers as is the case in the laparoscopic repair of inguinal hernias or in the open technique used by Rives in laparoplasty, but it is underlayed and in contact with the peritoneum. Therefore, in order to be colonised by fibroblasts and to allow satisfactory merging with the tissues, which is at the base of a successful plasty, the maximum extension of the mesh surface must be in contact with the wall, and contact between the prosthesis and the peritoneum should result in the exertion of equal pressure at all points, without the interposition of empty spaces.

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Metal Stitches

Currently, there are many aids to fixation on the market, including metallic (steel or titanium) appliances that fix the prosthesis to the abdominal wall and which are able to penetrate its thickness in various ways and at various depths.

Among the metallic fixation aids most commonly used in the laparoscopic repair of incisional hernias are "tackers" (Protac, US Surgical Corporation, USA), helicoidal titanium spirals that penetrate to a depth of 3.8 mm; "anchorettes" (EndoAnchor, Ethicon Johnson & Johnson, USA), in the shape of an anchor made of nitinol (nickel titanium) and which penetrate more deeply (5.9 mm) but whose disadvantage is that removal in the case of erroneous, dissatisfying or partial application is very difficult; and Q rings (Salute Fixation System, Bard Davol, USA), metal clips closed in a Q shape made of austenitic steel that penetrate to a depth of 4.1 mm and have the advantage of minimising tissue damage since they pass only once through the tissues and are therefore less compressive. The applicators of these metal devices consist of a rigid handpiece of 5 mm that is disposable for tackers and anchorettes and reusable with a rechargeable cartridges for the Q ring. With the latter, there is also the possibility to turn the handpiece and vary the rotation and therefore the direction in which the metallic clips penetrate the mesh.

Whichever appliance is used to fix the mesh, it is necessary to follow those principles that guarantee the best possible fixation. The metal devices should be applied peripherally in a crown (some surgeons prefer a double crown [3] but this does not seem to yield effective advantages compared to a single crown), at a distance of about 0.5 cm from the edge of the mesh, with a distance of 1 cm between each element. It is useful to apply a light counter-pressure with the hand on the abdominal wall at the point of application of the handpiece, orienting the wall, and therefore the prosthesis, in a direction orthogonal to the instrument. This helps to avoid slipping of the metal clip, which would otherwise be applied tangentially, allowing with this manoeuvre a greater penetration into the mesh and the tissues.

Transparietal Stitches

The usefulness of inserting transparietal stitches in addition to the metal fixation aids [6,7] continues to be debated. It is, in fact, true that transfixed stitches assure a more complete adhesion of the mesh to the peritoneum, thus favouring contact between the wall and the prosthesis for the entire time that the slowly re-absorbable stitches are present (they start to resorb only when the fibroplastic ingrowth within the mesh has started, or forever in the case of non-resorbable sutures. On the other hand, it is also true that transfixed stitches can increase morbidity and complications, causing parietal blood loss in the case of epigastric-vessel lesions and/or chronic post-operative neuralgia in the case of nerve entrapment [1–3].

According to some studies, the tensile strength of transfascial stitches is two and a half times greater than that obtained with trackers [8,9], and the percentage of relapse is influenced positively by suturing the mesh with whole-thickness stitches, decreasing from 5.6% (tackers), to 3.8% when the mesh is fixed with transparietal stitches [8]. There are other studies that affirm the exact opposite, reporting a 4% relapse rate with the use of sutures but only 1.8% when sutures are not used [7]. Some experimental studies carried out with pigs have shown that fixation of the prosthesis with transfascial sutures in the treatment of artificially induced incisional hernias is linked to longer surgical time, more numerous postoperative adhesions and no improvement in tensile strength or prosthetic ingrowth [10].

There are various methods to insert transparietal stitches for mesh fixation [11–14], such as the use of a grasping device (Endoclose, US Surgical, USA) or a Reverdin needle. If these instruments are not available, a catheter (e.g. Angiocath 14 G) can be used. Introduced from the outside through a small incision in the skin that is made with the point of a blade 11 scalpel, the catheter guides removal of the straight needle previously introduced into the abdomen through both the wall and the prosthesis, thus simplifying the entrance and exit of the needle through the same hole. This allows the slowly resorbable transfixed stitch to be knotted and left under the skin.

Adhesives

Synthetic adhesives and biological glues have not received consensus approval nor is there sufficient evidence of their advantages in the fixation of prostheses in the laparoscopic repair of incisional hernias. This is in contrast to inguinal hernia laparoplasty, in which their use has received ample consent, since the prosthesis is situated between two layers in a closed space and therefore the fixation of the mesh is not very important, as it is useful only in inducing prosthetic ingrowth [15,16].

Treatment of the Defect Before Mesh Fixation

In my opinion, even a partial closure of the parietal defect, contemporary with a reduction of the peritoneum of the hernial sac and prior to insertion of the prosthesis, is particularly useful. This method does not claim to reduce the size of the parietal defect and consequently the amount of mesh that is required, since the latter should always refer to the original defect size and have satisfactory overlap; however, we have documented a great decrease in the number of postoperative seromas secondary to the introflexion of the sac, which is due to the reduction of residual empty spaces. Moreover, a reduction or complete closure

of the defect means that the parietal region in direct contact with the prosthesis increases, such that fibroblastic ingrowth is stimulated on a larger surface. This would happen much later if the prosthesis were to come into contact with an empty subcutaneous space. With this aim in mind, a very long (25 cm), upturned, vicryl U stitch is inserted with a curved needle that first hooks one edge of the defect, then one or more points deep in the sac, then the other edge of the sac, knotting the stitch while the intra-abdominal pressure of the peritoneum is lowered to 6–7 mmHg (Fig. 1).

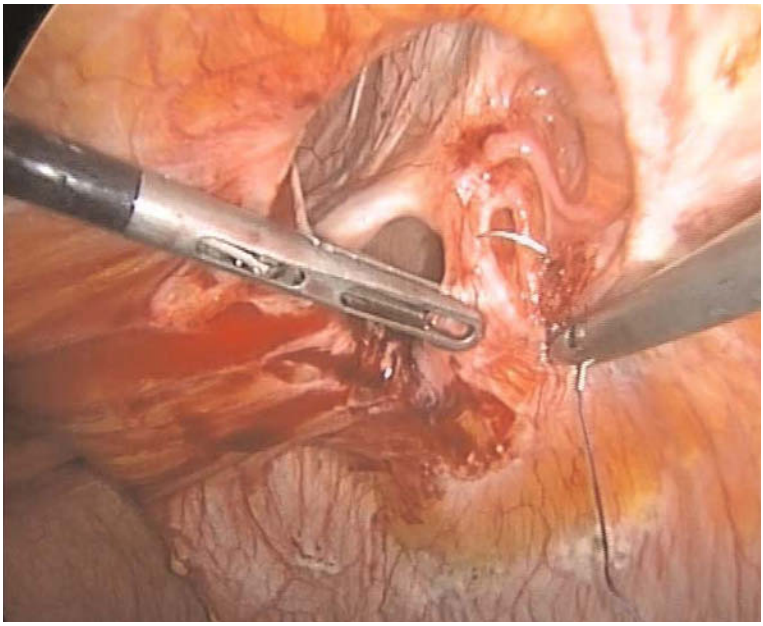

Fig. 1 Closure of the defect with a hook-bearing needle that grasps both the margin of the defect and, deeply, the hernial sac

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Biological Material

Salvatore Ramuscello

The evolution of new hospital-admission models and the change from a prolonged to a reduced stay, e.g., for a week following surgery, or to same-day surgery, is the result of enormous technological progress, including surgical and anaesthesia techniques, and of the greater availability of a range of therapeutic devices. The latter has stimulated the interest of the medical industry in the development of new materials that support the aim of current surgery to be minimally invasive.

Biological materials are an important component of surgical treatment of abdominal hernia. The ideal biological material must allow a perfect biological interaction with the environment in which it is implanted, and must therefore possess high biological compatibility and biodegradability. The biological materials currently on the market exhibit total resorption and are biologically compatible, carrying out four important physiological functions [1–5]: (1) adhesion, (2) haemostasis, (3) sealing and (4) repair.

The product that best demonstrates these features is fibrin glue, obtained from the combination of human fibrinogen and thrombin, thus duplicating the product formed in the last step of the coagulation cascade. Surgical applications of this readily integrated biological adhesive have developed quickly. Fibrin glue [6–9] is now used in the same way as traditional haemostasis agents in cardiac and hepatic surgery, and studies testing its ability to reduce the number of the sutures in vascular surgery, protect internal anastomoses, close fistulas, and facilitate surgery in haemophiliacs are in progress. Other applications are currently under evaluation as a support for cell growth in tissue engineering and as a matrix for the slow release of medications. The rationale behind the use of fibrin glue in the surgical treatment of abdominal hernia is derived from its fulfilling the above-described functions:

1. Adhesive. Used without dilution, fibrin glue allows fixation of a prosthesis inserted in the extraperitoneal position, limiting or obviating the need for pins or staples. The objective is to reduce the amount of non-resorbed material and to avoid areas of tension on the prosthesis due to the physiological reduction of its surface, resulting in increased patient discomfort [3,5].

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

2. Haemostasis. Best results are obtained by diluting 1 ml of thrombin with 100 ml of sterile water + 3 ml of sodium chloride. The haemostatic properties of fibrin glue reduce the risk of haematoma, especially in patients with altered haemostasis, either physiological or acquired (e.g. from drug therapy) [4].
3. Sealing. Dissection within the abdominal wall increases the risk of seroma. Fibrin glue is an effective sealant, although less so than other biological materials, but nonetheless sufficient to reduce the number and volume of seromas, thus recommending its use in hernia surgery [7].
4. Biological repair. The presence of fibrin glue locally increases scarring by stimulating an increase in the number of fibroblasts, which allows more rapid colonisation of the prosthesis (Figs. 1,2) [5].

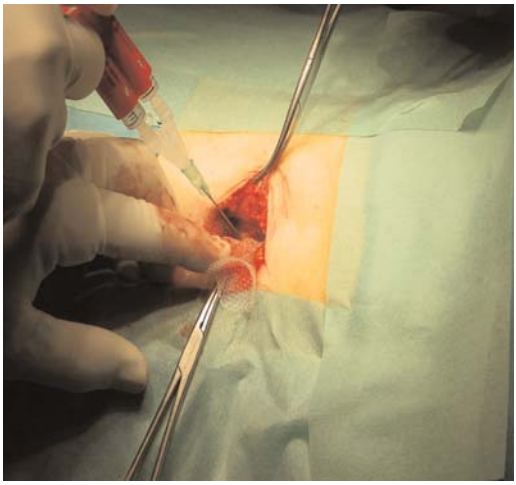

Fig. 1 Mesh fixation

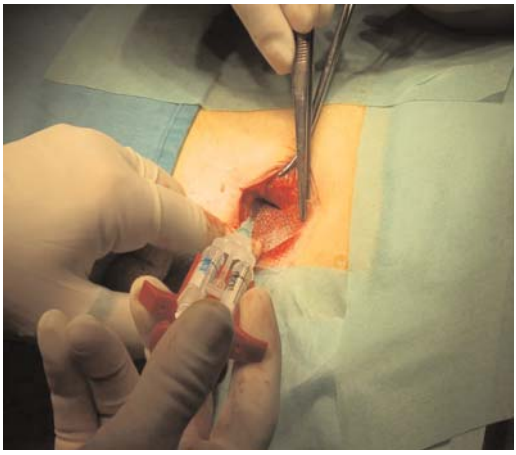

Fig. 2 Seroma reduction

Conclusions

In all surgical procedures, the objective is to employ the best technique, i.e. one that is simple, fast and offers the best results. Today, a short hospital stay with ready resumption of work is expected. Accordingly, surgical procedures must minimise the amount of pain and number of complications. In this regard, biological materials offer the following advantages:

1. Effective completion of surgical treatment
2. Biological compatibility
3. Effective costs-benefits relationship and improved patient compliance

Clearly, the increasing use of surgical procedures will increase the demand for effective biological procedures.

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Our Approach to the Rives-Stoppa Technique

Paolo Negro, Francesco Gossetti, Linda D'Amore

Most surgeons performing abdominal-wall surgery consider the Rives-Stoppa technique to be the gold standard procedure in the open treatment of midline ventral hernias, particularly incisional hernias. As is well-known, this procedure involves: (1) anatomic plasty of the posterior lamina of the rectus sheath, from the xyphoid apophysis to the linea arcuata (of Douglas) and from there, depending on the wall defect, dissection of the pre-peritoneal space to the pubic symphysis and the Bogros space; (2) implantation of the mesh in the newly formed retromuscular space above and/or below the umbilicus (sub-lay repair). Plasty of the linea alba concludes the layered reconstruction of the abdominal wall and separates the mesh from the subcutaneous tissue.

The Rives-Stoppa procedure achieves both an anatomic and a prosthetic repair. Anatomic plasty restores the structure of the abdominal wall while placement of the mesh targets the biological defect. Three objectives of ventral hernia surgery are thus achieved: treatment of the hernia (hernia reduction, containment and prevention of recurrence), restoration of the anatomo-physiologic properties of the abdominal wall and correction of the aesthetic defect.

The rationale of this procedure exceeds those of other surgical techniques involving supra-fascial placement of the prosthesis (onlay repair) close to the subcutaneous tissue or intra-peritoneal mesh implantation (inlay repair). Onlay procedures expose the patient to the risk of seroma, even long-lasting, or mesh infection. Inlay techniques can cause adhesions to the surrounding structures.

Experimental research and clinical investigations have demonstrated that more or less all synthetic materials induce varyingly significant adhesion formation, depending on the composition and the structural characteristics of the mesh (higher risks for polyester and polypropylene meshes; lower risks for composite prostheses and ePTFE) and the material used to fix the mesh to the abdominal wall. Intraperitoneal implantation cannot be justified by personal indications or commercial interests, when unnecessary.

Notwithstanding technical and clinical considerations, the intra-peritoneal onlay mesh (IPOM) laparoscopic technique cannot be considered the procedure of choice in the treatment of midline incisional hernias in spite of the fact that is less invasive. This approach does not realize an anatomic reconstruction of the

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

abdominal wall but only a bridge plasty of the margins of the parietal defect, without any aesthetic correction of the cutaneous scar and dermo-adipose complex (often necessary).

The use of prosthetic intra-peritoneal repair is justified only if the abdominal-wall defect makes restoration of the anatomic integrity impossible. In these cases, the use of a "dedicated" prosthesis (composite mesh or ePTFE) and up-to-date knowledge of the new devices are mandatory. More than 40 years after the first such operation, the Rives-Stoppa procedure has demonstrated excellent results, as also confirmed by recent studies [1,2]. The surgical technique is not difficult and it does not require any modifications that alter its principles [3]. However, the results could be improved, especially in light of new prosthetic materials. For 20 years, we have performed this technique as the procedure of choice in the treatment of midline ventral hernias. Here, we describe the main technical phases of the Rives-Stoppa procedure, step by step, and share our personal experience regarding its implementation.

The procedure comprises three main technical phases: (1) restoration of the deep fascial layer; (2) prosthetic repair and (3) reconstruction of the superficial layer.

In incisional hernia, it is important to excise an ellipse of skin large enough to include the old surgical scars. Better aesthetic results can be achieved by delaying the reduction of excess skin and subcutaneous tissue to the end of the operation. Instead, it is initially sufficient to identify the medial margin of rectus muscle on both sides and to lift the dermo-adipose complex only 1–2 cm above the fascial level. Complete preparation of the medial margin of the rectus muscle is made easier by lateral dissection of the hernial sac. This should be extended as much as possible to the pro-peritoneal retrofascial plane. Sac dissection should be completed with particular attention paid to the identification of parietal button-like defects. When possible, the hernial sac should be left closed to improve postoperative comfort and to reduce adhesion formation. If the sac is accidentally opened, it should be sutured at once. If it needs to be explored (i.e., sub-occlusive syndrome), its resection should be delayed until after plasty of the myoaponeurotic layer. The fibrous component of the sac could, in fact, be useful to complete the plasty. It is advisable to employ the median rather than the more commonly used peripheral section of the sac for better vascularisation of the residual lateral peritoneum.

The next surgical step consists of exposure of the retromuscular prefascial space, which is approached through a longitudinal dissection of the rectus sheath along its entire length. The dissection can directly start from the lower margin of the rectus muscle, near the cicatrised residual of the linea alba, or on the superficial fascia, in this case gaining 1–2 cm on each side, which makes the plasty easier to perform. The separation of the posterior sheath from the muscular belly laterally continues along an avascular space to reach the external margin of the rectus muscle, thus achieving posterior separation of the components (component-separation technique).

Along the lateral margin of the rectus muscle, the intercostal nerve branches (from the 7th to the 9th for the upper abdomen) penetrate the posterior belly of

the muscle together with the corresponding vessels (Fig. 1). These structures have to be preserved to ensure muscular trophism.

Cranial dissection of the posterior rectus sheath must extend up to the insertion of the sternum, thus separating the superior lamina of the linea alba and creating a space to implant the prosthesis on the pre-fascial layer (Fig. 2) [4]. Depending on the abdominal-wall defect, the dissection distally extends to the linea arcuata, on both sides of the umbilical scar or below it. At the end of the dissection, two aponeurotic flaps are created. Once sutured on the midline, these flaps will restore the deep layer of the abdominal wall, thus containing the hernial sac and defining a pre-fascial space, from the xyphoid apophysis to the linea arcuata, and a pro-peritoneal retromuscular space, from the linea arcuata to the pubic symphysis.

Plasty of the posterior rectus sheaths proceeds craniocaudally by a continuous non-absorbable (polypropylene) suture with U-shaped stitches (Fig. 3). This suture allows better distribution of the tension and avoids laceration of transversal aponeurotic fibres. If the tension is excessive, the suture needs to be interrupted and a second caudocranial semi-continuous suture must be done, so as to rejoin, in most cases, the first tract. If this is impossible, as is often the case in recurrent incisional hernias, a rhomboid parietal defect persists that can be repaired using a polyglactin (Vycril) patch or a residual of the previous, partially resected hernial sac. The aim is to guarantee the continuity of the posterior layer since it keeps the hernial sac reduced in the abdomen, delimits the retromuscular space and protects visceral structures against the inflammatory reaction induced by the prosthetic material.

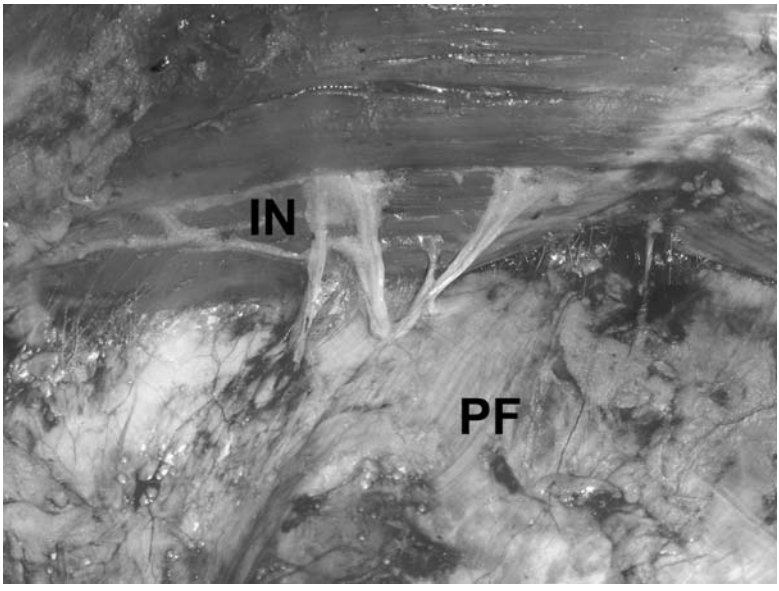

Fig. 1 Retromuscular dissection. *IN*, Intercostal nerves; *PF*, posterior fascia

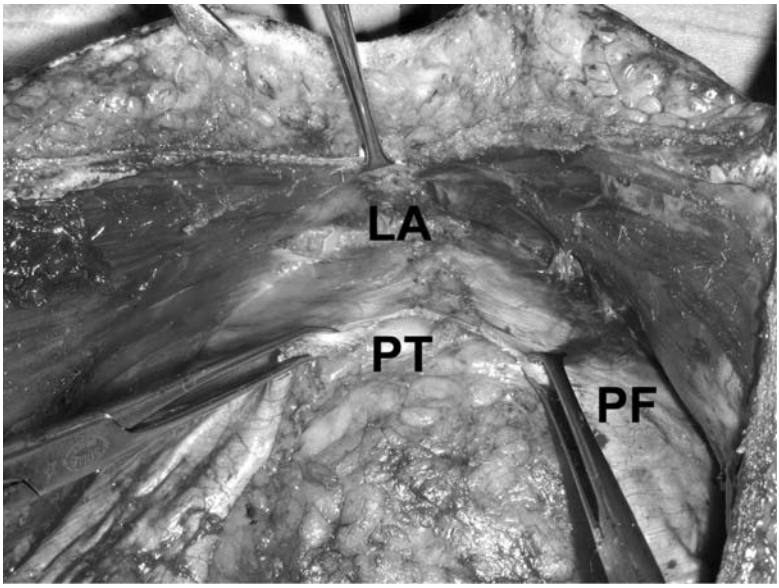

Fig. 2 Cranial retromuscular space. *LA*, Linea alba; *PF*, posterior fascia; *PT*, pro-peritoneal tissue

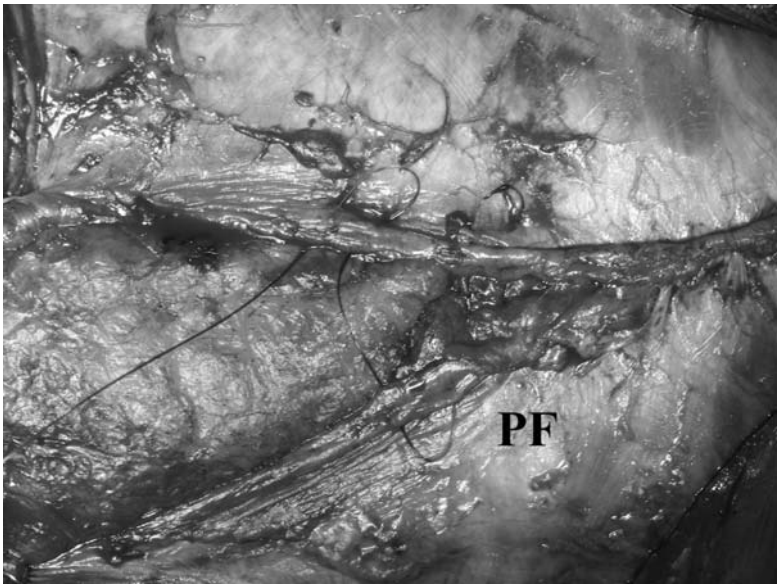

Fig. 3 Posterior fascia plasty with continuous suture. *PF*, Posterior fascia

Before the mesh is implanted, an accurate haemostasis of the retromuscular space is needed, with particular care given to controlling trickling from muscular fibres (ramifications of epigastric vessels). Repeated irrigations with saline

and iodine solutions may be useful. Surgical gloves are replaced and the operating field is newly prepared.

In the original description by the authors, the Rives-Stoppa technique made use of polyester (Dacron, Mersilene) as the prosthesis of choice, but it has been progressively replaced by polypropylene, particularly in Anglo-Saxon countries. The mesh is fixed to the abdominal wall by transcutaneous stitches [5]. Both polyester and polypropylene achieve a strong tissue incorporation but the induced inflammatory reaction could be excessive (especially for polypropylene), sometimes resulting in a stiff abdomen or painful sensation, also related to mesh shrinkage and traction on the anchorage stitches. Moreover, the inflammatory reaction may extend from the fascial layer to the parietal peritoneum below, thus resulting in adhesion formation and involving visceral structures. This sequence of events has occurred in some of our patients and is unforeseeable. It may be related to an individual reaction or to the trophism of the myoaponeurotic layer (Figs. 4,5). In case of re-operation (particularly in emergency cases), a re-laparotomy may be more difficult.

In recent years, significant progress in experimental and clinical research of biomaterials has been achieved, such that the currently available prostheses and devices have allowed improved surgical results.

The new configurations of polypropylene (medium-light, macroporous) and mixed prostheses (with absorbable materials) induce a less-intense inflammatory reaction and maintain the load-resistance capacity. Consequently, these prostheses should replace those traditionally used in the Rives-Stoppa procedure [6].

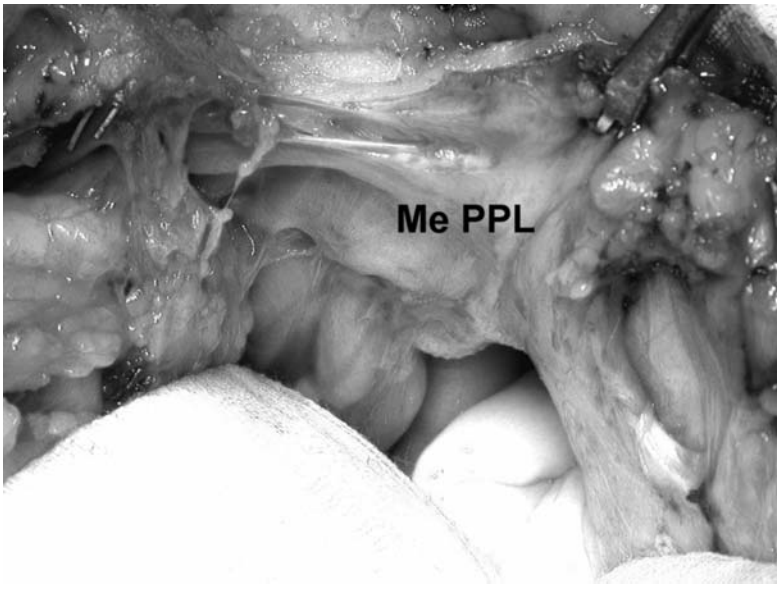

Fig. 4 Viscero-parietal adhesions after the Rives-Stoppa procedure. *Me PPL*, Polypropylene mesh

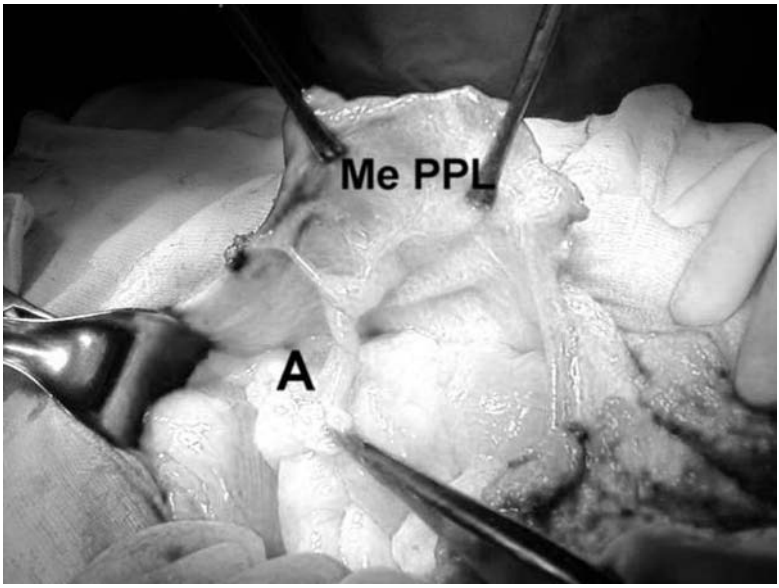

Fig. 5 Viscero-parietal adhesions after the Rives-Stoppa procedure. *Me PPL*, Polypropylene mesh; *A*, appendix

Problems persist concerning the fixation modality of the mesh to the abdominal wall. The less invasive and more aesthetic suture of the prosthesis to the deep aponeurotic layer is preferred over transcutaneous stitches, although there is still a risk of entrapping intercostal nerves. The use of a biological glue may offer the ideal solution but the rate of hernial recurrence could be greater, also due to the slower and less intense inflammatory reaction induced by the new generation of prostheses. Other indications for the use of biological glue (haemostasis, seroma reduction) remain to be validated by controlled studies.

We have recently addressed our attention to composite prostheses, made up of a layer of polyester or polypropylene and a layer of laminar ePTFE or absorbable, non-sticking material (collagen, polydioxanone, cellulose) [7]. The use of a dedicated mesh for intra-peritoneal implantation may appear contradictory to the Rives-Stoppa technique but it meets the surgical needs of our patients. Experience with the Rives-Stoppa procedure in which either two superimposed, different prostheses (not absorbable and absorbable) [8–10] or a ePTFE (Goretex) prosthesis [11,12] was used have been described.

Currently, our technique involves the use of a polypropylene + laminar ePTFE mesh (COMPOSIX) for supra-umbilical hernias and a tridimensional polyester + collagen film prosthesis (PARIETEX Composite) for sub-umbilical hernias. The COMPOSIX prosthesis can be shaped according to the dissection, placed on the deep fascial layer, in the retromuscular space, and then fixed on the midline to the abdominal wall with two stitches (one proximal and one distal). Due to its thickness (1.5 mm) and its structure, the mesh remains firm, thus

avoiding the need for lateral anchorage, as done in the past using metallic clips [13]. The PARIETEX Composite prosthesis is soft and fits itself to the concavity of the lower abdomen, overlapping the pubic symphysis and, laterally, Cooper's ligament, to which it is fixed with stitches. The collagen film that is in contact with the transversalis fascia protects the peritoneum below from the inflammatory reaction due to the synthetic overhanging layer. The mesh is secured proximally to the myoaponeurotic layer (linea arcuata of Douglas). The PARIETEX Composite prosthesis, also available in large size (37x27 cm), or the stiffer polypropylene variant (PARIETENE Composite) is also indicated in large supra-/sub-umbilical hernias, where special attention must be paid to suturing of the pre-fascial layer. For small and peri-umbilical hernias, in which it is possible to minimise the Rives-Stoppa technique, we prefer the COMPOSIX KUGEL. This prosthesis is provided with a memory ring, which facilitates its retromuscular implantation.

When the mesh is laid down, two laminar closed-suction drains are placed. The linea alba is then sutured in a continuous fashion, thus restoring the superficial aponeurotic layer and separating the mesh from the subcutaneous tissue, which should not make contact with the mesh. A large abdominal-wall defect necessitates a supra-fascial dissection of the dermo-adipose complex, up to the lateral margins of the rectus muscle, and either multiple staggered incisions or the component-separation technique through a longitudinal incision (laterally to the muscle and more or less relating to the linea semilunare). This allows approximation of the rectus muscles and the linea alba for 4–5 cm on each side [14].

The operation ends with aesthetic dermo-adipose correction, skin suture and elasto-compressive dressing. Drainages are removed 48–72 h later, with an average sero-haematic loss of about 400 ml.

In almost all patients, routine ultrasound demonstrated a light (<20 ml) asymptomatic peri-prosthetic seroma, which spontaneously recovered during the following months. In our experience, drainage of a persistent haematic fluid collection was needed only in exceptional cases.

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Retromuscular Prosthetic Repair of Incisional Hernia

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Introduction

Incisional hernia (IH) is an abdominal hernia that occurs after previous surgery [1]. It is one of the most frequent surgical problems, as the incidence following laparotomy is 10–20% [2–5]. Surgical treatment of incisional hernia involves either direct suture in patients with primary defects <3 cm in diameter, or a rather complex operation in patients with large defects that involve loss of wall substance and impairment of ventilation and cardiac circulation.

While the risk factors for incisional hernia are taken into account during primary surgery, prevention is not always possible. The problem is that these factors cannot be easily avoided or foreseen, even if an awareness of them allows for their control. Generally, the risk factors for incisional hernia can be divided into:

1. General risk factors, such as metabolic disturbances (obesity, diabetes, etc.), systemic diseases, such as hepatic and renal failures, malnutrition, chronic pulmonary diseases or chronic constipation, and the intake of cytostatic drugs or cortisone.
2. Local risk factors, such as wound infections and large (>10 cm), mainly longitudinal laparotomies, mistakes in the surgical procedure, suture-material intolerance, tissue laxity.

Side by side with these factors, many authors report "biological factors"; that is, derangements in collagen synthesis, with alterations of the normal ratio between type I and type III collagens and of metalloproteases activity [4,5]. Recently, Klinge et al. [4] demonstrated that the ratio between type I and type III collagens is lower in the fibroblastic cells of patients suffering from incisional hernia than in those of healthy subjects. This is all the more evident in patients with recurring incisional hernia [4–6].

Thus, an imbalance in normal wound healing may be one of the main factors determining both the formation of inguinal hernia and the development of incisional hernia in surgical patients. It also explains the high ratio of recurrence especially in direct suture repairs, i.e. without the implantation of a prosthesis to

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

strengthen unstable tissues [6]. Currently, there is still no consensus classification of incisional hernias. Generally, it is safe to say they are differentiated according to size, i.e., small (<5cm), medium (5–10 cm), large (>10 cm) and giant (>20 cm), and on the basis of their location, i.e. median (75–90%) and lateral. Medial incisional hernia can be further divided into supra-umbilical, subumbilical, and supra-subumbilical. Lateral incisional hernias are distinguished as subcostal, inguino-iliac, affecting the para-rectus abdominis or trans-rectus abdominis muscles, lumbo-iliac and peristomal.

Even if the diameter is used as the basic classifying criterion, recent studies have demonstrated that wall defects having the same surface area can have different clinical courses. Defects that are larger along the sagittal axis are much more at risk of herniation than those mostly following the longitudinal axis, which can be repaired with lower tension. According to Ammaturo et al., the ratio between the total abdominal surface area and the defect surface area is an additional parameter that should be kept in mind as a predictor of an excessive increase in tension [7].

Physiopathological Aspects

A small incisional hernia should be considered as a "local disease", with the associated risks and problems being closely linked to the defect. Larger defects, which are often linked to poor general and metabolic conditions, can be considered as "systemic diseases" since, normally, the abdominal-wall muscles work in pairs, with the diaphragm determining pulmonary function and favouring cardiac venous feedback. Thus, large incisional hernias lead to additional disturbances in cardiopulmonary function, trophism and the functionality of the herniated bowel.

When a voluminous bowel herniation is present, as a consequence of wall-substance loss, there is also a remarkable reduction in intra-abdominal pressure, which entails lowering of the diaphragm and its progressive atony. In addition, muscular-wall retraction causes progressive scleroadipose-type degeneration, consisting of impaired function and a progressive worsening of the clinical and anatomical conditions [8]. According to Dubay et al. [9], together these likely form the basis of an increased risk of recurrence subsequent to direct suture repair, because the reduced elasticity component increases tension on the sutures. Also, the bowel is affected by an imbalance between the intraluminal pressure and the reduced abdominal pressure, which entails distension of the viscera themselves and disturbances to both the microcirculatory system and motility.

A median incisional hernia can be considered as a large disinsertion of the lateral muscular aponeurosis from the linea alba, such that the fibres of the large muscles contract, leading to atrophy.

Another consequence of the medial disinsertion of the lateral muscles was noted by Rives: following the intra-abdominal pressure, the wall opens like a double-leaf door and the rectus abdominis muscles arrange themselves sagittally in an antero-

posterior direction. This allows the expulsion of the intestinal content towards a "second abdomen", represented by the cavity of the incisional hernia [10].

Surgical Technique

Hernia Reduction

Retromuscular prosthetic repair of incisional hernias takes place in two phases. The first consists of isolation and reduction of the sac; the second, reconstruction of the wall. Apart from the particular technique adopted for incisional-hernia repair, the first phase is substantially constant and involves the following two steps.

1. Incision. The cutaneous incision should be made along the main axis of the hernial defect, practically along the previous scar, which must be excised. This apparently banal step must be made very carefully, because the sac with its content may lie just below the incision.
2. Isolation and opening of the sac. This step also requires extreme care. The isolation must be carried out around the sac itself, avoiding its accidental opening, as far down as the margins of the hernial defect. Frequently, careful prior investigation is needed, because the sac, especially if it is large, chronic and has adhesions with the muscular fascia, must be freed from the latter as far as the narrow neck of the hernia. After the peritoneum has been mobilised from the margins of defect; the sac is opened so as to explore its content, the most serious viscero-visceral and viscero-parietal adhesions are lysed and the bowel in the abdominal cavity is reduced after carefully controlling for haemostasis.

For small defects (<3 cm), opening the sac can be readily avoided such that it can be reduced in the abdominal cavity. In most operations, however, it is better to open the sac because it allows the determination of any additional hernia holes (multiple incisional hernias).

Reconstruction Phase

The traditional repair of incisional hernia can involve several direct suture techniques: simple suture, suture with aponeurotic incisions for tension discharge and wall suture with double-breasted technique (Mayo-Judd). However, it has been demonstrated that even if these procedures are carried out by experienced surgeons, the recurrence rate is high (30–50%) [4,11–15]. Moreover, they do not solve the problems of tension on the suture; the vascularisation deficiency caused by this tension and loss of functional fibromuscular tissue, which never regains the elasticity and tensile strength of healthy tissue. The repair of a large incisional hernia in which the bowel is no longer in its proper location can lead to restrictive syndrome and cardiac circulation disorders. Fortunately, the use of

a prosthesis in abdominal-wall repair has greatly reduced the recurrence rate, to as low as 10–20% in numerous series [16–22].

The Rives' technique is an open retromuscular repair that, in our opinion and in the opinion of other authors, better achieves the final aim of a prosthetic repair, i.e. reducing the recurrence rate and preventing complications [23,24].

Nonetheless, the intraperitoneal approach is sometimes the most rapid and inevitable solution for the repair of large defects involving loss of wall substance. However, it must also take into account the risk of adherences or, even worse, bowel fistulas, especially if inadequate prosthetic materials are used. Finally, the intraperitoneal technique does not correct the physiopathology of the incisional hernia [25].

The onlay technique does not exploit the sandwich effect that is obtained when the prosthesis is placed in the intraparietal position. It is also responsible for a greater risk of infection since there is direct contact of the prosthesis with the subcutaneous layer [24,26]. In addition, according to many authors, this approach entails a greater risk of recurrence than associated with retromuscular allocation [26,27].

The Rives' procedure aims at restoring both the normal function of the abdominal wall and its consolidation by positioning a mesh on the retromuscular layer. This operation enables approaching of the rectus abdominis muscles and it re-establishes the fulcrum of the wall function at the midline level. Thus, the abdominal pressure is evenly re-distributed over the entire wall, thereby restoring the physiology and the pair-wise work of the abdominal muscles together with the diaphragm.

As illustrated by Rives, in 1977 [28], the reconstruction phase begins after the typical steps of isolation, opening and sac reduction have been taken and the margins of the defect have been prepared. Initially, the defect margins are lifted up by the surgical assistant using two clamps (Kocher or Hellis) while the primary surgeon makes a small incision, through the peritoneal layer, on the posterior sheath of the rectus abdominis muscle corresponding to the medial limit, thus entering the retromuscular space (Fig. 1). This incision is then prolonged, both in the cranial and caudal directions, with the surgeon using a scissors or electrosurgical knife to enlarge dissection of the muscles from their posterior sheath. The resulting cleavage plane is usually bloodless as far down as the perforans vessels of the intercostal nerves, at the level of the lateral margin of the rectus abdominis sheath (lateral linea alba) (Fig. 2); the procedure continues in a similar manner on the opposite side. After an adequate peritoneal flap is obtained, the peritoneal-sheath layer is sutured on the midline (Fig. 3). This plane assumes different connotations relative to the defect position. In fact, above the arcuate line, the peritoneum and the posterior muscle fascia are practically unified in a single layer, while under the arcuate line the posterior muscle sheath is no longer present, so that this plane is essentially a peritoneal one and therefore fragile and less tension-resistant. This layer is closed with a slowly absorbable suture. The main purpose of the plane is to avoid contact of the mesh with the bowel (Fig. 4).

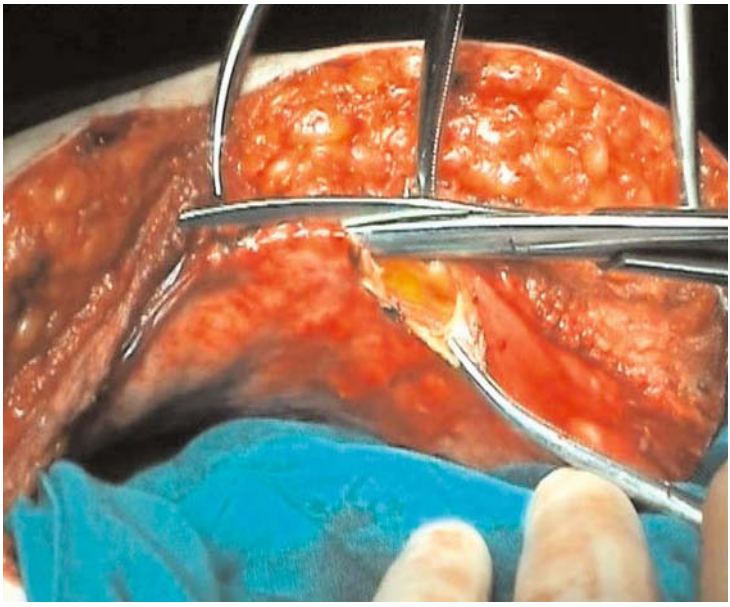

Fig. 1 Trans-peritoneal incision of the posterior rectus abdominis sheath and preparation of the retromuscular space

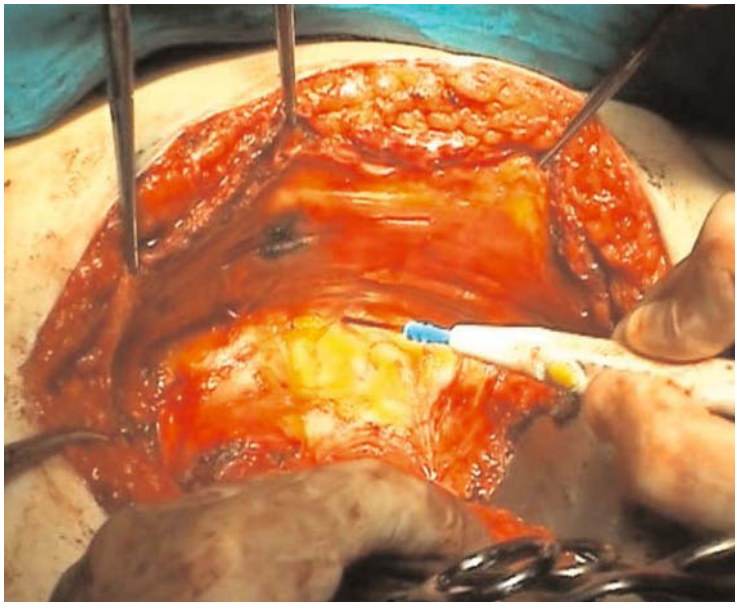

Fig. 2 Dissection of the posterior rectus abdominis sheath as far as its lateral margin

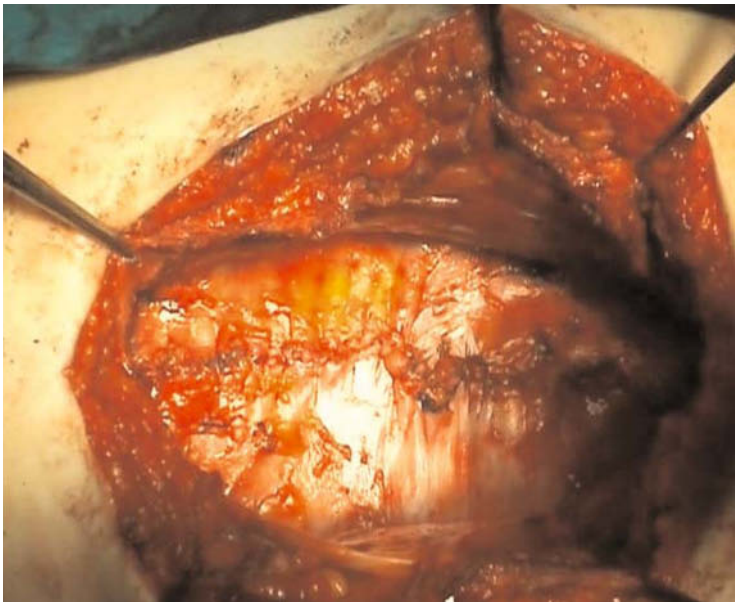

Fig. 3 The retromuscular space is completely prepared; the peritoneal-fascial layer is sutured along the midline

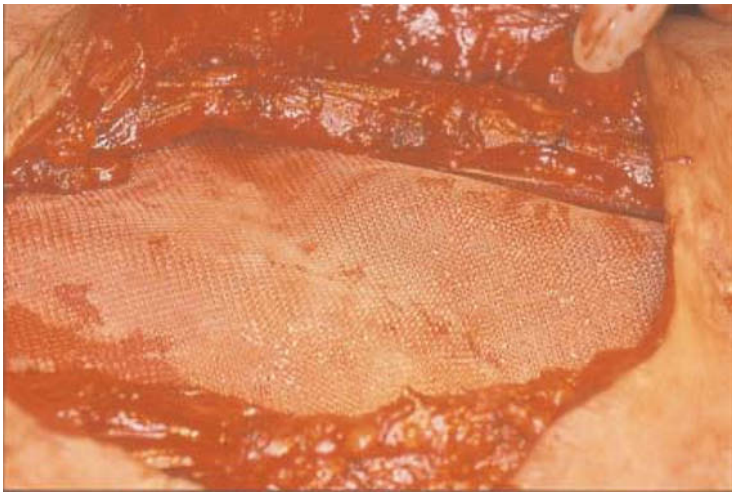

Fig. 4 Polypropylene mesh in site

When an approach to the midline is not practicable owing to loss of wall substance, a new peritoneum must be created, either by means of omentum, if present (Fig. 5), or by an absorbable mesh (Vycril or Dexon) that is sutured around the peritoneal-fascial edges (Fig. 6). Once the peritoneal plane and adequate

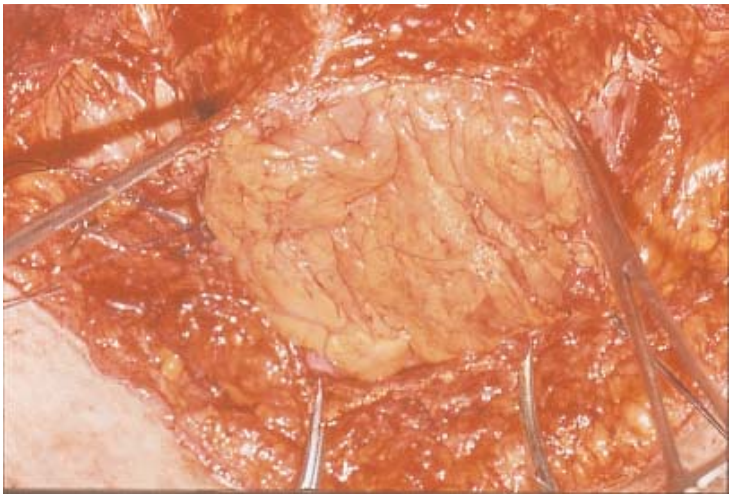

Fig. 5 Reconstruction of the new peritoneum with the omentum anchored circumferentially to the defect edges

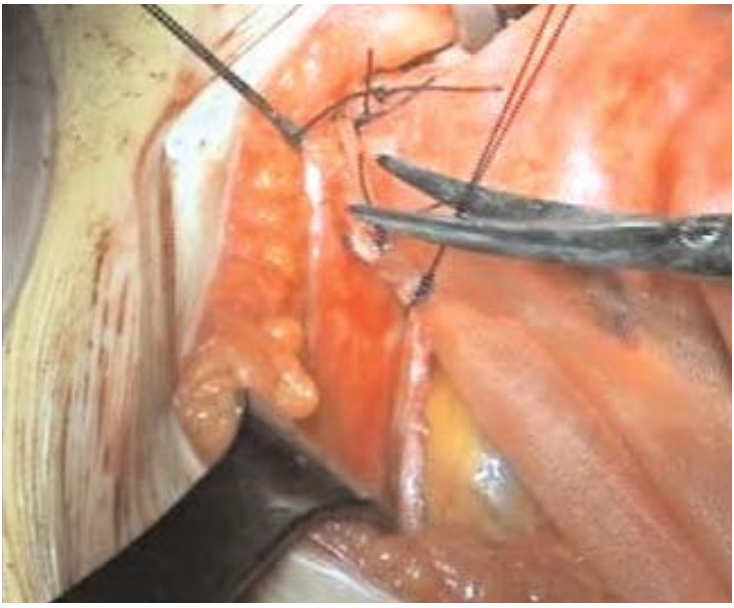

Fig. 6 Reconstruction of the new peritoneum, with absorbable mesh (Vicryl). The mesh is fixed by means of interrupted stitches

overlap (±5cm) have been obtained, the mesh is positioned in the pre-peritoneal retromuscular space, avoiding wrinkling, with a surface corresponding to the prepared overlap (Fig. 4). This procedure must be carried out with complete asepsis; for example, the surgeon should change his or her gloves at least twice

and the surgical field should be carefully washed with an antiseptic solution of povidone-iodine (Betadine).

Regarding the choice of prosthetic material, mersilene (Dacron) meshes are preferred in France [1,12,28], while American surgeons as well as our own surgical unit prefer polypropylene meshes [29–31].

Mesh Fixation

Generally, the sandwich effect determined by the abdominal pressure helps retain the mesh in the retromuscular space. Since the mesh is invaded by fibroblasts only after some time, it must be fixed properly in order to avoid any movement. Rives' original technique required the mesh to be fixed by means of 8–12 transparietal stitches and using slowly absorbable material. First, the stitches are passed through the mesh in a U shape, after which cutaneous microincisions corresponding to the margins of the prosthesis are made. These must overlap the lateral margins of the rectus abdominis muscle. Finally, the stitches are brought to the surface of the skin with a Reverdin's needle and then tied.

To avoid exposure of the stitches on the surface, we suggest preparing a subcutaneous layer so that there is sufficient room to knot the stitches directly on the supra-aponeurotic layer. The stitches should be tightened and tied only after all of them have been passed, so as to avoid tension or displacement. The mesh must be properly positioned without tension and well-extended (tension-free technique). It is always advisable to allocate one or two drainages according to the defect size; they are removed only where the risk of seroma is very low. Antibiotic prophylaxis is always advisable from the beginning of the anaesthesia and must be continued 24–48 h after the drainage is removed. However, recent studies, such as that of Aufenacker et al. [32], have not confirmed the effectiveness of antibiotic prophylaxis in the prevention of wound infections. Furthermore, there is no evidence that the use of drainages reduces the morbidity associated with repair (infection, seroma, etc.), as Gurusamy and Samraj discussed in a recent review [30]. What should be underlined here is the recent evolution of the Rives' technique, in an attempt to further improve the post-operative course in terms of complications (seroma, haematoma, chronic pain, infection).

In 1994, Amid et al. [29] proposed fixing the mesh using staples instead of stitches [31]. This method is associated with reduced operating time, less chronic pain, fewer haematomas and better cosmetic results, with equal effectiveness in the prevention of recurrences and better patient compliance.

Recently, partially absorbable composite meshes as well as lightweight ones have been introduced [31,33–35]. Due to the reduction of the non-absorbable component, this mesh induces a lower tissue inflammatory response, a reduced foreign-body reaction and fewer complications, such as seromas and chronic pain. However, a lightweight mesh is very soft and is therefore difficult to position properly. With the Ultrapro mesh, which is made of absorbable poliglecaprone 25 and

non-absorbable polypropylene, the implanted mass is reduced by 40% and the absorbable component strengthens the mesh so that it can be easily handled during implantation (Fig. 7). The preliminary results of our experience as well as those described in several recent studies seem to confirm this finding [30,35–37]. Another innovation is the use of fibrin glue to fix the mesh (Fig. 8). Even if kept

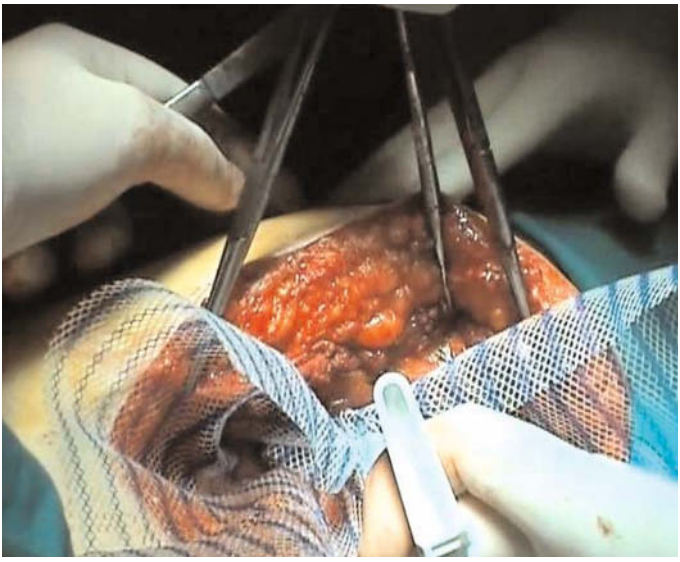

Fig. 7 Use of partially-absorbable mesh (Ultrapro). The mesh is fixed with metal staples

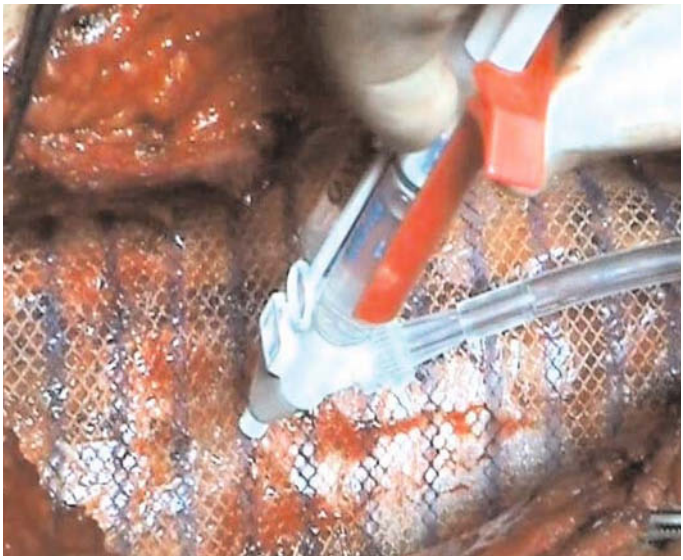

Fig. 8 Use of partially absorbable mesh (Ultrapro). The mesh is fixed with fibrin glue

in place by the "sandwich effect", which is determined by the abdominal pressure, it is useful to fix the mesh with fibrin glue before the beginning of the fibroblastic process, to avoid wrinkling and displacement, promote faster tissue in-growth, and reduce the incidence of seromas and chronic pain [37,38].

Our Experience

We evaluated 127 patients with a mean follow-up greater than 5 years who were treated by retromuscular prosthetic repair: 101 patients had a primary incisional hernia (46 males, 55 females, mean age 60.4±9.44; range 29–82 years) and 26 had recurrent incisional hernia (10 males, 16 females, mean age 62.1±12.3; range 39–85 years). The mean follow-up was 59.0±33.8 months (range 1–128 months). In patients with substantial loss of wall substance, in whom the peritoneal layer could not be closed, an omentum was employed in four cases, intraperitoneal Vicryl mesh in 11, and, a Vicryl mesh + omentum in one. In each operation, the procedure was completed by the positioning of a polypropylene mesh at a retromuscular site.

Mean hospitalisation was 6.7±3.4 days for primary incisional hernia and 6.7±3.1 days for recurrent hernias. In the primary incisional hernia group, 11 seromas (10.9 %), five haematomas (4.9%), and a 3% recurrence rate were observed. Among the patients with recurrent incisional hernia, there were four seromas (15.3%), one haematoma (3.9%), and two recurrences (7.6%).

We initially used a poplypropylene mesh fixed by metal staples; subsequently, with technological and material improvements, we decided to employ a partially absorbable mesh (Ultrapro) fixed with fibrin glue. Through the use of these devices, satisfying results have been obtained in terms of a reduction of seromas, haematomas and post-operative pain, and thus improvement in the patients' quality of life [30,37].

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Laparoscopic Treatment of Incisional Hernia: Advantages and Limits

Edmond Estour, Clotilde Crovella

Introduction

The laparoscopic technique as applied to incisional hernia can be defined as parietal laparoplasty or laparoscopic parietoplasty. This approach entails the use of a prosthesis positioned inside, or sometimes under, the peritoneum in the subumbilical area.

Abdominal-wall defects repaired by direct suture under tension have a very high relapse rate, as parietal injury can appear over a variable period of time depending on the age and the quality of the sutured tissues, but also on the mechanical stretching to which the suture is exposed. Moreover, when the abdominal cavity and its walls are exposed to an elevated increase in pressure, the tissues are traumatised by the suture material. In contrast, the experience gained from hernia surgery has shown that the relapse rate considerably decreases with the use of prostheses, for which reason their use has rapidly spread. The treatment of incisional hernia has undergone the same evolution such that the use of prosthetic material has become indispensable in the laparoscopic repair of this pathology. Laparoscopic parietoplasty therefore represents an alternative to the traditional laparotomic treatment.

This chapter discusses the disadvantages of the traditional methods of incisional-hernia repair, the advantages of laparoscopic parietoplasty but also the limits of this minimally invasive technique.

Traditional Laparotomic Treatment of Incisional Hernia

Laparotomic treatment of incisional hernia has been the sole therapeutic choice since 1990. The emergency treatment of complicated incisional hernia is accompanied by a high percentage of relapses that, with time, often become difficult to treat at both the parietal and abdominal levels. These complications are often accompanied by parietal disasters, which have a very high morbidity rate. This

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

traditional approach is therefore justified only in the treatment of small incisional hernias.

Parietal Deterioration

The traditional technique deteriorates the tissues, such that subsequent laparotomy at the same site as the previous surgery or very near it, often including or exceeding the length of the previous incision, exposes the abdominal wall to identical if not worse conditions. Further tissue deterioration, due to contusion, ischaemia, thermic insult and various traumas, in addition to the initial ones, is caused by the surgery itself. This explains why multiple relapses frequently occur in traditional surgery. Every new surgical action makes the local state of the tissues more precarious and creates the conditions for new parietal failure.

In direct suturing, the tension built up along the lateral walls favours the opening of the defect that is difficult to see from an anterior position. Some of these inconveniences can be solved by the use of the appropriate prosthesis, but at the same time this can increase the risk of tissue inflammation and sepsis.

Sepsis

Sepsis is common to all laparotomies because any open surgical intervention leaves both the peritoneum and the patient vulnerables to sepsis. Exposure to the air, serum and blood loss, the length of surgery, the presence of a prosthetic foreign body are all conditions that favour the development of a serious inflammatory reaction that can result in sepsis.

In the case of incisional hernia, the parietal incision crosses the area of the previous suture; the latter very often contains micro-abscesses and inflammatory breeding grounds around the threads or the non-absorbable suturing material. This risk can be worsened by the fact that the initial surgery responsible for the incisional hernia was very probably carried out in the presence of a septic pathology, e.g. sigmoiditis, acute cholecystitis, perforated ulcer or pelvic peritonitis.

When prosthetic material, which represents a foreign body, is implanted, air exposure, contact with surgical instruments and the surgical field itself are established for a variable period of time. In addition, once implantation is complete, the prosthesis is in direct contact with the suture material of the previous and next laparotomies.

Fragility

The repair of an incisional hernia includes a suture eventually associated with a prosthesis whose tissue integration and successful fixation to the abdominal wall requires several weeks. This process implies a temporary parietal fragility

that depends on the time needed by the tissues to heal together and on the prosthetic ingrowth. Any untimely exertion and rough movement that occur before healing is complete can cause the aponeurotic suture to sag onto the front of the prosthesis.

Initial compression of the surgical wound is followed by having the patient wear a truss. Since the patient's physical activity is restricted in the immediate postoperative period and during the first few weeks, to avoid local complications, he or she is not able to benefit fully from the advantages of a rapid and complete rehabilitation.

Difficulties in Carrying Out Adhesiolysis

Regardless of the surgical technique used to treat incisional hernia, adhesiolysis is often one of the most delicate and longest procedures. Surgeons who do not use the laparoscopic approach, as opposed to those who do, claim that adhesiolysis is more conveniently carried out with laparotomy, as it allows direct vision and bimanual palpation. Actually, however, laparoscopy allows a wider field of vision, magnification of the images and an excellent presentation of the intestinal loops that are adhered to the anterior abdominal wall. This is the most controversial point in the debate concerning the two methods.

Laparoscopic Parietoplasty

Compared to the traditional surgical technique for treating incisional hernia, laparoscopic parietoplasty presents intrinsic advantages and irrefutable benefits that go beyond those generally attributed to laparoscopy. It must be emphasised that, compared to other pathologies, the advantages that arise from the use of the laparoscopic technique in the treatment of incisional hernia are multiple and are analysed below in detail. Laparoscopic parietoplasty permits an accurate diagnosis and a very precise analysis of the lesion. This approach completes the clinical and instrumental analyses carried out in the pre-operative period.

This advantage greatly encouraged the surgeons who first used the laparoscopic approach. After an accurate adhesiolysis of the epiploic fringes and intestinal loops adhered to or closed in the hernial sac is carried out, the surgical team has a complete and precise vision of the parietal defect (Fig. 1). In addition to the clinically traceable main defect, secondary defects that should be included in the diameter of the prosthesis are often present. Non-diagnosis of these defects in a surgical intervention carried out anteriorly can be responsible for parietal relapse. It often happens that a neck of medium diameter is found in an incisional hernia that had been clinically indicated as voluminous, and this is a very favourable prognostic element in laparoscopy. During laparoscopy, the transcu-

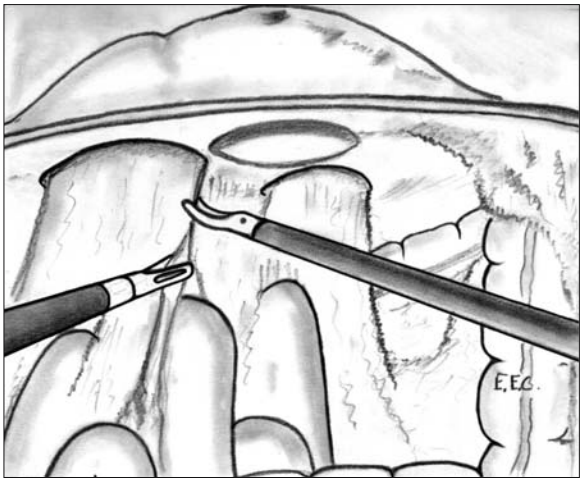

Fig. 1 Laparoscopic exploration and adhesiolysis

taneous insertion of a fine needle inserted allows the exact position and size of the defect to be determined, so the skin can be marked correctly (Fig. 2). This is extremely important for calculating the size of the prosthesis.

Laparoscopic parietoplasty respects the entire structure of the wall. When incisional hernia develops, tissue destruction results in scar-tissue bridges around the main defect. Further laparotomy interrupts this still-solid scar tissue; when adhesiolysis has been completed, an examination of the lesions shows the persistence of these fibro-muscular bridges and allows evaluation of their mechanical effects. They represent resistance elements and, even if variable, seriously contribute to the static quality of the wall, both in the anterior xyphopubic and lateral areas. By respecting the aponeurotic muscle structures and pre-

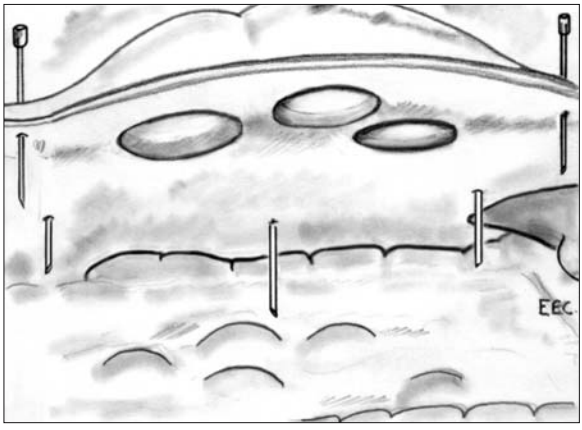

Fig. 2 Transparietal needle introduction for the measurement of prosthesis overlap

vious parietoplasty, the surgeon reduces the likelihood that a post-laparotomy inflammatory reaction, which discourages correct integration of the prosthesis, will occur.

Laparoplasty respects the optimum conditions of asepsis for the following reasons: access to the abdomen is carried out by a mini-invasive technique and neither the work space nor the intra-abdominal elements are ever exposed to the external environment. Furthermore, there is no manipulation of the scar-tissue area and therefore no contact with the inflammatory breeding grounds and micro-abscesses provoked by the sutures and material of the previous laparotomy.

Independent of the time needed for surgery, the "no touch" technique is strictly followed. The work space, i.e. the laparoscopic cavity, is kept at a positive pressure of 10–12 mmHg; gas or serum/blood flow cannot proceed from inside to outside, and in no way can it proceed from the skin to the abdominal cavity, Therefore, with adequate positive pressure there can be no contamination of external origin.

Extremely important is the fact that the prosthesis is exposed to the external environment only for the time necessary to insert it into the abdomen.

All of these conditions are favourable and indispensable for the correct integration of the prosthesis, which should have the correct physical and biochemical characteristics.

Laparoscopic parietoplasty confers an immediate solidity of the abdominal wall: tissue bridges present in the defect are respected, splanchnocranial, caudal and transverse parietal-arch loops, centred on the umbilical area, are not impaired as they are after median laparotomy. Surgery permits stable reinforcement due to the use of a suitable prosthesis and immediate solidity is guaranteed based on the laws of Pascal and Laplace. Moreover, this immediate solidity allows the patient's precocious mobilisation, liquid nutrition starting from reawakening and a short stay in hospital.

After induction of the pneumoperitoneum, adhesiolysis is one of the longest and most difficult steps of laparoscopic parietoplasty. Compared to open surgery, in which adhesiolysis is carried out frontally and with the help of digital palpation, laparoscopy has different but significant advantages. In difficult cases, delicate movements together with patience in freeing the bowel and in the lysis of the adherences are necessary, just as they are for laparotomy. Compared to the fixed and anterior view in laparotomy, the superiority of laparoscopic parietoplasty consists of the magnified lateral and posterior views as well as the possibility to vary the direction of the visual field. The epiploic fringes and intestinal loops are distended from the pneumoperitoneum, between the mesenteric root and their parietal adherences, and can be optimally seen for dissection. A nipper will increase traction while the adherences are sectioned using the right hand. In order to avoid small intestinal lesions when tenacious adherences are present, it is necessary to move along the aponeurotic-muscular-wall plane. Intestinal lesions are generally pointed, as in laparotomy, and when they have been recognised they can be repaired with a stitch after the lesioned area has been well-

washed and suctioned. By working patiently and delicately, it is possible to free the whole of the anterior abdominal vault.

Like Philippe Mouret, we maintain that adhesiolysis partially ameliorates the abdominal pain syndrome.

Laparoscopy presents numerous theoretical advantages compared to laparotomy. In the following, these are examined in order to better define the uses and limitations of laparoscopy.

Limits of Laparoscopy and Laparoscopic Parietoplasty

As in all surgical interventions, laparoscopic parietoplasty has its limits and contraindications, even if carried out by expert surgeons.

Every patient is a separate case, and it is obvious that even in an otherwise healthy patient there are limits linked to his or her general condition and to the kind of incisional hernia. The limits concerning a patient's general conditions are linked to the inherent risks of anaesthesia.

This depends on the anaesthesiology team's experience in laparoscopy. While most surgeons have no problems with ASA I, II, or III patients, ASA IV patients can present with contraindications for the procedure. For a team of anaesthesiologists with experience in laparoscopy, controlled general anaesthesia is safer than local or loco-regional anaesthesia, except in patients with severe cardiopathy and or decompensated pneumopathy, because it allows better control of vital parameters.

Specific limits are those related to the kind of incisional hernia, regardless of the patient's condition; these limits are in part surgeon-dependent.

Local factors predictive of difficulty include the pathology that provoked the previous surgical intervention and the size of the incisional hernia. The causes leading to previous surgery can indicate the extent and severity of the adherences, and thus the probable difficulty in gaining access to the abdominal cavity and in carrying out adhesiolysis. Uncomplicated cases are represented by aseptic and non-complex interventions, in contrast to those that involve multi-relapsed incisional hernia, a surgical outcome that is manifestly septic, and surgical wounds requiring multiple drainages, such as generalised or stercoraceous peritonitis. Also, the size of the lesion can predict difficulty but this is often an erroneous criterion.

A large incisional hernia is often associated with a small or medium-sized orifice, while a small or medium-sized incisional hernia may be associated with multiple dense adherences.

Reduction of the sac content is a positive predictor of outcome as it corresponds to the presence of few adherences, whereas non-reduction of the sac forecasts difficulty in adhesiolysis, especially if it contains the bowel and epiploic fringes. If this is the case, it is often necessary to section the neck in order to facilitate adhesiolysis.

Manual pressure exerted from the outside helps to expose the bottom of the

sac, where the most tenacious adherences are to be found. In addition to the foreseeable difficulties, the problems linked to the lack of surgical experience must be considered, as must those related to access to the cavity and the ability to carry out adhesiolysis.

Induction of the Pneumoperitoneum

The pneumoperitoneum can be induced with the help of a Palmer or Veress needle. The use of a needle is not dangerous except in the umbilical region when the incisional hernia is located on median scar tissue, in which case access may even be impossible due to numerous adherences. Induction of the peritoneum is, nonetheless, always possible by using a Veress needle in the left subcostal area. Pre-operative echography shows the absence of hypomobile loops adhered to the wall.

After the introduction of the needle and safety testing, it is better to create a small gas pocket that can be felt on palpation (Fig. 3). Then, if possible, it is opportune to introduce a 5-mm optical fibre close to the needle. The second trocar, which is visually placed and controlled, permits the start of adhesiolysis (Fig. 4). It is only then that the trocars needed for the operation can be introduced (Fig. 5).

Open access is also difficult and dangerous, above all in relation to the site of the incisional hernia, especially in the umbilical area and on the median line, which is likely to have numerous adherences.

As in laparotomy, all adhered loops are at risk of perforation; it is therefore necessary to proceed with great caution. Once inside the abdomen, the difficulties associated with adhesiolysis must be confronted.

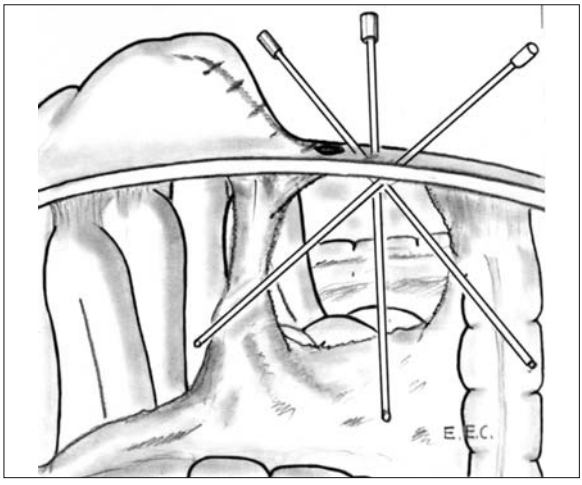

Fig. 3 Introduction of the needle, after safety testing and creation of a small gas pocket

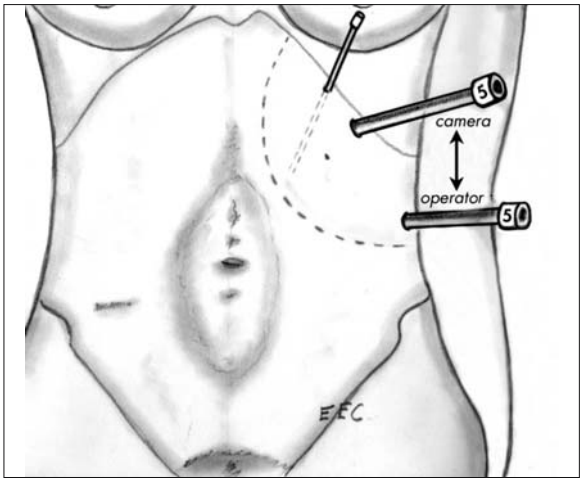

Fig. 4 Introduction of II trocar under direct visualization for starting adhesiolysis

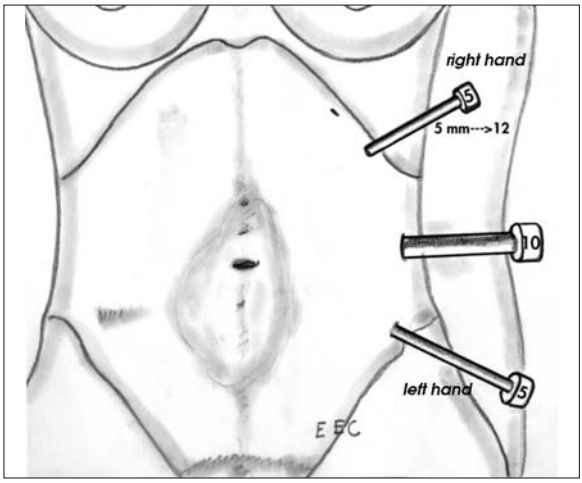

Fig. 5 Trocars in site for total adhesiolysis and laparoscopic mesh repair

Adhesiolysis

A surgeon carrying out laparoparietoplasty can be judged based on his or her capacity to perform adhesiolysis. The necessary qualities are: composure, caution, delicacy, patience and rigour in searching for eventual micro-traumatic intestinal lesions. Adhesiolysis can be easy if the area of adherences is limited or involves only a few epiploic fringes. It is much more difficult in widespread areas with multiple viscera and parietal adherences. Experience is needed in handling the intestinal loops, in dissecting adherences from the abdominal wall more than from the intestinal loops and, above all, in being always ready to recognise and treat a small, traumatic intestinal perforation whose non-recogni-

tion can cause disaster. The time needed for adhesiolysis is variable and unpredictable. Along with the surgeon-dependent limits, such as induction of the pneumoperitoneum and adhesiolysis, there are local, purely mechanical limits that are related to the kind of incisional hernia.

Mechanical Limits

In order to avoid precocious relapse, the size of the prosthesis must respect Pascal's and Laplace's laws of physics, originally applied to the repair of hot-air balloons. To be efficient, a prosthesis must be stable as far as the pressures it is subjected to are concerned: the pressure of CO_2 during surgery and the intra-abdominal pressure that develops later. The prosthesis must not be pushed outwards through fenestrations of the parietal defect. For this reason, the overlap of the prosthesis to be implanted must be calculated by considering the diameter of the parietal defect and must be equal or superior to the radius of the defect it is to cover (Fig. 6).

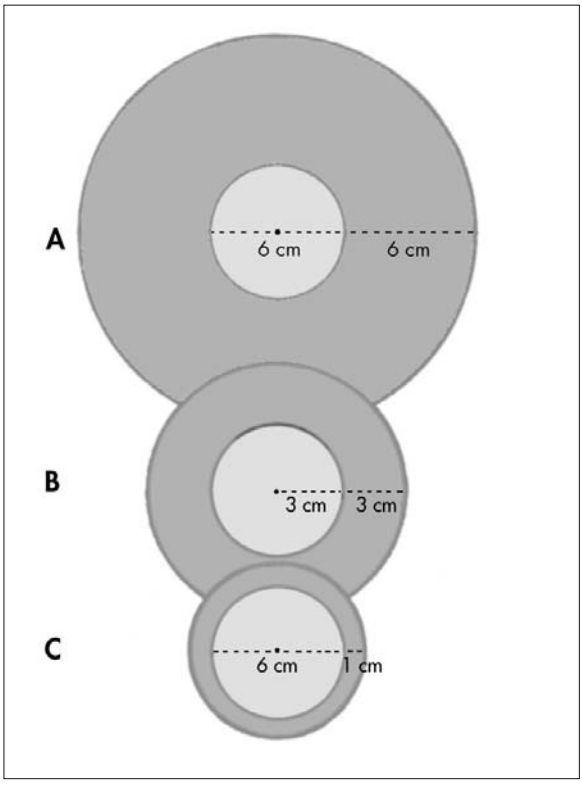

Fig. 6 *A*, Defect 88,8 cm^2, overlap 6 cm ➠ 710 cm^2; *B*, defect 88,8 cm^2, overlap 3 cm ➠ 266 cm^2; *C*, defect 88,8 cm^2, overlap 1 cm ➠ 69 cm^2

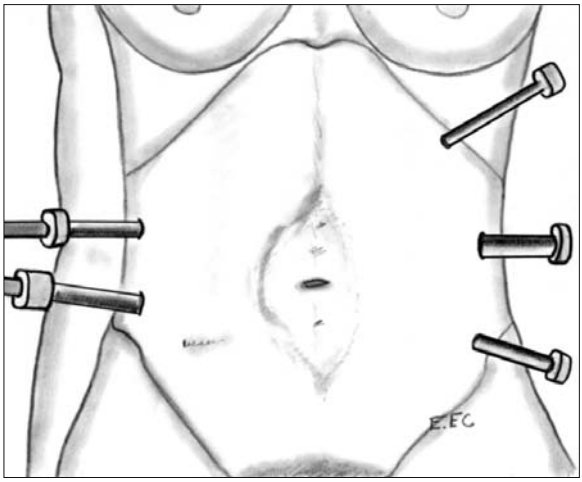

Fig. 7 Trocars distribution for left and right fixation of large mesh

In a defect with a diameter of 10 cm, a 5-cm overlap corresponds to half the size of the defect and gives the wall good stability. An overlap corresponding to the diameter of the defect, that is 10 cm, will give optimum stability. To obtain good stability in a 10-cm defect, a 20-cm (10+5x2) prosthesis will be necessary; but to obtain optimum stability with an overlap the size of the defect's diameter, a prosthesis of 30 cm (15+15x2) is needed. In a defect larger than 15 cm, the size of the prosthesis will be 30 cm (15+7.5x2) but the optimum size is 45 cm(15+15+15).

It is clear that it is not always possible to implant a prosthesis that is big enough to repair the defect in the wall. Moreover, positioning of a very large prosthesis provokes intra-operative difficulties; it requires a large intra-abdominal space and fixation with tacks on either side (Fig. 7). This is a serious mechanical limit, to which a biophysical limit, linked to the tolerance of the material used, must be added.

Biophysical Limits

The parietal prosthesis is a particular type of foreign body, different from the usual concept of one—for example, an orthopaedic prosthesis. The prosthesis must be soft and flexible in order for it to adapt to the movements of the abdominal wall and integrate with its tissues. The conditions for correct integration are lightness, hydrophilicity as well as micro- and macro-porosity, whereas volume, weight, hydrophobia and the absence of porosity are negative factors.

All incorporated foreign bodies provoke an inflammatory reaction in the recipient tissues. This reaction should be moderate and limited in time. An excessive or prolonged inflammatory reaction will cause sclerosis of the tissues, with hypertrophy and retraction accompanied by pain and relapse. The bigger the foreign body used, the greater the inflammatory reaction. This problem should not be underestimated when a large prosthesis, 30–35 cm or more than 1000 cm^2, is used.

A large, heavy, thick prosthesis in hydrophobic non-porous material can cause an excessive inflammatory reaction with intense hypertrophic and retractile sclerosis, seroma formation and dysesthesia, all of which favour secondary sepsis. A light, hydrophilic, micro- and macro-porous, wide-meshed prosthesis, associated with an anti-adherence barrier that is biological, hydrophilic and reabsorbable, can be correctly integrated into the abdominal wall and greatly reduces the possibilities of visceral adherences.

Conclusions

The technique for the laparoscopic treatment of incisional hernia that was standardised in 1994 has many advantages over the laparotomy technique: precise diagnosis of the parietal lesion, respect of the muscular structure, conditions of asepsis due to the "no touch" technique, a work zone kept at positive pressure, immediate solidity that allows for rapid rehabilitation and straightforwardness in carrying out adhesiolysis.

Nonetheless, laparoscopy is not always possible and it has limits associated with the patient's general condition and with potential anaesthetic complications. Further difficulties are often correlated to the number of previous surgical interventions, responsible for the incisional hernia, and their likelihood of invoking sepsis, the characteristics of the incisional hernia as well as the size and reducibility of the sac.

Induction of the pneumoperitoneum and adhesiolysis on a pluri-operated abdomen represent a surgeon-dependent limit, as the success of these procedures requires extensive experience.

There are also mechanical limits that prevent solid repair. A stable prosthesis is one that is consistent with the laws of pressure and respects the need for overlap equal to the radius, or better, to the diameter of the defect.

Another problem is the size of the prosthesis. The prosthesis, which is a foreign body, must precisely meet the biophysical criteria of lightness, micro- and macro-porosity and hydrophilicity in order to assure its tolerance and ingrowth. Disrespect of these criteria is a sure cause of complications leading to unfavourable results and very probable relapse.

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Incisional Hernia Repair with Intra-Peritoneal ePTFE Mesh: Technical Notes and Long-Term Results

Antonio Iuppa, Luigi Tenaglia, Giuseppe Iuppa, Gaetano Catania

Introduction

An incisional hernia can be defined as an iatrogenic post-operative hernia prevalently located in the anterior abdominal wall and level with the least resistant area identified in the linea alba. A preliminary and mandatory distinction should be made between primitive incisional hernias, which, according to the literature have an incidence between 0.5 and 12% [1–4], and recurrent incisonal hernias, the incidence of which varies depending on whether the initial operation was performed with direct suturing or by alloplasty. The incidence related to secondary incisional hernias after direct plasty is 24–50% [5–9], whilst in the aftermath of prosthetic-implant repair the percentage considerably decreases, fluctuating between 0 and 30% [10–12].

Serious complications have been associated with the use of a prosthetic device with respect to the implant site of the mesh in the abdominal wall [12,13]. Positioning of the prosthesis in the pre-fascial site is associated with a high rate of recurrence and a high incidence of post-operative complications, such as infections of the mesh surgical site, haematoma and seroma [12–15]. Intra-parietal procedures may lead to the development of adhesions but fewer post-operative complications [16]. A mesh positioned in the intra-peritoneal site is associated with serious adhesions, bowel injuries, mesh dislocation, bowel erosion and consequent development of an entero-cutaneous fistula if an inadequate amount of mesh is used [17–21]. A relationship between a fistula and intra-peritoneal positioning of a polypropylene mesh could not be demonstrated by Vrijland et al. [22].

The choice of the mesh material is closely related to the nature of the implant site. A reticular prosthesis (polypropylene or polyester) is used in pre-fascial and intra-parietal sites, as in the Chevrel and Rives procedures, while, a laminar (ePTFE) [23,24] or composite [25] prosthesis is preferred at the intra-peritoneal site, in order to avoid adhesions with the intra-abdominal viscera.

Over the last 20 years, the Rives procedure, which involves applying an ample amount of mesh in a retromuscular position, has been considered the

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

"gold standard" in the repair of incisional hernia [1,26,27]. Nonetheless, this method is not exempt from problems or complications, especially in the repair of large abdominal-wall defects, boundary incisional hernias (subcostal and/or suprapubic) or in patients in whom preservation of the peritoneum is impossible due to the potential danger of fistula formation from the polypropylene or polyester mesh that is normally used [28,29].

In our experience, which began in 1986, we have observed six patients with entero-cutaneous fistulas, with an onset 2–30 months after the operation, who required long-term hospitalisation. Two of these patients (33%) died. In five patients, the polypropylene or polyester mesh had been implanted in the preperitoneal site, as evidenced from case-history records. Only in one patient was it impossible to consult the treatment records. The available data led us to consider how, in large incisional hernias, an inadequate prosthesis could potentially come into contact with the viscera due to a poorly vital or absent peritoneum.

Consequently, our institute began a series of experimental studies on rats to test the biocompatibility of prostheses placed in the intra-peritoneal position [14,15]. We determined that ePTFE is the safest and thus the material of choice for use in the intra-peritoneal position, especially in those patients in whom the peritoneum cannot be preserved.

Starting in February 1987, we began to treat incisional-hernia patients by intra-peritoneal application of an ePTFE prosthesis. To date, we have carried out over 500 procedures. Intra-peritoneal placement is an appealing and proven alternative, especially when a formal Rives approach proves to be too difficult. Thus, ePTFE in the intra-peritoneal position is safe and effective, as confirmed by the results of thousands of laparoscopic procedures performed throughout the world [16].

Materials and Methods

This retrospective study is based on 211 patients treated from February 1987 to October 1988, with a follow-up ranging from a minimum of 60 months to a maximum of 178 months. The patients were contacted and personally examined by medical residents in General Surgery during their end-of-course thesis, between October and November 2003. Of these 211 patients, 194 (91.9%) responded to the follow-up call. All of the prostheses used from February 1987 to March 1994 were ePTFE (Soft Tissue Patch· W.L. Gore & Associates, Newark, DE, USA); afterwards and until November 1998, Dual Mesh ePTFE was used. The visceral surface of the latter does not allow the development of adhesions and is easily recognisable because of its smooth and polished surface. The micropores on the visceral surface of the mesh are <3 μm, which avoids mesh invasion by surrounding tissue and thus the formation of tenacious adhesions. The prosthesis that we currently use (Dual Mesh Plus Corduroy with Holes· W.L. Gore & Associates) is a natural evolution of the Dual Mesh. The lighter, rougher side is

in contact with the abdominal wall and promotes simple and rapid fibroblastic colonisation, allowing good parietal integration. In addition, the pluriforaminal structure minimises seroma formation, while impregnation of the mesh with silver salt and chlorhexidine confer good antiseptic qualities. Meshes 10x15 cm and 30x40cm in size were used.

Results

Thirty-six (17%) patients suffered recurrent incisional hernia; of these, eight were treated with direct sutures and 28 with prosthetic repair. In two cases, involving patients with incisional hernias and medically untreatable ascites, Denver shunts were applied 1 week before wall reconstruction. In three patients with local sepsis (perforated incisional hernia), the intra-peritoneal mesh was applied as a temporary prosthesis in order to close the abdomen.

Eight patients (3.7%) underwent other, related procedures (5 cholecystectomies, 1 splenectomy, 1 intra-mural gastric tumour, 1 appendectomy). Demographic and peri-operative data are shown in Table 1. The complications considered in the follow-up were classified as "major" or "minor", according to their severity. They included: mortality, haemorrhages, intra- and post-operative visceral lesions, recurrence, seromas, persistent pain, infections, prosthesis removal and post-operative ileus.

Table 1 Patient characteristics

Sex (M/F)	81/130
Age	50 (28–86)
BMI	31.5 (21–63)
Recurrent incisional hernia	36 (17%)
Prosthetic dimensions	≤285 cm2 in 123 (58.2%) ≥285 cm2 in 88 (41.7%)
Average operative time	80 min (range: 45–190)
Hospital stay	6.3 days (range: 2–16)

Surgical Technique

The patient is placed in the recumbent decubitus position, with the surgeon standing on his or her right side. The skin incision is made midline or transverse, depending on the type of incisional hernia and the necessity to also perform a lipectomy.

The hernial sac is detached from the subcutaneous tissue with scissors or by cauterisation. A detachment plane is created between the muscular fascia and the subcutaneous tissue and fashioned so that the transfixion sutures do not have to pass through the cutis. Particular attention should be paid to haemostasis. The hernial sac is then opened but not resected, so that it can be used to cover the prosthesis at the end of the operation. Visceral parietal lysis is continued until it completely clears the peritoneal surface of the anterior abdominal wall.

It is sometimes necessary to cut the falciform ligament of the liver in order to obtain a good supporting base for the prosthesis. In patients with a suprapubic defect, in order to avoid bladder injury, it is almost always necessary to detach the bladder from the abdominal wall until Cooper's ligaments are visualised and freed bilaterally. The bladder is then allowed to retract into the pelvis.

Once this posterior support base is created, the hernial defect is carefully measured. The ideal size of the prosthesis is then chosen accordingly. The mesh should be 3–4 cm larger than the defect, enabling gentle retraction of the margins without causing excessive tension. In cases involving large defects with loss of visceral contents, it is better to use a larger prosthesis to reduce the intra-abdominal pressure and subsequent risk of abdominal-compartment syndrome.

Fixation of the mesh starts from the most difficult side, which is usually the inferior margin of the hernial defect. Stitches of non-absorbable monofilament material are placed approximately 4 cm from the margin of the defect. The suture is passed in a "U" shape from the abdominal wall to the prosthesis, maintaining the same distance between the two sutures on the wall and on the prosthesis, thus avoiding curling of the prosthesis. The distance between the sides of the U-stitch should be of approximately 1.5 cm. The distance between the two anchoring U-stitches should be 2 cm (Fig. 1).

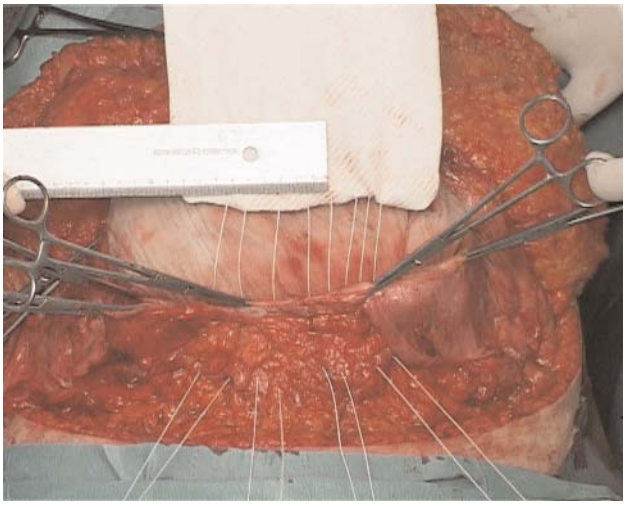

Fig. 1 The suture is passed in a "U" shape from the abdominal wall to the prosthesis, maintaining the same distance between the two sutures on the wall and on the prosthesis

Figure 2 shows that the distances are scrupulously observed on the prosthesis as well as on the abdominal wall. Once the first three or four stitches are placed, traction is applied to the sutures and the mesh assumes its correct position under the abdominal wall. After the inferior margin has been fixed, anchorage of the remaining prosthesis is continued with the same full-width U-shaped stitches. The fixation tension of the mesh can be controlled by alternating stitches on the left and right sides of the abdominal wall. This allows the mesh to follow the curvature of the abdominal wall without excessive tension or laxity, which cause anti-aesthetic relaxation of the abdominal wall. This is clearly shown in the CT scan in Fig. 3, which illustrates how the prosthesis faithfully

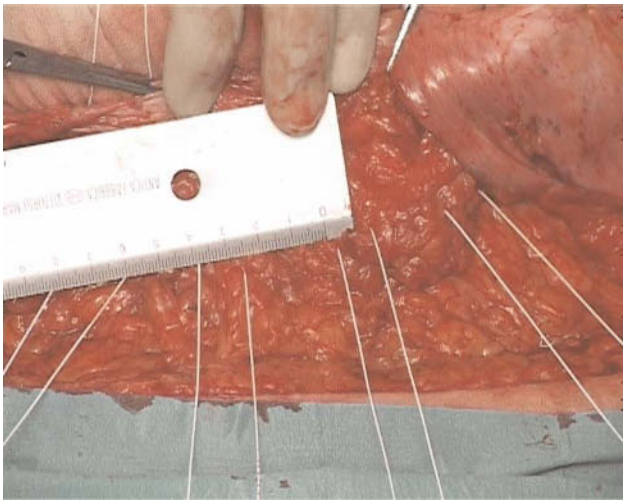

Fig. 2 The distances are observed on the prosthesis as well as on the abdominal wall, thus avoiding curling of the prosthesis

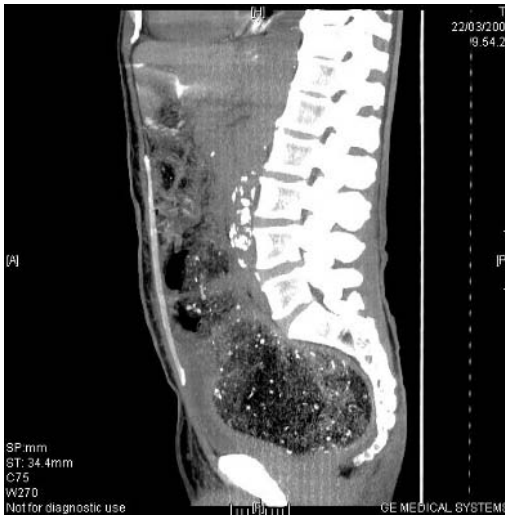

Fig. 3 A CT scan obtained 3 months post-operatively illustrates that the prosthesis faithfully reconstructs the natural muscular-aponeurotic profile

reconstructs the natural muscular-aponeurotic profile. To assure correct tension of the prosthesis, it may be useful to exert gentle traction on the defect margin while the surgeon ties the stitches.

As at the beginning of the procedure, the last section of the prosthesis is fixed with three to four stitches that are then pulled together simultaneously and tied in order to avoid inadvertent intestinal injury. After having assured that the tension is correct and uniform over the entire mesh, the procedure continues by covering the prosthesis with the residual hernial sac, using interrupted absorbable synthetic sutures. This important step isolates the prosthesis from the subcutaneous tissue, reduces the risk of infection, and supports the migration of fibroblasts into the prosthesis.

Once the accompanying lipectomy has been completed, two closed suction drains are placed in the subcutaneous plane and the skin is closed. The mean operative time is 80 min (min. 45, max. 190 min).

Results

The peri-operative mortality was null even in patients with severe respiratory deficiency. One patient with pulmonary emphysema required emergency surgery with endotracheal intubation and mechanical ventilation, followed by a 48-h stay in the intensive care unit. The mean hospitalisation time was 6.3 days (min. 2, max. 16 days). Another patient required emergency re-operation due to bleeding from the omentum. Two patients underwent surgical revision of the wound 2–6 h post-operatively due to subcutaneous bleeding. In six patients (2.8%), the hernia recurred; one of these was the consequence of a traumatic event at work 4 months after the procedure. Four patients underwent a second procedure at our department, three involving the open technique at 3, 4 and 6 years post-operatively and one, 11 years after the first reconstruction, entailing laparoscopic hernioplasty. One patient with recurring hernia was treated at another hospital (Table 2).

In two of the three patients with prosthetic infection (2 patients after 2 months, a third after 6 months), removal of the prosthesis was necessary and the hernia subsequently recurred, but both patients refused further treatment. The third patient was successfully treated with conservative therapy and had a normal recovery.

Table 2 Recurrences

Recurrences	Number of patients
Post-traumatic	1: after 4 months
Open re-operation	4: after 3, 4 (2 patients) and 6 years
Laparoscopic re-operation	1: after 11 years
Refused further surgery after prosthesis removal	3
Total	9 (4.2%)

In one of the three patients in whom the mesh had top be applied in an infected area, due to contamination with enteric liquid, the mesh was removed 4 months after implant.

The incidence of clinically evident seroma was 7.5% (18 patients), but only two of these patients required needle drainage. In the other patients, recovery was spontaneous 1–3 months after surgery (Table 3).

Two patients experienced visceral lesions (ileum and right colon); these were detected and sutured during surgery without adverse outcome.

Table 3 Complications

Prolonged ileus	1 (0.4%) (after 6 days)
Seroma (present for >8 weeks)	3 (1.4%)
Iatrogenic bowel lesions	2 (0.8%)
Chronic pain	0
Post-operative respiratory distress	1 (0.4%)
Mesh infection	3 (1.4%)
Mesh removal	2 (0.4%)

The immediate post-operative course proved to be painful and all patients required analgesic treatment, but none of them suffered prolonged pain requiring specific treatment.

Post-operative ileus lasting 48–72 h was a common occurrence in our patients in the absence of radiological signs of intestinal occlusion. A patient submitted to wall reconstruction for recurrent incisional hernia showed gas-fluid levels with peristalsis blockage, but the condition spontaneously resolved by the sixth post-operative day.

No occlusions and/or fistulas were recorded post-operatively.

Discussion

As demonstrated by the ample range of surgical approaches currently used in the repair of incisional hernia, this pathology presents a series of problems that cannot be standardised by a sole type of treatment. As is well-known, direct suture of the abdominal wall is associated with a high level of recurrence, which varies depending on the different case histories and may be as high as 50% [30–32]. The use of a prosthesis thus becomes imperative in minimising the risk of recurrence, thereby assuring repair without abdominal-wall tissue tension and restoring as much as possible the normal parietal anatomy.

The prosthesis can be positioned in a pre-fascial site (subcutaneous), intra-parietally (pre-peritoneal) or in an intra-peritoneal site. The choice of the prosthesis thus depends on the site where it will be implanted—a reticular mesh (polypropylene or polyester) in pre-fascial and intra-parietal sites (Chevrel or Rives procedure), a laminar (ePTFE) prosthesis intra-peritoneally [14,15] or a composite prostheses [17] since it avoids adhesions with the intra-abdominal viscera.

While the Rives technique has been the most commonly practiced over the last 20 years, in cases of large incisional hernias, it presents a series of technical obstacles that make it extremely complex. This is especially the case in obese patients and/or those with boundary incisional hernias or loss of "right of domain" of the intestinal loops. In these patients, it is practically impossible to perform a true "tension-free" technique, which has severe repercussions for respiratory dynamics. Furthermore, it is often difficult to assure a secure preservation of the peritoneum at the sub-umbilical site, thus exposing the prosthesis to the viscera. In our experience, there were six cases of entero-cutaneous fistulas in patients who underwent the Rives procedure, with, according to hospital records, intra-parietal implantation of the prosthesis.

A valid alternative to these operations is intra-peritoneal implantation of an ePTFE prosthesis for the repair of a hernial defect. There are several advantages to this approach: (1) the prosthesis can be easily positioned, even in obese patients and/or patients in whom the hernial defect is at a lateral site, such as subcostal and lumbar, and the operative time for simple standardisation of the same is minimal. (2) The implant tension of the prosthesis can be varied to accommodate patients with severe respiratory deficiency or loss of domain of the loops, thus avoiding the onset of post-operative respiratory stress or abdominal-compartment syndrome. Indeed, this technique has been used in patients with abdominal-compartment syndromes subsequent to intra-abdominal sepsis, allowing temporary expansion of the abdominal volume in patients in whom closure of the wall could otherwise lead to severe consequences. Moreover, deep positioning of the prosthesis reduces the possibility of external contamination. (3) This technique can be used in parietal reconstruction after exeresis of large fascial or muscular tumours that affect the full width of the abdominal wall; in these cases, the reconstruction time is very similar to the reconstruction time necessary for large incisional hernias.

The data on our series of 211 patients with long-term follow-up (60–178 months) provide evidence of a very low recurrence rate, with very few complications over time. The recurrence 11 years post-operatively, which was promptly repaired laparoscopically, demonstrates that the incidence rate of visceral-parietal adherences, even over the long term, is extremely low.

In three patients, removal of the prosthesis was necessary; in two, the prosthesis was applied in elective surgery and became infected after 2 and 6 months due to necrosis of the covering tissue. In the third patient, a prostheses implanted in an infected site during emergency surgery was removed 4 months post-operatively. Removal proved to be simple, and a neo-peritoneum had grown under the prosthesis, separating it from the abdominal cavity.

The incidence of clinically evident seroma was low, and evacuation was necessary in only two patients. The real incidence of peri-prosthetic seromas is much higher; in fact, if an ultrasound is obtained 1 week after implant, almost all patients can be seen to have seromas but they are rarely clinically evident. No long-term seromas were observed.

Accurate haemostasis is essential during detachment of the subcutis from the fascia and during viscerolysis, in order to avoid precocious re-operations due to haemorrhages, sometimes severe, and occurring even in the subcutis. In the two patients with visceral lesions that were repaired intra-operatively, prostheses were implanted without further complications.

Conclusions

Our 19-year experience during which more than 500 meshes were implanted intra-peritoneally has proven the efficiency of this procedure and its safety in the repair of incisional hernia [33]. The data regarding 211 patients with long-term follow-up (60–178 months) recommend this approach in the treatment of patients considered "surgically difficult", i.e. with severe respiratory deficiency and general complications. These characteristics, together with a rapid learning curve and relatively short operative time, even in obese patients, support the use of this technique as a valid alternative to the intra-parietal positioning of reticular prostheses, if not its being the treatment of choice in selected patients. Furthermore, the same reconstruction technique can be used in the surgical removal of large parietal tumours and in the treatment of severe abdominal-compartmental syndromes.

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Incisional Hernia Procedure with Mixed or Laparo-assisted Technique

Feliciano Crovella

Discussion of the procedure to be used for repairing incisional hernia, either an open or a laparoscopic reconstructive technique, is still ongoing, while the use of prosthetic material is gaining wider consensus. The advantages, indications and limits of the mini-invasive technique have been reported in numerous studies, the results of which have been published in the literature.

The laparo-assisted method that will be described here attempts to link the advantages of the laparoscopic technique with those of open surgery through the use of an endoperitoneal prosthesis. The method aims to reduce both the complications typical of laparoscopic technique and those arising from the open technique. Here, we examine the controversial points of the two methods, such as diagnostics, adhesiolysis, visceral lesions, size and introduction of the prostheses, seromas and parietal lifting.

In the pre-operative examination, modern diagnostics provide high-quality information on the pathological condition of the abdominal wall, even though a detailed mapping of wall defects is only possible with laparoscopy. If not included in wall alloplasty, small orifices can be a cause of relapse. In the open method, the same level of diagnostics is only possible by amply exposing the abdominal wall, thereby potentially inducing further weakness.

Adhesiolysis is an essential condition for the correct positioning of an intraperitoneal prosthesis and for its successful fixation. With laparoscopy, it is possible to carry out a complete adhesiolysis and avoid further weakening of the wall.

The lysis of viscero-visceral adherences often poses the risk of intestinal lesions. These micro-lesions are easily recognisable and repairable in open surgery while they represent the most fearful hazard in laparoscopic adhesiolysis.

One limit of the laparoscopic technique is the dimension of the parietal defect and the introduction of a prosthesis suitable to the size of the defect (Fig. 1). Care must be taken both to avoid damaging the prosthesis during its introduction into the abdominal cavity and to respect the stringent need for asepsis. Thus, the bigger the prosthesis the greater are the technical difficulties associated with its implantation and fixation.

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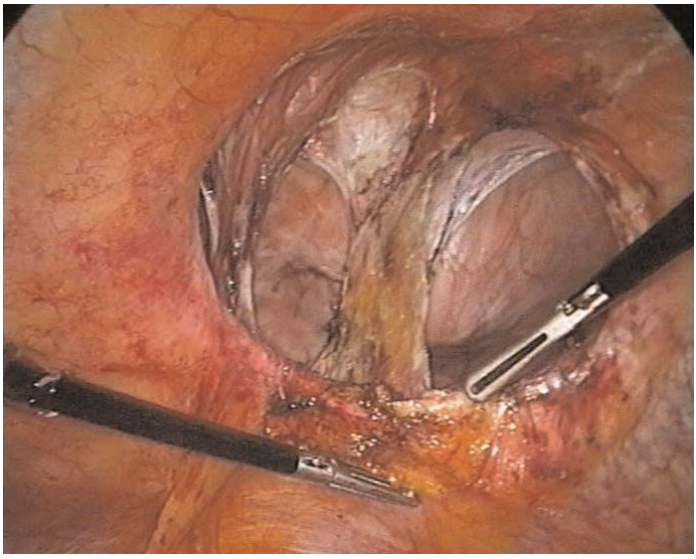

Fig. 1 Parietal defects highlighted in laparoscopy

In the laparoscopic technique, the hernial sac is often conserved; its presence can cause the formation of seromas, which are not a serious problem as long as they are small. When the sac is large or multiloculate, voluminous serosas are formed, and their treatment can expose the prosthesis to the risk of infection. In the end, the problem of skin lifting is only surmountable with small skin incisions.

In the mixed or laparo-assisted technique, entry is the same as for the classic laparoscopy technique, with three trocars positioned in the left-hand quadrants or as needed, depending on the defect to be treated.

Once adhesiolysis (Fig. 2) is completed, laparoscopic exploration allows a correct appraisal of the parietal defect and of possible associated defects that were not diagnosed in the pre-operative period.

Without reducing the pneumoperitoneum, which assists in highlighting the hernial sac, a small skin incision is made at its top. With the crucial help of the pneumoperitoneum, the sac is dissected as far as its neck and then resected (Fig. 3).

This easily carried out operation avoids the problem of seromas. Excision of the sac is of great importance, above all in the presence of large multiloculate formations that are unlikely to stick to each other and thus determine the persistence of serous cavities (Fig. 4).

Access to the abdominal cavity is also gained by excision of the sac; through this breach it is possible not only to easily perfect the lysis of viscero-visceral adherences but also to carry out a scrupulous examination of the intestinal loops to determine the presence of any previously unrecognised lesions (Fig. 5). Visceral lesions represent one of the most feared complications of laparoscopic adhesiolysis.

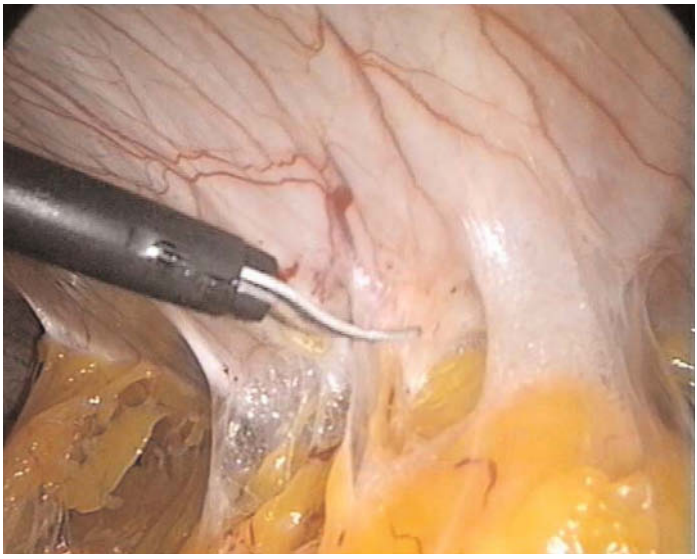

Fig. 2 Adhesiolysis

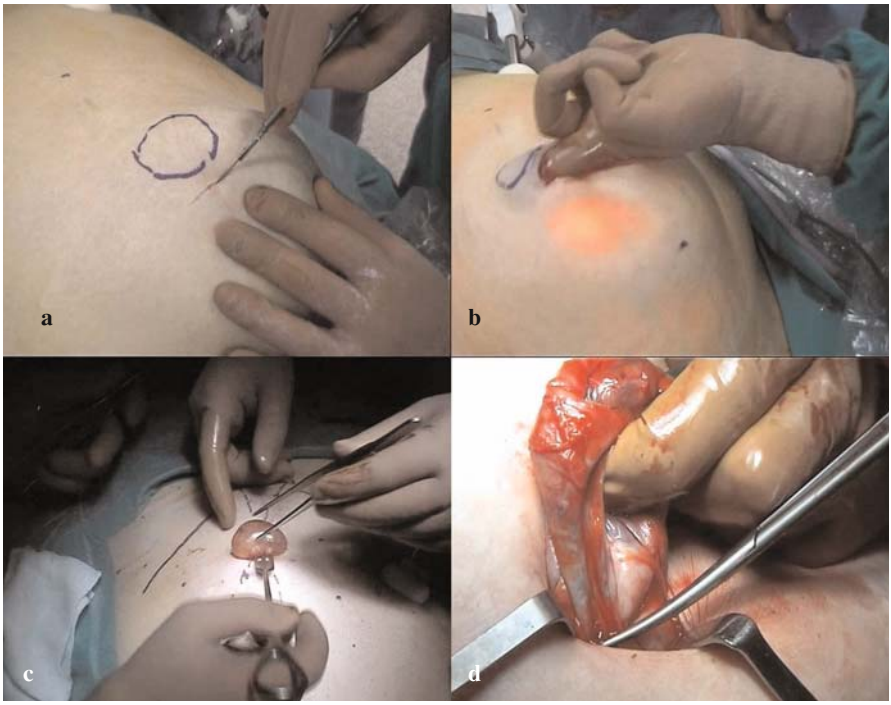

Fig. 3 a–d Skin incisions (**a**), finger dissection (**b**), preparation (**c**) and cutting (**d**) of the sac at its neck

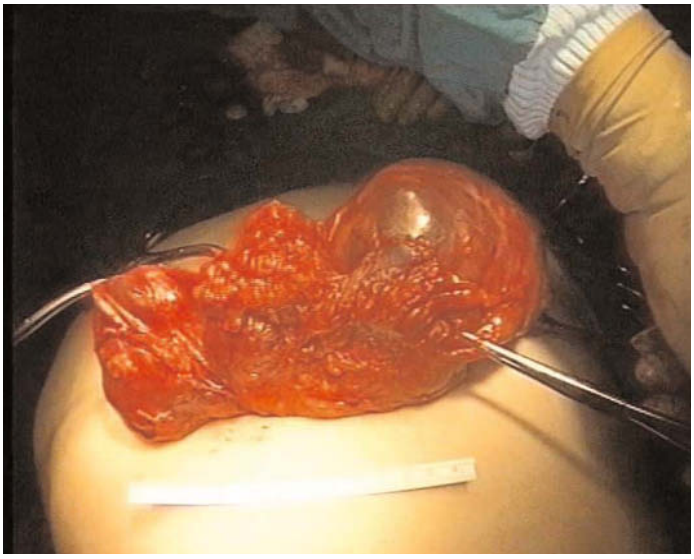

Fig. 4 Large sac distended with the help of the pneumoperitoneum

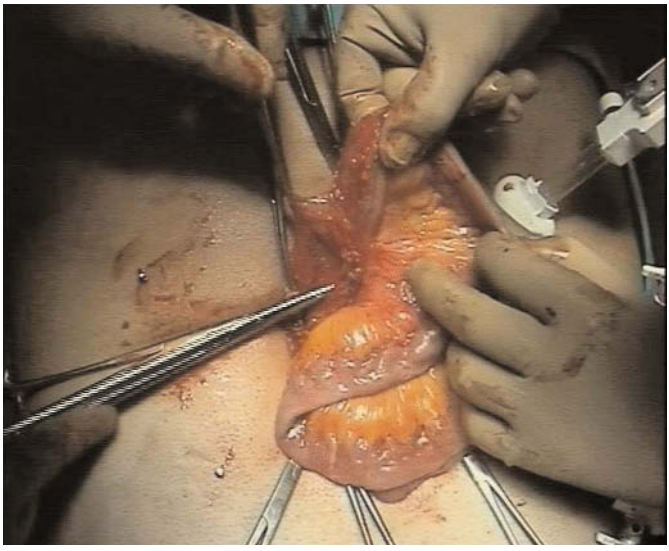

Fig. 5 Exploration of loops with adhesiolysis

Small lesions are caused both by the traction of the tenaculum forceps, which remain outside the field of vision, and by the dissection instruments. The tenacious adherences to be found between the intestinal loops or between the viscera and the wall do not always have a cleavage plane and even using cold scissors it

is very easy to cause lesions of the serosa. The recognition of small lesions is not always easy in laparoscopy, especially after extensive adhesiolysis. An accurate inspection through the small skin incision can avoid serious complications.

During the repair stage of the procedure, it is easy to introduce a large prosthesis into the abdominal cavity through a small incision. This step is carried out very rapidly, respecting asepsis and avoiding maltreatment of the prosthesis (Fig. 6). The prosthesis is fixed to the abdominal wall with a few suspension stitches, taking care to centre it in relation to the defect.

If the tension is not excessive, the edges of the hernial neck can be drawn to each other or fixed to the prosthesis with a few sutures. The use of fibrin glue is also possible.

When the skin has been closed, laparoscopy is again employed. In this phase, correct positioning of the prosthesis is controlled and its fixation to the wall is perfected (Fig. 7).

The method described combines the advantages of the laparoscopic and open techniques. It avoids the formation of seromas and allows discrete parietal lifting. The exploration of the intestinal loops carried out in the open technique avoids the fearful risk of unrecognised visceral lesions. The small skin incisions allows the introduction and placement of large prostheses, which is a limit of laparoparietoplasty. The prosthesis introduced in this way is neither contaminated nor maltreated. Fixation of the prosthesis to the abdominal wall is facilitated by manoeuvres, external as well as laparoscopic, the result of which is perfect positioning of the prosthesis and adequate overlap with the defect.

The method is certainly surgeon-dependent and requires extensive experience in laparoscopic surgery. It also represents a valid alternative in the treat-

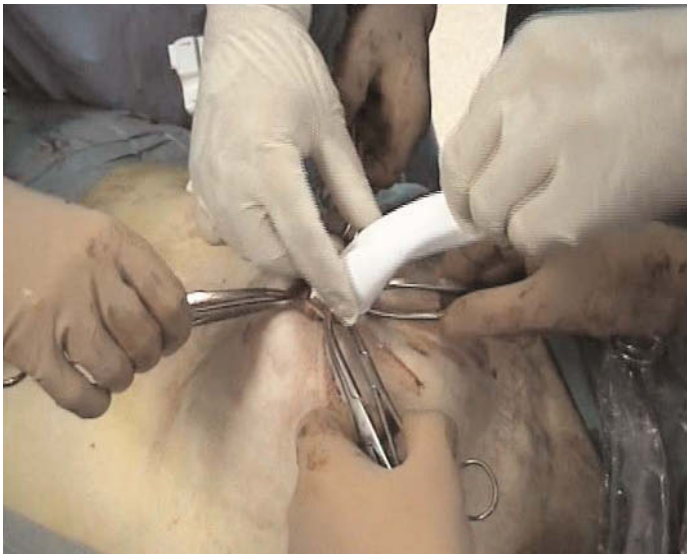

Fig. 6 Introduction of the prosthesis

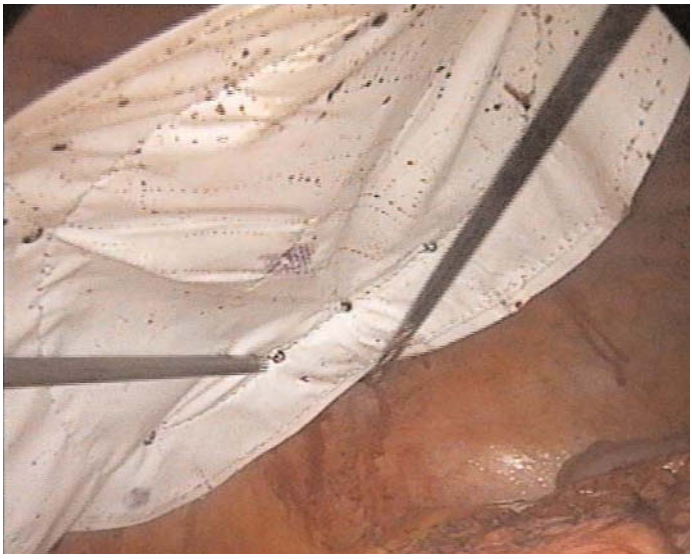

Fig. 7 Prosthesis fixation

ment of large incisional hernia with extensive parietal defects requiring the implantation of a large prosthesis, as this condition would not be able to be treated with an exclusively laparoscopic technique.

Suggested Reading

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Trocar-Site Hernia

Giovanni Bartone, Mario de Bellis, Feliciano Crovella

Introduction

Since laparoscopic cholecystectomy was first performed by Mouret, in March 1987, laparoscopic surgery has rapidly evolved as a major innovation in the history of surgery. Minimally invasive surgery has become an important specialty and has contributed to the drastic reduction of incisional hernia, which is a typical complication associated with open surgery [1,2]. However, laparoscopic surgery is also associated with a specific type of incisional hernia that occurs at the trocar site [2,3]. Trocar-site hernia was first described in 1968 by Fear, who reported this complication after diagnostic laparoscopy performed to rule out gynaecologic diseases [4].

The incidence of trocar-site hernias is lower than that of incisional hernias after open surgery, ranging from 0.021 to 6%, according to the literature. However, the real incidence of trocar-site hernias is probably higher [1,5–12]. Indeed, some patients are lost to follow-up, other patients are asymptomatic, and in some cases herniation is not evident because of obesity [13,14]. The incidence of trocar-site hernias also varies according to the type of laparoscopic surgery, with a higher incidence after procedures that require the use of large (diameter ≥10 mm) trocars [2,15–20].

Hernias at the trocar site can occur 3–5 days post-operatively (early-onset type) and are due to the entrapment of omentum or small bowel in the trocar wound. Therefore, the early-onset hernia is not a true herniation since there is no hernial sac and the bowel or the omentum transverse all the abdominal layers, which are open because of an incomplete closure. This can be the case in so-called Richter's hernia, which presents with exacerbating abdominal pain and small-bowel obstruction due to strangulation of an intestinal loop entrapped in a small trocar wound [20–22].

When the trocar-site hernia occurs several months after surgery, there is a typical hernial sac, with its content located between the musculofascial layers because of the dehiscence of the fascia. This type of trocar-site hernia is called the late-onset type. Tonouchi [3] classified trocar-site hernias, adding to the

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aforementioned types another variety, which he called the special type. The latter is characterised by the dehiscence of the complete abdominal wall with herniation of the omentum or the small bowel.

At present, there are no data that associate the incidence of trocar-site hernias with the type of technique used for establishing a pneumoperitoneum (either in the closed technique involving percutaneous insertion of a Verres needle or the open technique requiring skin incision and dissection of the abdominal wall to introduce the Hasson cannula) [3].

Aetiology

The risk factors associated with the occurrence of a trocar-site hernia are related to the patient's characteristics and the surgical technique. Advanced age, sex, nutritional status, presence of anaemia, diabetes, obesity, renal insufficiency, steroid therapy, concurrent cancer and infection of the wound contribute to the occurrence of a trocar-site hernia. Factors related to surgical technique include the direction of the skin incision, the lack of closure of some trocar wounds, the technique used for closing the cannula wounds and the tension exercised on the trocars during surgery, while those related to the surgical material include use of a Hasson cannula, trocars ≥10 mm, trocars with self-retaining collars that need to be screwed into the abdominal wall, blunt radially expanding plastic obturators, disposable trocars with built-in safety mechanisms and sutures [2,12,14].

Trocar Size

Among the possible causes of trocar-site hernias, the size of the trocars seems to play a significant role. The larger the size of the trocar, the higher the risk of a trocar-site hernia [14]. Data from the literature show that the majority of trocar-site hernias occur after the use of a trocar ≥10 mm, albeit there are also cases associated with the use of smaller trocars (5–8 mm) [8,9–23]. Trocar-site hernias ensuing from the use of 2- to 3-mm trocars in children who underwent paediatric urologic surgery have also been reported [24–26].

It is therefore recommended to use small trocars, when possible [11]. In a series of 840 patients, Montz reported that 86.3% (725/840) of trocar-site hernias were associated with the use of trocars >10 mm, while only 10.9% (92/840) were related to the use of trocars with a diameter of 8–10 mm, and only 2.7% (23/840) to trocars <8 mm [8]. In a recent work, Tonouchi revised 23/30 cases of trocar-site hernias in which the size of the trocar used was reported [3]. In this series, 78.3% (18/23) of hernias occurred when the trocar was 10–12 mm, but very few cases (21.7%=5/23) occurred with trocars ≤5 mm.

Trocar Site

The risk associated with the site where the trocar is inserted in the abdominal wall is also relevant. The highest risk for trocar-site hernias is associated with peri-umbilical insertion [1,20,23,27–30]. This is usually related to the fact that the abdominal wall is thinner in the umbilical area. The presence of a previously small umbilical hernia that was undetected at the time of laparoscopic surgery and contributed to the laxity of the cannula wound was reported [23]. Occasionally, the clinical examination of a supine patient does not allow the recognition of small hernias of the abdominal wall. Instead, the latter are usually revealed only by special manoeuvres (Valsalva, cough) with the patient in a standing position [31].

Some authors [1] proposed a para-median skin incision followed by two different incisions of the anterior and posterior fascias of the rectus abdominis muscle. This allows lateral displacement of this muscle and thus reduces the risk of herniation. The technique is based on the results of a series of 349 patients randomised by Kendall et al. to undergo laparotomy either a with para-median skin incision and closure of the abdominal wall as separate layers (group 1) or a median skin incision and closure of the abdominal wall as a combined unified layer (group 2), or median skin incision and closure of the abdominal wall as separate layers (group 3) [32]. After an 18-month follow-up, the patients in group 1 had no incisional hernias, whereas these defects were detected in 7 and 6% of patients in group 2 and 3, respectively. Moreover, oblique insertion with a zigzag technique preserved the musculofascial layers during removal of the trocars [1].

Plaus, in 1933, suggested inserting the trocar away from the linea alba, at a site in the abdominal wall where the risk of herniation is lower [28]. Indeed, the lateral abdominal wall is not only constituted by both the anterior and posterior aponeurosis of the rectus muscle, which contains the rectus itself, but is also less frequently in contact with the small bowel. Both aspects reduce the risk of a Richter's hernia at an extra-umbilical site [27]. However, Tonouchi found no difference in the incidence of trocar-site hernias between the anterolateral and median abdominal walls [3].

Trocar Type

In an animal model, trocars with different-shaped cannula tips were compared [24]; two had a pyramidal tip, one had a conical tip and two others had a cutting blade. In that study, the cannula with a conical tip resulted in smaller wounds (10–12 mm^2) in the aponeurotic layers compared to those made by the cannula with either the pyramidal tip (18–17 mm^2) or the cutting-blade tip (29–31 mm^2).

Leibl reported a reduction in trocar-site hernias from 2 to 0.2% when trocars with a conical tip instead of cannulas with retractile cutting blades were used [7]. Indeed, the conical tip allowed separation of the musculofascial fibres, which spontaneously sealed after removal of the trocar. This approach does not usually require suturing of the abdominal layers in the trocar site, except in the case of an umbilical incision, which has to be sutured as separate layers [33]. Instead, the cutting-blade tip creates a wound that arises from the sectioning of the aponeurotic layers, the rectus muscle and the peritoneum. This wound is certainly at risk for a trocar-site hernia [34].

The Hasson trocar is equipped with an olive-shaped sleeve that is screwed into the layers of the abdominal wall and anchors while sealing the wound, to avoid air leakage from the peritoneal cavity [31]. The insertion of this trocar is traumatic for the affected tissues, which undergo a temporary ischaemia that can affect subsequent sealing of the musculofascial layers. This represents a possible cause of the higher incidence of umbilical trocar-site hernias. The same aetiologic mechanism can be ascribed to the prolonged tension used on the trocars during lengthy procedures and to the manipulation of surgical specimens extracted from the peritoneal cavity. In the latter case, it is often necessary to enlarge the musculofascial wound and to use high tension on the borders of the wound to eventually extract the surgical specimen. This can lead to ischaemia of the musculofascial borders of the trocar-site wound [6,35,36].

Removal of Cannulas and Cannula Site Closure

Usually, cannula sites of 5- and 10-mm trocars that are outside the umbilicus do not require closure of the fascia, while the cannula site for the scope, which is located near or in the umbilicus, must always be closed. This is most often done with interrupted, slowly absorbable sutures (polyglycolic acid) as separate layers [31].

All cannulas should be removed under direct observation [23]. It is possible to completely close each trocar site (fascia, muscle and peritoneum) before removing the cannula by means of specific devices that allow a suture to be placed through all the layers of the abdominal wall under direct observation [21,37,38]. After all the stitches have been placed, the cannula is removed and the suture is pulled, tied and then knotted. This procedure guarantees that no omentum or small bowel becomes entrapped in the wound. Finally, the pneumoperitoneum is completely evacuated through the peri-umbilical trocar. This is the cannula through which the laparoscope was placed and it is eventually withdrawn with the laparoscope inside it so the tract can be observed. Maintaining the pneumoperitoneum during removal of the cannulas and closure of the port-site wounds separates the bowel from the abdominal wall, thus reducing the risk of iatrogenic lesions at the end of laparoscopic surgery [39].

There is still debate whether it is necessary to close small-cannula (≤5 mm) sites, especially in paediatric patients [40]. Recently, Chiu evaluated the effects

of placing a Surgicel plug in the layers of the abdominal wall to prevent trocar-site hernias [2]. The results of this study are encouraging (0.33%=2 trocar-site hernias out of 610 patients who underwent mini-gastric bypass), but longer follow-up is needed. It remains clear that leaving an open wound is a risk factor for trocar-site hernias.

The closure of cannula sites can be challenging in obese patients because of the thick subcutaneous tissue and the small skin incision [41]. The latter often needs to be enlarged in order to properly close the trocar-site wound [42]. However, some surgeons prefer not to enlarge the incision and instead use special devices to close these cannula-site wounds [43,44]. In a recent paper published by Shaer, three different types of devices to close trocar-site wounds were described [45]. The first type requires the use of three ports, including one for the laparoscope, in the peritoneal cavity. These types of devices are: (1) the Maciol needle (Core Dynamics, Jacksonville, FL, USA), (2) the Grice needle (Ideas for Medicine, Clearwater, FL, USA), (3) Endoclose (Tyco Auto Suture International, Norwalk, CT, USA) and (4) Suture Passer (W.L. Gore & Associates, Phoenix, AZ, USA).

The second type of device consists of those used partly outside the abdomen and requiring only the port for the laparoscope: (1) the Carter-Thomanson closure system, (2) the Endo-Judge wound closure device, (3) the disposable Tahoe Surgical Instrument ligature device, and (4) the Exit Disposable Puncture Closure, in which the closure technique is by means of a 5- to 2-mm trocar.

The third type of device can be used without need for direct intra-abdominal observation. It includes (1) the suture carrier, (2) the dual-haemostat technique, (3) the Lowsley retractor, (4) the Deschamps-Reverdin needle and standard manual techniques.

In the presence of ascites, closure of the entire abdominal wall as a combined unified layer is strongly recommended to avoid leakage of liquids through the wound.

Evacuation of the Peritoneal Cavity

Evacuation of the pneumoperitoneum before removal of the cannulas has been considered as a possible cause of early-onset trocar-site hernias [36]. Indeed, the omentum and the small bowel can herniate through the trocar wound and remain entrapped in the subcutaneous tissue during the closure of the trocar-site incisions. This can be the consequence of contraction of the abdominal wall during extubation of the patient at the end of anaesthesia.

Moreover, in obese patients, the thick pre-peritoneal fat is a space where both the omentum and the small bowel can remain entrapped because of the dissection made by the pneumoperitoneum. This could determine the occurrence of pre-peritoneal hernias at the trocar site. Therefore, in the obese patient it is recommended to begin closure of the trocar wound as a combined unified layer, including the peritoneum and the inner musculofascial layer [22]. The closure is

then completed as separate layers since it is difficult to include all the abdominal layers in one suture, especially in these patients. Incomplete closure of a trocar-site wound is a risk factor for trocar-site hernias both in the obese and in the normal/thin patient [21,31]

Infections

Post-operative wound infections are usually the consequence of the trocar or of infected specimens passed through the trocar-site incision. While the occurrence of these infections are rare compared to their incidence in open surgery, they are considered a risk factor for trocar-site hernias. The highest rate of infection occurs at the umbilical trocar site and this condition is considered the cause of trocar-site hernias in this location. Mayol reported that the rate of umbilical trocar-site hernias was higher after the use of the Verres needle than after the Hasson technique [6].

Clinical Symptoms and Diagnosis of Trocar-Site Hernias

The onset of a trocar-site hernia is a complication that can occur anytime in the post-operative period. The early-onset type usually occurs no later than 14 days after surgery. If the patient complains of exacerbating abdominal pain with vomiting and there is radiological evidence of intestinal obstruction, surgery is mandatory to solve the intestinal obstruction.

Surgery can be laparoscopic or open; the choice is based on the intra-operative findings. Usually the operation is started laparoscopically. Obviously, conversion to open surgery is required in the presence of massive distension of the small bowel or necrotic intestinal loops that have to be resected.

Richter's hernia is responsible for early-onset trocar-site hernias. The incidence varies from 47.6 [46] to 76.2% [3] of cases. Pre-operative abdominal ultrasound is mandatory to evaluate the abdominal wall and clearly diagnose the parietal defect. The latter can be identified with the patient standing and using special manoeuvres, such as the Valsalva manoeuvre [31], and diagnosed with a CT scan of the abdomen.

Surgery

For those cases of late-onset trocar site hernias that are not complicated but require surgery, laparoscopic surgery is indicated [47,48], especially if the parietal defect is small. In the presence of large trocar-site hernias, open surgery is

recommended. A few, selected cases of trocar-site hernias can even be treated by placing a polypropylene mesh under local anaesthesia.

Conclusions

Laparoscopic surgery has clearly contributed to the drastic reduction of incisional hernias typically associated with open surgery, but is still affected by the new post-operative complication of the trocar-site hernia, which can be considered a variant of the earlier incisional hernia.

Trocar-site hernias occur with a variable incidence according to the type of laparoscopy (surgical vs. diagnostic). Their aetiology seems to be related to the diameter and the type of trocar used. The most frequent location of trocar-site hernias is the umbilicus, although all trocar sites can be subject to herniation if they are not properly closed.

An accurate and complete closure of the abdominal layers as separate layers and an appropriate and correct technique at the time of laparoscopic surgery will no doubt contribute to reducing the incidence of trocar-site hernias.

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Giant Abdominal Wall Defects

Gianfranco Francioni, Vittorio Corso, Matteo Montesi, Massimiliano Todaro, Luigi Veneroni

The term "giant abdominal wall defects" effectively describes many clinical aspects that are characterised by a large ventral hernia associated with many difficult clinical situations [1]. The definition, the diagnosis, and the surgical technique are not standardised; rather, every clinical situation is unique, and the surgeon needs to plan the surgical treatment and select the best technique for each case.

The literature contains no randomised clinical trials or guidelines on giant ventral hernia: however, this definition is the one in current use, and we think that some further definitions are generally accepted:

- The abdominal wall is a true organ and must be preserved whenever possible.
- The abdominal wall must be sutured in such a way as to restore it to its original condition.
- If it is not possible to preserve the abdominal wall, the surgeon must plan a strategy for a good result of subsequent surgical treatments.
- Insertion of a biological prosthesis is the best treatment during infections of the abdominal wall.
- The VAC (Vacuum Assisted Closure) system is effective in the presence of septic complications affecting the abdominal wall.

General Considerations

The synthetic prostheses used for the past 30 years have yielded good clinical results in extremely difficult cases [2]: overall, they have reduced the number of relapses, and surgeons have lost sight of some negative aspects in their enthusiasm for the lower incidence of relapse.

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First Negative Aspect: The Graft's Recovery Is Characterised by a Significant and Long-term Inflammatory Response

This reaction depends on the synthetic material used and on the thickness and size of the prosthesis. It is important to identify such complications as hematomas, seromas and infections, which can protract the duration of the inflammatory reaction. Oedema is especially marked in the tissue near the prosthesis, as it is much less highly vascularised, as is adipose tissue (Fig. 1).

Ideally, the prosthesis should be placed in the muscular wall to avoid clinical complications.

Positioning the prosthesis between the aponeurosis and the muscle, as in Rives' technique, can lead to inadequate integration; it is true that the reaction is minimal in the muscle, but that at the aponeurosis is exacerbated and is associated with oedema and fluid collections (Figs. 2,3).

Oedema at the posterior aponeurosis is a frequent finding, being observed in about 60% of cases.

When relaparotomy is mandatory the surgeon will realise what the problem is: in this case the phrase "difficult abdomen" is a euphemism.

A prosthesis made of PTFE has less inflammatory reactivity than those made of polyester and polypropylene, but in the presence of an inflammatory reaction it is difficult to remove a PTFE prosthesis even if it is floating inside the residual pocket with minimal adhesions.

If the PTFE is infected, there is a homogenous inflammatory reaction that extends to the adjacent organs and it is impossible to cut it away with scissors because of the risk of perforating the bowel (Fig. 4).

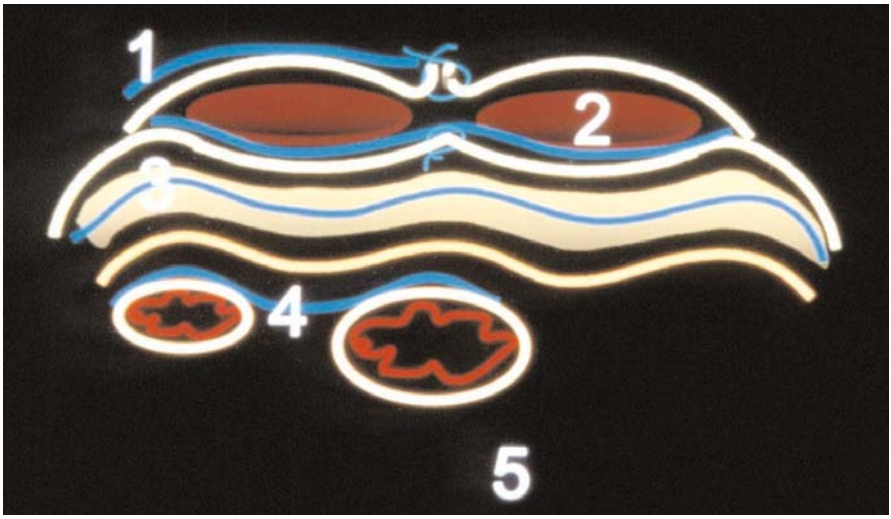

Fig. 1 Anatomic site of the mesh: *1*, subcutaneous; *2*, superficial aponeurosis; *3*, deep aponeurosis; *4*, preperitoneal; *5*, intraperitoneal

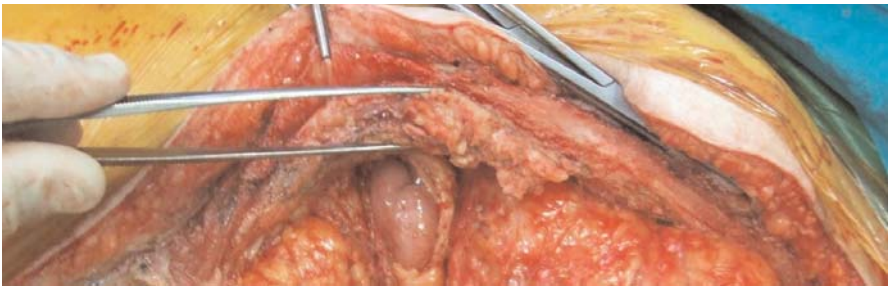

Fig. 2 Tissue oedema and chronic inflammatory response

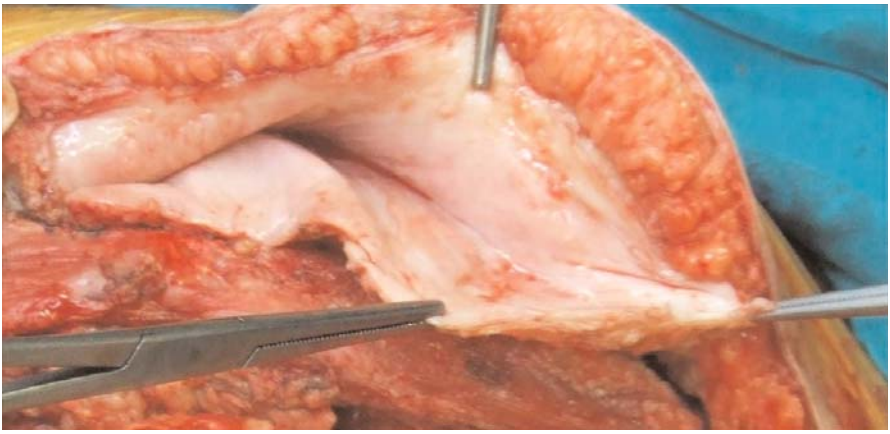

Fig. 3 Prosthesis and oedema of the serosa

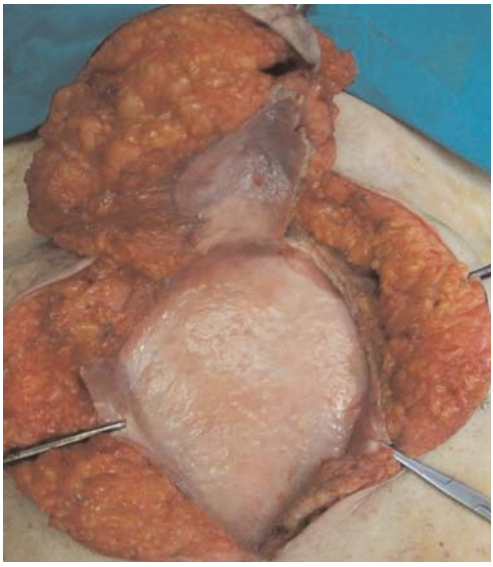

Fig. 4 PTFE infected mesh with inflammatory reaction

Any synthetic prosthesis causes tissue reactivity, the intensity varying widely with the thickness and type of synthetic material used. This reaction becomes more pronounced during an infectious process, becoming absolutely abnormal in the presence of hematomas or infections.

These considerations show that it is essential to elicit a careful clinical history to avoid unforeseen disastrous situations.

Second Negative Aspect: Poor Resistance of Synthetic Prosthesis to Infections

Despite a few publications reporting it, infection of an abdominal wall defect repaired with a synthetic prosthesis is a dramatic event. All the patients affected have long and complicated clinical histories.

PTFE has very low resistance to infection; Dacron and the polypropylene, in contrast, have properties that justify implementation of a conservative treatment of infection; such therapy is not successful in the case of an infection located in a thickening of the prosthesis. It is helpful to use prostheses that are not very thick, using them to cover the defect completely and spreading them very carefully to avoid thicker or thinner patches.

Third Negative Aspect: Visceral Lesions Caused by the Prosthesis

Except for PTFE, putting a nonresorbable prosthesis in contact with the visceral organs is not helpful, because an adhesion is likely to form and such adhesions are always tenacious. If the prosthesis is rigid and is near to anatomic structures that move (e.g., esophagus, stomach, bowel, bladder, veins, or arteries) it will be inside the "lumen" of the organ. This happens every time, with or without formation of a fistula or fistulas.

To strengthen this hypothesis, we can report that we have treated many patients with pericolostomic hernias for abscesses or formation of fistulas. These surgical procedures are difficult; we use a median incision to remove the prosthesis and the stoma, and we create a new contralateral stoma. In these instances, we use biological prostheses to verify the results of this new device (Fig. 5).

In conclusion, the use of polypropylene and Dacron prostheses can lead to visceral erosions of the bowel, bladder, esophagus, stomach and other visceral organs: we recommend avoiding the use of synthetic prostheses in the peritoneum, exception for those made of PTFE (Figs. 6,7).

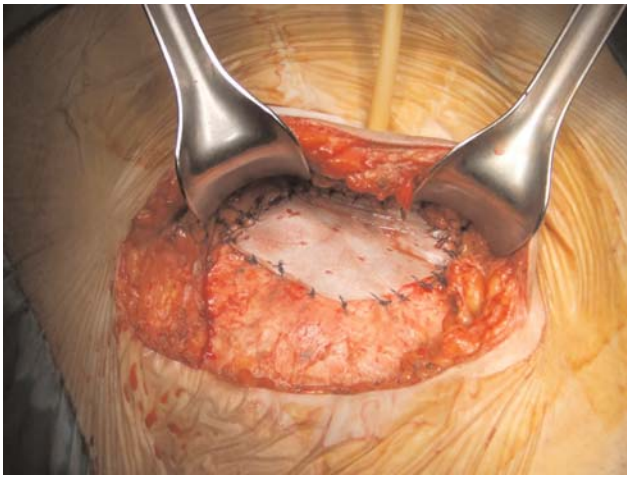

Fig. 5 Biological prosthesis

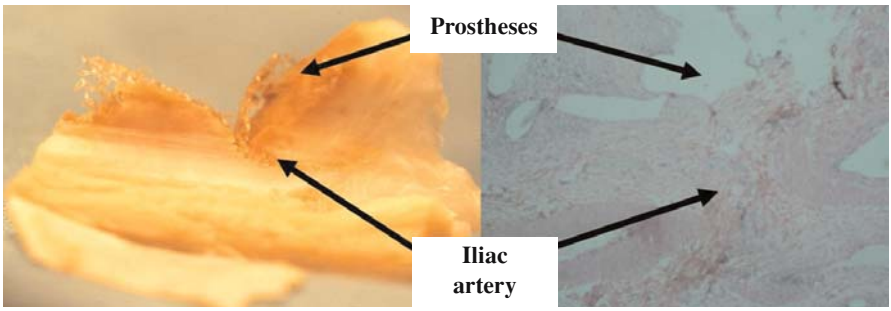

Fig. 6 Prostheses near the iliac artery

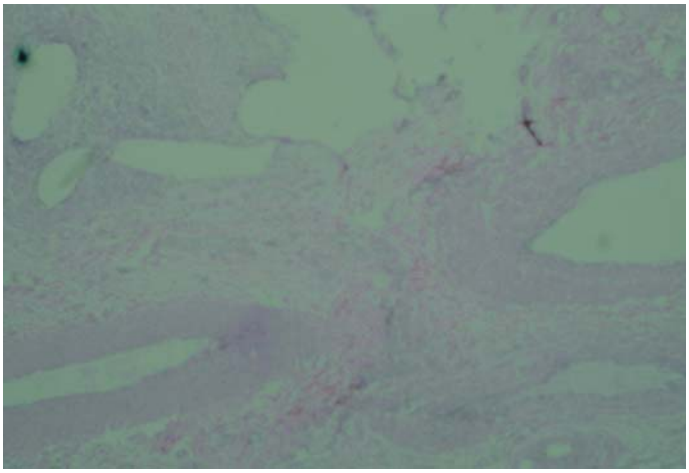

Fig. 7 Mesh near the iliac artery (histopathologic finding)

Fourth Negative Aspect: Once in Position the Prosthesis Can No Longer Be Extended and Is Completely Adherent to the Tissue

This situation occurs in patients with ventral hernia who are treated with Rives' technique. Even if a perfect surgical treatment is implemented, the abdominal wall is not elastic. A further clinical problem correlated with this technique is that the symptoms of chronic respiratory insufficiency are made worse in the presence of a giant ventral hernia by the abdominal transplant and the reduced mobility of the diaphragm [3,4].

These four negative aspects do not apply when a biological prosthesis is used; we know this even though no randomised studies are available. We think that prostheses of this kind are resistant to infections; they do not cause visceral adhesions during intraperitoneal use; and they do not cause tissue reactions or visceral erosion. Our preliminary results obtained in cooperation with Frankfurt University indicate that:

- The biological prosthesis does not produce adhesions
- The biological prosthesis is markedly resistant to infections
- The biological prosthesis is colonised by connective tissue
- The biological prosthesis is difficult to lay down
- The tension exerted on tissues by biological prostheses is lower than that observed with synthetic prostheses

Definition

Giant abdominal wall defect is a clinical entity that varies in its manifestations but is characterised by complex ventral hernia associated with wall substance loss and/or a wall defect that is so large that it cannot be repaired by means of the simple suturing technique used in some anatomic regions to hold the edges together [5] and is associated with:

- Multiple parietal defects
- Atrophy of very large muscular wall areas
- Relapses after abdominal transplants with utilisation of synthetic prostheses
- Bowel loop extending into the parietal prosthesis
- Bowel obstruction
- Infected prosthesis
- Chronic infection of abdominal wall, with or without enterocutaneous fistula
- Simple or complex enterocutaneous fistula
- Abdominal hypertension
- Affected skin area >10–15 cm
- Obesity

In our experience, these clinical situations are frequently associated: we have personally observed:

– Relapse of a giant ventral hernia with a defect of over one eighth or one tenth the size of the abdominal circumference
– Chronic infection of the prosthesis
– Bowel adhesions on the prosthesis

In our experience the incidence is very low at just under 3 or 4 cases per year. In 20 years we have treated 65 cases, with a peak around the 1990s, when there was overtreatment with synthetic prostheses.

Diagnosis

Clinical evaluation is important, and sometimes it allows a clear diagnosis, but it is important to plan the surgical treatment with CT scan: this is mandatory for a complex giant ventral hernia. There are three possible conclusions we might reach: (1) pathology of the abdominal wall; (2) intraabdominal pathologies associated with the abdominal wall; and (3) independent pathologies not strictly correlated with the abdominal wall.

Pathologies of the Abdominal Wall
– Size and localisation of abdominal wall defects
– Residual musculature
– Collection in the abdominal wall
– Prostheses in the abdominal wall
– Size and direction of any fistula
– Foreign bodies in the abdominal wall
– Extension of the organ concerned into the defect in the abdominal wall

Intraabdominal Pathologies Associated with the Abdominal Wall
– Deep infections with fistula in the abdominal wall
– Enterocutaneous fistulas
– Mass-forming lesions infiltrating the abdominal wall

Independent Pathologies Not Strictly Correlated with the Abdominal Wall
– Any concomitant surgical pathology that is scheduled for treatment with surgery

Surgical Therapy

If the defect in the abdominal wall is complex, with substance' loss and/or infection (enterocutaneous fistula, chronic infection of the prosthesis), or involves a high risk of infection (e.g., bowel resection) we plan the surgical treatment in two or more steps. In the first step we concentrate on the priorities:

– Removal of the infected prosthesis
– Treatment of enterocutaneous fistulas
– Treatment of any other deep infections

We repair the giant abdominal wall defect only when we have removed the deep mass or performed a bowel resection, being concerned to make an ideal suture of the abdominal wall with minimal tension (Fig. 8). In these cases we use a biological prosthesis made from bovine pericardium (Tutogen, Tutomesh) to strengthen the deep wall or to replace any small wall areas that are lacking. The biological prosthesis can create the possibility of new surgical treatment in the case of a relapse of the ventral hernia.

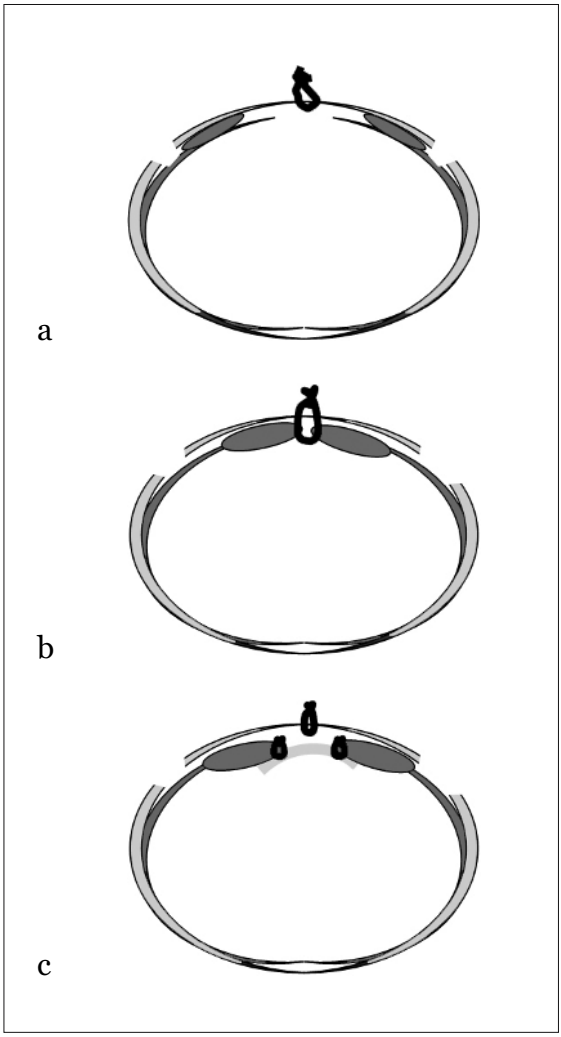

Fig. 8 a–c Modalities of definitive closure. **a** Direct suture with or without lateral incisions; **b** complete suture of the abdominal wall; **c** use of biological prosthesis or synthetic prosthesis

Parietal Tension and Abdominal Hypertension

Repair of a giant wall abdominal defect is associated with elevated abdominal hypertension. An elevated abdominal wall tension causes (1) parietal tissue ischemia and (2) abdominal hypertension.

In these two clinical situations we plan two or more surgical treatments.

The compliance of the abdominal wall is conditioned by the fact that the aponeurosis hardly relaxes. Indeed, if the aponeurosis is undamaged the abdominal wall does not give up its tension until close to the navel.

Prosthesis

In the first surgical step, if an infection is present it is not a good idea to use a synthetic prosthesis. For the past year in complex cases of giant abdominal wall defects we have been using biological prostheses, in some cases associated with resorbable materials. When there is septic surgery with an extensive bowel resection and acceptable wall tension (measure of the intraabdominal pressure), we suture the abdominal wall without a mesh. If the abdominal wall tension is high or if there is no tissue we suture only the skin, and the prosthesis is sent back to be used in a different surgical treatment. For the last two years we have been using biological prostheses in association with a resorbable prosthesis (Fig. 9).

Once the biological prosthesis has been inserted in the defect we use VAC [6,7] (KCI, San Antonio, Texas) to cover the mesh and to obtain a faster recov-

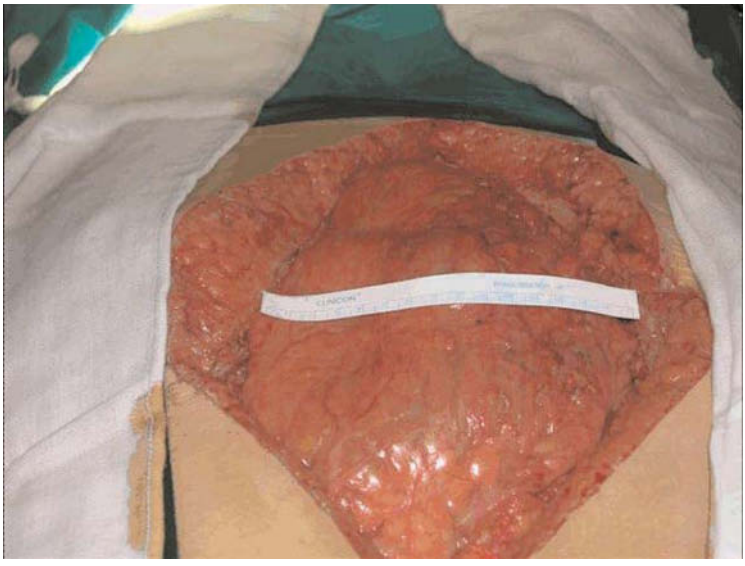

Fig. 9 Giant abdominal wall defect

ery (Figs. 10,11), especially if there is too little skin to close the defect: within a few days granulation tissue has formed and the patient is ready to receive a skin graft.

We use absorbable and nonabsorbable sutures indiscriminately for fixing the mesh; we insert only one very soft, short drain.

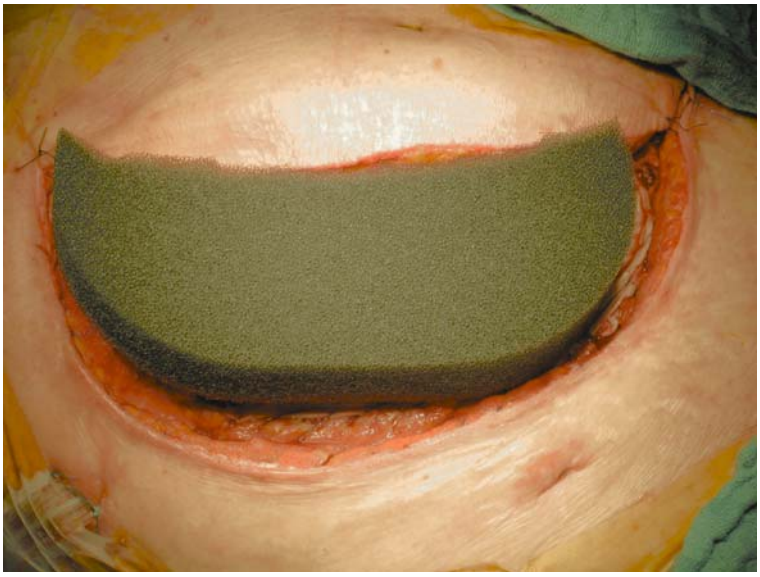

Fig. 10 Vacuum assisted closure (VAC) spoam biological prosthesis in a giant abdominal wall defect

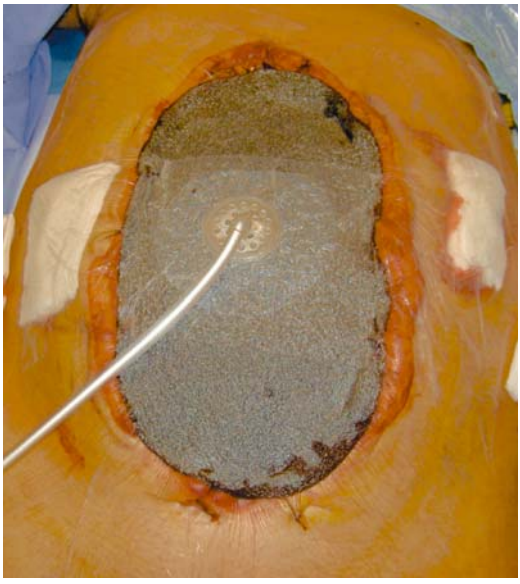

Fig. 11 Vacuum assisted closure (VAC) system in a giant abdominal wall defect

Conclusions

Giant abdominal wall defect is a complex surgical problem that must be treated in two or more steps. The widespread use of temporary abdominal closure during damage control surgery (Table 1) has allowed new options in the treatment of this severe surgical pathology. The standardised use of synthetic prostheses is never justified. We think the use of biological material can be considered the way of the future for this pathology.

Table 1. Temporary abdominal closure

Technique and material	Indications	Advantages	Disadvantages
Direct suture	Emergency	Cheap Rapid Little fluid loss	Ventral hernia Skin lesions and necrosis Abdominal compartment syndrome No fluid balance
Bogota bag	Emergency Planned relaparotomy	Cheap	Ventral hernia Abdominal compartment syndrome
Absorbable mesh	Planned surgery	Absorbable Few invections Definitive closure with skin graft	Ventral hernia (50%) Aponeurosis retraction Enterocutaneous fistula Abdominal compartment syndrome
ePTFE	Planned surgery	Simple relaparotomy Two-step surgery Good results	Expensive Difficult Many relaparotomies
Composix Bard	Planned surgery	Simple Good results	Expensive Difficult Many relaparotomies

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Incisional Hernia in Obese Patients

Luigi Angrisani, Michele Lorenzo, Pier Paolo Cutolo

Introduction

Incisional hernia is one of the most frequent complications of abdominal surgery [1,2]. Different aetiologies have been hypothesized, including patient factors such as older age, cancer, diabetes, malnutrition, chronic steroid therapy, and wound factors such as lower midline incision, re-incision and wound infections [3,4]. In abdominal surgery, by far, obesity has long been recognised as one of the most relevant conditions predisposing to the development of this very frequent complication of laparotomic surgery [4–6]. However, the introduction of laparoscopy in abdominal surgery for cholecystectomy and hysterectomy has produced a remarkable decrease in the incidence of incisional hernias. The wide diffusion of laparoscopy for the surgical treatment of obesity has also sharply reduced the dimension of this problem among bariatric surgical patients [7,8]. Nevertheless a consistent number of obese patients with incisional and/or recurrent incisional hernia are often referred to bariatric surgery centres because of the importance of extensive surgical and anaesthesiological experience in treating patients with this complex condition. By definition, in fact, obese patients are classified by the American Society of Anaesthesiology (ASA) as type III–IV, as respiratory insufficiency is obviously aggravated by the incisional hernia and potentially by its repair.

Staging of Obesity

Morbid obesity has been documented throughout history. Nonetheless, in several countries there has been an unprecedented increase in the last 25 years in the proportion of the population above the ideal body weight [9,10]. Several guidelines and classifications stratify the obese population according to body mass index (BMI), calculated as weight (in kg)/height (in m^2) [11,12] (Table 1). Comorbidities, i.e. disease associated with obesity (Table 2), may be various, at dif-

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ferent stages of progression and severely complicate the management of this complex clinical condition [13,14].

Table 1 International classification of adult underweight, overweight, and obesity according to body mass index (BMI)

Classification	BMI (Kg/m2) Principal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe thinness	<16.00	<16.00
Moderate thinness	16.00–16.99	16.00–16.99
Mild thinness	17.00–18.49	17.00–18.49
Normal range	18.50–24.99	18.50–22.99 23.00–24.99
Overweight	≥25.00	≥25.00
Pre-obese	25.00–29.99	25.00–27.49 27.50–29.99
Obese	≥30.00	≥30.00
Class I	30.00–34.99	30.00–32.49 32.50–34.99
Class II	35.00–39.99	35.00–37.49 37.50–39.99
Class III	≥40.00	≥40.00
Super-obesity	≥50.00	≥50.00
Malignant obesity	≥60.00	≥60.00

Table 2 Co-morbidities in morbidly obese patients

- Hypertension, left ventricular hypertrophy and heart failure, coronary artery disease (CAD)
- Diabetes and metabolic syndrome
- Obstructive sleep apnoea syndrome (OSAS), pulmonary hypertension, asthma
- Osteoarthritis, plantar fasciitis
- Cancer (pulmonary, breast, prostate, renal)
- Non-alcoholic steatohepatitis (NASH), cholelithiasis, acute pancreatitis
- Prothrombotic state, chronic venous insufficiency
- Polycystic ovary, birth defects, menstrual irregularities, infertility
- Intracranial hypertension, non-epileptic seizure
- Hernia and incisional hernia

Abdominal Compartment Syndrome

In the morbidly obese population, there is a high incidence and recurrence of incisional hernias following surgical procedures. Several studies have reported that obesity is a major risk factor for the development of incisional hernia [4–6]. This risk increased from 13% in patients with BMI <25 kg/m^2 to 39% in those with BMI ≥35 kg/m^2 [6], mainly due to elevated intra-abdominal pressure and decreased abdominal-wall resistance. The sequelae and deleterious multisystem effects of an intra-abdominal pressure >0–5 mmHg are well-documented in the acute setting and referred to as abdominal compartment syndrome [15,16]. While adequate weight loss is generally recommended before elective surgery, significant weight loss by conventional diet therapy is not feasible in obese patients.

Staging of Abdominal Hernia

Several classifications of incisional hernia have been proposed, none of which has been considered complete or gained wide acceptance [2,17,18]. The Schumpelick classification includes defect size, clinical finding and the intra-abdominal reducibility [17], but hernia size and reducibility have very little prognostic relevance as they give no indication of the best surgical treatment for each patient. The Chevrel and Rath classification differentiates between median and lateral hernia [2]. It also considers hernia size, number of recurrences and four anatomic subgroups. The drawback to this classification is its failure to consider the risk factors of body type and hernia morphology. Patient phenotype should be taken into account in planning the surgical approach for incisional hernia repair in obese patients; however, the recently developed laparoscopic intra-peritoneal technique of mesh placement independent of hernia size, morphology, recurrence, reducibility and risk factors has made the classification of incisional hernia of secondary importance.

Surgical Technique

Several studies have evaluated the various sites of abdominal incision, the different types of suture materials and the closure techniques needed to prevent and reduce the incidence of incisional hernia in the obese population undergoing laparotomic bariatric or non-bariatric procedures [4,19,20]. Most of these studies reported unsatisfactory results for wound infection and a high recurrence rate. These problems have been sharply reduced by the wide diffusion of laparoscopic access [21–24]. Indeed, the surgical management of incisional abdominal

hernia repair has undergone a remarkable transformation over the last two decades. The recurrence of the direct defect closure was previously reported to be 49% in obese patients [25–27]. Since the development and adoption of the tension-free principle of hernia repair together with the use of prosthetic materials, the outcome of surgical therapy of these lesions has markedly improved such that recurrence has been reduced to 8–17% [25–27]. The evolution and current technique of laparotomic access for incisional hernia repair (Rives-Stoppa technique) will not be discussed in this chapter, nor will the treatment and therapeutic strategy of managing acute clinical conditions.

Clinical and Surgical Scenario

In morbidly obese patients with incisional hernia, in the chronic setting, the bariatric surgeon is often called to offer advice regarding the various alternatives. Timing and technique depend upon the patient's requirements and the type of defect. The obese patient with incisional hernia who seeks treatment only for abdominal-wall repair should be extensively informed of the risks and prognosis of the obesity co-morbidities. While pre-operative weight loss is always advised, rarely, and only in very compromised and/or geriatric patients, can this goal be accomplished.

The majority of obese patients with incisional hernia are referred for treatment of both conditions. Two options are presently available:

1. Repair the incisional hernia at the same time of bariatric procedure.
2. Delay repair of the incisional hernia until after the patient has achieved optimal or significant weight loss.

Safety is the primary goal in surgery and the benefit of even minimal pre-operative weight loss (10% of excess weight) is well-documented in bariatric patients [13–28]. Although a diet very low in calories is usually recommended, the best approach to achieve even better weight-loss results is the endoscopic positioning of an intra-gastric balloon [28,29]. This procedure is usually performed under conscious sedation and it produces a space-filling effect with gastric distension and reduced food consumption. The balloon must be removed within 6 months after implantation and can be done so under local anaesthesia. A mean BMI loss of 4–5 kg/m^2 is generally achieved in 75% of patients who undergo this treatment [28,29]. In particular, super-obese patients with incisional hernia should be considered for pre-operative weight reduction with an intragastric balloon.

Timing of Incisional Hernia Repair

Once optimal or sub-optimal pre-operative weight loss is obtained, the choice of the bariatric procedure is discussed with the patient. Laparoscopic adjustable gastric banding (LAGB) and laparoscopic Roux en Y gastric bypass (LRYGBP)

are the two most common bariatric procedures performed world wide. The decision to treat at the same time or to defer repair of the abdominal defect is dependent on the hernia size. In patients with para-umbilical hernia (usually 3–5 cm in diameter), either primary or recurrent, the defect is closed during the same session, at the end of bariatric procedure. In such patients, the defect can be repaired by direct closure with trans-abdominal stitches, as done for closure of 12-mm trocar sites. A high recurrence rate (22%) has been reported with this technique [30]. The adoption of this strategy implies the possibility of definitive defect repair at the time of reconstructive abdomino-lipectomy. Mesh repair could also be considered for these small defects in order to reduce the risk of recurrence by simultaneously treating the obesity and the incisional hernia [19, 21,31–33].

In obese patients with large incisional hernias (>5 cm), treatment strategy and timing are controversial because there is a significant risk of complication and the need for re-operation. Eid et al. reported the deferred treatment of incisional hernia in LRYGBP as a dangerous strategy, resulting in more than one-third of small-bowel obstructions and requiring urgent surgical management [30]. Although unproven, those authors suggested that the high incidence of bowel incarceration could be the result of adhesiolysis, leading to freshly dissected edges of the defects and thus promoting accelerated bowel adhesion. However, adhesiolysis is mandatory to safely perform LRYGBP, especially in patients with an incarcerated bowel loop into a non-treated hernial sac. Simultaneous LRYGBP and direct closure of large abdominal-wall defect is discouraged because of the high rate of recurrence and the increased risk of bowel strangulation. Simultaneous LRYGBP and prosthetic repair of a large defect poses two main problems: the first is the immediate risk of post-operative mesh infection because of bowel contamination [34-36]; although not well-documented, this risk is absent in patients undergoing LAGB. The second problem common to both bariatric operations is the potential occurrence of anterolateral-wall shrinkage, with consequent mesh plication and bowel entrapment due to changes in abdominal-wall pressure and distension after weight loss, which modifies the hernia/mesh ratio.

Mesh Repair

The recently developed laparoscopic technique of incisional hernia repair is strongly based on the principle of intraperitoneal mesh implantation with radial and transparietal fixation. This technique is referred to as intra-peritoneal onlay mesh (IPOM) because the mesh is positioned on the bowel [18]. There are two main preconditions to laparoscopic IPOM: hernial sac resection and radial adhesiolysis. Mesh encapsulation of a non-resected hernial sac may lead to the accumulation of cystic fluid, which can be erroneously diagnosed as a recurrence. For the same reason, a hernial ring should be closed since mesh protrusion can mimic hernial recurrence [18].

Dual-layer meshes are commonly used since they remain directly in touch with intestinal loops without serious complications. The real limit of these prostheses is their very low torsion and tensile resistance, and thus the possibility of recurrence [22,37]. Recently, a xenogenic prosthesis derived from porcine small-intestinal submucosa was introduced into surgical practice [32–35]. This naturally occurring extracellular matrix is easily absorbed, supports early and abundant new vessel growth, and serves as a template for constructive remodelling. It is a non-allergenic, non-toxic and non-antigenic biological prosthesis, and its use has also been reported for laparoscopic repair in contaminated fields [34–36].

Laparoscopic Surgical Technique

Before undergoing any kind of bariatric procedure, all patients receive a detailed preoperative protocol study with clinical, laboratory, ultrasound (US) and X-ray examinations (Table 3).

Table 3 Protocol of preoperative investigations in patients who are candidates for bariatric surgery

Blood tests:
• Routine
• Thyroid hormones
• Serum cortisol
• Gastrin
• Hepatitis markers
Ultrasonographic scan of:
• Liver and biliary tract, pancreas and pelvic organs
• Thyroid
• Heart
X-rays examination of:
• Head
• Chest
• Gastrointestinal tract
Clinical consultation with:
• Cardiology
• Endocrinology
• Dietology
• Psychiatry
• Anaesthesiology
• Orthopaedics
• Gastroenterology
• Pneumology
Others:
• Spirometry
• ECG
• EGDS (*Helicobacter pilori* test)
• Doppler sonography of lower limbs

Pneumoperitoneum is usually created through the closed technique, with the Veress needle inserted 2–3 cm below the left costal margin, crossing the mid-clavicular line only if this area is made distant by the wall defect. Open access by the Hasson trocar can also be used but it essentially requires a mini-laparotomy because of the abdominal-wall thickness that is common in the obese. Due to the lack of intra-abdominal space in most such patients, it is crucial to place the trocar accurately, avoiding previous abdominal incisions and far from the incisional hernia, to facilitate the dissection manoeuvres and, ultimately, mesh fixation. Once the pneumoperitoneum is established, a 10-mm trocar is inserted and the abdomen is explored with a 30°–35° optic. During the operation, the optic is frequently changed in its orientation, including the inverted position, for correct visualisation of the posterior aspect of the wall defect. Three or four additional trocars are inserted laterally through the abdominal wall. Blunt and sharp omental and bowel dissection is usually necessary, possibly without ultrasonic, radiofrequency or monopolar energy sources, to avoid life-threatening intestinal complications. Atraumatic bowel forceps are usually used for intestinal manipulation. Once the hernia is identified, it is gently reduced by traction and counter-traction. Hernial borders are prepared and cleared of any adhesion for 4–6 cm radially. Sterile technique is used to place the mesh into a sterile dish. The mesh is then trimmed to overlap the abdominal defect for 4–6 cm, after which the prosthesis is introduced into the abdomen via a 10-mm trocar. Four full-thickness stitches are passed through a small abdominal incision to fix each prosthetic angle (Fig. 1). This fixation is followed by placement of titanium hel-

Fig. 1 Fixation of the prosthesis to the abdominal wall with non-absorbable stitches

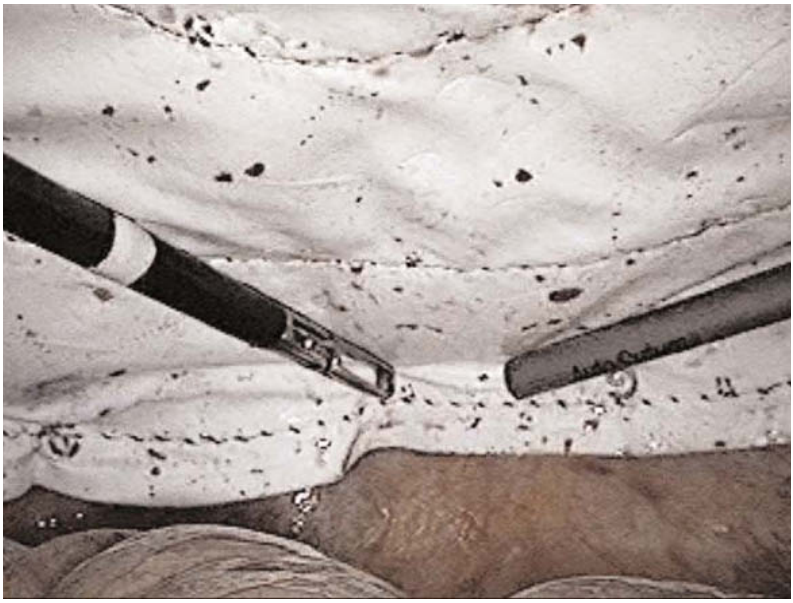

Fig. 2 Fixation of the prosthesis with titanium helical tacks at intervals of about 1 cm

ical tacks at about 1-cm intervals (Fig. 2). When this manoeuvre is done, the presence of abundant pro-peritoneal fat between the peritoneal layer and the posterior rectal sheet has to be taken into account in obese individuals.

Conclusions

Little information is available that defines optimal incisional hernia repair in morbidly obese patients. Studies that match patient co-morbidities, body habitus, hernia size and surgical treatment with long-term follow up are needed to develop evidence-based guidelines. In the absence of these guidelines, many surgeons proceed with careful patient assessment followed by planning for individual, tailored surgical treatment.

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Boundary Incisional Hernias. Diagnosis and Therapy of a Rare Pathology

Giuseppe Paolo Ferulano, Saverio Dilillo, Ruggero Lionetti, Michele D'Ambra, Domenico Fico, Domenico Pelaggi

Background

Incisional hernia is a frequent complication of abdominal surgery with an incidence reported in the literature of 2–20%. The condition is associated with local and systemic, potentially severe risks. The incidence of incisional-hernia recurrence is even higher, between 8 and 55%, depending on the initial type of repair technique. Thus, incisional hernia should be regarded as a serious and disabling clinical condition, with a poorly understood aetiology and dangerous complications, especially incarceration with resulting obstruction or necrosis of the bowel and omentum. Other aspects of incisional hernia must also be mentioned, such as total loss of the abdominal contents due to postural, respiratory, and dynamic deficiencies that impair overall physical activity and the daily quality of life.

Several risk factors associated with incisional hernia have been described, such as nutritional status, malignancy, obesity, metabolic diseases, wound complications or infection, gender and age; but the roles played by the type of laparotomy and the suturing technique are among the most important. An optimal laparotomy should balance adequate exposure for a safe visceral dissection with the risk of probable incision-related morbidity [1]. In fact, transverse abdominal incisions, compared with vertical incisions, are associated with a lower incidence of dehiscence, incisional hernia, wound complications [2] and chest complications, the latter due to the reduced muscular pain, which allows an earlier recovery of respiratory function. Suture techniques and materials have also been implied in the onset of local ischaemia and infection, which many authors regard as the main cause of early incisional hernia, as shown by Pollock, in an experimental clinical study [3,4], and more recently by Burger, in the abdominal wall computerised tomography (TC) [5]. It is well-accepted that in most patients a hernia forms within 3 months after the initial procedure [6], but in the literature a late incidence of more than 10 years was also reported. The latter case was most probably due to a progressive weakening of the abdominal wall, even after a perfectly healed abdominal wound [7,8]. This implicates other, largely unknown mechanisms, such as connective-tissue disorders, in the development of incisional hernia [9].

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

In order to more adequately treat incisional hernias, it is crucial to avail of criteria such as clinical data, surgical approach and the optimal material for repairing the abdominal wall with minimum complications. However, to date, there is no classification of incisional hernia that acceptably predicts surgical outcome, since the literature does not offer sufficient prospective or multi-centric studies or meta-analyses of randomised controlled trials. Recently, a classification was published that takes into account routine clinical scoring of the characteristics of the hernia as well as the prognostic risk factors for recurrence and provides evidence for the indications and limitations of the main surgical techniques [10].

The incidence of hernia following surgical incision of the lateral abdominal quadrants along the borders of bones, or more limited incision, is significantly lower than that following midline or extended incisions. These "boundary incisional hernias" also include perineal and lumbar hernias occurring in extra-abdominal areas.

Lateral Incisional Hernia

These hernias occur following subcostal or lumbar trans- and extra-peritoneal approaches during elective surgery, or as an outcome of emergency surgical reconstruction of traumatic lesions in an area extending from the intercostal region to the iliac crest, i.e. the lateral abdominal wall (Fig. 1). As is well-known, three muscle layers, the external and internal obliques and the transverse abdominis, form a barrier with different levels of resistance to endo-abdominal pressure. Lateral incisional hernias account for 15–43% of all incisional hernias [11]. Many of them occur near the attachment of the aponeurosis to the bone, which makes repair more difficult, particularly when prostheses for large or recurrent hernias are required (Fig. 2). The goal of mesh augmentation is integration of the mesh with the muscular and aponeurotic layers. This is mediated by the penetration of fibroblasts and results in a mesh/tissue compound able to prevent recurrence of the hernia.

Foreign-body-related irregular shrinkage of the mesh is quite unavoidable and requires an overlapping edge of at least 4–5 cm beyond the hernia in all directions, which precludes a correct subfascial preparation near the insertion to the osteochondral structure of the ribs or the pelvis.

Different techniques of mesh implantation have been described, such as mesh fixation, which is done with closely placed horizontal mattress sutures or with small loops of mesh placed around the costal arch and connected with the main body of the mesh [12]. However, the most frequent outcome of this approach is persistent pain, which results from encirclement of the bones with foreign material, which puts them under tension because the costal cartilages are ensheathed by a well-innervated perichondrium. Therefore, chondral or osseous mesh fixation should be avoided by skilled surgeons, who should instead dissect the pos-

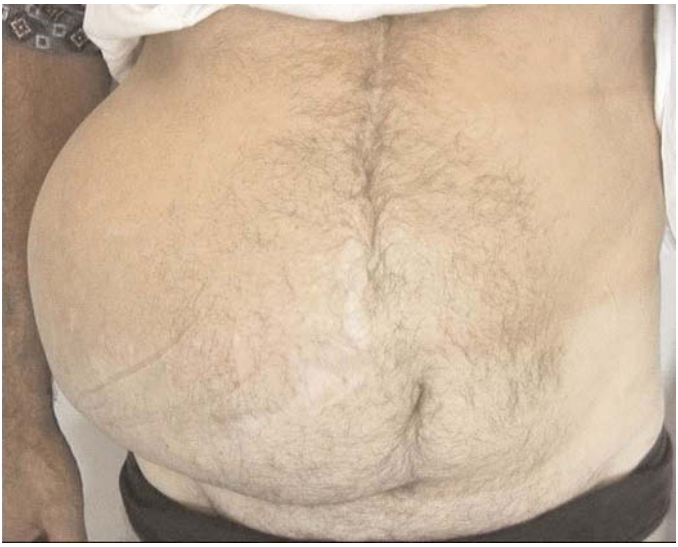

Fig. 1 Right subcostal incisional hernia

terior sheet of the rectus muscle from the side to the midline, from the dorsal or posterior side of the xiphoid, opening a retroxiphoid space sufficient to allow implantation of the mesh which can be furtherly enlarged, if necessary [13].

The laparoscopic approach, if indicated, allows implantation and fixation of the mesh without risk of osteochondral lesions or vascular or neural damage, as long as adequate amounts of non-invasive fixation material are used (Fig. 3).

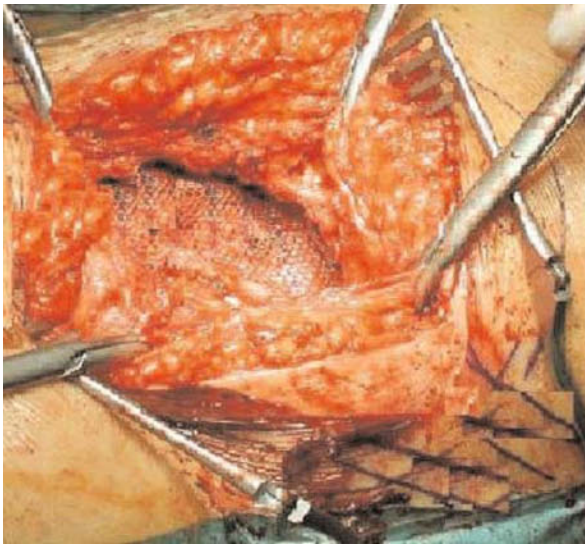

Fig. 2 Inlay prosthetic mesh in a left intercostal incisional hernia

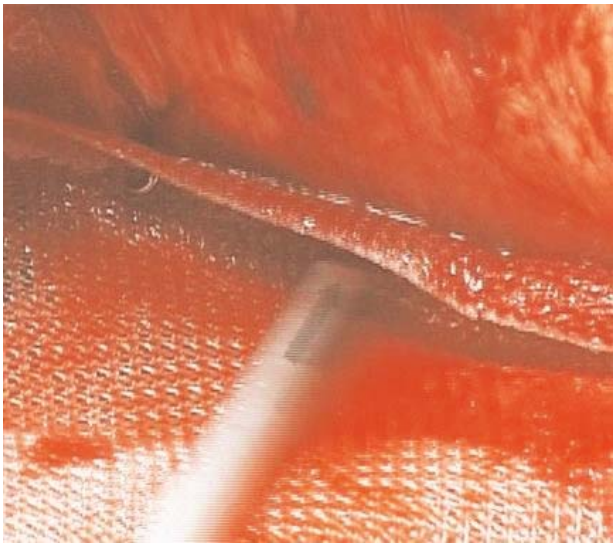

Fig. 3 Laparoscopic atraumatic fixation system in a subcostal incisional hernia (Q-ring fixation system, SALUTE)

Two factors determine the surgical approach and procedure: the size and type of hernia and whether it is primitive or recurrent. According to the literature, in cases involving a primary incisional hernia measuring less than 28–30 cm^2, in which the muscle and aponeurotic layers are easily detectable and detachable, and in patients suffering from deep local or general infection or sepsis, a simple layered suture is recommended because of the lower incidence of complications, such as mesh infection with subsequent extrusion and entero-cutaneous fistula. The recurrence rate is similar to that of mesh implantation, but the advantage of a layered suture is that the dynamic function of muscle contractility is preserved [14]. In the midline, the site of more than 75% of incisional hernias, primary approximation is possible and complete closure, which prevents visceral eventration, in a single step is possible when the "component separation" technique or its variations, i.e. aponeurotic partition/release, "sliding door" technique [15], and abdominal-wall partitioning [16], is used. These methods allow for a primary approximation of the aponeurotic defect without high-tension closures. They also allow mobilization of the lateral aspects of the abdominal wall towards the midline fascia of the rectus muscles in order to achieve closure of the hernia. Unfortunately, in lateral hernias or near the edges of the bones, component separation is ineffective since the primary approximation forces result in high tension on the hernial margins, with a subsequent recurrence as high as 50%. Nonetheless, over 90% of surgeons still implant polypropylene and polyester meshes mesh for recurrent lateral hernias [11].

Abdominal intercostal hernias are rare and difficult to diagnose; they occur through disrupted diaphragmatic and intercostal muscles as an acquired hernia of the abdominal viscera (colon or liver). Previously, surgeries such as radical

nephrectomy were the main cause, but many patients have a history of penetrating or blunt thoraco-abdominal injuries with rib fractures, such that the hernias are often located on the left-side distal to the eighth rib [17]. Clinical examination together with ultrasonography allow evaluation of the aponeurotic defect, which can be repaired by the placement of a non-absorbable synthetic mesh underlay. This technique has the lowest recurrence rate, since it provides continuity in the layer dividing the abdominal cavity from the abdominal wall, as in the Rives technique [18].

McBurney Incisional Hernia

Incisional hernia after appendectomy through a Mc Burney approach is rare today, occurring in less than 0.12% of operations for appendicitis, compared to 15% in 1950. The decline is mainly due to the improvement of surgical techniques and material [19]. Several anatomic factors seem to predispose patients to hernia: first, the transversalis fascia in this region may be obliterated, so that intra-abdominal pressure is placed on the internal oblique muscle, which easily thins and spreads apart. Consequently, the sac is directly exposed to the external oblique muscle and fascia, which is progressively attenuated laterally. The external oblique alone cannot hold the sutures and incisional hernia results.

Predisposing factors are often associated with poor tissue quality, challenging the surgeon's ability to treat post-appendectomy incisional hernia. Direct suture of this form of hernia is especially difficult due to the attenuated fascia created by the hernia, because the endo-abdominal fascia may not hold sutures well, particularly in patients with large defects. This type of hernia can be repaired by one of three techniques: (1) using a polypropylene or polyesther 12x10-cm tapered onlay mesh implanted into the external oblique fascia, (2) more effectively, by the placement of a "mesh sandwich" anteriorly and posteriorly to the rectus sheath [20] or (3) using the "giant prosthetic reinforcement of the visceral sac" repair described by Wantz [21]. The recurrence rate associated with each type of repair ranges from 7 to 17%.

Incisional Hernia from an Iliac-bone Grafting Site

Autologous bone grafting with material obtained from the anterior or posterior iliac crests is a frequent procedure in orthopaedic and maxillofacial surgery. The anterior iliac crest is the preferred site for harvesting bone cells because it is easily accessible, provides abundant bone with a high concentration of osteocompetent cells and is associated with a low morbidity. However, complications such as local pain, pathological fractures sensory loss, haematoma and herniation of the abdominal contents through the donor site have been reported. The elderly,

the obese, and individuals with poor abdominal musculature are at a higher risk of developing this type of hernia, particularly if a full-thickness graft or a graft larger than 5x5 cm is harvested. These hernias are usually noticed after several years but may manifest as early as 3–4 weeks after the primary surgery [22,23].

Diagnosis is best achieved with CT, since it yields high-quality images of the pelvic-bone anatomy and the aponeurotic planes following previous surgical repair, and shows the herniated bowel. CT can also guide the best surgical strategy and is useful in assessing surgical outcome.

Different surgical techniques have been described, each with the main goal of reducing the hernia by closing down the defect. Tissues advancement, imbrication and flaps have been used, as well as tantalium- or polypropylene-mesh prostheses. Another method of repair is to modify the iliac crest by moving the anterior superior iliac spine distally to reinforce the defect with its muscular and ligamentous attachments [24,25]. However, the best therapy is prevention, taking particular care while harvesting the bone, avoiding a full-thickness graft and preserving the inner surface of the ileum. If the defect is larger than 4–5 cm, repair should be made during the primary surgery, by implanting a polypropylene mesh after the bone has been sampled [23].

Pubic Incisional Hernia

Pubic and parapubic hernias are uncommon types of incisional hernia that follow abdomino-perineal or pelvic surgery, such as radical prostatectomy, but also other pelvic operations (bladder, uterus and rectosigmoid surgery) and bone traumas. Twenty-one cases are described in the literature [26], all of them rather complex, particularly those which are a consequence of malformations of the pelvic ring. In some cases, abdomino-pelvic ultrasonography is sufficient to differentiate these hernias from giant direct inguinal hernias, but indications for a laparoscopic approach must be based on a CT contrast scan that offers a detailed image of the pelvic anatomy. Such scans are very useful in locating the fixation sites for the polypropylene mesh, following the technique of Hirasa [27], which uses the peritoneum of the pubis and Cooper's ligament inferiorly. In open surgery, Bendavid [28] recommended plasty by entering the pre-peritoneal space; however, in case of polytrauma, when the patient has already undergone several operations, use of the intra-abdominal plane through an anterior transperitoneal approach provides a more secure vision of the perivisceral adhesions [29].

Perineal Incisional Hernia

Perineal hernias are infrequent complications of elective abdomino-perineal operations, including total pelvic exenteration, or following pelvic trauma.

These hernias were described by Scarpa, in 1821, as an abdominal visceral protrusion through a pelvic-floor defect. Moschcowitz, in the early twentieth century, studied the details of this complication and found an incidence of symptomatic hernia of approximately 7%. In recent reports, the incidence is much lower (0.2–1%) because of the prevalence of primary suturing of all the layers of the perineal wound. However, it should be added that many patients are asymptomatic or present with a more or less severe grade of perineal bulging, associated with sensation/discomfort in the upright position.

These complaints are very non-specific so that patients seldom attach any importance to them and thus do not consult their practitioners until more severe symptoms reflecting urinary or gastro-enteric disorders occur (about 7% of cases). Routine direct suture of the perineal wound at the conclusion of a surgical pelvic demolition, together with the overall progress that has been made in repair materials and the numerous types of patient support, explains the decreasing incidence of this pathology. The current literature ascribes other patient factors, such as obesity, diabetes, age, gender and smoking habits, to the development of perineal incisional hernia. The incidence of this pathology is particularly increased when more extensive surgery is performed, e.g. exeresis of the coccyx and sacrum, proctectomy associated with removal of the elevator ani muscles, or in patients with previous hystero-ovariectomy or radio-chemotherapy. All these elements make primary suture in the perineum more difficult or delay the scarring process. Contrary to published reports, immunodepression due to corticosteroids, such as in patients with inflammatory bowel disease, does not seem to be a risk factor for perineal incisional hernia.

Most patients suffering from hernia without severe symptoms need only a perineal T-bandage or elastic pants, but if there is interference with the quality of life surgical treatment is required. Two important studies, by the Massachusetts General Hospital in 1997 and the Mayo Clinic in 2006, compared three different access routes, abdominal, perineal and combined abdominoperineal, and evaluated the outcome and risks [30,31].

In the abdominal approach, the sac is isolated from above, after adhesiolisys of the viscera, and excised at the level of the defect to reveal the edges of the aponeurotic layers. While the omentum can be mobilised by an omentoplasty and used to cover the defect, more recently, for large hernias, a prosthetic polypropylene mesh is implanted, fixed on the aponeurosis and then covered by peritoneum and omentum. The incidence of recurrence after mesh placement, according to the two studies cited above, is 0%.

The perineal approach is based on vertical incision of the sac from below in order to free and reduce the visceral content in the abdominal cavity. This procedure is slightly more difficult because of the narrow space, such that a contemporary abdominal anterior access may be necessary at the conclusion. This approach has a recurrence of 15–37.5%, also in patients with mesh implantation [31], but perineal mesh implantation has the advantage of being less invasive and should be considered adequate as first surgical approach to the perineal hernia repair [32].

Alternative techniques include those using muscular flaps (gracilis, rectus abdominis, gluteus maximus) or free fascia lata flaps or, more recently, expensive bioprosthetic materials. The latter should be used in selected cases of infection that could lead to contamination of the synthetic mesh, or following a recurrence after mesh implantation.

Conclusions

Boundary incisional hernias have a lower incidence than hernias occurring in the midline and include most of the rare hernias. In some cases, they pose specific difficulties regarding their clinical diagnosis and the definition of the edges of the defect. However, both questions can be readily solved by ultrasound or CT examinations, which reveal both the anatomical details of the defect and evidence of visceral involvement. Problems related to the surgical procedure are more numerous and complex, particularly with respect to whether an open or laparoscopic approach is indicated, or to the optimal repair technique. Indeed, in these types of incisional hernias a more conservative approach, such as primary approximation suturing or aponeurotic transposition, is indicated more often than is the case for midline hernias, because of the smaller dimensions of the defect and, sometimes, the adverse local or systemic conditions that rule out implantation of a prosthetic mesh due to the higher risks of infection.

Furthermore, conservative non-prosthetic methods either allow the formation of a more elastic abdominal wall, with its own innervation and vascularisation, which preserves the dynamics of the muscular and aponeurotic layers, or dramatically lower the risk of infections and the formation of reactive seromas and haematomas. These procedures have a 10% rate of recurrence, similar or even less than that of mesh-type procedures.

In all cases of large or recurrent incisional hernias occurring in the borderline areas of the abdomen, the gold standard today, particularly in the laparoscopic approach, is mesh implantation, which assures good resistance to abdominal pressure and does not lead to painful abdominal tension.

In the future, a new generation of biologic prostheses will no doubt combine the advantages of the two repair techniques.

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Parastomal Hernia

Franco Catuogno, Giovanni Bartone, Maura C. Tracey, Feliciano Crovella

Introduction

Stomas should be considered as distinct organ since it has its own anatomy (made by the surgeon), physiology (strictly dependent on the gastrointestinal tract) and pathophysiology (variable and present in approximately 30% of patients with colostomy or ileostomy) [1]. The construction of a stoma, considered a simple surgical procedure, is associated with a high rate of complications. This should convince the surgeon that these complications must be prevented at the time of stoma construction "since quality is not due to chance, but it is always the result of intelligent efforts" (J. Ruskin, art critic, 1819–1900). Therefore, stomal complications should be avoided, even when the stoma is initially presented to the patient as a temporary situation (50% of the patients will never undergo bowel reconstruction).

However, complications can also be the consequences of inappropriate management of the stoma, since patients often are not adequately informed nor are they sent to the Stoma Unit, where they could be instructed and followed after appropriate rehabilitation [2].

The aetiology of stomal dysfunction can be primary, due to structural or functional alterations of the stoma, or secondary, due to recurrence of either the primary disease or other diseases affecting the stoma [1].

Primary aetiology is divided into acute (life-threatening and requiring emergency surgery), early (occurring in the first 30 postoperative days) and late. A secondary aetiology is always late. In both cases, the hospital stay is prolonged and the cost of hospitalisation rises, while rehabilitation of the patient is compromised as is his/her return to normal activities (family, work, society).

Predictive factors for complications after stoma construction are: (1) advanced age, (2) type of primary disease that required the construction of the stoma (cancer, colo-ileal ischaemia, intestinal obstruction, intestinal perforation), (3) presence of concurrent diseases (diabetes, obesity, liver cirrhosis), (4) urgency of surgery, (5) type of stoma constructed (transverse colostomy is associated with the highest rate of complications which is approximately 78%), and

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

(6) experience of the surgeon and (7) the degree of preoperative consultation with the stoma specialist [2].

Parastomal Hernia

Parastomal hernia is the most frequent complication and occurs in approximately 30% of patients with stomas who are followed for more than 2 years. It is more frequent after colostomy (2–37%) than after ileostomy (2–16%) [2]. The abdominal wall enlarges progressively because of detachment of the aponeurotic fascia from the loop of bowel used to construct the stoma, which allows the contents of the hernial sac and the peritoneum to migrate into the subcutaneous tissue. This complication occurs more often when (1) the bowel is brought through the apex of the laparotomy or laterally rather than through the rectus muscle, (2) the surgical incision of the muscles and fascia is larger than 3 cm, (3) conditions that increase abdominal pressure (obesity, constipation, chronic bronchitis, ascites, prostate hypertrophy) are present, (4) there is laxity of the abdominal muscles and (5) there is evidence of previous parastomal abscess or stomal stricture.

The diagnosis of parastomal hernia is usually made at the time of physical examination, with inspection and palpation of the stoma. Some manoeuvres that increase the abdominal pressure (the Valsalva manoeuvre or making the patient cough) allow better visualisation and palpation of the hernia, especially with the patient in the standing position [3].

A lateral stoma can be complicated by the complete herniation of the stoma or by a parastomal hernia. The latter can determine entrapment and strangulation of an intestinal loop in the subcutaneous tissue. This is a condition requiring immediate surgical treatment.

A terminal stoma, according to Malafosse [4], can be affected by the central herniation of the stoma (complete dehiscence of the abdominal wall, without a hernial sac) or by an incomplete herniation, which is characterised by an eccentric stomal orifice associated with a hernial sac containing small bowel (Fig. 1). This type of hernia has a slow evolution, with the patient complaining of slowly exacerbating abdominal pain and progressive difficulty in maintaining an adequate seal around the stoma. The latter can be usually managed by the patient thanks to the stoma bags currently available, which are soft, adaptable and manageable to the point that they can be firmly sealed to the stoma.

Moreover, in this situation, colonic irrigation (used to regulate the mechanical void of the colon) and the tests used to follow-up the primary disease (colonoscopy and/or double contrast-barium enema) become more difficult to perform.

In approximately 20% of cases, the parastomal hernia requires surgery. Indications for surgical hernia repair are usually recurrent intestinal obstruction and the inability of the patient to manage the stoma, which often compromise

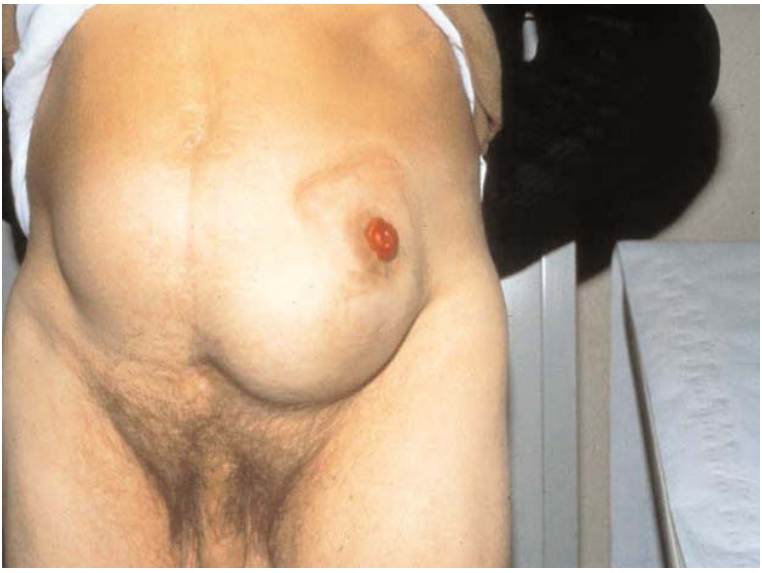

Fig. 1 Eccentric stomal orifice associated with a hernial sac containing small bowel

his/her quality of life. Sometimes, parastomal hernia repair is performed when the patient undergoes surgery for other concurrent complications of the stoma, such as prolapse, stenosis of the orifice or displacement of the stoma or during a planned bowel reconstruction (Figs. 2,3).

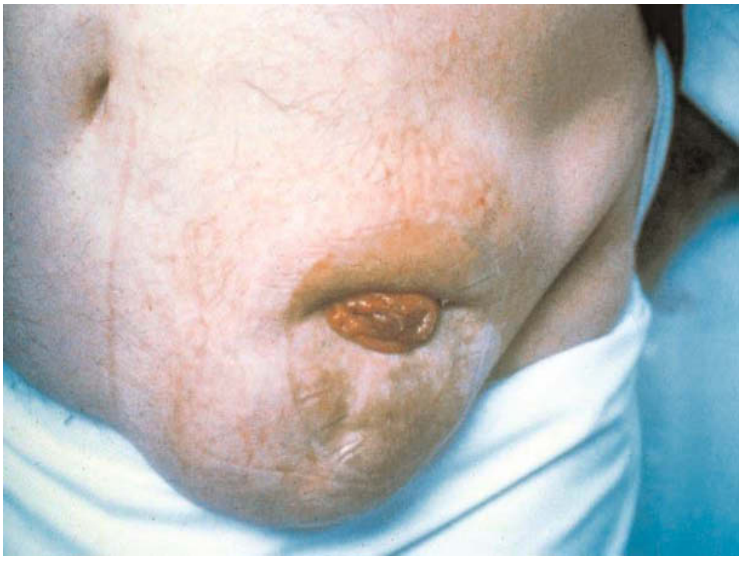

Fig. 2 Associated pathology: stenosis

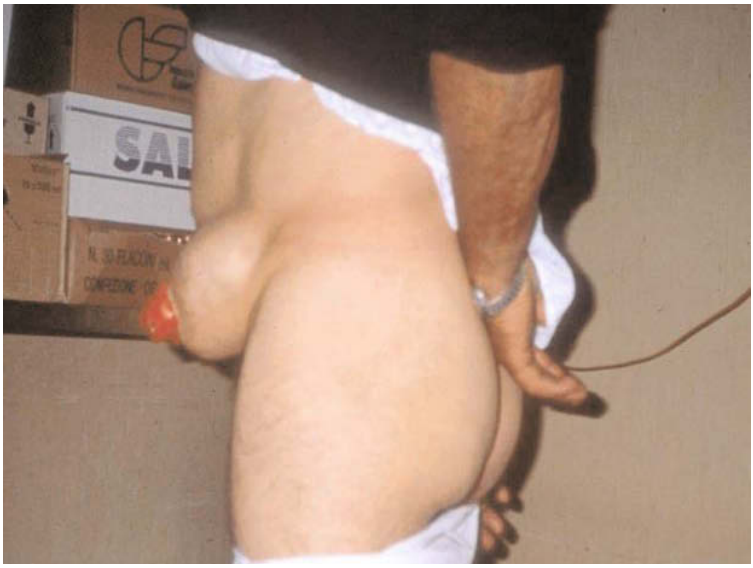

Fig. 3 Associated pathology: prolapse

In the case of parastomal hernia repair, it is difficult for the surgeon to decide when to intervene, i.e. at the time of the onset of the symptoms, to avoid the risk of bowel entrapment, or when the symptoms are frankly unbearable for the patient. Similarly, the choice of the surgical technique can be difficult because of the contradictory results reported in the literature. Surgery is indicated for patients in good health and with a permanent stoma. There are several surgical techniques available for parastomal hernia repair; however all of them are associated with a high recurrence rate of 33–75%. Whatever the surgical technique, the following are necessary: (1) standard bowel preparation including a fibre-free diet, consumption of oral laxatives and irrigation of the bowel if possible, (2) short-term antibiotic prophylaxis starting at the time of the anaesthesia, (3) careful surgical technique, with special attention to haemostasis and sterile technique, e.g. changing gloves after manipulation of the stoma and (4) suction drainage in the subcutaneous tissue.

Surgical Technique

For a small parastomal hernia, a parastomal access without a mesh is indicated. Thorlakson [3] suggested performing a semicircular skin incision in the lower abdominal quadrants, with the concavity towards the orifice of the stoma, approximately 5 cm away from the stoma itself. After the sac has been identified and then dissected away from the surrounding tissues, its contents are placed in

the peritoneal cavity and it is closed. Finally, the fascia and the muscles are closed with non-absorbable interrupted sutures.

In cases of parastomal access with superficial mesh, Lesile [5] recommended an L incision with a median incision carried down from the umbilicus to the pubis and a transverse incision from the inferior apex to the lateral border of the rectus muscle. The L incision allows better dissection of the sac. After replacement of the sac in the peritoneal cavity and closure of both the aponeurosis and the muscles, two Marlex meshes are placed around the stomal loop, surrounding it completely. A new mucocutaneous anastomosis is then performed to complete construction of the stoma.

Tekkis [5] modified the technique proposed by Thorlakson. The skin incision and the steps used for the identification, dissection and closure of the sac are the same, while closure of the abdominal wall is completed by the placement of a Marlex mesh around the orifice of the abdominal wall through which the bowel exits to the skin for the stoma construction. However, the Marlex mesh is not directly in contact with the bowel due to a V cut in its superior border of approximately 30°.

Both techniques avoid a laparotomy, and are simple, but they require placement of the mesh above the superficial aponeurosis, which is a septic space!

Parastomal access with deep mesh is carried out to avoid placement of a mesh in a septic space. Instead, a fenestrated mesh (polyester or polypropylene mesh) is placed between the two layers of the aponeurosis. The stoma is dissected from the skin and the subcutaneous tissue and then temporarily closed with a linear stapler. At the same time, an appropriate space between the posterior aponeurosis and the anterior aponeurosis is prepared. The mesh is then placed in this surgical space and fixed to the posterior layer, while the anterior layer is closed above the mesh. Surgery is concluded by a new mucocutaneous incision and reopening of the bowel to reconstruct the stoma.

A transperitoneal parastomal repair without transposition of the bowel loop is carried out either without or with a mesh. The former is used only for the repair parastomal hernias associated with other problems of the stoma, such as retraction, stricture or perforation. The fundamental technical step is the passage of the bowel loop under the peritoneum. The procedure involving a mesh was suggested to avoid the risk of local infection.

Culleret [5] used a median laparotomy, followed by dissection and closure of the sac, which is placed into the peritoneal cavity. Subsequently, the internal orifice is closed with the help of a mesh placed below the parietal peritoneum.

Kasperk [5] recently suggested placing a non-absorbable mesh posterior to the muscles and anterior to the parietal peritoneum. Also in this case, surgery begins with a median laparotomy, followed by dissection and closure of the sac, with its placement within the peritoneal cavity. A large mesh is then placed between the rectus muscle (posterior) and the posterior aponeurosis (anterior). The mesh contains a hole that allows passage of the bowel loop, which is fixed to the aponeurosis for the construction of the stoma.

Laparoscopic Access

Recently (2000), a laparoscopic approach has been used to repair parastomal hernias. The technique is similar to laparoscopic repair of ventral and incisional hernias. The parietal defects due to parastomal hernias are localised in a critical area, where the large muscles of the abdomen and the rectus muscles exert opposing forces. Therefore, it is mandatory to use meshes for to repair parastomal hernias at the time of laparoscopic surgery.

Peristalsis of the bowel is a continuous force that determines and then progressively enlarges a parastomal hernia. The latter is made worse by concomitant factors, such as the side effects of chemotherapy and/or radiation therapy, which are often necessary for treating neoplastic patients with a stoma. Indeed, the incidence of recurrent parastomal hernia in the subset of neoplastic patients is high, even when a mesh was placed in the initial repair of the hernia.

Open surgery is the gold standard for repairing parastomal hernias by means of a mesh. However, the operative field is often septic such that there is a high risk of contamination of the mesh. Furthermore, it is sometimes difficult to place the mesh properly, large incisions may be necessary and/or the original stoma must be removed and a a new stoma constructed in a different position.

Laparoscopic surgery for the repair of parastomal hernias is minimally invasive and a sterile field to be maintained. Therefore, laparoscopy should become the gold standard for the repair of parastomal hernias in selected cases, such as when there is a high risk of bacterial contamination. However, laparoscopic surgery is difficult in those patients requiring the repair of a parastomal hernia. In these patients, previous surgery has usually resulted in visceral adhesions, which are often worsened by chemotherapy and/or radiation therapy. In fact, adhesions make difficult the identification of the bowel which had been used for the construction of the stoma. The latter is sometimes identified with the help of a colonoscope passed intraoperatively through the stoma itself. Finally, it may be difficult to properly identify and dissect the hernial sac, with a high risk of vascular lesions.

After complete dissection of the hernial sac and identification of the parietal defect, the hernia is surgically repaired by following all the laparoscopic steps used for repairing incisional hernias. However, in this case, the mesh has to allow passage of the bowel used for the construction of the stoma. Therefore, it is necessary to choose a mesh with a central hole, or the mesh has to be large enough to enwrap the bowel segment used for construction of the stoma.

The first technique is simple and has been the best choice in our hands. However, the hole in the mesh is a weak point that can jeopardise repair of the hernia. The bowel is sutured to the hole of the mesh by means of non-absorbable interrupted sutures, but these can compromise vascularisation of the bowel itself. Moreover, the bowel can slide into the residual space between the mesh and the sac.

In the second technique, the mesh enwraps the bowel used for the construction of the stoma while the parietal defect is closed to repair the parastomal hernia. A large mesh is used to close the parietal defect and then enwrap 6–7 cm of

bowel. After the parietal defect has been closed, the mesh is sutured to construct a tunnel around the bowel (Fig. 4). The latter is maintained in a straight position, without folding of the mesh, and easily reaches the stoma without the creation of dead space between the mesh and the parietal wall. While the initial results of this technique have been positive, further randomised studies are needed.

In the laparascopic approach, a transperitoneal parastomal repair with transposition of the bowel loop (Fig. 5) can also be carried out without or with a

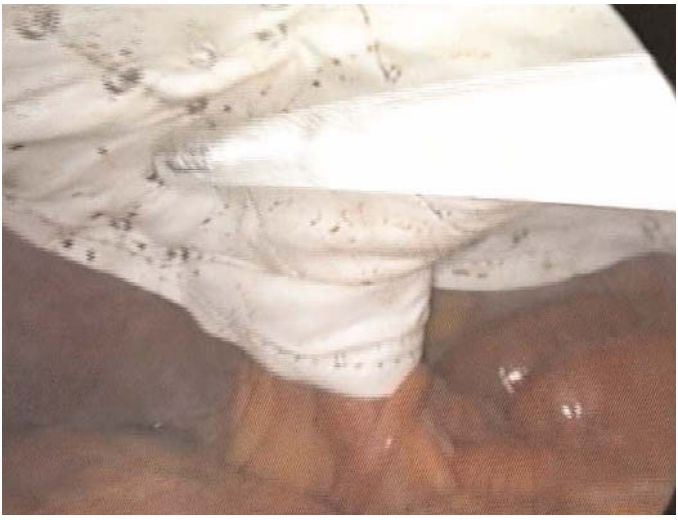

Fig. 4 The mesh is sutured to construct a tunnel around the bowel

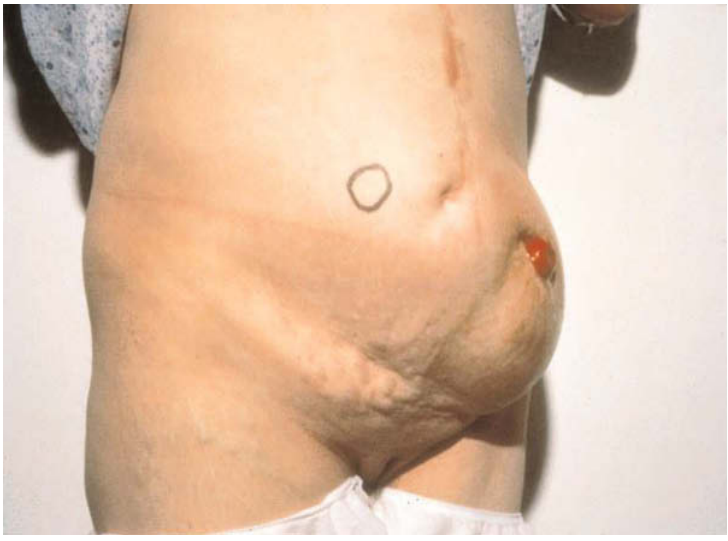

Fig. 5 The new site of transposition of the bowel loop

mesh. The former is the simplest technique and consists of a median laparotomy, followed by elimination of the previous stoma and closure of all the abdominal layers. A a new stoma is then constructed in a different, appropriately chosen site. However, there are several problems with this type of surgery: (1) a long operative time, (2) frequent postoperative paralytic ileus, and (3) a high rate of incisional hernia. Thus, this procedure is indicated only if a local approach is contraindicated or there is clinical suspicion of hernial strangulation.

In a surgical approach involving implantation of a mesh, the procedure of Alexandre [3] included all the advantages of the aforementioned surgical procedures: (1) peristomal access, (2) dissection and temporary closure of the stoma with the bowel loop left in the abdominal cavity; (3) identification and dissection of the sac which is then closed and placed in the peritoneal cavity, (4) preparation of an appropriate surgical plane and placement of a 20x25-cm fenestrated Mersilene mesh. This plane is delimited by the posterior aponeurosis of the rectus muscle, the rectus itself and the small oblique, large oblique and transverse muscles. The plane needs to be large enough to overcome the site of the new stoma and the colon has to be long and mobile in order to easily reach the site of the new stoma. The mesh is sutured to the posterior layer with absorbable interrupted sutures and a drain is left in the anterior musculofacial plane for a few days. The site of the previous stoma is then closed by suturing all the layers, and a new skin incision of approximately 3 cm is made. Through the latter, the anterior aponeurosis, the rectus muscle, the mesh and the posterior aponeurosis are sectioned to allow passage of the bowel loop. Eventually, this will be sutured to the fascia and then to the skin in order to construct the new stoma, which is completed by the opening of the bowel mucosa.

Conclusions

The use of a mesh, although avoided by some surgeons because of the risk of infection, seems to give positive results in the repair of parastomal hernia. By contrast, the simple suture of the abdominal layers around the stoma, made by means of a local access, is associated with a high rate of recurrence (75%). The soft mesh (polyester, polypropylene or mixed) does not create strong adhesions among the bowel loop, the mesh and the abdominal wall. Indeed, the mesh reinforces the wall and is necessary in the treatment of a recurrent parastomal hernia. The mesh has to be placed deeply between the two muscle layers, which reduces the risk of infection due to the fact that the mesh is thus not in contact with possible postoperative haematomas or subcutaneous fluid collections. However, this technique still has a high rate of recurrences (33%), while the feared complication of perforation of the bowel loop has been reported only once, to date [5].

Recently, some authors proposed using a mesh at the time of primary construction of the stoma, to prevent parastomal hernias [6–8]. The mesh can be

placed even when access is local. The latter approach does not preclude a median laparotomy, if needed.

The laparoscopic approach is too recent and cannot be properly evaluated due to the lack of follow-up. It may be indicated for the repair of small parastomal hernias that do not require new placement of the stoma. Since it is not possible to avoid the surgical repair of parastomal hernia, when needed, despite the low-level performance of this surgery, we believe that there is a need to construct primary stomas with high accuracy, taking all the time necessary to do the job well. In our opinion, this is the best answer to the English surgeon who asked himself "why to save the life of a patient if it entails the loss of her/his joy of life and social life?" [9].

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Emergency Laparoscopic Repair of Complicated Ventral and Incisional Hernias

Micaela Piccoli, Marco Ferronato, Riccardo Morici, Ivan Gentile, Fouzia Mecheri, Gianluigi Melotti

Introduction

Laparoscopic repair of ventral and incisional hernias has gained wider acceptance among surgeons than the open technique, due to the favorable results in terms of incidence of recurrences, complications, and patient satisfaction. Most of the series published in the literature concern elective cases [1–7]. By contrast, the role of laparoscopy in the treatment of incarcerated or strangulated ventral hernias is not yet established because of the small number of case series and case reports [8–12].

We analyzed retrospective data on complicated (strangulated or acutely incarcerated) ventral and incisional hernias that required emergency treatment. The series consisted of patients treated by a laparoscopic approach during a 5-year period, from January 2002 to December 2006. For each patient, the following demographic, preoperative and postoperative data were reviewed retrospectively: age, sex, co-morbidities, previous hernia repair, operating time, size of the defect, type of prosthetic mesh implanted, intra- and postoperative complications, conversions to open technique and recurrences.

All patients were admitted to the Emergency Department of our hospital and the diagnosis of incarceration or strangulation was made by clinical examination, blood tests and abdominal imaging (plain radiograph, contrast enema, ultrasound, CT scan). After a failed attempt at gentle manual reduction of the hernia's content, the decision of repair using a laparoscopic approach was made by the senior surgeon on call, who was experienced in laparoscopic surgery. Contraindications to laparoscopic repair included clinical, blood test and/or radiological findings of intestinal gangrene [13], severe abdominal-wall infection, very large defect and the presence of comorbidities that precluded induction of the pneumoperitoneum. The patients were operated under general anaesthesia within 6 h after their admission to the Emergency Department. A single dose of 3 g ampicillin/sulbactam was administered intravenously after induction and repeated if needed during the operation and the postoperative period. Discharge from the hospital was allowed when the patient was afebrile and had clean wounds, regular bowel movements and well-tolerated pain.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

Operative Technique

The pneumoperitoneum was obtained with a Veress needle inserted at a site far from the previous scar or hernia in the upper abdominal quadrants (generally on the left side) (Fig. 1). After the insertion of a 30° endoscope, through an optical trocar, the abdomen was carefully inspected to assess the feasibility of the procedure (Fig. 2). Two or three additional trocars were typically placed laterally in the left abdomen under direct visualisation. After cautious adhesiolysis (if necessary) with sharp dissection (Fig. 3) followed by identification of the defect with its content, the first step of the procedure was to create a releasing incision of the hernial ring using cold scissors (Fig. 4), which aided in spontaneous reduction of the content in the abdominal cavity without any traction. The content of the defect was then accurately checked, examining its vascularisation, motility and integrity. No bowel resection was performed by laparoscopy. The peritoneal sac was left in situ; in some patients, argon-beam scarification of the hernial sac was performed to achieve a satisfactory haemostasis and to prevent seroma formation. After the dissection was completed, the hernial defect was measured and the prosthesis mesh was appropriately tailored to overlap all edges of the defect by at least 4–5 cm. In 11 patients, expanded polytetrafluoroethylene (ePTFE) (Gore-Tex Dual Mesh Plus; WL Gore & Associates, Flagstaff, AZ, USA) and in three patients polypropylene + ePTFE (Bard Composix E/X; Davol, Cranston, RI, USA) was used to cover the defect. After the mesh was positioned and unrolled intracorporeally, sutures placed in the prosthesis at the four cardinal points before its insertion (Fig. 5) were used to accurately place the mesh due to their traction from the outside (Fig. 6). The mesh was then secured to the abdominal wall by 5-mm spiral tacks (Protack Tyco Healthcare Group LP,

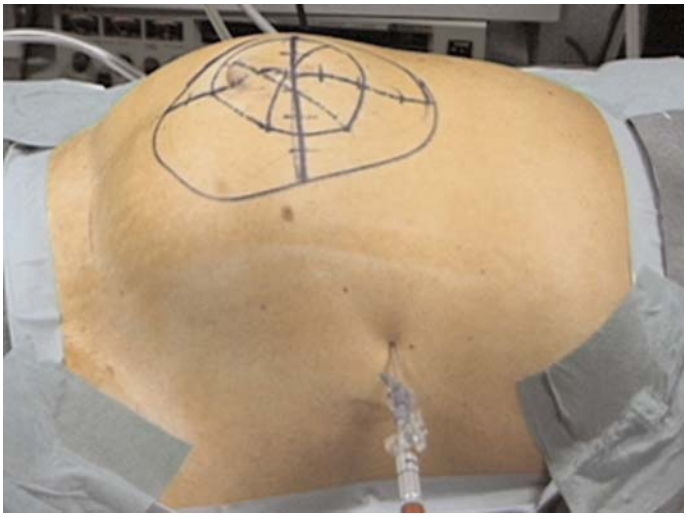

Fig. 1 Pneuperitoneum induction with Vereness needle in left hypocondrium

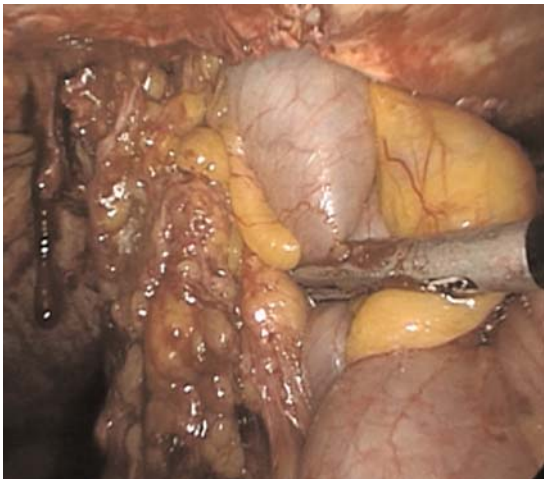

Fig. 2 Incisional hernia with incarcerated ileum and omentum

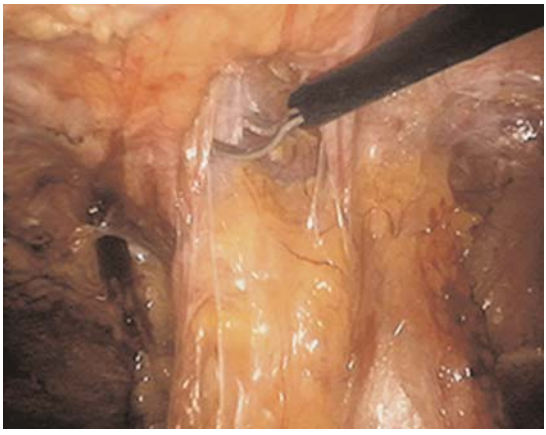

Fig. 3 Cautious adhesiolysis with cold scissors

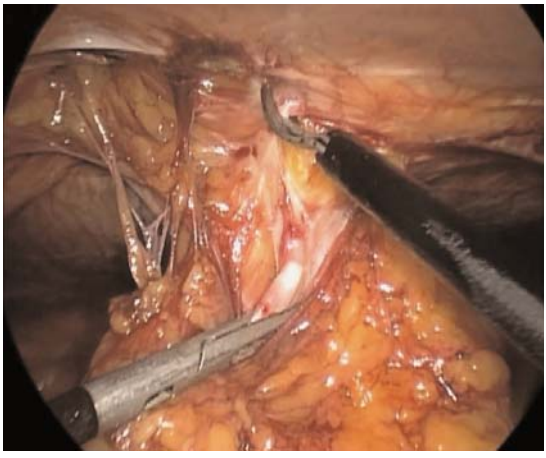

Fig. 4 Releasing incision of the hernia ring with cold scissors

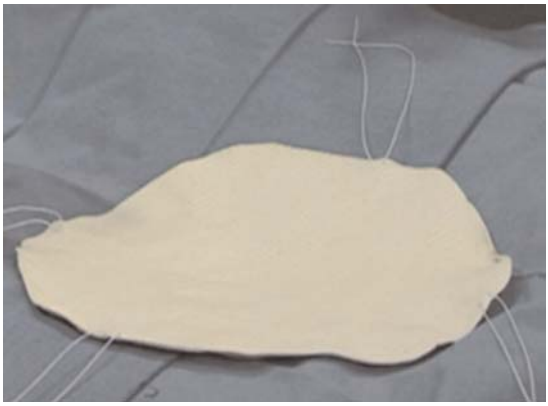

Fig. 5 Mesh with sutures placed at the four cardinal points

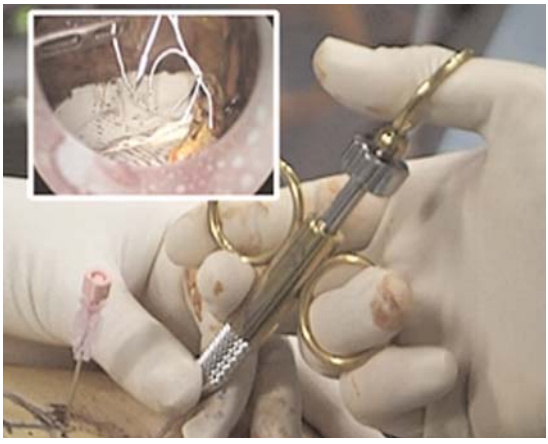

Fig. 6 Mesh placement through traction of the sutures from the outside

Norwalk, CT), with an outer crown of tacks placed directly on the edge of the mesh and several placed internally to attach the mesh firmly to the fascia. The four cardinal sutures were removed at the end of the procedure from the outside. No drains were inserted.

Results

From January 2002 to December 2006, 19 patients underwent laparoscopic emergency surgery for complicated ventral hernias. There were 16 women and three men; the median age was 66.4 years (range: 45–94). The comorbidities were hypertension (5 patients), diabetes mellitus (2 patients), obesity (5 moderate, 1 morbid), chronic obstructive pulmonary disease (2 patients) and chronic

heart failure (1 patient). The type of hernia, site, diameter of the fascial defect, content and recurrence, according to the Chevrel classification [14], are listed in Table 1. In four patients, repair started by a laparoscopic approach was converted to laparotomy (conversion rate 21%): in three patients conversion was necessary due to massive bowel dilatation and in one patient due to a necrotic ileal segment incarcerated in an umbilical hernia. These patients were excluded from further analysis. The mean operative time was 106.8 min (range 50–180) and the mean postoperative hospital stay was 5.75 days (range 2–12). In two patients, a necrotic omentum was resected. Peri-operative complications occurred in two patients (14%) and included one serosal colic tear and a full-thickness small-bowel injury, both of which were repaired intraoperatively. In one patient, a concomitant left ovariectomy was performed for a 10-cm adnexal mass, discovered on preoperative CT scan (ovarian teratoma). In another patient, a metastatic omentum, associated with an unknown peritoneal carcinosis, was incarcerated in a small incisional hernia that was treated by a releasing incision of the hernial ring, without placing a patch. The patient died 1 month later due to the neoplastic disease.

Table 1 Study characteristics

Hernia type	Defect site	Defect size	Content	Recurrence
Ventral (9)	Umbilical (6)	W1	Omentum/ileum	R0 (3) R1 (2) R2 (1)
	Epigastric (1)	W1	Necrotic hepatic falciform ligament	R0
	Right spigelian (2)	W2 W1	Omentum	R0 R1
Incisional (10)	L3 (1 right, 1 left)	W1	Necrotic omentum	R0
	M1 (2)	W2	Omentum (1) Omentun/stomach (1)	R0 R1
	M2 (4)	W1 (3) W2	Omentum (3) Omentum/transverse colon (1)	R0 (3) R1 (1)
	M3 (2)	W1	Omentum (1) Ileum (1)	R0

One patient developed peritonitis (morbidity rate 7%) on the fourth postoperative day. This was the result of an unrecognised colonic injury that required re-laparotomy with a stoma creation and removal of the mesh; the abdominal

wall was then simply sutured. The patient was discharged after 12 days and the ileostomy was closed, some months later, at another hospital. Seromas developed in two patients in the early postoperative period and were treated conservatively; in both patients, the condition was completely resolved within 6 weeks. The mortality rate was 0% (barring the patient who died due to neoplastic disease). The follow-up period ranged from 2 to 42 months (median 17 months). During the follow-up period, none of the patients manifested clinical signs of mesh infection or hernia recurrence.

Discussion

Laparoscopic repair of incisional and ventral hernia is a good therapeutic option in selected patients with complicated conditions requiring emergency surgery. This strategy is particularly recommended in cases of strangulation or incarceration, which could have an unfavourable outcome especially in elderly patients and patients with severe comorbidities. Following the first report of laparoscopic ventral hernia repair, in 1993 [15], the operation has grown in popularity, since it leads to fewer complications, shorter hospital stays and better outcomes than the traditional open procedure. Several comparative studies have confirmed this assertion in elective situations [1–7]. However, apart from case reports [11,12] and a few case series [8–10], the role of laparoscopic treatment of ventral hernias in emergency situations involving strangulation and/or incarceration has yet to be established, due to the reluctance of clinicians to use this approach in these situations. Instead, a traditional open approach is still preferred, usually without placement of a mesh. The aim is thus resolution of the life-threatening condition whereas permanent repair is postponed. Nonetheless, there is evidence for the superiority of the laparoscopic approach in treating various abdominal emergencies [16–20].

In 2005, the Consensus Conference of the European Association of Endoscopic Surgery (EAES) developed evidence-based recommendations for the laparoscopic treatment of abdominal emergencies. These stated that the open approach remains the standard treatment for incarcerated hernia, although laparoscopic surgery may be considered in carefully selected patients albeit restricted to surgeons with maximum expertise in this field [21]. The promising results of our initial experience support this recommendation.

We began performing elective, laparoscopic repair of ventral hernias in 1999; since then more than 250 patients have been treated by this minimally invasive surgery, with results comparable to those of series published in the literature. Our experience in the treatment of emergency cases started in 2002, after a reasonable learning curve that yielded satisfying results.

The main issues regarding emergency laparoscopic treatment of complicated ventral hernias are technical feasibility, the increased risk of infection of the

mesh, procedure-related complications weighed against the potential benefits of minimally invasive surgery.

Laparoscopic repair of abdominal hernias modifies the complications that can be expected after the conventional open approach. In the latter, morbidity depends almost exclusively on the wound and on the systemic complications, due to the augmented invasiveness of the technique. In laparoscopic repair, the risks of visceral lesions and subsequent sepsis with fatal consequences are significant [22–24]. It is therefore crucial to perform proper adhesiolysis in order to adequately identify the hernia defect, thus allowing proper placement of the mesh. This is particularly important in the emergency setting due to bowel distension, associated with vascular compromise with possible development of necrosis and contaminated effusion together with the impossibility of adequately cleaning the bowel preoperatively. During our experience, three patients were quickly converted to an open technique due to the dense adhesions (precluding complete inspection or adhesiolysis) and massive bowel dilatation. As reported by Suter et al., a bowel diameter exceeding 4 cm on plain abdominal film sets a lower threshold for conversion but is not considered a contraindication to laparoscopy [25]. In a fourth patient, the presence of a necrotic ileal segment with contamination of the abdominal cavity required the conversion to open repair. There were two intraoperative complications in our series: in one patient, a serosal colonic tear occurred during adhesiolysis and in another patient an accidental small-bowel injury, without spillage of intestinal fluid into the abdominal cavity, was discovered. Each of these injuries was repaired laparoscopically; a mesh was placed intraperitoneally and the postoperative period was uneventful. The incidence of recognised enterotomies ranges from 6 to 14.3% [26,27], and management of this condition is somewhat controversial. In many centres, the injury is repaired either laparoscopically or by conversion to open technique, with repair of the hernia deferred [28]. Recently, some clinicians, including ourselves, have reported the feasibility of repairing the enterotomy laparoscopically. In those patients whose injury is not associated with a large amount of spillage of the intestinal contents, the procedure can be completed by the application of a mesh [29,30].

The major postoperative complication in our experience was the development of peritonitis due to unrecognised colonic injury. This condition is known to occur in up to 6% of patients [31,32] and can lead to fatal consequences, with a 0.3% risk of mortality [33,34] Two mechanisms of bowel injury have been described: (1) direct trauma from scissors with no intraoperative manifestation and (2) an indirect lesion due to energy source and the formation of ischaemic tissue, with subsequent necrosis causing perforation [24,35]. This means that a strict early-postoperative examination is necessary to identify suspicious symptoms and signs, such as fever, leucocytosis and increasing abdominal pain, in order to establish a correct diagnosis and reoperate as soon as possible. As some authors have suggested, bowel injuries and mortality risk both tend to decrease as the surgeon’s experience exceeds 50 cases [22,23,27].

Conclusions

Our initial experience of emergency laparoscopic ventral hernia repair has confirmed the feasibility of this strategy and the advantages of the minimally invasive approach, in particular for the elderly. Nonetheless, it should be restricted to carefully selected patients and must be adopted by well-trained surgeons. The contraindications are: massive bowel dilatation, very large defect and the presence of contamination of the abdominal cavity. Accurate control of the intestinal loops should be performed at the end of the procedure to confirm the absence of injury and thus avoid complications. However, if adhesiolysis or release of the incarcerated bowel cannot be done safely, the procedure should be converted as soon as possible.

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Porcine Dermal Collagen Graft in Complicated Incisional Hernia

Mariano Fortunato Armellino, Guglielmo De Stefano, Giovanni Bartone, Giovanni De Stefano

Introduction

Several techniques for the repair of abdominal-wall defects and incisional hernia have been described. Primary repair, with or without discharge incision on the rectus muscle sheath, and other closure techniques such as aponeurotic flap, myocutaneous flap, skin or fascial graft, are still associated with high recurrence rates, especially in complicated incisional hernias.

The use of new prosthetic meshes has been an advance in incisional-hernia repair and has become prevalent worldwide, allowing easy surgical repair of large and complicated abdominal-wall defects and associated with lower recurrence rates. Polypropylene-mesh repair is the gold standard for inguinal hernia and incisional hernia. These meshes have led to an evolution in abdominal-wall surgery through surgical repair of complicated incisional hernia and bilateral giant groin hernias.

Nonetheless, wound infection and bowel fistulas are contraindications to polypropylene-mesh repair. In addition, synthetic meshes are known to cause severe peritoneal adhesions and enteric fistulas if placed close to the bowel. When a synthetic-mesh repair is performed in a patient with a wound infection, enteric fistula, or stoma, there is a high risk of mesh infection or mesh rejection.

Reabsorbable meshes (e.g. polyglactin) may be placed close to the bowel, but they are associated with a high recurrence risk because they weaken as they dissolve.

Nonabsorbable PTFE meshes have the advantages of both polypropylene and absorbable meshes, but they do not become integrated with host granulation tissue and there is a consistent risk of seroma formation.

A new, recently introduced material in the surgical armamentarium is porcine dermal collagen graft (Permacol® Tissue Science Laboratories, Hampshire, UK), which is a xenogenic mesh. After several tests on animals, it has proved to be safe and thus useful in many types of surgery.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

Animal Studies

Porcine intestinal submucosa has been used successfully to repair large abdominal-wall defects in dogs and rats [1,2]. Porcine intestinal submucosa initially elicited a granulation and foreign-body response; later, the granulation tissue was replaced by fibroblasts and incorporated into the host tissue [2]. The connective tissue formed was organised, with fibroblasts and fibres aligned in a direction parallel to that of the adjacent fascia [1]. Conversely the connective tissue formed by polypropylene mesh was poorly organised, with fibres orientated around the mesh, foreign-body reaction and persistent inflammation [1]. Porcine intestinal submucosa was also associated with fewer adhesions than polypropylene mesh and was resistant to infection despite bacterial challenge [1].

A histological evaluation of Permacol as a subcutaneous implant in the Sprague-Dawley rat model showed that the material was well-tolerated as a subcutaneous implant, with only a minor chronic inflammatory response 20 weeks after implantation [3]. Another study evaluated adhesion formation following intraperitoneal implantation of either acellular porcine dermal collagen (PDC) or a polypropylene mesh in Wistar rats. The rats were examined at 4 and at 12 weeks post-operatively and the extension, severity and histology of the adhesions were evaluated. PDC was associated with fewer adhesions and a more favourable cellular response (infiltration with neovascular channels, qualitatively less intense foreign-body reaction) than was the case with the polypropylene mesh [4].

Properties of Porcine Dermal Collagen

Porcine dermal collagen is the result of 25 years of research by scientists at Dundee University. The mesh consists of a sterile, off-white, moist, tough but flexible, flat sheet of acellular PDC and its constituent elastin fibres. The manufacturing process renders the collagen acellular and thus non-immunogenic while enzymatic treatment removes non-collagenous proteins and cellular debris. However, the native 3D natural collagen structure is neither modified nor compromised. Cross-linking of PDC with hexamethylene diisocyanate (HMDI) prevents collagenase digestion and biodegradation of the implant; it also stabilises the PDC and thus extends the lifetime of the graft, reduces the inflammatory response and immunological reaction to the graft and allows neovascularisation of the implant.

Unlike other medical collagen products, PDC collagen is maintained in its original three-dimensional form rather than being reconstituted. This material is non-allergenic, non-immunogenic and non-toxic and does not elicit a rejection or foreign-body response. In addition to having a tensile strength comparable to that of synthetic meshes and a biocompatibility similar to that of natural tissues, PDC is rapidly colonised by small blood vessels and by fibroblasts and incorpo-

rated into the host tissue. This product has been approved for use in Europe since 1998 and received clearance from the Food and Drug Administration in February 2000 for use in the USA [5].

Clinical Applications of PDC

In 2001, Harper [5] described the results of 60 different surgical procedures (27% of them being gynaecological or urological procedures), across eight specialities, in over 140 patients in whom PDC was implanted. For use in urological and gynaecological applications, PDC is distributed by Bard, in the UK and the rest of the world, under the trade name Pelvicol [5].

In gynaecology, Ruparelia [6] reported successful repairs of anterior and posterior vaginal prolapse using Pelvicol. In urology, long strips of PDC have been successfully used as suburethral slings to treat female urinary stress incontinence [7], in cystoplasty for mixed and urge incontinence [8] and in Peyronie's disease to correct penile curvature [9].

Other disciplines in which PDC has been implanted are ear, nose and throat surgical procedures, plastic surgery, and maxillofacial and orthopaedic surgery. In general surgery, PDC has been used for repair of internal rectal prolapse [10], treatment of anastomotic recto-vaginal fistula [11], repair of parastomal hernia [12] and paraoesophageal hernia [13], and in procedures to correct abdominal-wall defects, such as primary inguinal hernia [14], incisional hernias and umbilical hernia.

PDC and Incisional Hernia

Porcine dermal collagen, due to its smooth surface and lack of foreign-body response, can be implanted close to the bowel and to adipose tissue, without any risk of adhesions or formation of intestinal fistulas. Since it does not stimulate biofilm formation in the presence of infection, PDC is ideal for use in surgical procedures in which there is a high risk of infection or contamination and in infected wounds. These features allow the avoidance of primary closure techniques, with their high recurrence rates, and delayed or two-stage repair of the abdominal wall. PDC has been successfully used in surgical procedures in contaminated areas (urinary incontinence [7], parastomal hernia [11], rectal prolapse [10]) without any post-operative infection or rejection of the prosthesis.

In a literature review, there were 29 cases in which PDC was used in the repair of incisional hernia (Table 1). In a child, a PDC graft was used to facilitate closure of the abdominal wall following pediatric renal intra-peritoneal transplantation of an adult cadaveric kidney [15]. In fact, the restricted volume of the recipient abdominal cavity and the size discrepancy of a donor adult kidney may lead

to graft compromise. Pressure on the graft may be exacerbated further in the post-operative period by oedema, with abdominal-compartment syndrome. Thus, successful closure of the anterior abdominal wall in infants while avoiding such complications allows renal transplantation despite donor/recipient size disparity, which remains the major obstacle in infant renal transplantation. In the remaining patients (17 women and 11 men, mean age of 62.9 years, range 30–83), PDC graft repair was performed in 26 with wound infection or surgical-field contamination [16–21] and in two after abdominal-wall tumour resection [19].

In contaminated or septic surgery for recurrent or strangulated incisional hernia, PDC was used to repair small- or large-bowel resection, wound infection, intra-abdominal abscesses and excision of an infected, previously implanted mesh.

Adedeji [16] was the first to describe the use of PDC grafts in the repair of abdominal-wall defects. In that case, a woman developed abdominal wound dehiscence with a colocutaneous fistula after Hartmann's procedure for a large-bowel obstruction secondary to rectosigmoid diverticular stricture, and had a new abdominal primary repair. Her wound dehisced again and, because of a marked deficiency in the abdominal wall, a temporary polypropylene mesh containing an Ethizip was sutured to the edge of the abdominal wall. This was removed eight days later, at the fourth laparotomy, and a definitive wound closure with PDC graft was undertaken.

In a similar case report described by Liyanage [17], a woman with a large ventral hernia, who had previously undergone an emergency Hartmann's procedure, was treated for faecal peritonitis secondary to perforated sigmoid diverticulitis. After multiple laparotomies for abdominal sepsis, she had a laparostomy. A year later, because of a recto-vaginal fistula and firm adhesions in the pelvis, the colostomy was not reversed and the abdominal-wall defect was repaired using a PDC implant.

Chave [18] reported four cases of incisional hernia repair using PDC, one of which involved a recurrent incisional hernia.

Table 1 Literature review

Year	Author	Journal	Number of cases
2002	Adedeji [16]	British Journal of Plastic Surgery	1
2005	Richards [15]	Pediatric Transplant	1
2006	Liyanage [17]	Journal of Plastic Reconstruction and Aesthetic Surgery	1
2006	Chave [18]	Journal of Wound Care	4
2006	Parker [19]	Current Surgery	9
2006	Armellino [20]	Chirurgia Italiana	6
2007	Catena [21]	Hernia	7

Parker [19] provided the most consistent series, describing nine cases of PDC repair of abdominal-wall defects. In those patients, the indications for surgery included reoperative incisional hernia repair after removal of an infected mesh (3 patients), reconstruction of a fascial defect after resection of an abdominal-wall tumour (2 patients), repair of recurrent incisional hernia involving a previous abdominal-wall infection after a primary incisional-hernia repair (1 patient), incisional-hernia repair involving ostomy and an open midline wound (1 patient), repair of an incisional hernia in the presence of a strangulated bowel and multiple intra-abdominal abscesses (1 patient), and excision of an infected mesh with drainage of intra-abdominal abscesses and synchronous repair of the abdominal-wall defect (1 patient).

Catena [21] described PDC repair in seven patients with strangulated incisional hernia, associated with a small-bowel resection in four patients and a colon resection in two.

We used PDC in six complicated incisional hernias [20]. In a woman who had previously undergone hysterectomy for cancer, the incisional hernia was associated with an entero-vaginal fistula and intra-abdominal abscesses. After the fistula was removed and the small bowel resected, only one large PDC sheet was implanted to repair both the pelvic floor and the anterior abdominal-wall defect. Three patients had incisional hernias and wound infections, two cases of which were related to an infected polypropylene mesh placed in a previous repair. In these two patients, the infected mesh was excised and PDC repair was performed at the same time. The third incisional hernia with a wound infection was in a woman who was operated on for an occlusion from a sigmoid cancer. She had undergone a Hartmann procedure and subsequently developed a wound infection with dehiscence of the laparotomy. The last two cases were an eviscer-ation in a woman who had had a nephrectomy for cancer several weeks before, and a patient with a strangulated recurrent incisional hernia.

In 28 patients, the abdominal-wall defect was closed using a single PDC implant and the mesh was shaped as necessary. Only in one patient was the defect closed, by suturing eight small pieces of mesh together [16].

The PDC graft is placed using a subfascial underlay technique with an overlap of at least 3 cm [17,19,21], or overlying the muscles (onlay technique) (Fig. 1) [16,20,21]. The graft is secured to the fascia with interrupted sutures [16,17,19,20] using nonabsorbable suture [17,19] or a long-lasting absorbable suture [16,20,21]. Sometimes, the wound is drained using suction drains placed superficial to the graft [16,20].

Results

Among the general postoperative complications, only an acute postoperative pneumonia has been described [21]. Local postoperative complications were: seroma [17] with superficial wound dehiscence, requiring drainage and primary

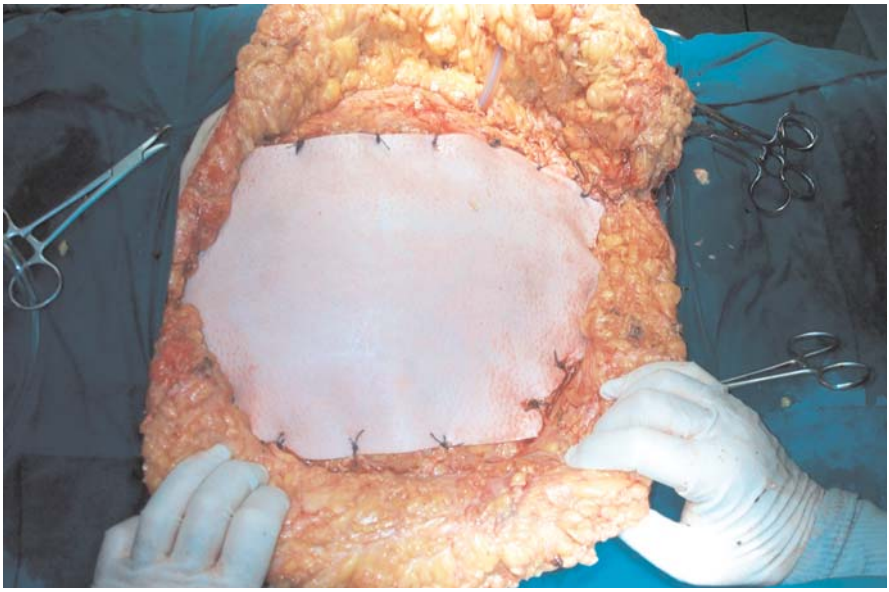

Fig. 1 The porcine dermal collagen (PDC) graft overlying the muscles and secured to the fascia with an interrupted long-lasting absorbable suture. A drain has been placed superficial to the graft

closure; skin separation with exposure of the underlying graft [19] treated with local wound care and subsequently healed with no evidence of graft infection; wound abscesses [18], in four patients who were treated, after surgical wound debridement and abscess drainage with mesh exposure, wound packing consisting of Betadine gauze and, after 48 h, vacuum-assisted closure with topical negative pressure therapy, which was discontinued when the PDC graft was covered by granulation tissue. Pus culture in these four patients showed the presence of coliform, proteus, *Staphylococcus aureus* and methicillin-resistant *S. aureus*.

Only one recurrent hernia [19], after intentional removal of the PDC graft, was reported. This patient developed a wound infection 13 months after the repair of his incisional hernia, subsequent to a small enterotomy from suture erosion with extension of the abscess through the graft, which required drainage of the abscess and PDC debridement.

At follow up 1 patient died from unrelated causes 6 months after surgery [19].

No incisional hernia recurrences were reported at 1 year of follow-up [17,19,20,21] and in some cases 18 and 24 months of follow-up [20,21] .

Conclusions

PDC mesh, based on its properties of biocompatibility and incorporation into the surrounding tissue, has been demonstrated to be a highly versatile surgical mate-

rial. This biomaterial, which can be placed in contact with a hollow viscus or an intestinal anastomosis, is resistant to infection and exhibits a permanent tensile strength. These properties make it a superior surgical tool in the repair of incisional hernia.

The indications for a PDC-mesh repair, according to the literature, are complicated incisional hernias, such as abdominal-wall repair in a contaminated or septic surgical field; a repair in which the mesh is in contact with the bowel; in cases involving stoma, bowel resection or anastomosis; in patients with wound infection or in whom a previously implanted polypropylene mesh has become infected.

The limited number of published cases describing incisional-hernia repair with PDC support the use of PDC prostheses as a good alternative to polypropylene mesh in complicated incisional-hernia repairs. This is especially true in emergency cases, including repairs of abdominal-wall defects associated with difficult and extreme surgical situations, a consistent risk of recurrence of the incisional hernia and wound infection.

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The Complications of Surgical Treatment of Incisional Hernia

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Incisional hernia is a highly frequent clinical entity that affects between 1 and 16%, and according to some reports more than 20% of abdominal surgery patients because of additional decisive or favourable factors that may be of a general or local nature [1,2]. Even small incisions that entail the insertion of a trocar in laparoscopic surgery result in an incidence of 1–3% [3,4]. While most incisional hernias appear during the first 6 months post-operatively, adopting different forms with regard to wall areas and entities. The timing, exact manifestation and progression of the pathology are extremely variable. A common and important feature is that the abdominal wall is anatomically and morphologically damaged, with progressive local and general functional involvement. Moreover, this pathology also has psychological and aesthetic consequences for the patient.

The clinical forms of incisional hernia range from the unrecognised or well-tolerated, small, paucisymptomatic ventral hernias with minimal visceral involvement and only a slight tendency to progressively worsen to extreme manifestations of "parietal disaster" that eventually become "incisional hernia disease" or "eventration disease" and result in major functional impairment.

In large incisional hernias, the anatomical-functional relationships of the chest wall, i.e. the rib cage, the diaphragm and the abdominal wall, are radically altered because of the progressive reduction in endo-abdominal pressure caused by the significant visceral hernia. In a median ventral hernia, the tensing of large muscles opens the rectus muscles such that the normal respiratory activity of the intrabdominal muscles is altered, and the spillage of the internal organs through the parietal fault is stimulated.

The creation of an "abdominal volet" leads to a chronic respiratory syndrome with dyspnea, due to the mechanical effort, and a pulmonary emphysema that depends on the dimensions and persistence of the abdominal hernia as well as the atrophy of the parietal musculature. The latter includes muddy and fatty degeneration with progressive atrophy, necrobiosis and fragmentation of fibres such as in myopathy associated with tendinous rupture [5–7]. Alterations of the pressure gradient inside and outside the lumen interfere with the microcirculation of the intestinal wall, resulting in stretching and hypoperistalsis.

F. Crovella, G. Bartone, L. Fei (eds.) *Incisional Hernia*.

The treatment of incisional hernia dates back to the middle of the twentieth century; the high recurrence rates associated with the repair procedure led to the use of synthetic prostheses by the 1970s. This approach resulted in a marked reduction in the number of recurrences but a relatively high rate of local infectious complications and other, related problems [8]. Beginning in the 1990s, the use of minimally invasive surgical techniques became widespread and greatly influenced prosthetic "open" surgery [6]. Currently, prosthetic surgery makes use of diverse biomaterials, with numerous forms and mesh structure, surgical techniques and implantation sites.

Synthetic prostheses made of polyglactin and polyglycolic acid are reabsorbable and increase the parietal resistance but only temporarily, because reabsorption takes place after 3–6 months. They are especially used in technically difficult repairs with particular anatomical features [9], such as infected tissues or in the "sandwich" technique in association with a non-reabsorbable prosthesis [10–12]. Reabsorbable prostheses frequently cause recurrences, since after their reabsorption by hydrolysis only a loose connective tissue with little mechanical capacity remains [12]. However, there are fewer local complications and better tolerance by infected tissues of organs in which the use of non-reabsorbable mesh would require its removal. Thus, the use of a reabsorbable mesh is recommended until the septic process has resolved, after which other kinds of prostheses can be implanted [13].

Non-reabsorbable prostheses with a permanent structural function consist of mono-constituent or heterogeneous synthetic polymerics, such as polypropylene, polyester and expanded polytetrafluoroethylene (ePTFE). Due to their physicochemical features, they cause only a slight inflammatory reaction in the tissues and generally do not give rise to infective complications. The monoconstituent meshes of polyester and polypropylene used in abdominal-wall surgery have a high structural porosity and resistance, good stability and allow quick and complete tissue integration as well as an intense connective-tissue proliferation. However, when the prosthesis positioning is properitoneal or, even worse, intraperitoneal, these same features produce dangerous visceral adhesions, erosions, and fistulizations [14,15]. The use of a hydrophobic material with a low porosity, such as PTFE, inside the wall, is associated with a reduced infiltration of fibroblasts and thus poor tissue integration and a high recurrence rate [16]. Nonetheless, the low adhesion of this mesh makes it suitable for being placed in close contact with internal organs in either open or laparoscopic repair.

The creation of mesh with pronounced non-stick properties and consisting of layers of hydrophilic reabsorbable polymers on permanent supports (polypropylene/ePTFE; polypropylene/sodium hyaluronate-carboxymethylcellulose foam; polyester/hydrophilic collagen; polypropylene/regenerated oxidised cellulose/polydioxanone), combined with ePTFE with a double microporous structure, allows good apposition to the peritoneal surface.

Possible sites of intraparietal implants where non-reabsorbable prostheses are used include retromuscular-prefascial [17–20] and premuscular-aponeurotical tissues. In such cases, the extent of dissection and the duration of surgery are reduced [21].

Intraperitoneal collocation can be realised with the open technique in certain situations [22], but can also be done in elective procedures, with well-defined indications, in laparoscopy [23]. The surgical strategy, even if perfectly and fully realised, must be compatible with the clinical manifestation of the pathology and characteristics of the patient. For the latter, this takes into account the patient's global state of health as well as biological features of the tissues, psychological state, immunological fitness, life style, individual compliance and readiness to participate in appropriate clinical follow-up.

Many of the elements involved in the pathogenesis of incisional hernia play a role in the development of complications following surgical repair: metabolic disease and organ failure, tissue hypoxia caused by anaemia or ageing, condition of hypo/malnutrition, wall adiposity, chronic bronchopulmonary disease and previous immunodepressant therapies. In addition, there is the risk of an inadequate surgical procedure or the occurrence of technical mistakes and deficiencies, insufficient patient qualification and a lack of preventive and protective measures [24].

A complete analysis of the complications associated with the surgical repair of incisional hernias, by either laparotomy or laparoscopy, should make reference to homogeneous patient groups with respect to the pathological entity, as this provides recourse to shared classifications, technical principles and the chosen approach, as defined by the results of large prospective studies [25,26].

Recurrence

The recurrence rate is an important element to establish the efficiency of surgical treatment. The incidence of recurrence in incisional hernia prosthetic surgery is markedly lower than in direct plasties. Indeed after the autoplasties of the preprosthetic period, the recurrence rate ranged from 14–50% for ventral hernias [27,28]. Chevrel and Flament, in 1990, reported on 1,033 patients who had undergone laparotomy. The recurrence rate at 10-year follow-up was 14–24% for patients treated without the use of prostheses but only 8.6% for those in whom a prosthesis was implanted [10]. A similar incidence was reported by Chevrel in 1995: 18.3% recurrence without prostheses, 5.5% with prostheses [29]. Likewise, Wantz, in 1991, noted a recurrence rate of 0–18.5% in prosthetic laparo-alloplasties [30].

At the European Hernia Society (EHS)-GREPA meeting in 1986, the recurrence rate without prostheses was reported to be between 7.2 and 17% whereas in patients who had been treated with a prosthesis the recurrence was between 1 and 5.8% [25].

A case study published by Flament in 1999 showed a 5.6% recurrence rate for operations with prostheses placed behind the muscles and in front of the fascia, and a 3.6% of such figure consisted of a small-sized lateroprosthetic recurrence. These rates were in contrast to the 26.8% recurrence reported by other surgeons for operations without prostheses [31].

Studies of recurrence are, of course, influenced by the size of the initial defect and the length of follow-up. Nevertheless, it is beyond dispute that the use of prostheses is associated with a lower rate of recurrence independent of the nature of the incisional hernia [32].

The factors that lead to relapse are recognisable in the original features of the ventral hernia, i.e. combined musculo-aponeurotic parietal involvement, septic complications in the first operation, the nature and appropriateness of treatment, the kind of prosthesis and its position. Also important is whether the surgery was an emergency case and the relation to occlusive phenomena, visceral damage and whether these problems were addressed at the same time.

Obesity is also an important risk factor for recurrence. In addition to its association with a higher surgical complications rate, related to the high intra-abdominal pressure, there are deficits in wound cicatrisation as well as respiratory and metabolic pathologies. In such patients, the laparoscopic approach is very useful to significantly reduce the onset of general and wall complications, and the data concerning recurrence are encouraging [33,34], ranging between 1 and 9% in the largest laparoscopic case studies [35–39]. The important multicentric study of Heniford et al., in 2000, reported a recurrence rate of 3.4% after 23 months [1]. In 2003, the same author, in a study with an average follow-up of 20 months (range 1–96) showed a recurrence rate of 4.7% for different, identifiable causes: intestinal iatrogenic injuries and mesh infection with its removal, insufficient fixation of the prosthesis and abdominal trauma in the first postoperative period [40].

The incidence of recurrence after laparoscopic treatment may also be related to general patient factors and to the onset of local complications, mistakes in opting for laparoscopic treatment and deficits in implanting and fixing the prosthesis. With respect to the latter, it is very important to allow a large overlap compared to the diameter of the defect.

Long-term data analysis, with large case studies, is still needed to obtain detailed information about recurrence, and this is particularly true in the assessment of relatively new techniques.

Respiratory Disease Caused by Postoperative Abdominal Hypertension: Abdominal Compartment Syndrome

In the treatment of large eventrations, the forced reduction of the viscera caused by this pathology and by reconstruction and closure of the wall under high tension, may lead to intra-abdominal hypertension and secondary organic malfunction. In addition, the surgical effort to re-establish wall functionality to curb evolution of the pathology through large and multiple prostheses exposes the patient to the risk of a serious intra-abdominal hypertension. Dangerous or even lethal

clinical manifestations can appear during the first 30 h post-operatively. The abdominal hypertension may also have local consequences, including intestinal, renal, hepatic, circulatory, respiratory and neurological ones, which in the absence of proper decompression and identification of the aetiology, can lead to multi-organ failure. Patients may also have an important dyspnoea, tachypnoea and reduction of the tidal volume. Radiological examination of the thorax will highlight a lifting of the diaphragmatic cupulae and an evident basal atelectasis. Blood-gas analysis may indicate hypoxia, acidosis and hypercapnia.

Abdominal hypertension can be determined subjectively as a sensation of heaviness; the pain felt by the patient during palpation of the abdomen is intense.

The alterations in renal haemodynamic parameters described in the abdominal compartment syndrome (ACS) are similar to those of adult respiratory distress syndrome (ARDS), multi-organ failure (MOF) and sepsis. ACS may initially be misdiagnosed or even go unrecognised. Many of its clinical manifestations are identical to those observed in the syndrome of systemic inflammatory response (SIRS) or in septic shock.

It is therefore fundamental to surgically respect the compliance of abdominal cavity [41–43], to administer a respiratory functional evaluation and to suitably prepare the patient for surgery. The technique of pre-operative pneumoperitoneum, which was aimed at reducing many of the above-described complications, was described by Moreno in 1947 [44].

In laparoscopic treatment, the intraperitoneal position of the prosthesis does not restrict the wall, thus complying with the “tension free” principle. While reduction of a large intestinal mass in the abdomen could, at least theoretically, lead to this complication following the treatment of large ventral hernias, there is no consensus as to whether laparoscopy is indicated in such cases.

Mortality

From the above discussion it is clear that there are serious risks in terms of the postoperative respiratory and multivisceral insufficiencies caused by the abdominal compartment syndrome. Postoperative mortality is predominantly a consequence of septic complications, especially in cases of unrecognised intestinal-loop perforation and intra-abdominal abscess, both of which may arise during laparoscopic surgery; this is in contrast to open surgery in which morbidity is most often due to wall complications [45,46].

Throemboembolism causes deaths in 1% of cases [47]. In a large case study carried out in 1990 by the French Surgical Association and involving 1,825 prosthetic alloplasties, the mortality rate was 1.2% [10]. A mortality rate of 0.6% was determined by Flament in a series comprising 1,517 operations carried out in 1999 [31].

Protracted Postoperative Ileum

Postoperative ileum has an unpredictable duration and clinical course. The incidence of this complication following laparotomic surgery was found to be 8% according to a 1998 study [47]. In laparoscopic treatment, it appears occasionally, especially as a consequence of difficult operations, extensive adhesiolysis, intestinal tractions and the use of large prostheses [38]. Heniford quoted an incidence of 2.2%, based on 407 laparoscopic operations carried out in 2002, and 3% in a series of 850 treatments performed in 2003 [40].

Pain

Postoperative pain is reduced in prosthetic surgery compared to direct plasty [48] and is further minimised in laparoscopic surgery. In either case, pain can be well-controlled pharmacologically.

Symptomatology is usually related to areas of particular tension, especially sites of transparietal stitches, and the methods of intraperitoneal fixation. However, with time, pain in these regions eases and disappears due to the plastic adaptation of the involved anatomical structures.

Chronic pain may be a consequence of prosthesis retraction and the method of fixation, both of which may produce algogenic tension on the affected tissues [49]. An inadequately fixed prosthesis or one placed in a reduced space can adopt the conformation of a "meshoma" and act as a pain-producing stimulus [50].

Infiltration with a local anaesthetic prior to skin incision of trocar sites is very useful in laparoscopy [35,38] and provides pain control when the patient wakes up from anaesthesia.

Parietal Rigidity in Prosthetic Surgery

Non-reabsorbable mesh must be able to adapt a form compatible with the parietal wall while maintaining adequate tensile resistance. These prerequisites are fulfilled by most of the currently avalable prostheses. Indeed, with respect to resistance to pressure and tension forces, they are more than adequate.

A surgical technique that does not respect the "tension free" principle, when combined with an exuberant fibroblastic integration, can influence the rigidity of abdominal wall. As a result, the patient may feel constant discomfort, with the potential development of clinical respiratory and/or haemodynamic disorders due to the reduced parietal excursion [51].

When surgeons place a mesh during laparoscopic treatment, attention must

be paid to the distensibility of the prosthesis, which, when fixed after reduction of the pneumoperitoneal pressure, must have a flexible configuration. Also important is the surgeon's awareness of the pressure established with surgical clips, the composition of the clips and the use of biological glues either alone or in combination with other fixation methods. The retraction factor of some prostheses must also be considered; with time, there may be a 7–8% reduction in surface area.

Seroma

Seroma is one of the most frequent complications in laparoscopic prosthetic surgery and in open surgery but its resolution is in most cases spontaneous. It is commonly noted on postoperative ultrasound but it is otherwise subclinical. According to large clinical trials, seromas lasting more than 8 weeks are considered as a complication [52]. An incidence of 1.97% [1] among 407 patients treated with laparoscopic technique in 2000 and 2.6% in a series published in 2003 was noted by Heniford [40].

The disappearance rate of clinically relevant seroma is around 7% (range 4–15%) [18,53] in laparotomic surgery and between 4 and 16% [35,38,54] in laparoscopy.

The tissue reaction to the prosthesis in the first postoperative days resembles that of a physiological inflammatory response and precedes the invasion by fibroblasts. It is a consequence of the residual space and the large detachments of skin flaps.

Seroma may become manifest as late as 6 weeks postoperatively, and even later in cases of encysted chronic seroma, which sometimes have a multilocular structure. It most frequently arises from the use of a premuscular position technique (Chevrel) compared to a position behind the muscles and in front of the fascia [24].

In laparoscopic treatment, seroma appears between the intraperitoneal mesh and the wall, in the cavity of abdominal hernial sac.

Surgeons recommend compression for 4–6 weeks, with a bandage shaped according to the diameter of the defect, to reduce the residual space and to allow adhesion of the prosthesis to the hernial sac. In addition, the use of drainages and local compression, in open surgery and in laparoscopic surgery, reduces the incidence of seroma [55].

The repeated aspiration of inflammatory fluid can lead to contamination, with serious consequences that must be surgically managed. A technique that avoids the appearance of this fluid following surgical placement of the laparoscopic prosthesis is to sear the hernial sac with monopolar current or a "harmonic scalpel" or to treat it with laser-argon applications [56].

Wall Haematoma

The frequency of wall haematomas is variable: for laparo-alloplasty it was 4.7% in a 1990 AFC case study [10], 1.8% in Chrevel's case study of 1997 [57], 3% in the 1998 case study of Leber [47] and 0.7% in a trial carried out in 1999 by Flament [31]. In the large review of Heniford, in 2003, the incidence of haematoma following laparoscopic surgery was 0.7% [40].

Haematoma is a predictable complication in prosthetic laparotomy. It can entail huge abrasions and dissections in patients on anticoagulants for the treatment of cardiovascular pathologies or prophylactically to avoid thromboembolic disease. Nonetheless, it is the responsibility of the surgeon to prevent wall haematomas through rigorous haemostasis and proper use of aspiration drainages.

In laparoscopic surgery, wall haematomas can appear when the surgeons places the trocars but they are not a specific complication of the treatment of abdominal hernias; rather, slight bleeding, haemorrhagic suffusions and haematomas can arise due to vessel damage caused by prosthetic fixation methods. These can be recognised by the surgeon and treated immediately.

Cutaneous Necrosis

Cutaneous damage that appears with necrosis has an incidence of 1.2%, according to the AFC study [10], and 0.9% according to Chevrel [57].

Vascular damage caused by traction, extreme compression or devascularisation and thermal insult can cause large areas of necrosis, thus jeopardising the cutaneous integrity and barrier effect towards pathogens. This can lead to a secondary subcutaneous cellulitis and even deep sepsis, with frank prosthetic infection and fistulation.

Particular attention must be given to wall reconstructions involving extensive dermolipectomies and abdominoplasties, because tractions on the skin flaps can evolve into serious necroses that are detrimental for prosthetic alloplasty.

In laparoscopy, a cutaneous necrosis next to an abdominal hernia may develop as a consequence of diathermocoagulation of the sac.

Prosthesis Infection

Septic complication can appear precociously or after a rather long period of time. Laparotomic techniques are historically linked to cellulitis as well as wall and prostheses infections. Stoppa reported a septic complication rate of 12% in 1989 [18].

Surface sepses following prosthetic laparotomy surgery were found in 5.35% of patients in a 1990 AFC study [10], in 7% in the series of Leber in 1998 [47] and in 1% of cases in the Flament series of 1999 [31].

For laparo-alloplasties, Koehler quoted an incidence of 0.5–6%, based on a case study and a literature review [58]. In the important case study on 850 laparoscopic treatments, Heniford reported an incidence of cellulitis of 1.1% at the trocar site while the frequency of mesh infection was 0.7%, thus establishing that such complication are rare in this approach [40].

Prosthesis infection is not an improbable event in large soft-tissue detachments of the abdominal wall. Laparoscopic prosthetic alloplasty, by contrast, which respects parietal structures, avoids the vascular and tissue damage that causes bleedings, haematomas and serious septic complications.

Prosthetic laparoscopic contamination has repercussions at the visceral level, with the potential development of peritonitis, visceral and parietal adherences and coalescences.

It is essential to observe rigorous asepsis during surgical placement of the prosthesis and to employ all possible devices to avoid the formation of intraparietal haematomas. The use of antibiotic prophylaxis [59,60] and biomaterials impregnated with antimicrobial substances [61] reduces the frequency of such complication. In addition, precautionary measures related to surgical technique and details of the procedure, as well as proper care and instruction of the patient play important roles.

Most prosthetic infections are due to cutaneous pathogens that are transported by contaminated prostheses or cutaneous solutions and promoted by conditions favouring necrosis [52].

Deep sepses in the abdominal wall in laparotomic surgery have dramatic consequences. Frequencies of 0.75% [10], 4% [47] and 2.72% [21] have been reported. The EHS-GREPA published a deep suppuration rate of 3–21% [25].

It may be necessary to remove the prosthesis if it becomes septic and causes problems related to wall reconstruction; in other cases, the prosthesis can be preserved by treatment cleansing, extensive mesh exposure and appropriate dressings.

Late infections depend mostly on the kind of prosthetic material used [62]. The incidence of such complication is low, and for polyester prostheses is 0.2–1% according to the round-table findings coordinated by Wantz at the American College of Surgeouns in 1999 [63]. The frequency quoted by Leber in 1998 was 5.9% of late chronic infections and 3.5% of infections related to enterocutaneous fistulas [19].

With the use of ePTFE (expanded polytetrafluoroethylene) prostheses, Martinez showed, in an important literature review, a global late suppuration rate of 4.1% with the consequent need of mesh removal in 8.2% of cases and thus a recurrence rate of 17.5% [64].

Intestinal migration phenomena in isolated cases have been cited in the literature. True migration, if it exists, must be differentiated from enterocutaneous fistulas, which appear after ignored intestinal lesions, precarious suture or

destructive wall phlogosis with visceral involvement. Leber found an incidence of 3.5% in 1998 [47]. Migration of the prosthetic material in the intestinal lumen is more likely to occur in intraperitoneal as opposed to intraparietal positioning [25].

Veress Needle and First Trocar Visceral Lesions

Veress and first trocar visceral lesions refer to general laparoscopic procedures and have an incidence <1% [65]. However, they represent inauspicious events that can be disastrous in the case of large vascular lesions and intestinal perforations or lacerations with massive septic peritoneal contamination.

The choice of access method improves with experience, sensitivity and surgical preferences, but should be made cautiously. Significant reliability of the open access technique has not been proved. In one study, it was only used in 2.5–9% of cases with the remaining being treated with the Veress technique [66,67].

The insertion site of a Veress needle must be far from surgical laparotomy scars or drainages, common sites of intraperitoneal adherences, and from the defect wall or a defect that is diagnosed preoperatively. Sites with both adherent or outspread viscera, and parenchymatous or pathological organs should also be avoided. When the first trocar is placed, the surgeon must respect the triangulations of the laparoscopic implantation, avoiding the wall defect and bony projections that would limit the instruments' excursion [68].

Intestinal Perforation

Intestinal perforation is a serious visceral complication of laparoscopic procedures. In large case studies, the percentage of accidental enterotomies was between 0.5 and 6% [36,37,69]. It most frequently occurs during adhesiolysis necessary to expose the hernial defect and to establish a wall surface that allows placement of the prosthesis with sufficient overlap.

Intestinal perforations arise by different mechanisms: through the direct action of scissors or traumatic instruments or through the indirect insult of energy sources, with the creation of an eschar, or an ischaemic area of intestinal wall with subsequent necrosis and perforation [47].

Intraoperative recognition of intestinal lesion mandates their immediate repair; since ignored visceral damage causes the fearful complication of a deferred perforation with problems of diagnostic timeliness and treatment.

Adhesiolysis must be done cautiously, without traction, with blunt instruments, and should follow the cleavage and avascular planes. Furthermore, it

must be done “cold”, with cautious use of monopolar coagulation; ultrasound and radiofrequency coagulation spread less heat but are not always safe [58,70].

Identification of intestinal damage may require the laparotomy conversion; this must be considered as a necessary treatment strategy rather than a complication.

Conclusions

Surgery to repair incisional hernia has reached a very high efficiency and safety level. Consolidated and recent techniques allow the treatment of all kinds of structural and functional involvements, with important reductions in complications rates. Nonetheless, current findings must be supported by additional numerical and qualitative data as well as careful observations.

For the surgeon, it is important to operate respecting the traditional techniques but with a desire to know and, as needed, employ state-of-the-art techniques. Knowledge of clinical, technical and organisational aspects must be deep-rooted. Similarly, the various kinds of prevention, clinical assessment, training and choice of treatment must be integrated and supported in the surgical procedure.

Currently, the laparoscopic revolution is gaining increasing attention and credibility, thus confirming its feasibility, advantages and reduced rate of postoperative complications. However, an awareness of the postoperative complications together with efforts to prevent them are fundamental elements in achieving therapeutic success.

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Subject Index

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