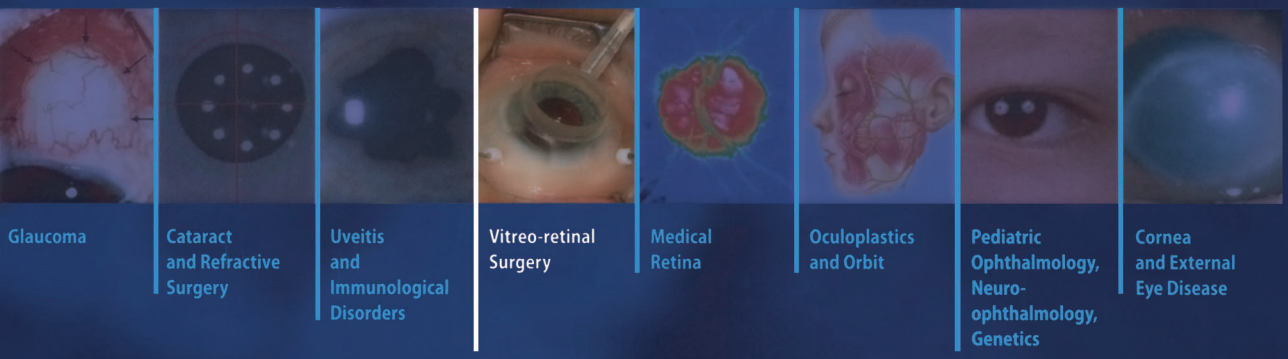
ESSENTIALS IN OPHTHALMOLOGY

G. K. KRIEGLSTEIN · R. N. WEINREB

Series Editors



Vitreo-retinal Surgery

PROGRESS III

Edited by

S. RIZZO

F. PATELLI

D. R. CHOW

Springer

Essentials in Ophthalmology

Vitreo-retinal Surgery

S. Rizzo F. Patelli D. R. Chow
Editors

Essentials in Ophthalmology

G. K. Krieglstein R. N. Weinreb
Series Editors

Glaucoma

Cataract and Refractive Surgery

Uveitis and Immunological Disorders

Vitreo-retinal Surgery

Medical Retina

Oculoplastics and Orbit

**Pediatric Ophthalmology,
Neuro-Ophthalmology, Genetics**

Cornea and External Eye Disease

Vitreo-retinal Surgery

Editors Stanislao Rizzo
Fabio Patelli
David R. Chow

With 50 Figures, Mostly in Colour
and 12 Tables

Series Editors

Günter K. Krieglstein, MD
Professor and Chairman
Department of Ophthalmology
University of Cologne
Kerpener Straße 62
50924 Cologne
Germany

Robert N. Weinreb, MD
Professor and Director
Hamilton Glaucoma Center
Department of Ophthalmology
University of California at San Diego
9500 Gilman Drive
La Jolla, CA 92093-0946
USA

Volume Editors

Stanislao Rizzo, MD
Professor and Chairman of Ophthalmology
Eye Surgery Clinic
Santa Chiara Hospital
Via Roma, 67
56100 Pisa
Italy

Fabio Patelli, MD
Milano Retina Center
via Pietro Mascagni, 20
20122 Milano
Italy

David R. Chow, MD
University of Toronto
23 Ivor Rd., North York
Ontario M4N 2H3
Canada

ISBN 978-3-540-69461-8

e-ISBN 978-3-540-68586-9

ISSN 1612-3212

Library of Congress Control Number: 2008929530

Cover picture 'Oculoplastics and Orbit' modified from Katowitz, A., Pediatric Oculoplastic Surgery (Springer New York 2002).

Cover Design: WMXDesign GmbH, Heidelberg, Germany

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Foreword

The Essentials in Ophthalmology series represents an unique updating publication on the progress in all subspecialties of ophthalmology.

In a quarterly rhythm, eight issues are published covering clinically relevant achievements in the whole field of ophthalmology. This timely transfer of advancements for the best possible care of our eye patients has proven to be effective. The initial working hypothesis of providing new knowledge immediately following publication in the peer-reviewed journal and not waiting for the textbook appears to be highly workable.

We are now entering the third cycle of the Essentials in Ophthalmology series, having been encouraged by readership acceptance of the first two series, each of eight volumes. This is a success that was made possible predominantly by the numerous opinion-leading authors and the outstanding section editors, as well as with the constructive support of the publisher. There are many good reasons to continue andstill improve the dissemination of this didactic and clinically relevant information.

G.K. Krieglstein
R.N. Weinreb
Series Editors
September 2008

Preface

"All progress occurs because people dare to be different".

Harry Milner

Every so often, changes occur in the technology of our day-to-day lives that truly alter how we do things. As retinal surgeons, the development of sutureless vitrectomy systems is one of these revolutionary changes that have altered how most of us perform surgery. Since Dr Eugene de Juan introduced us to a 25-gauge transconjunctival sutureless cannula system, there has been almost a dizzying pace of change in our field, as instrumentation companies refine and improve the 25-gauge experience. Given some of the early limitations of 25-gauge technologies, Dr Claus Eckardt introduced us to an alternative, a 23-gauge sutureless cannula system, which is becoming increasingly popular. At the present time, there is considerable debate and confusion amongst our community about the direction our field is going to take. Are we all going to become 23-gauge surgeons? Will 20-gauge vitrectomy disappear? Can technologic improvements make the 25-gauge experience easier? We have put together this textbook to try and answer some of these questions, and to give you some help on when and how these new sutureless vitrectomy systems can be used. To aid us in this endeavour, we have recruited the leading surgeons in our field to offer their insights into the sutureless techniques they perform. We think you will enjoy the practical approach that many of the authors have taken in their chapters, and the "surgical tips" that are offered that can be used in your operating room right away.

Enjoy the textbook!

Stanislao Rizzo
Fabio Patelli
David R. Chow
September 2008

Contents

Chapter 10
25-Gauge Sutureless Vitrectomy for Diabetic Retinopathy

T.S. Hassan

Chapter 11
Small-Gauge Vitrectomy for Retinal Detachment

F. Patelli, P. Radice

Chapter 12
Perfluorocarbon-Perfused 25-Gauge Vitrectomy

G. Garcia-Aguirre, H. Quiroz-Mercado

Chapter 13
Primary 25-Gauge Vitrectomy with Topical Anesthesia for Persistent Vitreous Floaters

G. Garcia-Aguirre, V. Morales-Canton, H. Quiroz-Mercado

Contributors

F. Altomare
Department of Ophthalmology and Vision Sciences
University of Toronto, Toronto
ON, Canada
and
Department of Ophthalmology
St. Michael's Hospital, Toronto
ON, Canada
and
Department of Ocular Oncology
Princess Margaret Hospital
University Health Network, Toronto
ON, Canada

J. Fernando Arevalo
Professor and Chairman
Retina and Vitreous Service
Clinica Oftalmológica Centro Caracas
The Arevalo-Coutinho Foundation for Research
in Ophthalmology
Caracas, Venezuela

A. Augustin
Direktor der Augenklinik
Moltkestrasse 90
76133 Karlsruhe

C.C. Awh
Retina-Vitreous Associates
Baptist North Medical Office Bldg.
2011 Murphy Avenue, Suite 603
Nashville, TN 37203
USA

Aaron Barnes
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

Prashant Bhadri
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

S. Binder
Department of Ophthalmology
The Ludwig Boltzmann Institute for Retinology
and Biomicroscopic Lasersurgery
Rudolf Foundation Clinic
Juchgasse 25 A-1030, Vienna, Austria

A. Capone
1493 Fairfax Street
Birmingham, MI 48009, USA

S.T. Charles
Charles Retina Institute
6401 Poplar Avenue, Suite 190
Memphis, TN 38119, USA

Lawrence Chong
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

D.R. Chow
University of Toronto
23 Ivor Road, North York, Ontario M4N 2H3
Canada

C. Claes
Department of Vitreoretinal Surgery
St. Augustinus Hospital
Oosterveldlaan 24
Wilrijk-Antwerp 2610
Belgium

Charles DeBoer
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

C. Eckardt
Augenklinik
Staedtische Kliniken
Frankfurt, 65929
Germany

P.J. Ferrone
600 Northern Blvd.
Suite 216
Great Neck, NY 11021, USA

William R. Freeman
Jacobs Retina Center
Shiley Eye Center
University of California San Diego
La Jolla, CA
USA

G. Garcia-Aguirre
Retina Department
Hospital "Dr. Luis Sanchez Bulnes"
Asociacion para Evitar la Ceguera en Mexico
Vicente Garcia Torres 46
San Lucas Coyoacan 04030
Mexico City, Mexico

F. Genovesi-Ebert
Eye Surgery Clinic
Santa Chiara Hospital
Via Roma, 67
56100 Pisa
Italy

Stratos Gotzaridis
66 Vas. Sophias Av.
Athens 115 28
Greece

A. Gupta
Jules Stein Eye Institute, David Geffen
School of Medicine at UCLA
Los Angeles, CA, USA

T.S. Hassan
Associated Retinal Consultants, PC
3535 W. 13 Mile Road
Suite 632
Royal Oak, MI 48073
USA

Suber Huang
Professor and Vice-Chairman
Director, Center for Retinal and Macular Disease
Department of Ophthalmology and Visual Sciences
University Hospitals Eye Institute/Case
Western Reserve University
11100 Euclid Avenue, Lakeside 4115
Cleveland, Ohio 44106, USA

Mark Humayun
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

Peter K. Kaiser
Director, Digital OCT Reading Center
Staff, Cole Eye Institute
Cleveland Clinic
9500 Euclid Avenue, Desk i3
Cleveland, OH 44195

L. Kellner
Department of Ophthalmology
The Ludwig Boltzmann Institute for Retinology
and Biomicroscopic Lasersurgery
Rudolf Foundation Clinic, Juchgasse 25 A-1030
Vienna, Austria

Ralph Kerns
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

M. Kickinger
Rua Coronel Paulo Malta Rezende, 35/2006 - Barra da Tijuca
Rio de Janeiro, RJ - 22631-005
Brazil

A. Lafeta
Vitreo-Retinal Department,
Sint-Augustinus Hospital, Wilrijk
Belgium

Octaviano Magalhaes
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

C.A. McCannel
Mayo Foundation for Medical Education and Research
200 First Street SW
Rochester, MN 55905, USA

Matthew McCormick
Eye Concepts, Doheny Eye Institute
University of Southern California
1450 San Pablo Street, DEI 1900
Los Angeles, CA, USA – 90033

V. Morales-Canton
Director Retina Department
Hospital "Dr. Luis Sanchez Bulnes"
Asociacion para Evitar la Ceguera en Mexico
Vicente Garcia Torres 46
San Lucas Coyoacan 04030
Mexico City, Mexico

M. Ohji
1-4-33 Aoshinke
Mino 562-0024, Japan

Y. Oshima
Department of Ophthalmology
Osaka University Medical School
Osaka
Japan

M. Palla
Eye Surgery Clinic
Santa Chiara Hospital
Via Roma, 67
56100 Pisa, Italy
and
U.O. Chirurgia Oftalmica
S. Chiara Hospital
Azienda Ospedaliero-Universitaria
Pisana via Roma
Pisa
Italy

F. Patelli
Milano Retina Center
via Pietro Mascagni, 20
20122 Milano
and
Director Vitreoretinal Service
Department of Ophthalmology
Igea Clinic, Milan, Italy

D. Polya
University of Toronto,
23 Ivor Road, North York
Ontario M4N 2H3, Canada

J.L. Prenner
Assitant Clinical Professor
Retina Vitreous Center, PA
Robert Wood Johnson Medical School, UMDNJ
125 Patterson Street
New Brunswick, NJ 08901

H. Quiroz-Mercado
Chief of Ophthalmology
Denver Health Medical Center
Professor of Ophthalmology
University of Colorado, School of Medicine
700 Delaware Street
Denver, CO 80204

P. Radice
Department of Ophthalmology
Vitreoretinal Service
Ophthalmic Hospital "fatebenefratelli"
Milan, Italy

F.A. Rezende
Rua Humaitá, 244/1202 - bloco 2 - Humaitá
Rio de Janeiro, RJ - 22261-001
Brazil

S. Rizzo
Professor and Chairman of Ophthalmology
Eye Surgery Clinic
Santa Chiara Hospital
Via Roma, 67
56100 Pisa, Italy

Juan G. Sanchez
Retina and Vitreous Fellow
Retina and Vitreous Service
Clinica Oftalmológica Centro Caracas
The Arevalo-Coutinho Foundation for Research
in Ophthalmology
Caracas, Venezuela

S.S.D. Schwartz
Department of Ophthalmology
Jules Stein Eye Institute
100 Stein Plaza
Los Angeles, CA 90095
USA

T.M. Soe
Department of Ophthalmology
Osaka University Medical School
Osaka, Japan

Y. Tano
Professor of Ophthalmology
Osaka University Medical School
Osaka, Japan

Paul Tornambe
12630 Monte Vista Rd #104
Poway, California
USA 92064

B. Wimpissinger
Department of Ophthalmology
The Ludwig Boltzmann
Institute for Retinology
and Biomicroscopic Lasersurgery
Rudolf Foundation Clinic
Juchgasse 25 A-1030
Vienna, Austria

Chapter 1

Historical Overview of Microincision Surgery

A. J. Augustin

Core Message

- Ever since the introduction of pars plana vitrectomy, the development of vitrectomy systems has been directed towards ever smaller and at the same time ever more efficient instruments.
- Especially the accelerated progress seen in the development of the 25-gauge and 23-gauge vitrectomy systems over the last 5 years, contributed to shortened intervention times and low-profile invasive interventions, affording shorter rehabilitation times and less postoperative discomfort.
- In spite of its considerably widened range of applications, 25-gauge vitrectomy to-date continues to be associated with certain disadvantages: the high flexibility and delicate nature of 25-gauge instruments require specific prior training on the part of the surgeon, while rendering some surgical manipulations altogether impossible.
- For these reasons, and also in view of its reduced flow rate, 25-gauge vitrectomy is still not an option for all applications and is not an all-purpose vitrectomy system, which means that in addition to the 25-gauge instrumentarium surgeons should always have access to a 20-gauge system (added costs/logistics).
- By comparison with 25-gauge instruments, the 23-gauge system provides distinctly higher instrument stability and increased flow rates – while permitting transconjunctival access at the same time.
- The 23-gauge system thus combines the benefits of the 25-gauge and the 20-gauge systems; it attains an application range of almost 100%, and as a result may become the new standard in vitrectomy.

1.1 Introduction

The last decade has seen a general trend toward efficient, minimal invasive interventions in several areas of medicine [12, 13, 17, 23]. Ever since the introduction of pars plana vitrectomy over 30 years ago, the instrumentarium of posterior segment surgery, too, has been subject to incessant change (Table 1.1). In this, two objectives have been in the foreground: one is reducing surgery times, and the other speeding the recovery of the eye. The primary means of reaching these targets lies in instruments that are smaller – and thus induce less surgical trauma – and at the same time more efficient, while affording improved visualization and illumination of the operating field. On the other hand, the minimization of the instrument diameter and the smaller lumen going with it may have a counterproductive effect on the functionality and efficiency of vitrectomy instruments. For according to Poiseuille's Law the volume flow rate along a pipe is directly proportional to the fourth power of the pipe's radius. When reducing the instrument diameter it is, therefore, to be remembered that the infusion and aspiration rates obtained with this instrument also will be reduced. General improvement or advancement of the instrumentarium has thus relied on balancing the requirements for reduced diameter and the performance of an instrument. The outer diameter of vitrectomy instruments, and others, is given in "gauge" which is derived from the US-American unit for wires, the American wire gauge (AWG). The gauge numbering relates to the number of drawing operations necessary to produce a wire of a desired diameter. This means the thinner the desired wire, the more passes through the drawing dies are needed and the higher the gauge number. The gauge number also corresponds to the number of wires going into one square centimeter. In other words: the higher the gauge number, the smaller the outer diameter of an instrument (see Table 1.2). According to Poiseuille's Law, lower infusion and aspiration rates have to be taken into account when high-gauge instruments (i.e., smaller

instrument diameters) are being used and this, in turn, may affect their functionality and efficiency.

Ever smaller instrument diameters have been designed since the early days of "pars plana vitrectomy" in the 1970s, when Machemer, closely followed by Klöti, relocated the access for vitreous removal to the pars plana area to preserve the crystalline lens [16, 24]. While Machemer et al. [25] started out by developing a 17-gauge instrument, i.e., the vitreous infusion suction cutter (VISC), that still needed a 2.3-mm sclerotomy port, two decisive advancements were introduced as early as in 1974: for the first time it was now possible to reduce instrument diameters to a marked degree by separating the infusion system and the cutting system. The 20-gauge vitrectomy system (0.9-mm diameter) was born, with infusion, vitrectome and illumination being introduced into the pars plana via three separate ports. Interestingly, splinting to protect the scleral incisions and facilitate instrument change had been propagated already in those days – this concept has been reintroduced, and today is applied to the microtrocar cannulas of the 25-gauge and 23-gauge systems [16]. While the 20-gauge vitrectomy system still is considered the "gold standard" of pars plana vitrectomy [30], the last 5 years, in particular, have seen fast-paced innovation in the field of the posterior segment instrumentarium toward smaller, more efficient 25-gauge and 23-gauge vitrectomy systems, which nowadays are routinely used in everyday clinical practice. Figure 1.1 compares the sizes of the vitrectomy cannulas of the three different systems (20-, 23-, and 25-gauge). An extensive overview of the clinical studies on safety and efficiency, as well as an assessment of the limits and potential of these innovative vitrectomy systems, has recently been published [1].

Table 1.1. Milestones of pars plana vitrectomy

Early 1970s	Machemer and Klöti both have the idea of shifting the site of vitrectomy access to the pars plana area in an effort to preserve the lens. "Birth of pars plana vitrectomy"
1974	O'Malley and Heintz introduce the 20-gauge vitrectomy system, today's "gold standard"
1974	Klöti recommends the use of guiding cannulas — the precursors of microcannulas — for ease of and added eye protection during instrument change.
1990	de Juan and Hickingbotham present first 25-gauge vitrectomy set, and recommend its use in pediatric interventions in particular
1995	At the ARVO meeting, Singh et al. present a 23-gauge vitrectomy system whose use, however, clearly is restricted to specific office-based interventions
2002	Fujii et al. present first fully integrated 25-gauge system, consisting of microtrocar cannulas, vitrectome and infusion, and demonstrate its safety and efficiency, especially in "simple" vitrectomies
2004/2005	Eckardt introduces first fully integrated 23-gauge vitrectomy system, and demonstrates its safety and efficiency
Up to 2007	Ongoing enhancement of instrumentation and ranges of application for the 25-gauge and 23-gauge systems

Table 1.2. Cannula gauge numbers and corresponding outer diameters

Gauge	Outer diameter (mm)
17-G	2.3
19-G	1.1
20-G	0.9
23-G	0.6
25-G	0.5

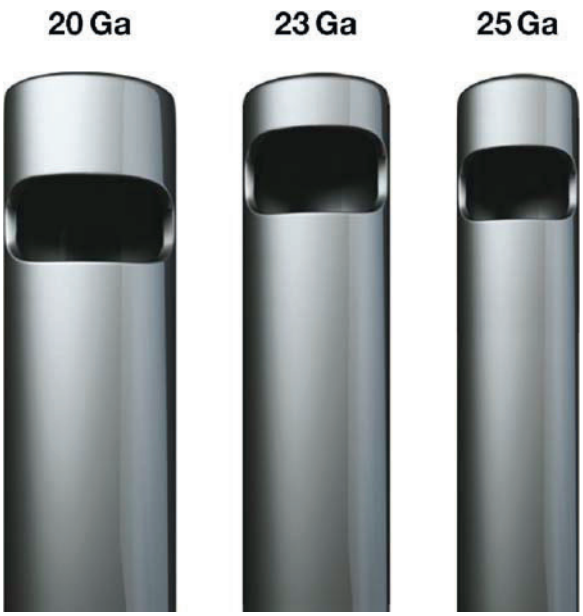


Fig. 1.1 Comparison of 20-gauge, 23-gauge, and 25-gauge vitrectomy cannulas for size. From Augustin AJ, Offermann J (2007) Möglichkeiten und Grenzen der innovativen Vitrektomiessysteme, eine Übersicht. Klin Monatsbl Augenheilkd 224:707–715

Summary for the Clinician

- The outer diameter of the instruments is given in gauge numbers, in a seemingly counterintuitive fashion: the higher the gauge number, the smaller the diameter.
- The 20-gauge vitrectomy system has been considered the "gold standard" since 1974; the last 5 years, in particular, have seen fast-paced innovation in the field of the posterior segment instrumentarium, directed toward smaller, more efficient 25-gauge and 23-gauge vitrectomy systems.
- However, when reducing the instrument diameter, it is to be remembered that flow rates also will be reduced (Poiseuille's Law), which may affect the functionality and performance of the instruments.
- It needs to be ensured, therefore, that the performance of instruments with reduced diameters at least equals that of the well-established 20-gauge system.

1.2 Pros and Cons of 25-Gauge Vitrectomy Systems

De Juan and Hickingbotham developed a 25-gauge instrument set for pediatric use already in 1990, since the "conventional" 20-gauge vitreous cutters had proven to be big and lacking in precision, especially in children [7, 42]. This first 25-gauge instrument set, which consisted of just a pneumatic vitrectome, scissors, and a manipulator for membrane removal, at first was used mainly in pediatric surgery, to allow for higher precision and permit controlled operation even in difficult maneuvers in that particular field [6]. De Juan and Hickingbotham explicitly stated in their publication that due to its reduced aspiration rate the 25-gauge vitrectome was to be used solely in selected, delicate cases requiring particularly precise and careful intervention. It was 12 years later, when eventually a complete 25-gauge vitrectomy system was introduced by Fuji et al. [10] which consisted of microtrocar cannulas, affording ease and safety of instrument introduction and withdrawal, as well as an array of integrated 25-gauge instruments. Due to their small diameter (0.5 mm), 25-gauge cannulas allow transconjunctival introduction, thus avoiding the time-consuming preparation of the conjunctiva that is required in conventional 20-gauge sclerotomies. Using a trocar with forceps, the conjunctiva, in this procedure, is pulled back a little prior to inserting the cannula, and this displacement provides a slight staggering of the wounds in the sclera and conjunctiva in relation to each other. In 25-gauge vitrectomy, the trocar is introduced perpendicularly to the sclera, i.e., it is directed to the center of the eye. This does not, in fact, create a two-step self-sealing wound. But since the conjunctiva will slip back to its more anterior position, where it is bound to cover the sclerotomy and probably provides a temporary tamponade to the opening – and also in view of the small sclerotomy diameter – no suturing should be required.

As already described, Poiseuille's Law (see above) indicated that the infusion and aspiration rates obtained by the 25-gauge system would be distinctly lower than those of the 20-gauge system. This was confirmed by Fuji et al. [10] in their first evaluation study of the 25-gauge system, where they established markedly reduced infusion and aspiration rates as against the 20-gauge system. To ensure sufficient aspiration rates also for the 25-gauge system, high vacuum settings (500 mmHg) should be used with this system, together with high cutting rates (1,500 cpm), so that optimum tissue fragmentation is guaranteed and "plugging" of the 25-gauge vitrectome is prevented. While the 25-gauge vitrectomy system principally is considered safe and efficient, opinions on the integrity of the sutureless 25-gauge sclerotomies are at variance [11, 15, 18, 19, 35, 36, 43]. Only recently, a modified incision technique was recommended to improve the integrity of sutureless 25-gauge sclerotomies [22, 37]. No significant difference has been identified between 25-gauge vitrectomy and 20-gauge vitrectomy as regards postoperative complications [4, 15, 26–28, 35, 38]. Sutureless sclerotomies have been at the center of constant concern as regards an increased risk of postoperative endophthalmitis following 25-gauge vitrectomy; however, to date but this has never been established [11, 15, 19, 21, 35, 43]. Interestingly, similar apprehensions have been expressed in connection with clear cornea incisions in cataract surgery, but despite some case reports [29, 40] again no increased rate of endophthalmitis could be confirmed.

Due to the limited instrumentarium and high flexibility of the instruments available in the first years, use of the 25-gauge system initially was restricted to "simple vitrectomies" such as removal of epiretinal membranes or macula surgery, procedures which in the opinion of some surgeons did not involve peripheral work or the removal of major vitreous portions [11, 15, 19]. It is controversially discussed and, in fact, even considered a main limitation of 25-gauge technology whether the deliberately accepted incompleteness of vitreous removal is at all sufficient in these indications, or may

even represent an increased hazard potential. More involved pathologies, demanding extensive removal of the vitreous, initially required the use of 20-gauge vitrectomy systems. Over recent years, widening the array of instruments (e.g., forceps, picks, and other manipulating devices, endolaser), better illumination systems, and specific improvement of the instruments – i.e., by increasing instrument stiffness – has contributed to finally broadening the application range of 25-gauge vitrectomy [31]. The use of silicone oil also was long considered a contraindication of the 25-gauge system [33], but meanwhile has been made possible by a 25/20-gauge hybrid system for silicone oil infusion [3]. While nowadays silicone oil may be infused through a 25-gauge sclerotomy, this process clearly prolongs surgery times.

Apart from this expanded range of applications, the increasing experience of surgeons as well as commercial aspects certainly contribute to the fact that 25-gauge technology to some extent is now being used in complicated findings such as proliferative vitreoretinopathy, diabetic retinopathy, and retinal detachment, i.e., in pathologies that require the removal of the peripheral vitreous or the complicated removal of membranes [33]. As before, however, 25-gauge vitrectomy is not suitable for all indications, and in these cases the surgeon must be able to resort to the 20-gauge system. This "dual equipment" is, of course, an additional and not trifling cost factor. On a whole, opinions on the applicability of the 25-gauge system vary widely: in a survey the "American Society of Retina Specialists" carried out in 2006, numerous surgeons (26.8%) stated that the 25-gauge system was a viable means in 26–50% of their cases [32]. On the other hand, almost as many surgeons (24%) feel the 25-gauge system can be used in only 11–25% of cases, while a further 22% of surgeons are of the opinion that they can use it in 51–75% of their cases. However, these data cannot be applied to Germany or Europe without difficulty, since in the US-American system the majority of procedures are carried out on an outpatient basis, and rapid patient recovery may rank higher than other aspects as compared with Germany/Europe.

25-gauge systems presently are available from two manufacturers (Alcon Laboratories, Ft. Worth, TX, USA; Bausch & Lomb, Rochester, NY, USA) and differ essentially in two aspects [31]. While the trocar of the first-generation 25-gauge system by Bausch & Lomb was developed on the principle of a hollow needle, which sometimes makes it difficult to introduce, the trocar of the Alcon 25-gauge system is based on a modified V-shaped stiletto blade, so that only a small amount of force is necessary for insertion [3]. The Bausch & Lomb vitrectome is operated electrically, while the Alcon vitrectome is pneumatically driven. Its low weight and resulting ease of handling is considered another advantage of the Alcon system [3].

There are two decisive benefits invariably mentioned in connection with the 25-gauge system, viz. faster patient rehabilitation and shorter surgery times. As a subjective assessment, most surgeons register more rapid patient rehabilitation or "less postoperative ocular trauma" following the application of a 25-gauge system [11, 15, 19, 35, 43]. It should be remembered, though, that shortened surgery times are primarily due to the fact that opening and closing the eye globe are considerably less time-consuming when a 25-gauge system is used, while vitreous removal is likely to take a little longer, because of the small lumen of the instrument [10]. In complicated procedures, requiring the extensive removal of vitreous, overall intervention time may actually be prolonged when using the 25-gauge system versus the 20-gauge system [11, 19].

In spite of its essentially positive aspects, certain limitations to the 25-gauge system persist to date. For instance, the higher flexibility and delicateness that is associated with 25-gauge instruments, as against the considerably more stable 20-gauge (and 23-gauge) instruments, make specific surgeon training a prerequisite [3, 10, 15, 19]. Moreover, high instrument flexibility renders certain surgical maneuvers impossible or feasible only subject to limitations [15, 20]. While, for example, the 20-gauge instrument may be used to rotate the eye for a better view of the periphery, this is hardly, if at all, possible with a 25-gauge instrument [20]. This is bound to create problems for the removal of peripheral vitreous. Introduction of the microcannulas also has been known to be difficult in some cases. Some reports describe detachment of a 25-gauge cannula from the trocar, as well as damage and bending of the cannula during introduction, so that inserting and retrieving the delicate 25-gauge instruments presented distinctly more problems and sometimes resulted in warping of the instrument [2, 20].

The disadvantages of the 25-gauge described may not necessarily entail serious complications, but may be the cause of time-consuming procedures. The time saved in opening and closing the eye may subsequently have to be "wasted," for instance, on more intricate surgical manipulations, that may become necessary because of instrument flexibility, or on intraoperative problems such as workflow that are complicated by the loss or damage of cannulas and instruments, or because extensive removal of the vitreous with a 25-gauge systems makes considerably higher demands on time.

Summary for the Clinician

- A complete 25-gauge vitrectomy system is first introduced in 2002 (Fujii et al. [10]).
- Due to small diameters this affords sutureless transconjunctival access and thus shorter surgery times (mainly because opening and closing the globe is less time-consuming), and faster patient rehabilitation.
- High vacuum settings (500 mmHg) and at the same time high cutting rates (1,500 cpm) are necessary to avoid the "plugging" of a 25-gauge vitrectome.
- 25-gauge is judged to be principally safe and efficient; complications do not occur more frequently than with 20-gauge vitrectomy.
- Application range initially was limited to "simple vitrectomies"; in the meantime this has been expanded thanks, for instance, to the wider array of instruments.
- Certain surgical maneuvers are impossible or feasible only subject to limitations; not applicable for thorough and extensive vitreous removal.
- Additional 20-gauge system may be necessary (dual instrumentarium/added cost).
- Switching to 25-gauge requires a specific training period (due to the higher flexibility and vulnerability of the instruments).

1.3 23-Gauge Vitrectomy Systems: The Future Gold Standard?

The accelerated efforts seen over the last 3 years in the development of a 23-gauge system designed to unite the benefits of the 20-gauge and the 25-gauge system were mainly driven by the limitations described for the 25-gauge system. Singh et al. [39] had, in fact, introduced a first electronic 23-gauge vitrectome as early as 1995, which they later complemented by a 23-gauge infusion system. This, however, was not a complete 23-gauge system providing a wide array of instruments, but just a portable system whose use was meant exclusively for vitreous biopsies and minor office-based interventions – as carried out mainly in the USA [5, 14]. Almost 10 years passed before a fully integrated 23-gauge vitrectomy system for routine clinical use had been designed: in 2005 Eckardt [8] in cooperation with DORC (The Netherlands) eventually introduced a complete 23-gauge instrumentarium and demonstrated its safety and efficiency in a first evaluation study. Presently, 23-gauge systems are available on a larger scale from four manufacturers: Alcon Laboratories (Ft. Worth, TX, USA; Figs. 1.2 and 1.3), DORC (The Netherlands), Oertli

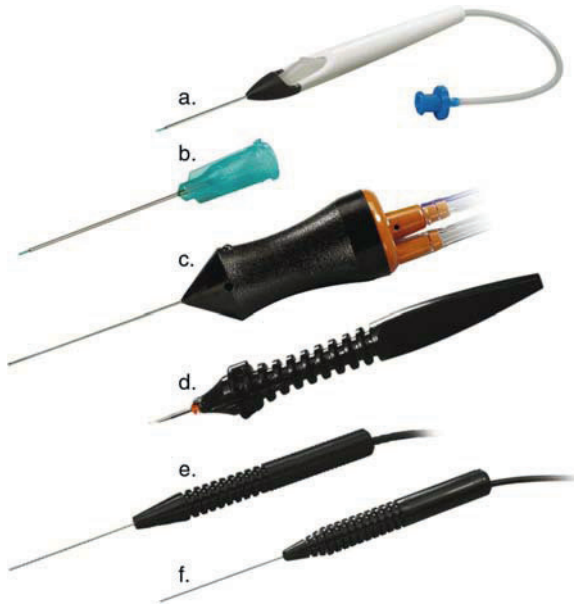


Fig. 1.2 23-gauge vitrectomy system: flute needle (**a**), soft-tip cannula (**b**), vitrectome (**c**), microtrocar (**d**), endoillumination probe (**e**), and endolaser probe (**f**). From Augustin AJ, Offermann J (2007) Möglichkeiten und Grenzen der innovativen Vitrektomiessysteme, eine Übersicht. Klin Monatsbl Augenheilkd 224:707–715

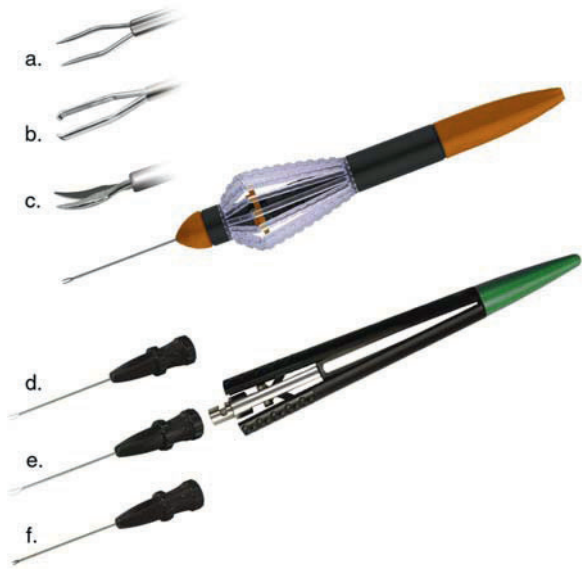


Fig. 1.3 23-gauge instruments: end-gripping forceps (**a**), ILM forceps (**b**), disposable curved scissors and resterilizable handpiece (**c**) with end-gripping forceps tip (**d**), ILM forceps tip (**e**), and curved scissors tip (**f**). From Augustin AJ, Offermann J (2007) Möglichkeiten und Grenzen der innovativen Vitrektomiessysteme, eine Übersicht. Klin Monatsbl Augenheilkd 224:707–715

(Switzerland), and Geuder AG (Heidelberg, Germany). Figures 1.2 and 1.3 show a 23-gauge vitrectomy system as well as a 23-gauge instrument portfolio. 23-gauge instruments combine considerably higher stiffness and stability than 25-gauge instruments, with a diameter that is smaller than that of 20-gauge instruments; this permits them to be introduced into the eye through transconjunctival sutureless sclerotomies [8]. Unlike the 25-gauge trocars, 23-gauge trocars are not introduced perpendicular to the scleral surface, but at an angle, and instrumentation is brought to a vertical position in subsequent steps. This type of two-step access is designed to facilitate postoperative closure of the sclerotomies by intraocular pressure, ensuring higher integrity of wound closure than with 25-gauge sclerotomies. As early as 2005, Eckardt [8] was able to demonstrate that all 23-gauge sclerotomies were self-sealing and tight. Another very interesting and plausible method under anatomical physiological aspects was recently proposed by Rizzo et al., who suggested turning the blade by 30° or a little more. This wound configuration considers the course of the collagen fibers, which ensures even better wound closure [34]. Since 23-gauge instruments can be said to be similar to 20-gauge instruments for stiffness and stability, the training period for a surgeon when switching to 23-gauge is much shorter than with 25-gauge instruments, and might more aptly be termed a familiarizing phase. In addition, distinctly higher infusion and aspiration rates could safely be expected with the 23-gauge system than are obtained with the 25-gauge system (Poiseuille's Law, see above), so that careful and extensive vitreous removal – which should continue to be the standard routine – would pose no problem when using the 23-gauge system. This is corroborated by the fact that, at a vacuum level of 600 mmHg and depending on the cutting rate, the same or even higher flow rates are obtained than with the 20-gauge system (Table 1.3). Thanks to higher flow rates plus increased instrument stability, the 23-gauge system may be employed in simple as well as in complicated vitrectomies, and thus is suitable for a wider application range than the 25-gauge systems. The application range of 23-gauge vitrectomy is almost identical to that of the 20-gauge system, while surgery times are shortened and interventions are less invasive [41]; it follows, therefore, that it does combine the benefits of the 25-gauge and 20-gauge systems. First experience suggests that solely the use of silicone oil may lead to sclerotomy leakage, so that in these cases sutures are required for wound closure. First experiments have been carried out investigating "dual-diameter" devices (23-gauge for infusion and illumination, 20-gauge for the working channel). While there is, of course, the advantage that surgeons can continue to use available 20-gauge systems, the potential benefits of the 23-gauge system (more rapid rehabilitation, no opening of the conjunctiva) are not turned to maximum profit.

The preliminary results and experience obtained with 23-gauge systems are extremely promising in principle, and with few exceptions 23-gauge vitrectomy may well be able to replace 20-gauge vitrectomy in the near future [9].

Summary for the Clinician

- The first complete 23-gauge vitrectomy system was introduced in 2005 and is judged to be safe and efficient (Eckardt).
- It also affords transconjunctival sutureless access, and thus shortened surgery times and faster patient rehabilitation.
- At a vacuum level of 600 mmHg, the same or even higher flow rates are obtained than with the 20-gauge system.
- Unlike 25-gauge vitrectomy, switching to 23-gauge systems merely requires a "familiarizing" phase, since instrument characteristics are similar to those of 20-gauge instruments (stiffness, robustness).

Table 1.3. Comparison of different vitrectomes (20-, 23-, and 25-gauge) for cutting rates, inherent stability, as well as flow rates at given aspiration and cutting rates

	20-gauge	23-gauge	25-gauge
Max. cutting rate (cpm)	**2,500**	**2,500**	**1,500**
Inherent stability (g/4 mm)	130	35	14
Flow rates (ml min^{-1}) at given vacuum levels and zero cuts	18 (150 mmHg)	23 (600 mmHg)	10 (600 mmHg)
Flow rates (ml min^{-1}) at given vacuum levels and max. cutting rate	9 (150 mmHg)	9 (600 mmHg)	5 (600 mmHg)

When working with the 23-gauge and 25-gauge systems, high suction levels are required to obtain sufficient flow rates. However, flow rates with the 25-gauge systems continue to remain distinctly lower (even at high suction levels) than those of the two other systems.

Summary for the Clinician

- The system has a very wide application range, therefore no additional vitrectomy system is necessary.
- The 23-gauge system combines the benefits of the 25-gauge and 20-gauge systems: it provides shortened surgery times and less invasive interventions, while at the same time its application range is almost identical to that of the 20-gauge system.
- 23-gauge vitrectomy has the potential to become the future "gold standard."

References

1. Augustin AJ, Offermann I (2007) Scope and limitations of innovative vitrectomy systems. Klin Monatsbl Augenheilkd 224:707–715
2. Byeon SH, Chu YK, Lee SC et al (2006) Problems associated with the transconjunctival sutureless vitrectomy system during and after surgery. Ophthalmologica 220:259–265
3. Charles S (2005) Tips and tricks for 25-gauge sutureless vitrectomy. Rev Ophthalmol. http://www.revophth.com/index.asp?page=1_670.htm
4. De Bustros S, Thomson JT, Michels RG et al (1988) Vitrectomy for idiopathic epiretinal membranes causing macular pucker. Br J Ophthalmol 72:692–695
5. De Juan E (2003) Sutureless vitrectomy surgery. Author reply. Ophthalmology 110:2427
6. De Juan E, Hickingbotham D (1990) Refinements in microinstrumentation for vitreous surgery. Am J Ophthalmol 109:218–220
7. De Juan E, Machemer R (1987) Retinopathy of prematurity. Surgical technique. Retina 7:63
8. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
9. Eckardt C (2006) Further experience with 23-gauge transconjunctival vitrectomy. Retina Today. http://www.retinatoday.com/html Pages/1106/RT1106_CF_Eckhardt.h
10. Fuji GY, de Juan E, Humayun MS et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1813
11. Fuji GY, de Juan E, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
12. Goldstein DJ, Oz MC (1999) Current status and future directions of minimally invasive cardiac surgery. Curr Opin Cardiol 14:419–425
13. Harell AG, Heniford BT (2005) Minimally invasive abdominal surgery: lux et veritas past present and future. Am J Surg 190:239–243
14. Hilton GF, Josephberg RG, Halperin LS et al (2002) Office-based sutureless transconjunctival Pars Plana Vitrectomy. Retina 22:725–732
15. Ibarra M, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
16. Klöti R, Vitrektomie I (1973) Ein neues Instrument für die hintere Vitrektomie. Graefes Arch Clin Exp Ophthalmol 187:161
17. Koh CH, Janik GM (1999) Laparoscopic microsurgery: current and future status. Curr Opin Obstet Gynecol 11: 401–407
18. Korobelnik JF, Devin F, Tadayoni R et al (2005) Safety of 25-gauge 3 ports pars plana vitrectomy. ARVO 2005; Invest Ophthalmol Vis Sci 46:5462
19. Lakhanpal RR, Humayun MS, de Juan E et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for poaterior segment disease. Ophthalmology 112:817–824
20. Lam DSC, Yuen CYF, Tam BSM et al (2003) Sutureless vitrectomy surgery. Ophthalmology 110:2428–2429
21. Lommatzsch A, Spital G, Trieschmann M, Pauleikoff D (2008) Langzeitergebnisse nach pars-plana Vitrektomie in 25-Gauge Technik. [Long-term results after pars plana vitrectomy with 25-gauge technique.] *Ophthalmologe* 105: 445–451 [Epub ahead of print 4 Oct 2007]
22. López-Guajardo L, Pareja-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 141(6):1154–1156
23. Lundell L (2000) Anti-reflux surgery in laparoscopic era. Baillieres Best Pract Res Clin Gastroenterol 18:272–277
24. Machemer R, Buettner H, Norton EWD, Parel JM (1971) Vitrectomy: a pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 75:813
25. Machemer R, Parel JM, Buettner H (1972) A new concept for vitreous surgery. 1. Instrumentation. Am J Ophthalmol 73:1
26. Mango CW, Gupta A, Chen CS et al (2005) 25-gauge transconjunctival safety: post-operative complications. ARVO 2005; Invest Ophthalmol Vis Sci 46:E-Abstract 5459
27. Margherio RR, Cox MS Jr, Trese MT et al (1985) Removal of epimacular membranes. Ophthalmology 92:1075–1083
28. McDonald HR, Verre WP, Aaberg TM (1986) Surgical management of idiopathic epiretinal membranes. Ophthalmology 93:978–983
29. Miller KM, Glasgow BJ (1993) Bacterial endophthalmitis following sutureless cataract surgery. Arch Ophthalmol 111:377–379
30. O'Malley C, Heintz RM (1972) Vitrectomy via the pars plana – a new instrument system. Trans Pac Coast Otoophthalmol Soc Annu Meet 53:121–137
31. Packo K (2004) Early experience reveals benefits of 25-gauge technology. Rev Ophthalmol. http://www.revophth.com/index.asp?page=1_563.htm

32. PAT Survey (2006) http://www.asrs.org/pat/2006/header.php?s=54
33. Riemann CD, Miller DM, Foster RE, Petersen MR (2007) Outcomes of transconjunctival sutureless 25-gauge vitrectomy with silicone oil infusion. Retina 27:296–303
34. Rizzo S, Genovesi-Ebert F (2007) Angled incision techniques for 25-g and 23-g surgery. Euretina, 17–20 May 2007
35. Rizzo S, Genovesi-Ebert F, Murri S et al (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol 244:472–479
36. Rizzo S, Belting C, Cresti F, Genovesi-Ebert F (2007) Sutureless 25-gauge vitrectomy for idiopathic macular hole repair. Graefes Arch Clin Exp Ophthalmol 245(10):1437–1440 [Epub 15 March 2007]
37. Rizzo S, Genovesi-Ebert F, Vento A, Miniaci S, Cresti F, Palla M (2007) Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicroscopic study. Graefes Arch Clin Exp Ophthalmol 245(9):1281–1288 [Epub 21 February 2007]
38. Scartozzi R, Bessa AS, Gupta OP, Regillo CD (2007) Intraoperative sclerotomy-related retinal breaks for macula surgery, 20- vs. 25-gauge vitrectomy systems. Am J Ophthalmol 143:155–156
39. Singh S, Josephberg RJ, Zaidman GW (1996) Office-based diagnostic pars plana vitrectomy. Invest Ophthalmol Vis Sci 37:402
40. Stonecipher KG, Parmley VC, Jensen H, Rowsey JJ (1991) Infectious endophthalmitis following sutureless cataract surgery. Arch Ophthalmol 109:1562–1563
41. Tewari A, Shah GK (2006) 23-gauge: the further evolution of vitrectomy. Rev Ophthalmol. http://www.revophth.com/index.asp?page=1_984.htm
42. Trese M (1986) Two hand dissection technique during closed vitrectomy for retinopathy of prematurity. Am J Ophthalmol 101:251
43. Yanyali A, Celik E, Horozoglu F et al (2006) 25-gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16:141–147

Chapter 2

25-Gauge Instrumentation: Engineering Challenges and Tradeoffs

A.C. Barnes, C.M. DeBoer, P.R. Bhadri, O. Magalhaes Jr., R.M. Kerns, M.T. McCormick, L.P. Chong, M.S. Humayun

Core Message

- 25-gauge instrumentation has reduced the surgical incision size. This reduction in size has made vitreoretinal procedures not only sutureless but, more importantly, made the procedures less invasive and potentially safer.
- The sutureless 25-gauge pars plana vitrectomy reduces the postoperative inflammation at sclerotomy sites, thus reducing patient discomfort after surgery and hastening postoperative recovery.
- The majority of experienced vitreoretinal surgeons have now been exposed at some level to 25-gauge instrumentation, and many use it on a routine basis. However, only a few surgeons have experience with the engineering development challenges and tradeoffs associated with small-diameter instrumentation.
- This chapter will explore some of the key areas of the design and functioning of small-diameter instruments, so that surgeons may better understand their performance.

2.1 Introduction

25-gauge instrumentation refers to the body of devices designed specifically to work in conjunction with the 25-gauge Entry Site Alignment system (ESA) or microcannula system. The ESA system is the key to 25-gauge instrumentation, and allows the surgeon pars plana access to the vitreous chamber without having to perform conjunctival peritomy (i.e., transconjunctival access), and the ability to remove the system without the need for sutures [1]. The main components used with the ESA system include: a fiber optic light pipe, vitreous cutter, and a range of manipulation and task-specific instruments (Fig. 2.1).

The main advantage of 25-gauge instrumentation — and that which creates engineering challenges — is the dimensional constraint of instruments 0.5 mm in diameter. Compared to 20-gauge, 25-gauge instruments have 70% less cross-sectional area to recreate the functionality surgeons expect (Fig. 2.2). This chapter will explore how the size of 25-gauge instrumentation affects mechanical properties, such as fluid dynamics and stiffness, and optical properties associated with illumination. As engineering solutions to these challenges continue to be developed, transconjunctival 25-gauge instrumentation will continue to improve as well.

Currently, there are at least four major brands of 25-gauge instrumentation Bausch and Lomb Inc. (St. Louis, MO, USA), Alcon Laboratories, Inc (Fort Worth, TX, USA), Dutch Ophthalmic, USA (Kingston, NH, USA), Synergetics Inc. (O'Fallon, MO, USA), as well as others) (Fig. 2.3). There are differences between these systems that affect their performance, and some of these will be highlighted. But, as designs evolve and new instrumentation is launched, the comparative landscape is constantly in flux. The goal of this chapter is to provide information on how the design parameters of 25-gauge instruments affect their performance, so that surgeons are better prepared to evaluate and operate current and future instrumentation. For example, 23-gauge instrumentation systems for use with tunneling scleral incisions are just beginning to be evaluated and compared to 20 and 25-gauge instrumentation [9]. Journal articles, conference presentations, and manufacturer information highlighting various comparisons may lead to confusion. Hopefully, this chapter will allow a better understanding of the underlying scientific reasons behind any performance differences.

2.2 Microcannula System

The 25-gauge Entry Site Alignment system (ESA) is the primary component of 25-gauge instrumentation. The ESA system establishes the pars plana transconjunctival

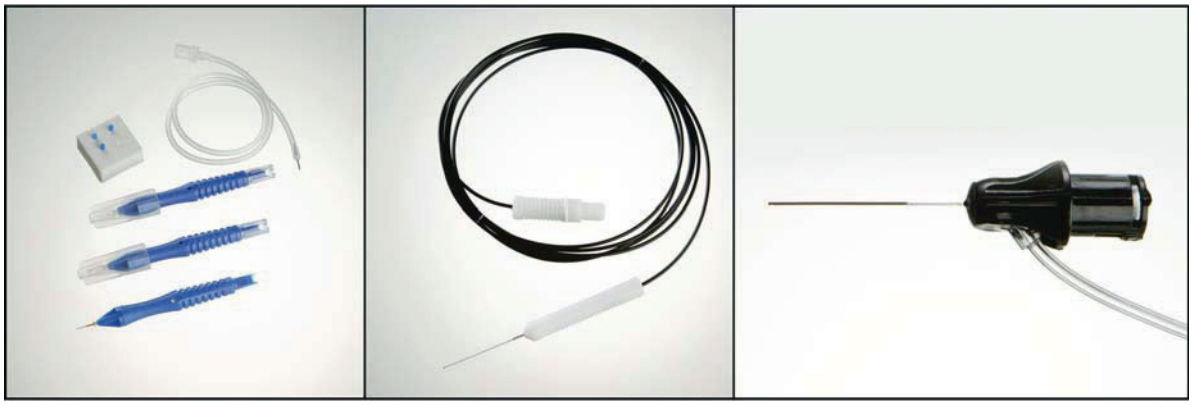


Fig. 2.1 Main components of 25-gauge instrumentation

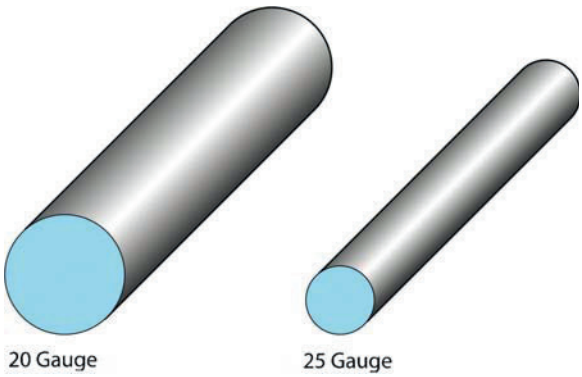


Fig. 2.2 Comparison of cross-sectional areas (20-gauge vs. 25-gauge)

entry ports into the vitreous chamber, and provides access for the balance of the 25-gauge instruments. As the name suggests, the ESA system serves to maintain alignment between the entry holes in the conjunctiva and sclera, as well as provide unobstructed instrument access. This is especially important due to the small size of 25-gauge wounds and the technique of conjunctival displacement prior to the insertion of the ESA system. While microcannula systems are optional for 20-gauge instrumentation, it is not recommended to attempt 25-gauge cases without the use of the ESA system. It is not feasible to attempt to locate and align 25-gauge conjunctival and scleral entry ports each time an instrument is inserted.

The ESA system components include: the 25-gauge trocar-mounted microcannulas, cannula plugs, and infusion line (Fig. 2.4). The microcannulas are preloaded on the 25-gauge needle trocars and the combined components of the trocar needle, microcannula, and trocar handle is referred to as the trocar/cannula assembly. The trocar handle allows the surgeon to securely grasp the assembly during insertion. Some trocar handles provide advanced features such as built-in marking calipers for consistent cannula placement within the pars plana.

The microcannulas consist of two components: a polyimide cannula and a polymer cannula hub. The polyimide cannula is mounted within the polymer hub or collar. The cannula forms the entry port, and utilizes a distal bevel to facilitate insertion through the tissue. The polyimide cannula material provides both strength and flexibility, allowing the cannula wall to be thin and to avoid collapsing or buckling. The hub maintains the position of the cannula, and prevents it from sliding too far into the vitreous chamber. In addition, the hub allows

Fig. 2.3 25-gauge microcannula systems from various manufacturers

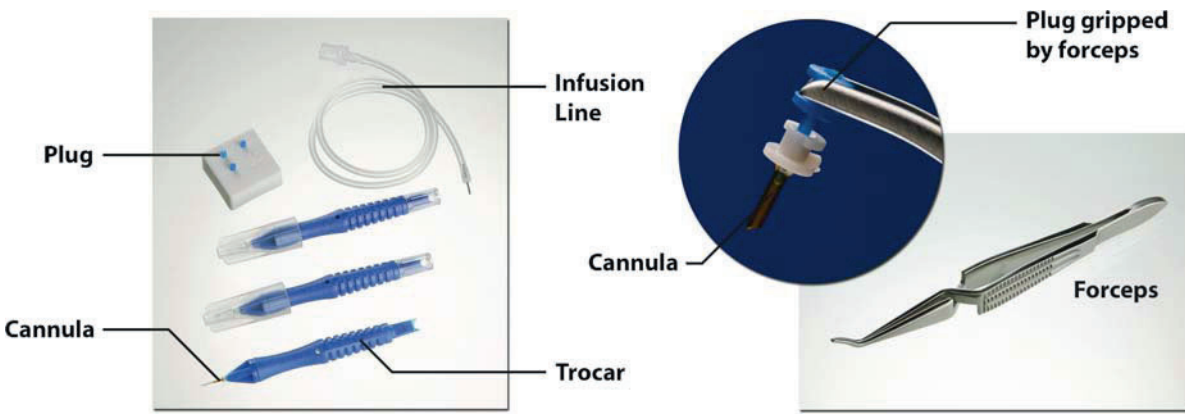


Fig. 2.4 25-gauge Entry Sight Alignment system components

surgeons to grasp the cannula, and provides an entry funnel to assist during instrument insertion.

The cannula plug is used to seal the cannula after insertion into the eye wall. It is designed with a tapered shaft or a tight sliding fit to seal within the cannula port. The plug should be inserted only as far as necessary to seal the cannula. Forcing the plug too far within the cannula may cause problems during removal. Even with proper plug insertion, counter-force should be applied to the cannula hub when removing a plug. Both the plug and the cannula hub are designed to facilitate manipulation using standard ophthalmic forceps or specialized scleral plug forceps. The infusion line is designed to have a tight sliding fit within the cannula port, and provides a standard female Luer-lock adapter on the proximal end of the tubing. The infusion line may be relocated to any available cannula as necessary.

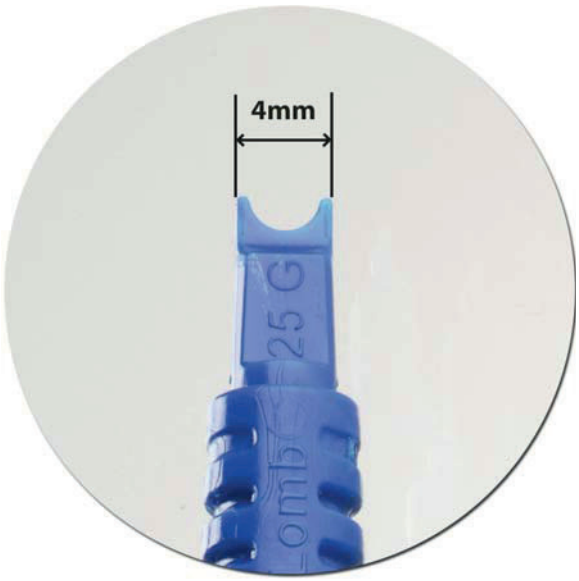


Fig. 2.5 Integrated scleral markers

2.3 Entry

The ESA system is designed to transconjunctivally insert the 25-gauge microcannulas within the pars plana. Entry points may be indicated with standard calipers or, for some systems, utilizing the integrated scleral markers (Fig. 2.5). These markers provide three possible measurements. The distance between the centers of each marker is 3.5 mm, while the distance from each outside edge and each inside edge is 4.0 mm and 3.0 mm respectively.

The performance of the trocar/cannula insertion (Fig. 2.6) is influenced by a number of factors and forces, including: the trocar needle puncture, sliding friction, cannula insertion, and the overall size of the wound. The initial puncture which begins the insertion process is accomplished when the distal end of the trocar needle tip applies enough pressure to cause the tissue structure to fail or displace. Various parameters play a role during the initial puncture,

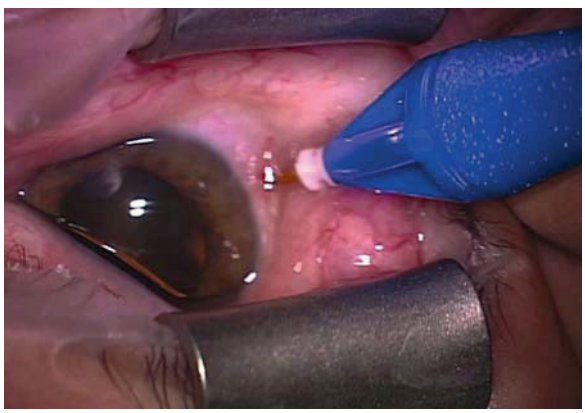


Fig. 2.6 Trocar/cannula insertion

including the size of the trocar point (sharpness), the tissue condition, and the intraocular pressure. The total force applied to the trocar handle to initiate the puncture is affected by the trocar point size and the state of the patient's tissue. The pressure necessary for puncture is dictated by the composition of the tissue, while the total force needed to reach this pressure is governed by the area of the trocar point (pressure = force per unit area).

For the trocar to reach the critical puncture pressure, the tissue must oppose the applied force. The tissue at or near the puncture site will usually deflect prior to fully opposing the applied trocar force. The amount of deflection is affected by the tissue and the intraocular pressure. As the tissue deflects away from the trocar point, the intraocular volume is reduced and the intraocular pressure increases until it opposes the trocar force. This allows the point pressure to rise until the tissue is punctured. Lower initial intraocular pressure may allow greater eye wall deflection prior to trocar puncture. To minimize eye wall deflection and intraocular pressure spikes during trocar/cannula insertion, the trocar needle should have a sharp undamaged point.

Once the trocar point punctures, the trocar side bevels begin to slice and enlarge the wound so that it may accommodate the trocar shaft. As the trocar enters, the wound tissue exerts a normal force on the trocar surface. This force provides sliding resistance or friction based on the frictional coefficient and surface area of the shaft. The sliding friction may be improved by reducing the frictional coefficient of the trocar shaft.

The next critical event during the trocar/cannula entry is the insertion of the polyimide cannula into the wound created by the trocar. The distal end of the cannula is cut at approximately a 30° angle to assist the introduction of the cannula into the wound. The bottom bevel cut introduces a small portion of the cannula into the wound, and allows the wound to progressively stretch to accommodate the full cannula diameter. This feature minimizes the potential for the leading edge of the cannula to catch on tissue, which may result in increased insertion force and cannula buckling. When this situation is encountered during cannula insertion, the tendency is to apply more force which may exacerbate the problem. Decreasing insertion pressure and slightly withdrawing the trocar/cannula can allow any tissue caught on the cannula to be dislodged prior to proceeding with the cannula insertion.

One metric that impacts cannula insertion into the trocar wound, as well as cannula performance during the case is the Trocar/Cannula Delta (T/C Delta). The T/C Delta provides a measure of the gap between the outer diameter of the trocar and the inner diameter of the cannula (Fig. 2.7).

The larger the T/C Delta, the more the trocar wound has to stretch to accommodate the cannula, and the greater the risk of tissue incarceration into the T/C gap during cannula insertion. The increased insertion force associated with the cannula becoming caught on tissue can cause greater eye wall deflection, increased intraocular pressure, and potential cannula buckling. Obviously, it is important to minimize the T/C Delta, just as it is important to maintain a sharp trocar point.

As with most design parameters, there are tradeoffs associated with the T/C Delta. First, the T/C Delta

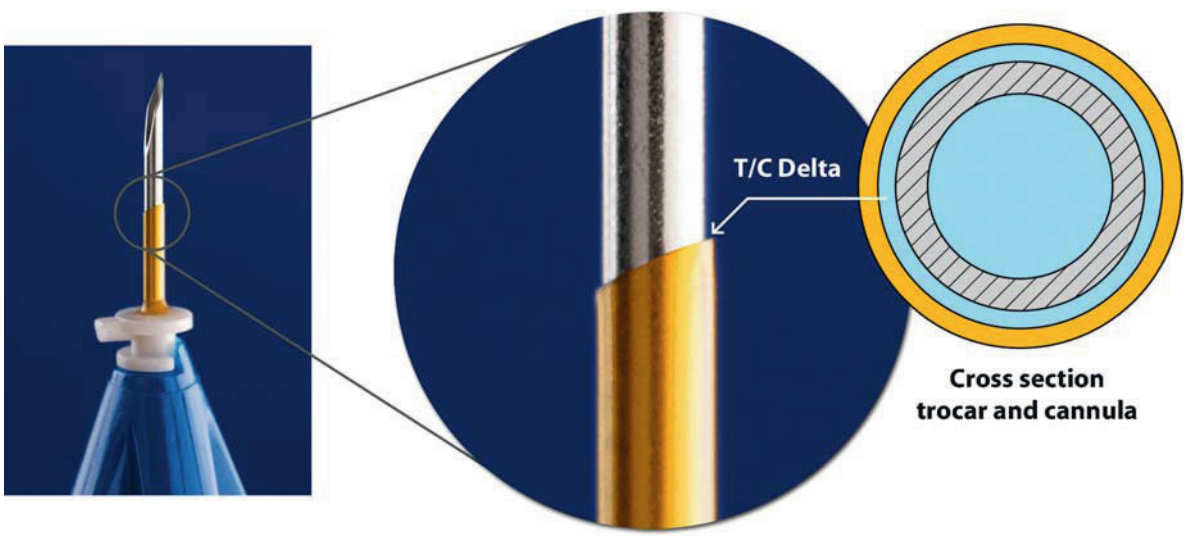


Fig. 2.7 Illustration of Trocar/Cannula Delta

provides a measure of how easily the cannula is able to slide relative to the trocar shaft. If the T/C Delta is too small, the cannula insertion will be smooth but it may be difficult for the surgeon to remove the trocar from the cannula. A large trocar handle force and a large cannula counterforce may be necessary to remove the trocar. As the trocar slides free of the cannula under a large retraction force, the surgeon's hand can accelerate away from the eye, leading to a number of adverse events, including: contact with non-sterile portions of the surgical microscope, contact with or sticking of the needle to the assistant or self, or over-compensation leading to an inadvertent sticking of the trocar to the patient's eye. Secondly, the T/C Delta governs the extent the wound stretches to accept the cannula and thus the normal force applied to the outer surface of the cannula. This normal force affects both the amount of friction holding the cannula in place during the case, and the amount of force required for cannula removal at the conclusion.

A T/C Delta that is too small may allow an easy insertion, but may not provide enough wound holding force to prevent inadvertent cannula removal during the case. Too large a T/C Delta may lead to large insertion forces, cannula buckling, and large cannula removal forces.

2.4 Infusion

Each ESA system includes a cannula-based infusion line with a female Luer-lock connector, to allow a secure connection to the balanced salt solution (BSS) infusion tubing and bottle (Fig. 2.8). The infusion cannula is designed to have a precise sliding fit within the microcannula. This allows insertion by the surgeon, but provides enough friction to prevent ejection of the line during the case. If necessary, the infusion line may be relocated to any microcannula.

The role of the infusion cannula is to maintain the intraocular pressure at the level selected by the surgeon via the microsurgical system. The infusion cannula must provide adequate volume flow rate to maintain this pressure while fluid is being removed from the eye either by aspiration or leakage [3]. A more detailed discussion of fluid dynamics is covered in the Fluid Dynamics Sidebar. The relationship between the various parameters established in the sidebar will be utilized in the fluidics discussion relating to the infusion line and the vitreous cutter.

The cannula-based infusion line of the ESA system is similar to its 20-gauge counterpart until about the last centimeter. The extension line, Luer connector, stopcock, and BSS bottle connection tubing are substantially equivalent for both 25 and 20-gauge infusion lines. The difference is found relatively close to the eye in the size of the infusion cannula. (Note: some early 25-gauge infusion line extension tubing was significantly smaller than that of a 20-gauge line and could affect flow, but for this chapter, extension line effects will be assumed similar to 20-gauge) As one would expect, and may be seen in the Fluid Dynamics Sidebar, the smaller inner diameter of the 25-gauge infusion cannula provides greater flow resistance than 20-gauge infusion cannulas. To generate a volume flow rate similar to that of a 20-gauge infusion cannula, the 25-gauge cannula requires a greater pressure differential. In addition, from the continuity equation, the flow velocity of the 25-gauge cannula will be higher at the same volume flow rate, due to the smaller cross-sectional area.

The lower average volume flow rate associated with the small size of the 25-gauge infusion cannula is balanced by the corresponding increase in flow resistance of the

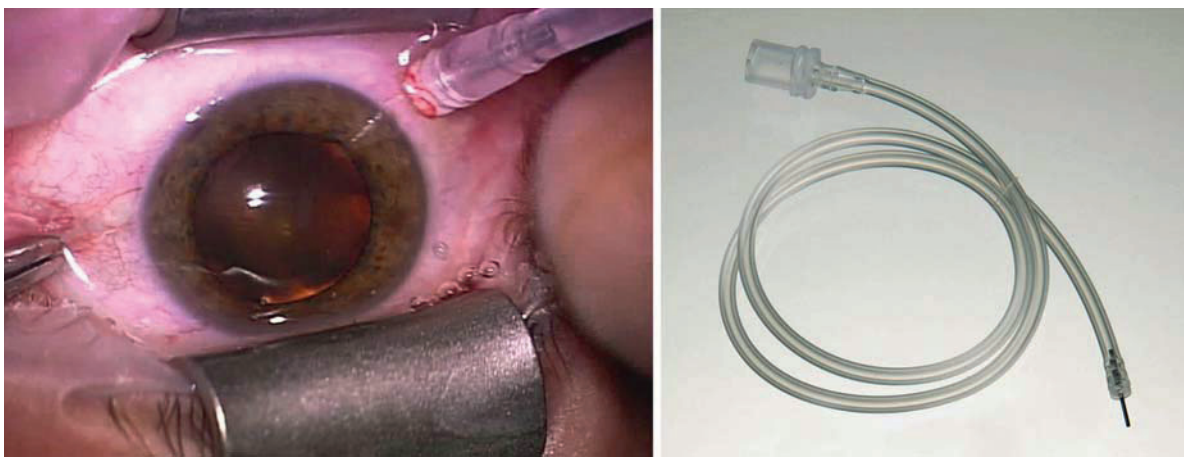


Fig. 2.8 25-gauge cannula based infusion line

vitreous cutter. During 25-gauge vitrectomy, the infusion cannula is not required to deliver the volume flow rate needed for a 20-gauge case. In general, 25-gauge cases require less BSS than 20-gauge cases, due to reduced fluid turnover during 25-gauge vitrectomy and minimal leakage from the ESA system.

The principles of infusion can be used to understand procedures like air/fluid exchange. In this situation, the infusion enters the eye and directly impacts the retina. This has been shown to cause damage [10–13]. As the velocity of the infusion increases, more pressure is applied to the retina, which may increase damage. As discussed above, the smaller diameter of the 25-gauge infusion cannula can generate higher velocities, potentially increasing the force on the retina. The infusion parameters should be adjusted to minimize these effects. One possible solution is an atraumatic infusion cannula, which perturbs the infusion flow as it enters the eye [14].

Summary for the Clinician

- Entry Site Alignment system (ESA is the key to 25-gauge instrumentation).
- The ESA system serves to maintain alignment between the entry holes in the conjunctiva and sclera, as well as provide unobstructed instrument access. It is not recommended to attempt 25-gauge cases without the use of the ESA system.
- The performance of the trocar/cannula insertion is influenced by a number of factors and forces, including: the trocar needle puncture, sliding friction, cannula insertion, and the overall size of the wound.
- The infusion cannula is designed to have a precise sliding fit within the microcannula. This allows insertion by the surgeon, but provides enough friction to prevent ejection of the line during the case. If necessary, the infusion line may be relocated to any microcannula.
- The lower average volume flow rate associated with the small size of the 25-gauge infusion cannula is balanced by the corresponding increase in flow resistance of the vitreous cutter.

2.5 Fluid Dynamics Sidebar

Surgeons encounter many critical intraoperative situations when they have to determine appropriate infusion and aspiration variables. With knowledge of the relationships between the various parameters, a surgeon will be better equipped to adjust the flow settings for the desired outcome, and will understand how 25-gauge instrumentation differs from 20-gauge. This sidebar is intended to give a more detailed description of the underlying fluid dynamics governing infusion and aspiration flow. It is not a complete tutorial for fluid dynamics. The equations are shown to highlight the relationships between flow variables, and may not provide a full description of the flow situation, boundary conditions, and assumptions necessary to apply the equations directly.

Rolf H. Sabersky et al. describes a fluid as "A substance that, when at rest, cannot sustain a shear force (that is, a force exerted tangentially to the surface on which it acts)." [15] The fluid in this case is primarily BSS, or water, an incompressible viscous fluid. One of the principal equations governing incompressible fluid flow is the continuity equation. This equation is a result of mass conservation, and may be applied to incompressible fluids. It states that for a control volume, the net flux of fluid into the volume is equal to the net flow out. The mass flow rate into or out of a pipe, which is constant, may be taken as the fluid density multiplied by the fluid velocity times the area of the pipe:

$$Mass\ flow\ rate = \rho \cdot V \cdot A = Constant$$

The volume flow rate (Q) may be obtained by dividing through by the fluid density, and the continuity equation may be used to compare the velocity at one point in a tube to another point.

It may be seen in Fig. 2.9 that the cross-sectional area and velocity are inversely proportional. As the area of the cross-section increases, the velocity decreases. For the same volume flow rate, a smaller diameter tube will produce a higher velocity fluid flow. Therefore, as instrumentation becomes smaller, larger flow velocities are required to maintain comparable volumetric flow rates to larger systems.

While the continuity equation may be used to describe the velocity in tubing with varying diameters, the Bernoulli equation may be used to describe flow into and out of the eye. The Bernoulli equation is typically used to describe an inviscid, incompressible fluid moving along a streamline from point A to point B. Bernoulli's equation states that the total energy (or head) along the streamline remains constant. It shows the relationship between the three main forms of head: velocity head, gravity head, and pressure head.

$$Bernoulli\ equation: \quad \frac{V^2}{2} + gh + \frac{p}{\rho} = Constant$$

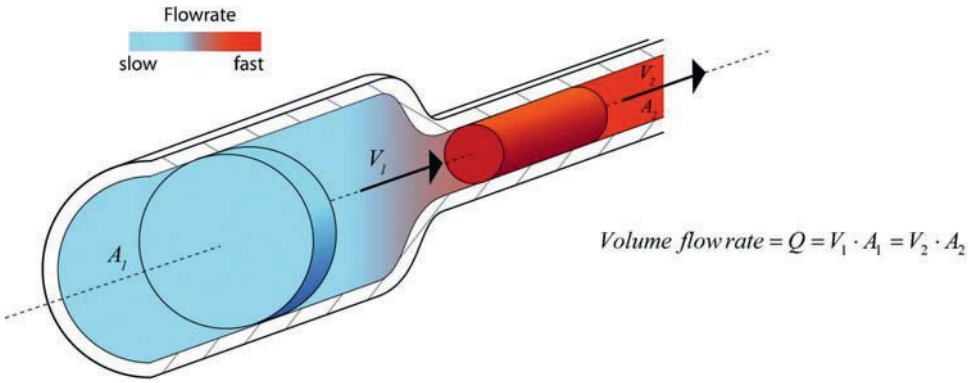


Fig. 2.9 Volume flow rate in a pipe

where:

V = fluid velocity
g = gravitational acceleration
h = height above a datum point
p = pressure
ρ = fluid density

For viscous fluids, such as BSS, some of the energy of the fluid is transferred out as heat, and loss terms, or viscous head, must be added to the equation. Substituting in the variables associated with infusion into the eye, the

$$\frac{V_{bottle}^2}{2} + gh_{bottle} + \frac{p_{bottle}}{\rho_{BSS}} + Losses = \frac{V_{eye}^2}{2} + gh_{eye} + \frac{p_{eye}}{\rho_{BSS}}$$

equation becomes:

The losses due to friction, transitions, or diameter changes of the infusion line are on the left hand side of the equation. To simplify the equation, a number of terms may be canceled. The fluid in the bottle is near stationary, and therefore V_{bottle} is approximated as zero. The height of the eye is typically chosen as the datum level, and therefore h_{eye} is zero relative to the bottle (the bottle height is referenced off the eye).

$$gh_{bottle} + \frac{p_{bottle}}{\rho_{BSS}} + Losses = \frac{V_{eye}^2}{2} + \frac{p_{eye}}{\rho_{BSS}}$$

From this equation it is evident that the height of the bottle or the pressure in the bottle provides the driving force for the intraocular pressure. To drive the flow into the eye, either the pressure in the bottle (e.g., VGFI) or the bottle height (e.g., IV pole) can be increased.

The losses on the left hand side of the equation are dependent on flow; as the flow velocity reaches zero so do the loss terms, resulting in the hydrostatic pressure equation for an incompressible fluid.

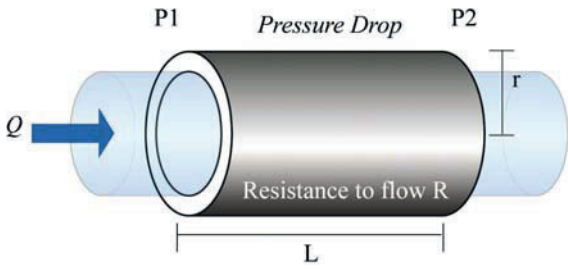
$$p_{bottle} - p_{eye} = -\rho_{BSS} gh_{bottle}$$

In general, the viscous head is a function of the fluid velocity, tubing diameter, and position along the streamline (viscous head builds or integrates as it removes head from the other terms). It is also scaled by the tube or pipe friction factor, which depends on the Reynolds number and the roughness of the tube surface. For low Reynolds number laminar flow, such as that encountered in the infusion line, the friction factor depends solely on the Reynolds number. For more detailed information on the viscous loss terms, consult your favorite fluid dynamics reference.

While the Bernoulli equation describes how fluid moves along a streamline, Poiseuille's law describes the volume flow rate of an incompressible viscous fluid through a tube of constant circular cross-section. This equation may be derived from the Bernoulli equation by accounting for frictional losses (which are solely a function of Reynolds number in laminar flow).

Poiseuille's law illustrates the key relationships between the flow parameters and volume flow rate. In particular, note the strong influence of the inner radius on flow. If the inner radius is reduced by half, the volume flow rate decreases by a factor of sixteen. The remaining terms show that the volume flow rate is directly proportional to the pressure differential, while inversely proportional to the fluid viscosity and the length of tube (Fig. 2.10).

The principal differences between the 25- and 20-gauge infusion line and vitreous cutter are found at the distal tubes (cannulas) that enter the eye. Poiseuille's law may be used to illustrate the increased driving force required for smaller diameter instruments. When the inner diameter



$$Q = V \cdot A = V\pi r^2 = \frac{\Delta P \cdot \pi r^4}{8\eta L}$$

where:

Q = volume flow rate
V = fluid velocity
A = cross-sectional area
r = inner radius
ΔP = pressure differential
η = fluid viscosity (*dynamic*)
L = length

Fig. 2.10 Poiseuille's law

Fig. 2.11 25-gauge vitreous cutter tip

Fig. 2.12 Vitreous demonstrating solid characteristics

of the instrument is reduced, a larger pressure differential is required to maintain equivalent flow rates. For example, in 25-gauge vitrectomy cases, higher pressures are typically required to produce similar flow rates to corresponding 20-gauge procedures.

2.6 Vitreous Cutter

25-gauge vitreous cutters are designed to function through the ESA microcannula system (Fig. 2.11). They are currently available as high-speed guillotine-style cutters, driven either electrically or pneumatically. Other than their size differences, current 25-gauge vitrectomy cutters are the same as their 20-gauge counterparts, and operate at similar cut rates.

Unlike the infusion cannula, the vitrectomy handpiece is used in both vitreous and BSS (as well as other intraocular solids and fluids). BSS is a fluid, and obeys fluidics laws such as the Bernoulli equation. In contrast, vitreous is not a fluid. This may seem counterintuitive, as it is aspirated in a similar manner to BSS and does flow through the lines. When considered a little more, it becomes more evident. It is primarily water (98%), with the remaining material (2%) consisting mainly of collagen, hyaluronic acid (HA) and other noncollagenous

proteins and glycoproteins. This remaining matrix of material accounts for the gelatin-like structure of vitreous, which allows it to sustain a shear force (Fig. 2.12).

In order to remove vitreous, aspiration is not enough. As vitreous is aspirated into the cutter port, the cutter blade extends across the port and sections off a portion of the vitreous. This portion of vitreous, in suspension with BSS, can then travel through the aspiration line as the cutter begins the next cut.

Although the flow through the vitrectomy cutter is more complex than the infusion flow, many of the concepts are similar, especially if BSS flow is considered. When considering BSS flow, the constraints that apply to the infusion line are also applicable to the aspiration line. Aspiration flow may be modeled with the Bernoulli equation (see: Fluid Dynamics Sidebar). The difference between the eye pressure and microsurgical system vacuum pressure supplies the driving force for aspiration. Thus, higher vacuum pressure and/or greater intraocular pressure (i.e., a higher infusion pressure) will result in a higher flow rate.

In order to maintain eye pressure, the infusion line must be able to deliver flow at a higher rate than the cutter's aspiration rate and leakage losses. If the aspiration rate is greater than the infusion rate, hypotony and its related risks (choroidal hemorrhage, retinal contact, etc.) may result. If the eye pressure is too high, blood flow to the eye will stop and retinal damage may occur. Therefore, it is critical to maintain adequate pressures and provide a "safe zone for vitrectomy."

During 25-gauge vitrectomy, the infusion cannula is not required to deliver the volume flow rate needed for 20-gauge cases. The vitrectomy cutter tip provides a smaller aspiration diameter than the infusion cannula, due to the two-cannula design. The outer housing provides the tip structure, as well as the distal port for vitreous to enter the cutting chamber. The inner cannula slides within the outer housing, and provides the guillotine action used to cut the vitreous. Aspiration occurs when fluid and material flow into the outer housing and through the inner cannula. Therefore, the inside diameter of the inner cannula dictates the flow characteristics. While the outer tip housing is 25-gauge, the inner tip is smaller. For example, 25-gauge cutters can have an inner tip that is approximately 30-gauge. From the Fluid Dynamics Sidebar, Poiseuille's law shows that flow is proportional to the fourth power of the radius. This indicates that the inner cutter will have greater flow losses than the infusion cannula. Furthermore, the inner cutter is longer than the infusion cannula, further increasing flow friction (and decreasing flow rate). The increased flow losses associated with smaller diameter cutters require higher pressure differentials for aspiration. For 25-gauge cases, an aspiration vacuum setting of 550 mmHg is a typical operating parameter.

2.6.1 Drive Mechanism

There are three major types of drive systems used for vitrectomy handpieces: guillotine electric, guillotine pneumatic, and reciprocating rotary pneumatic. The first type is an electric drive with a sinusoidal transmission which is currently used for both 20- and 25-gauge instruments. The sinusoidal transmission translates the rotary motion of an electric motor shaft to the linear guillotine motion of the inner cutter tip. The drive contains a ball bearing that rides in a sinusoidal track. The position of the ball bearing is constrained, yet the ball is free to rotate. As the sinusoid cam rotates with the motor, the ball follows the track and forces the ball housing to linearly translate, raising and lowering the cutter (Fig. 2.13). The profile of the motion remains constant (although faster) as cut rate is increased. Thus, the duty cycle (ratio of time the cutter port is open or closed) remains constant as the cut rate is increased and decreased. One can think of the motion profile as a sinusoidal wave of increasing or decreasing frequency (cut rate), but of constant amplitude.

Pneumatically driven cutters use air pulses provided by the surgical system to extend the cutter tip. The first type of pneumatic cutter is a guillotine-type cutter (Fig. 2.14). The cutter tip is attached to a diaphragm. When the surgical system provides an air pulse, the diaphragm is extended and the cutter tip closes, completing a cut. When air is released, a spring returns the tip to the open position. This closing and opening has a characteristic constant time. As cut rate is increased, the duration of open time per cut decreases, while the closed time remains constant. This causes the total fraction of time the cutter port is open over the time it is closed to decrease as cut rate is increased (decreasing duty-cycle). Furthermore, some systems have been shown to stop opening completely as speed increases. This is not typical for most pneumatic cutters.

The second type of pneumatic drive mechanism utilizes a dual drive line system. The surgical system supplies intermittent air pulses, alternating between each line. The first drive line acts to close the port, while the second line opens the port. The mechanism is shown in Fig. 2.15. Air pulses from the dual line system are supplied to either side of a horizontal piston, and act to move the piston laterally from side to side. A gear rack attached to the piston meshes with a geared section of the inner cutter. As the piston moves from side to side, the inner cutter tip reciprocates in a radial fashion. With this mechanism, the

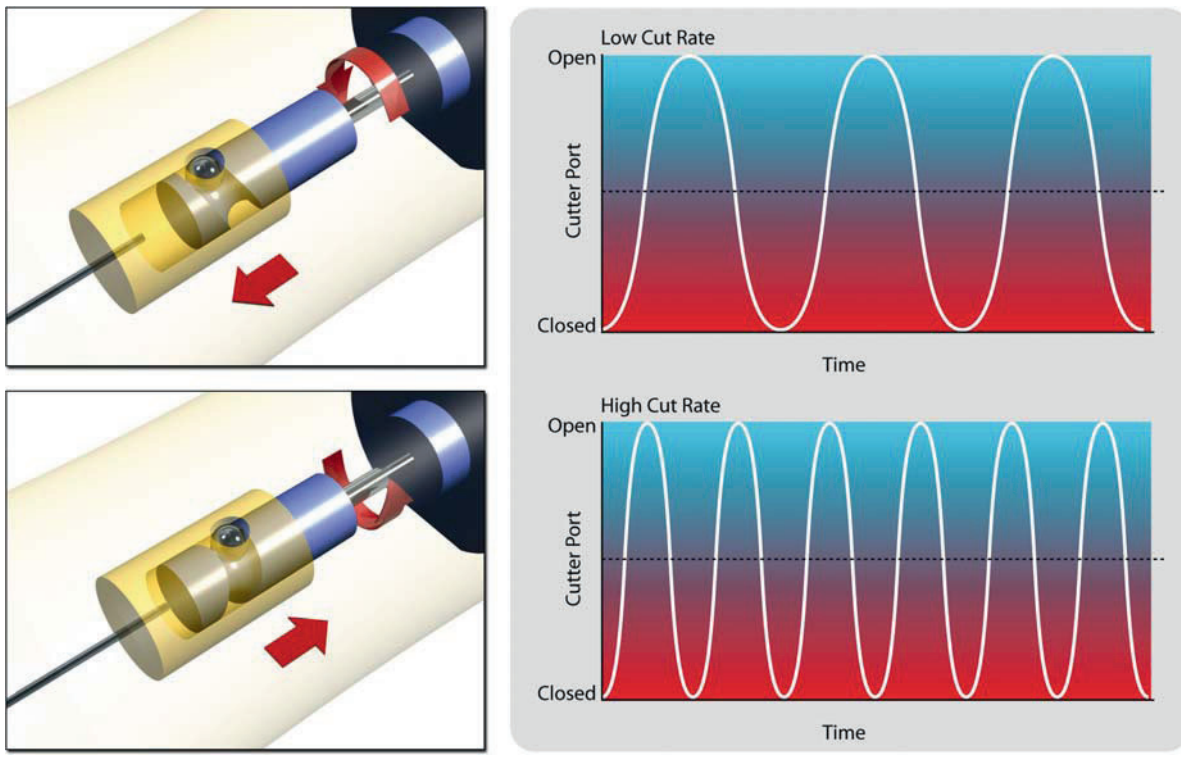


Fig. 2.13 Guillotine electric drive mechanism with sinusoidal cam

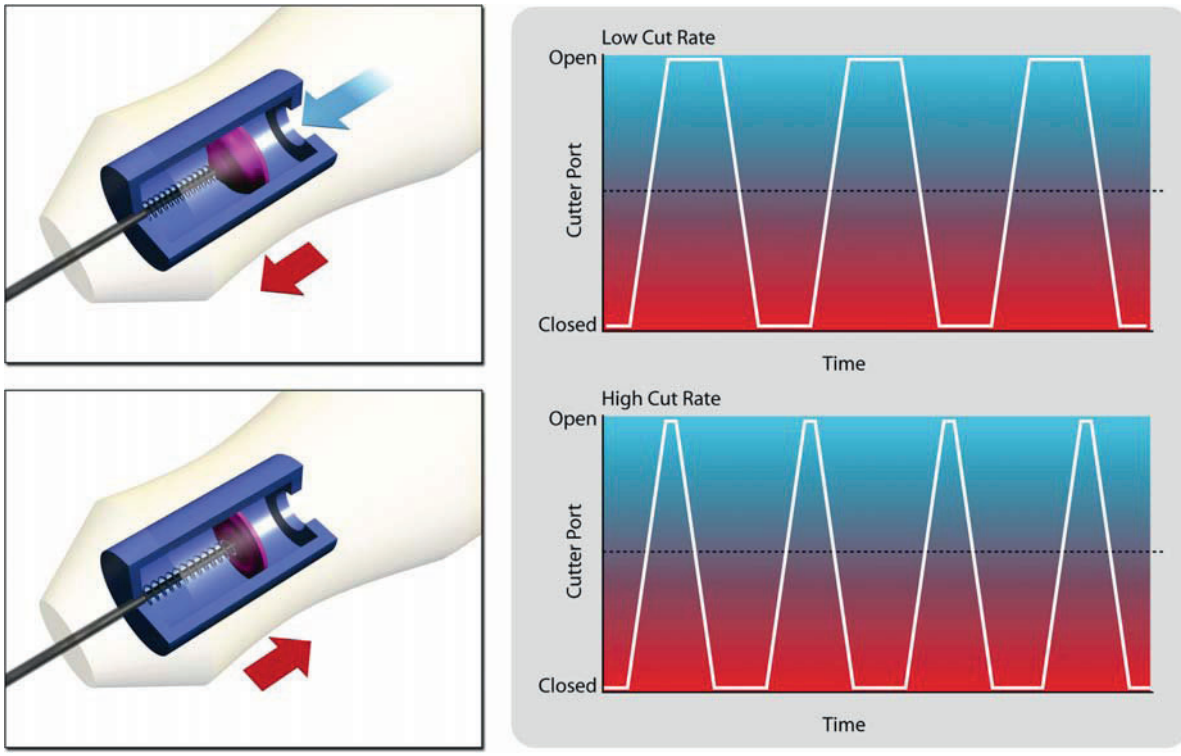


Fig. 2.14 Guillotine pneumatic drive mechanism with spring return

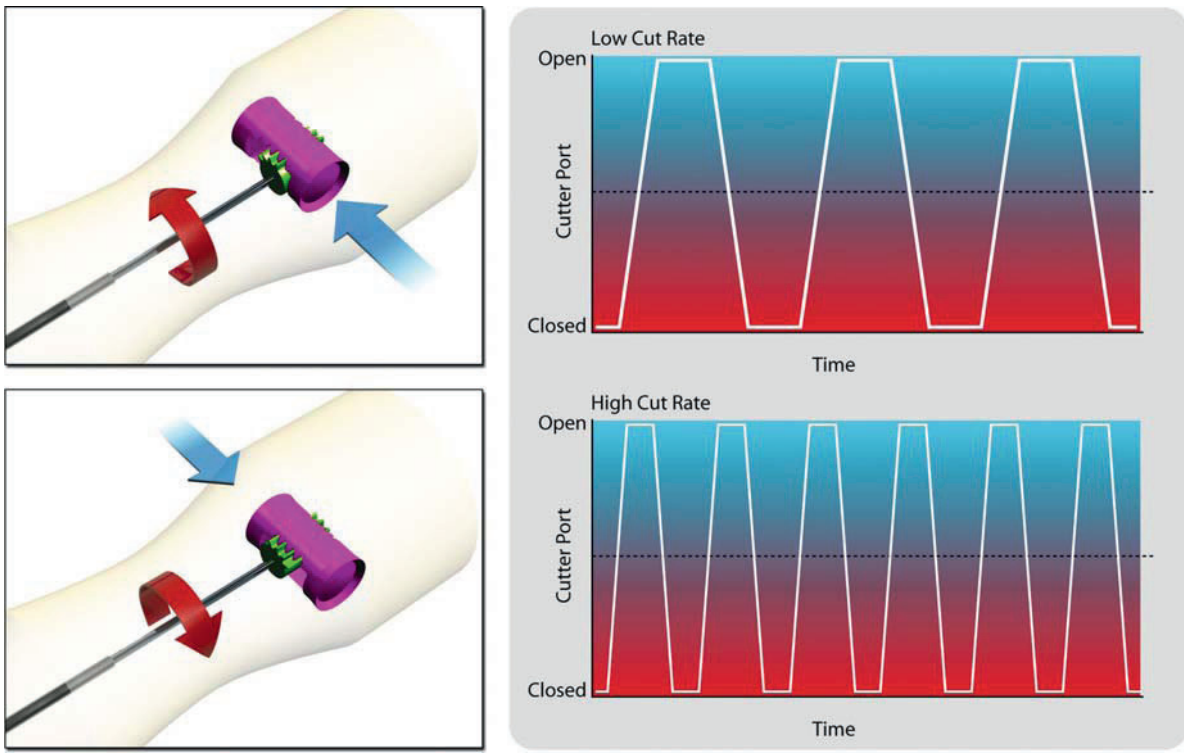


Fig. 2.15 Reciprocating rotary pneumatic drive mechanism with dual drive lines

cutter can maintain a constant duty-cycle. This type of pneumatic drive is currently only used on 20-gauge vitrectomy cutters.

2.6.2 Flow Rate

Vitreous cutter flow rates in BSS and in vitreous have been shown to be different [16]. Flow rates in BSS are indicative of the duty cycle of the cutter. Constant duty cycle electric cutters demonstrate constant flow rates in BSS as cut rate varies. However, for 25-gauge electric cutters, vitreous flow increases as cut rate increases. This has been demonstrated with the 25-gauge Bausch & Lomb Lightning cutter. For single drive line, spring-return pneumatic cutters, the duty cycle and BSS flow decreases as the cut rate increases. For this type of guillotine pneumatic cutter, vitreous flow follows the BSS trend and also decreases with increasing cut rate. This has been demonstrated with the 25-gauge Alcon Accurus cutter (Table 1, Fig. 2.16).

2.7 Traction

Traction is an important dynamic of vitrectomy. It is the pulling force that is applied to tissue due to aspiration flow. Traction is necessary for vitreous and other material

Table 2.1 25-gauge cutter flow rates at 550 mmHg aspiration

25-gauge Accurus and B&L flow characteristics in porcine vitreous (ml/s)			
	600 cpm	1,000 cpm	1,500 cpm
Alcon Accurus	0.013	0.013	0.006
B&L Lightning	0.008	0.012	0.014

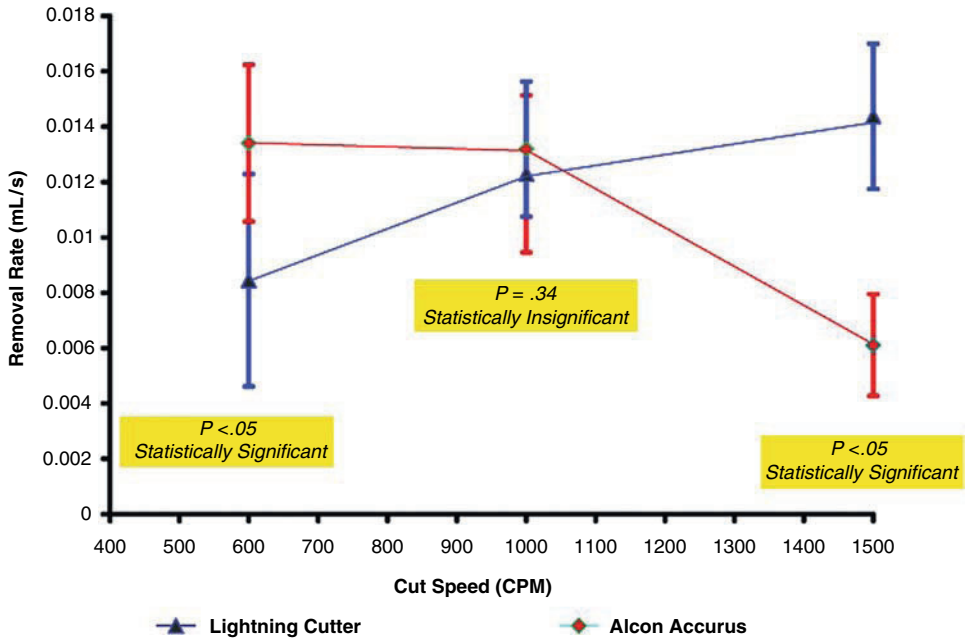


Fig. 2.16 25-Gauge lightning cutter and alcon accurus removal rates of porcine vitreous

to enter the cutter port, but should be maintained at a safe level. This is especially critical when cutting next to the retina. High traction forces may lead to small retinal tears, possibly resulting in retinal detachment.

Traction is a complex relationship between the cutter port pressure differential, the port configuration, aspiration flow, cut speed, vitrectomy cutter movement, and the nature of the tissue (e.g., the ratio of fluid to tissue or the degree of tissue connectivity). Traction is typically controlled by the surgeon varying aspiration pressure, cut speed, and the movement of the cutter tip. A higher aspiration pressure leads to a larger volume of fluid and vitreous being pulled into the port per cut. The driving force for removal is high and the surrounding tissue feels a large removal force, corresponding to a high traction situation. When the aspiration pressure is lower, there is less volume of fluid and tissue entering the cutter tip per cut, thus less traction.

In general, higher cutting rates (number of cuts-per-minute) allow less fluid and tissue to enter the port per cut. This allows the surgeon to remove vitreous consistently and accurately by limiting the distance the tissue is pulled with each cut. Thus, higher cutting rates are typically used close to the retina. In conjunction with cut rate, duty-cycle, port size and port shape also affect traction. These factors have fueled debate concerning the optimal method of vitreous removal. Consult recent literature articles for more information, and look to upcoming talks and articles to continue to shed light on the mechanics of vitrectomy.

The factors and effects discussed above hold when adjusting parameters for a certain cutter design and size. 25-gauge cutters have greater flow losses and lower flow than 20-gauge cutters operating at the same parameters. 25-gauge cutters are operated at higher aspiration settings (e.g., 550 mmHg) to overcome these greater flow losses and provide adequate flow. Thus, higher aspiration settings do not necessarily indicate that a 25-gauge cutter has greater traction than a 20-gauge cutter. For 25-gauge cutting, high cut speeds are important for reduced traction, and can have the added benefit of more consistent flow. The smaller portions of vitreous produced by higher cut speeds flow more easily through the small diameter cutter cannula. While the increased flow resistance and decreased flow rate of 25-gauge cutters may extend the vitrectomy time, as compared to 20-gauge, the overall 25-gauge instrumentation system has the potential to make up the differential [1].

2.8 Illumination

For 25-gauge instrumentation to be utilized intraocular, the surgeon needs illumination. As with the vitreous cutter, 25-gauge fiber optic light pipes are designed to operate through the microcannula system, and provide intraocular illumination. The primary distinction between 20- and 25-gauge light pipes is the diameter of the distal shaft, which requires a smaller fiber optic for 25-gauge light pipes.

The transmission of light from the illumination source to the eye is more complex than the infusion fluid path. For the illumination system, the smaller fiber optic associated with 25-gauge does not provide a direct restriction of light "flow" to the eye, but does affect how light is coupled into the light pipe connector. This effect may be dramatic when 25-gauge light pipes are utilized on illumination systems with optics designed for larger instrumentation. The following sections provide information on illumination systems in general, and highlight aspects that affect 25-gauge light pipe performance.

2.8.1 Terminology

An understanding of the fundamental parameters is essential in quantifying illumination in ophthalmology, especially since there has been confusion in the use of terminologies related to the surgical domain. This section addresses these fundamental parameters and terminology.

Luminance and *illuminance* are the two primary terms mentioned in the photometric domain. *Luminance* is defined as the optical energy leaving a surface, whereas *illuminance* describes the intensity of light that is falling on a surface. Imagine a sphere surrounding a light source, the energy exiting this boundary is characterized in *lumens*. If the light distribution from a point source is in all directions, then characterization is difficult. Therefore, directionality on a viewing surface is what determines the terminology.

Distribution of optical energy density on a given surface is measured by a lux-meter. For the case of quantifying output from a light pipe, the units of measure are *lux* or *lumens/area* [2]. Lamp manufacturers specify *candela* on their specification sheets, which is defined as *lumen/steradian*. It is the figure of merit of the light energy in a specific direction within the sphere which relates to a spot in the center of the beam. Higher *candela* means higher energy distribution in an area.

Other terminology is the *radiance* or *brightness* of the source, and is the amount of optical power emitted in a specific direction per unit time by a unit area of emitting surface. In a majority of light sources, only a fraction of the power emitted by the source is coupled into the optical fiber. It is also common for the medical community to liberally use *brightness* and *whiteness*, as a figure of merit to quantify light sources. This is misleading, although qualitatively it may have some credibility. *Brightness* depends on the *luminance*, which in turn is related to the *candela/area* [2] of the viewing surface. When a surgeon views, he or she views the energy reflected from a surface. It is difficult to quantify brightness, and therefore the accurate figure of merit is *lux* or *lumens*.

Whiteness on the other hand depends on the color temperature of the light source. For example, xenon lamps are whiter than incandescent lamps. When a blackbody radiates energy, it changes color with increasing temperature. The spectrum shifts from far visible (red) to short visible (blue). Therefore, high intensity discharge (HID) lamps with higher efficacy and wattage tend to produce a *whitish* light. Other factors that influence the visualization are glare, uniformity of *illuminance,* and color rendition. Color Rendering describes how an optical source depicts the colors of an object to human eyes, and how fine faint variations are revealed in color shades. The figure of merit is defined in terms of the color rendering index (CRI) which uses a scale ranging from 0to 100%. The higher the CRI is on the scale, the better a source's color-rendering ability. One important factor is that CRI is independent of color temperature.

2.8.2 System Approach

An illumination system for ophthalmic applications is comprised of five basic building blocks as shown in Fig. 2.17. The power supply module drives the illumination source, which couples light into the fiber optic light pipe through an optical system. In the development of illumination systems, it is essential to ensure the proper operation of each module for maximum optical output. The design of the power supply module depends on its drivability, whether the system is based on current or voltage. The key to an efficient optical design depends on the illumination source module. The type of lamp, intensity, spectral signature and thermal cooling contribute to the design of this module. The optical system module consists of a combination of lens and filters that improve system coupling efficiency. Lens devices are used to focus or collimate the optical energy, and are made of shaped glass or plastic. Alternatively, a filter assists in the removal of unwanted spectral signatures, and provides safety by limiting photo toxicity or damage in the eye.

The way in which the light from the source is translated into the eye is via an optical fiber which is small enough to fit through a 20-gauge or 25-gauge cannula. This phenomenon is referred to as coupling, where the energy is transferred from a free space into an optical fiber. An optical fiber is a cylindrical dielectric waveguide that transmits light along its axis by the process of total internal reflection. The loss in the illumination system depends on each interface, and is determined through coupling efficiency, a figure of merit of the energy distribution from the input to the output. The following sections address each of the modules in detail.

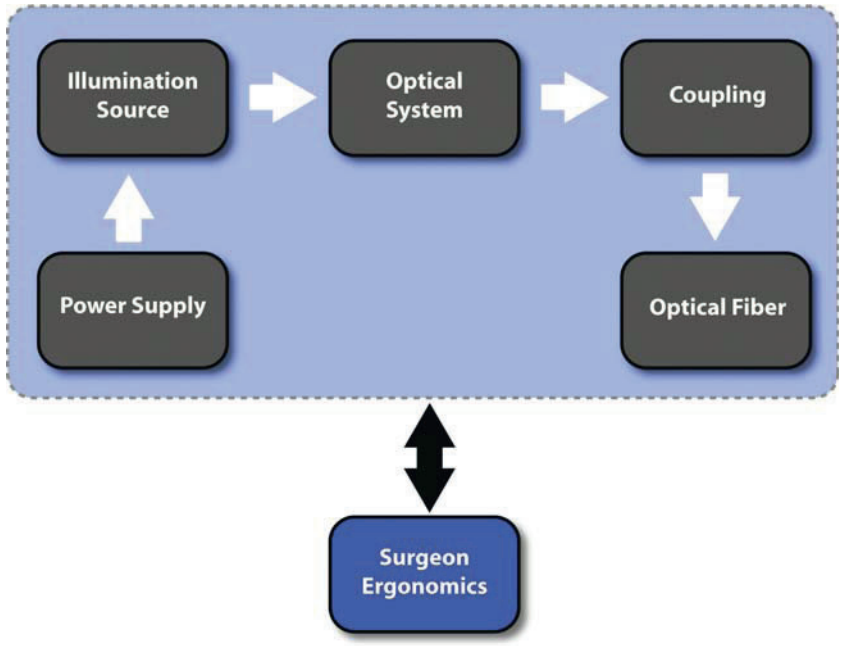


Fig. 2.17 Illumination system design overview

2.8.3 Power Supply Module

Ballast [17] is an essential component the power supply module that drives high discharge lamps that are currently used for ophthalmic lighting. A majority of high discharge lamps require a higher voltage at start, and then plateau out at a nominal lower voltage. The ballast functionality is to provide an acceptable starting voltage when the system is initially activated. Secondly, the ballast allows impedance matching, where the supply line voltage is matched with the operating voltage of the lamp under all conditions. Efficient ballast is an essential part of the illumination system, and prevents fluctuations in light output. An incorrect ballast design could lead to significant loss of energy, reduction in lamp life, incorrect light output levels and increased system cost [18]. There are two categories of ballast design: magnetic and electronic. Magnetic ballast is mainly used for fluorescent lamps, and electronic ballast is used for high-discharge lamps, which are used in ophthalmic lighting applications. Current lamps are designed with electronic ballast that converts standard 60 Hz input frequency to a higher frequency, as high as 40,000 Hz. This allows the lamp to operate at low wattage and incorporate a variable light output intensity feature. Another part of the power supply is a quick-start circuit, which assists in providing constant heating of the filament after the bulb is activated. This allows the light source to maintain a constant spectral output signature.

2.8.4 Illumination Source

The selection of the light source is critical to the efficiency and quality of the illumination system [19]. In general, the choice of the light source depends primarily on its application. Other factors include the cost of the lamp, intensity, spectral and color issues, and whether the system needs a variable output. Incandescent, fluorescent, and high intensity discharge are categories of lamps available in the market, although new semiconductor lighting is making inroads [20]. For ophthalmic applications, high intensity discharge lamps are primarily used.

Light source selection depends on *efficacy*, a figure of merit for the conversion of electrical into optical energy. It is defined as the output lumens per input wattage, and has units of lumens per watt. The higher the efficacy, the less energy the lamp needs to operate. Parameters such as color temperature, color rendering index and efficiency are also critical. Incandescent and high intensity discharge (HID) lamps are prominent, and suitable for ophthalmology applications. HID lamps are used in the current illumination systems available, for example Photon from Synergetics Inc. (O'Fallon, MO, USA),

Millennium from Bausch and Lomb Inc. (St. Louis, MO, USA) and Accurus from Alcon Laboratories, Inc (Fort Worth, TX, USA).

HID lamps have short arcs that are generated between two electrodes under high pressure. Although short, the arc can generate high temperature, high efficacy, and long life (20,000+ h) in an efficient package. Although they are efficient, they have limitations, which may be observed in surgery. Lamp warm-up, or the time to obtain a full spectral signature with desired intensity, takes between 2–5 min. The other potential issue for HID lamps is re-striking, where if the power supply switches off, to bring it to an on state would require 15–20 min to cool the lamp before turning it on. In ophthalmic applications, re-strike is not a major problem, as the bulbs are never turned off and on from the power supply. There are four categories of HID lamps; mercury vapor, metal halide, high-pressure sodium and low-pressure sodium. We will be discussing only two HID lamps: metal halide and high-pressure sodium, as they are the primary light sources used in ophthalmology.

Metal halide lamps utilize mercury and argon gases inside the arc tube to improve efficacy and allow variable wattage of the lamp. Unfortunately, metal halides suffer from spectrum shifting with the change of voltage, and lower life than other HID lamps. Currently, metal halide lamps are used in the Millennium system from Bausch and Lomb Inc. (St. Louis, MO, USA). High-pressure sodium lamps consist of high-voltage starter ballast with an arc tube that is filled with gases such as xenon, sodium and mercury. These lamps can be used at high wattages, and have higher efficacy with minimal spectrum shifting. The disadvantage is that they require an additional cooling system, which increases cost and space requirements. Currently, xenon lamps are used in the Accurus system from Alcon Laboratories, Inc (Fort Worth, TX, USA) and the Photon light source from Synergetics Inc. (O'Fallon, MO, USA).

2.8.5 Optical System

An optical system module enhances the coupling efficiency of the illumination system with the aid of a combination of reflectors, lenses and filters. The system assists in focusing light to a desired spot with maximum energy distribution. This is achieved through lens devices which either concentrate or diverge light, and filters which assist in the removal of harmful spectral signatures. Design parameters are determined depending on the path of the light from the source. The direction of the optical energy is established by optical system efficiency, reflective and shielding material properties. Some illumination sources utilize reflectors which redirect the light emitted from a lamp in order to achieve a desired distribution of light intensity outside of the luminaire. These reflectors are coated with either silver, anodized aluminum sheet or dichroic coatings which are effective in removing ultra-violet (UV) spectrum.

The lens system design [21] depends primarily on the directionality of the incoming optical rays. Maximum coupling efficiency is achieved if the incoming rays are parallel. There are a number of different types of lenses available for optical design. In ophthalmic lighting applications, biconvex or plano-convex lens types are employed, as they collimate the beam of light traveling parallel to the lens axis, which then, passing through the lens, converges to a spot on the axis at a certain distance behind the lens (focal length). The optical fiber is placed at the focal point for maximum coupling of energy. These types of lenses are also referred to as *positive* or *converging* lens. A combination of collimating and converging spherical lenses can increase the coupling efficiency of an optical system [22].

$$Reflectivity = R = \left(\frac{n-1}{n+1}\right)^2$$

Whenever optical energy passes through an interface, in this case an uncoated lens or filter, there is loss of energy. Therefore, optical component designers use antireflective coatings to reduce the amount of light lost to reflection at the surfaces of individual transmissive elements. Mathematically, surface reflection is predicted using Fresnel's equation for normally incident light [23]:
Reflectivity or R of uncoated glass is a function of refractive index, n; where increased index leads to high reflectivity. The use of antireflective coatings like magnesium fluoride (MgF_2) can reduce reflection at a glass surface by approximately 2%. Increasing the layering of coatings can minimize losses by almost 50%. Therefore, the choice of lenses and their coatings is critical in reducing coupling loss.

The final element in the optical design module is a filter, which is a device that selectively transmits light with certain properties while blocking the remainder. This is essential in attempting to minimize illumination system photo-toxicity inside the eye, as it is dependent on the spectral signature. The ANSI spectrum consideration for a light source ranges from 420–690 nm. Therefore, medical illuminators use filters to selectively remove unwanted

wavelengths. These filters may be integrated into a lens, included within the optical fiber, or a combination of both to reduce toxicity in patients. The filters are either intensity-based or spectral-based.

2.8.6 Optical Fiber

The light from the source is translated into the eye through an optical fiber based light pipe. An optical fiber is a dielectric waveguide, cylindrical in shape, which transmits light parallel to its axis. It consists of a core surrounded by a cladding layer and jacket for protection. There are two parameters used to distinguish fiber types, mode and index. We assume step index fiber for simplicity, where the fiber refracts the light sharply at the point where the cladding meets the core material. In addition, there are two categories of fibers: glass and plastic [24]. Glass fibers made of silica have resistance to high temperatures, improved transparency, chemical durability and low attenuation or loss. Mechanical durability is the primary disadvantage, and may be rectified by using plastic fibers that are made from PMMA (poly-methyl-metha-acrylate). Polymer fibers are inexpensive and flexible. Although they have a high loss over long distances, this loss is minimal for light-pipe applications. Currently, most light pipes are designed of plastic fibers.

We are going to discuss the basic principle of light transmission, and not the modes and index, as it is outside the scope of this chapter.

2.8.6.1 Principle of Total Internal Reflection

Figure 2.18 shows the light traversing through an interface separated by two distinct media: n_{core}, index of the core and n_{clad}, the index of the cladding. The index parameters are also known as index of refraction, and are defined as the ratio of the speed of light in a vacuum. For the light to transmit, $n_{core} > n_{clad}$ should be satisfied. Part of the light changes direction either through refraction or reflection when traversing from one media to another. Snell's law, shown below, defines how much bending takes place when the light strikes the respective boundary. Let's analyze the light traveling from the core to the cladding.

$$n_{\text{core}} \sin\phi_1 = n_{\text{clad}} \sin\phi_2$$

or

$$n_{\text{core}} \cos\alpha_1 = n_{\text{clad}} \cos\alpha_2$$

The rays traveling from a medium of lower refractive index into a medium of higher refractive index bend toward the normal. Vice versa, if the light travels from a medium of higher refractive index to a medium of lower index, it is bent away from the normal [25]. Therefore, a light ray launched into the core of an optical fiber propagates through the principle of total internal reflection, a condition when the refracted ray is reflected back completely as in Fig. 2.19. Incident light striking the interface is bent away from the normal; the departing angle

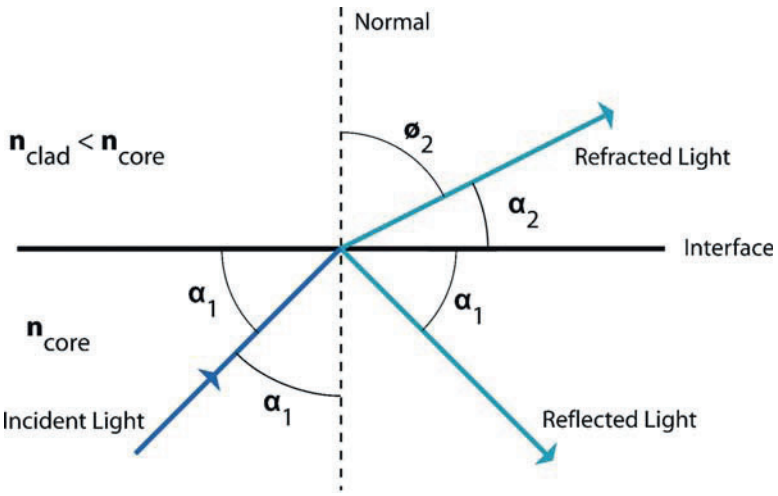


Fig. 2.18 Transmission of light rays through the core-clad fiber optic interface

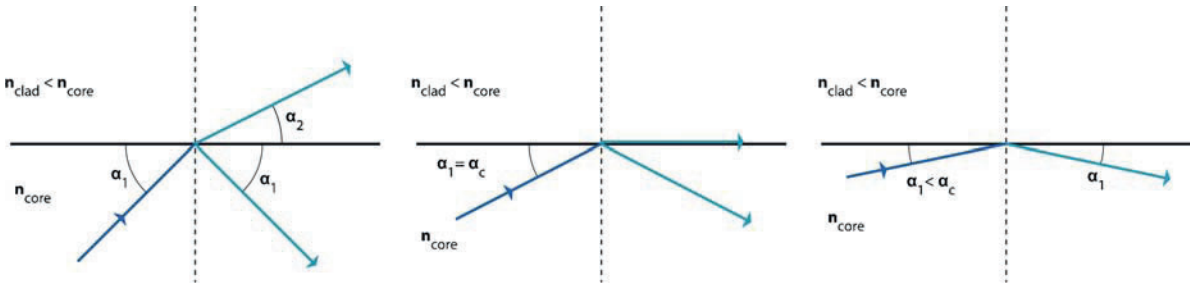


Fig. 2.19 Condition for ray propagation through core-clad interface

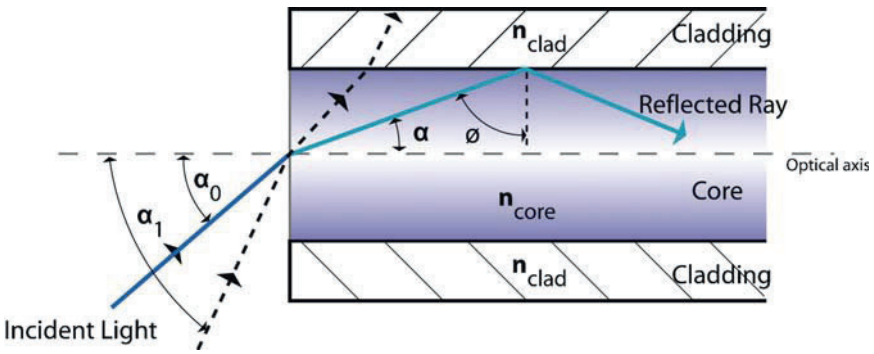


Fig. 2.20 Ray propagation through an optical fiber

(α_2) is less than α_1. If the departing angle approaches 0° for some critical incident angle α_c, the incident angle is smaller than the critical angle, which leads to total internal reflection. Therefore, the condition for minimum loss at the fiber core-clad interface occurs when $\alpha_1 < \alpha_c$.

A significant parameter that determines the coupling efficiency of the light pipe is the numerical aperture (*NA*), as shown in Fig. 2.20, where the light is striking the air/fiber interface. The incident striking angle is defined by α_0 to α_1. So which angle leads to maximum coupling? This light-gathering angle is determined by the *NA*. Typical values of index of refraction for air ($n_{air} = 1$), core ($n_{core} = 1.5$) and clad ($n_{clad} = 1.46$).

$$\begin{aligned} \textit{Numerical Aperture} = NA &= n_{air} \sin \alpha_{0MAX} \\ &= n_{core} \sin \alpha_c = \sqrt{\left(n_{core}^2 - n_{clad}^2\right)} \end{aligned}$$

A dimensional number, it lies between 0 and 1. If $NA = 0$ ($\alpha_{0MAX} = 0°$), it means that the fiber gathers no light, and if $NA = 1$ ($\alpha_{0MAX} = 90°$), the fiber gathers all the light that falls onto it. Current fibers used in light pipes have an *NA* of approximately 0.4–0.6.

A higher *NA* fiber captures increased light into the fiber. Consider two light pipes, one with a 1-mm diameter fiber with $NA = 0.5$, and one with a 0.5-mm diameter fiber with $NA = 0.7$. Assume the spot size is 0.4 mm. The 0.5-mm diameter light pipe would capture more light than the 1-mm diameter light pipe. Therefore, it is important to note the role the *NA* of the fiber plays, and it is the parameter to look for when investigating optical fibers. The size of the fiber also plays a role in coupling, but a larger diameter fiber with a lower *NA* has a lower coupling capability than a smaller diameter fiber with a higher *NA*.

2.8.7 System Loss

The efficiency of the illumination system, or the output of a light pipe, depends on its *coupling efficiency,* a measure of the power emitted from the optical source which can be coupled into the fiber. System efficiency dependence is addressed by two fundamental issues. First, launching of the optical energy from the illumination source into a fiber, and second, the effect of the coupling or energy transfer from the free space to the enclosed space of a fiber. The amount of energy launched from the source into a fiber depends on the optical properties of both the source and the fiber, in addition to the radiance of the source. Therefore,

optical system designers maximize the efficiency by tweaking the parameters.

Coupling efficiency is defined as the ratio of power coupled into the optical fiber P_{OF} to the power emitted by the illumination source $P_{IS.}$ The higher the coupling efficiency, the higher is the coupled output power.

$$Coupling\ Efficiency = \eta = \frac{P_{OF}}{P_{IS}}$$

where:

P_{IS} = power emitted by illumination source
P_{OF} = power coupled into the optical fiber

There are a number of factors that influence illumination system loss[25], and thus are critical to the design. These include numerical aperture, core size, radiance, power distribution, and spot size. For the fiber optic, coupling losses may also be due to the fiber position, lateral and angular alignment, refractive index profiles of core/clad, and poor termination of the fiber edge. A smooth and clean fiber with its faces at a 90° angle to the fiber axis is of paramount importance.

A significant amount of coupling loss occurs at the air/fiber interface. Ineffective capturing of the energy from the source, losses due to reflection from the lens system and inefficiency of the optical design also contribute to coupling losses. In addition, an illumination system designed for a particular technology, for example 20-gauge, may be ineffective with another technology, 25-gauge, as the fiber dimensions change and reduce performance, as discussed in the Optical Fiber section.

One issue worth particular mention, especially in the discussion of 20- and 25-gauge instrumentation, is spot size and the effect of spot size on coupling performance. Consider a condition where the optical power is launched into a step index fiber. The source is symmetric with an even brightness and surface area. The optical rays from an illumination source with parallel output (parabolic reflector with the source) traverse through a lens system and converge to a point with a known spot diameter. The total power concentrated at the spot is P_{SPOT} with an area of A_S or $(2\pi R_S)$, R_S being the radius of the emitting area. The area of the fiber core is A_{OF}, with R_{OF} as its radius. Assume the fiber is placed in an optimum alignment position for maximum power transfer with a numerical aperture of *NA*. The power at the source with radiance B_{IS} is given by:

$$Source\ Power = P_{IS} = \pi R_S^2 B_{IS}$$

where:

R_S = radius of emitting area
B_{IS} = source radiance

So, what is the effect of the spot size and fiber area on the coupling? Let us consider two cases; first, when the spot diameter is smaller than the fiber core diameter, and second, when the spot diameter is larger than the fiber core, as shown in Fig. 2.21. Please note the derivations are outside the scope of this chapter. When the spot diameter is smaller than the fiber core diameter, the power launched into the fiber is approximated by:

$$P_{COUPLED} = P_{IS}(NA)^2 \quad when\ \ R_{SPOT} \le R_{OF}$$

where:

R_{SPOT} = radius of spot
R_{OF} = fiber core radius

When the spot diameter is larger than the fiber core diameter, the power launched into the fiber is approximated by:

$$P_{COUPLED} = \left(\frac{R_{SPOT}}{R_{OF}}\right)^2 P_{IS}(NA)^2 \ \ when\ \ R_{SPOT} \ge R_{OF}$$

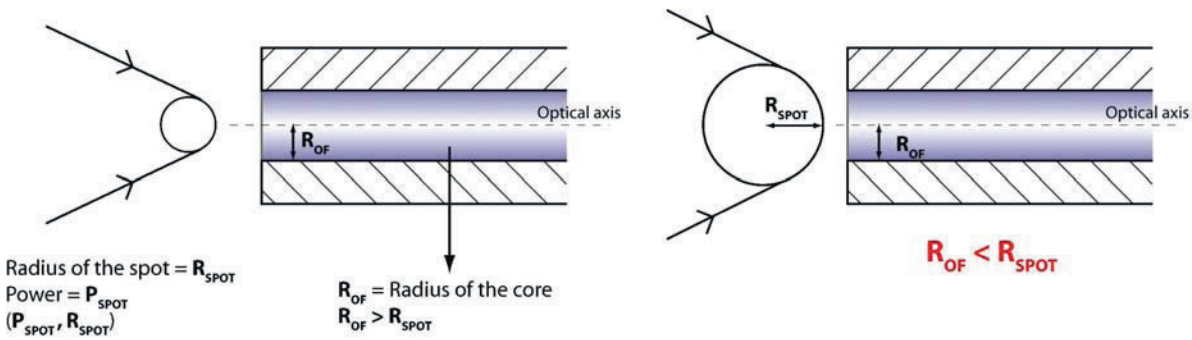


Fig. 2.21 Graphical representation of spot – fiber core sizes

For the case where the fiber core end area is less than the spot diameter, the coupled power is reduced with respect to a ratio of the radii squared. Thus, the use of a 25-gauge light pipe on a system with a spot size optimized for a larger fiber may operate with reduced performance. This is important, as the spot size can only be reduced to an extent through a lens system. As ophthalmic surgery moves towards smaller instrumentation and smaller fibers, the design of the optical system is critical, challenging and essential in improving light intensity out of a light pipe.

2.8.8 System Compatibility

In terms of illumination, 25-gauge instrumentation is not completely compatible with systems designed for 20-gauge. Optical systems are built for a specific technology, and decrease in performance if there is an alteration, as seen in 25-gauge systems. The optical system performance depends on numerical aperture, core size, radiance, power distribution and spot size. Other factors include fiber position, lateral and angular alignment, refractive index profiles of core and clad and poor termination of the fiber edge [26]. Currently, optical engineers are redesigning high efficient systems for 25-gauge ophthalmic applications. Approaches include novel lens and reflector design with efficient fiber-coupling techniques for improved light output. In the future, provisions could be made during the design to account for smaller instrumentation.

Summary for the Clinician

- The principal differences between the 25- and 20-gauge infusion line and vitreous cutter are found at the distal tubes (cannulas) that enter the eye. When the inner diameter of the instrument is reduced, a larger pressure differential is required to maintain equivalent flow rates.
- In 25-gauge vitrectomy cases, higher pressures are typically required to produce similar flow rates to corresponding 20-gauge procedures.
- Higher vacuum pressure and/or greater intraocular pressure (i.e., a higher infusion pressure) will result in a higher flow rate.
- For 25-gauge cases, an aspiration vacuum setting of 550 mmHg is a typical operating parameter
- Traction is an important dynamic of vitrectomy. It is the pulling force that is applied to tissue due to aspiration flow. Traction is necessary for vitreous and other material to enter the cutter port.
- Traction is typically controlled by the surgeon varying aspiration pressure, cut speed, and the movement of the cutter tip. Higher cutting rates are typically used close to the retina.

2.9 Instrument Rigidity

One of the mechanical challenges associated with small diameter instruments is instrument rigidity. As the diameter of the instrument decreases, the rigidity also decreases, causing increased flexing in 25-gauge instrument shafts. This is best understood by examining the bending equations that govern the displacement of the instruments under a load. The amount of displacement of a beam held with a fixed wall constraint is given by the equation below:

$$\omega_{\max} = \omega(L) = -\frac{PL^3}{3EI}$$

Where ω_{max} is maximum displacement, L is the length of the beam, E is the modulus of elasticity, and I is the area moment of inertia of the beam (or second moment of area). The length of the shaft (L) for the case of an instrument inserted through an ESA microcannula is the distance from the cannula to the instrument handle. Thus, the length of shaft exposed to bending varies with the instrument insertion depth. A diagram of the beam and plot of beam displacement is shown in Fig. 2.22.

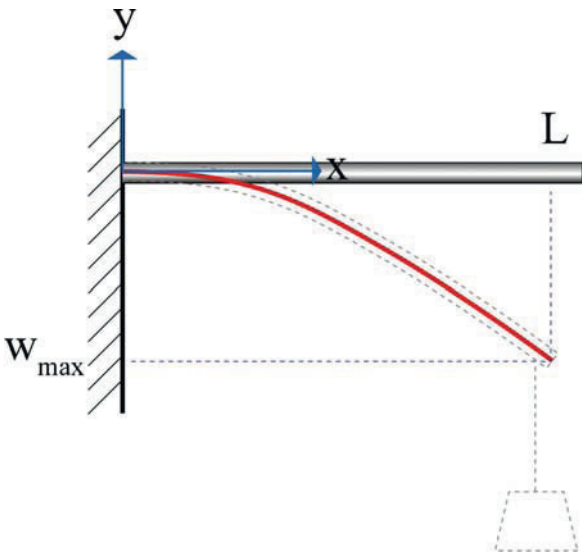


Fig. 2.22 Beam bending

From the equation, it may be seen that the three methods to reduce shaft deflection (increase rigidity) are: (1) to decrease the instrument length exposed to a bending load (L), (2) increase the modulus of elasticity (E), or (3) increase the area moment of inertia (I). The parameter having the greatest impact on shaft rigidity is the length of the shaft. Shaft deflection is proportional to the third power of the length.

The modulus of elasticity is a material property. Most instrument shafts use stainless steel, which has a modulus of elasticity of approximately 200 GPa. This is fairly high compared with other materials. Altering the shaft material to increase the modulus of elasticity is possible, but it is difficult to achieve significant gains over stainless steel. Stiffer materials may also reduce the toughness of the instruments, increasing the likelihood of shaft fracture.

The area moment of inertia is related to the shaft cross-sectional area and the distance the area is from the bending centerline. Mathematically, it is expressed as: where:

$$Area\ moment\ of\ inertia = I = \int y^2\, dA$$

dA = elemental area
y = perpendicular distance from bending axis to dA

This illustrates that the further the mass is from the center of the instrument, the higher the area moment of inertia. For the specific case of a tube of circular cross-section, the area moment of inertia with respect to its central axis is:

$$I = \frac{1}{4}\pi(r_{\text{outer}}^4 - r_{\text{inner}}^4)$$

The area moment of inertia is ultimately limited by the outer shaft diameter (25-gauge) and the wall thickness of the tubing. The wall thickness is limited by the inner diameter required for any functional components of the instrument (e.g., inner cutter mechanism, fiber optic, forceps). Minimizing wall thickness allows a larger fiber or greater cutter aspiration, but also reduces instrument rigidity. The length of the instrument shaft is governed by the diameter of the eye. The surgeon needs to have full access to the interior of the eye for almost all instruments.

As shown above, reducing the length of the shaft exposed to a bending load has the greatest impact on shaft rigidity. For example, a light pipe may employ a small stiffening sleeve on the light pipe shaft to reduce the length of 25-gauge shaft exposed between the instrument handle and cannula hub. Since the light pipe is used in conjunction with the other instruments, a stiffer light pipe provides increased ability to move the eye during surgery. Finger-positioning techniques may also be used to support instrument shafts. By positioning a finger on the instrument shaft, the surgeon can provide increased support. This may be especially useful when the instrument is inserted to a shallow depth with a large length exposed to bending.

2.10 Discussion

The sutureless 25-gauge pars plana vitrectomy reduces the postoperative inflammation at sclerotomy sites, thus reducing patient discomfort after surgery and hastening postoperative recovery [1–8]. The smaller incisions also result in less vitreous incarceration to the scleral wound, therefore possibly reducing the risk of peripheral retinal tears and retinal detachments. However, because of the small size of the instruments, there are engineering development challenges and trade-offs associated with 25-gauge instruments. Many critical intraoperative situations require surgeons to decide on microsurgical system parameters and instrument technique. With an understanding of the performance differences between 20 and 25-gauge instrumentation, surgeons will be better prepared to select the most appropriate system for the case and adjust system parameters in order to result in a safe surgical procedure.

This knowledge will also assist the surgeon in evaluating performance differences between existing systems and new instrumentation and techniques, such as 23-gauge instrumentation utilizing tunneling sclera incisions. The increased diameter of 23-gauge instrumentation (relative to 25-gauge) provides the potential for stiffer instruments, higher maximum volume flow rates, and greater maximum endoillumination. However, the larger 23-gauge wounds require an oblique incision that tunnels through the sclera to allow a sutureless close. This incision technique and 23-gauge instrumentation are just beginning to be evaluated by the vitreoretinal community.

The majority of 25-gauge instrumentation currently available has been developed by modifying the design of existing 20-gauge instruments, and is being utilized on microsurgical systems optimized for 20-gauge. While many of the engineering development challenges of 25-gauge instruments may be attributed to their small diameter, there are a significant number of trade-offs associated with utilizing 25-gauge instruments on equipment designed for larger instruments. As new equipment is developed, optimized for both small and large diameter instrumentation, the performance of transconjunctival 25-gauge instrumentation will continue to improve.

References

1. Born M, Emil W (1999) Principles of optics: electromagnetic theory of propagation, interference and diffraction of light, 7th expand edn. Cambridge University Press, Cambridge
2. Chen JC (1996) Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 114(10):1273–1275
3 DeBoer C et al (2006) Vitreous removal rates and high-speed video analysis of 25-gauge vitrectomy cutters. ARVO Annual Meeting (2006) Abstract
4. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina (Philadelphia, Pa.) 25(2):208–211
5. Fischer RE, Biljana T-G (2000) Optical system Design. McGraw Hill, New York
6. Flesch PG (2006) Light and light sources: high-intensity discharge lamps, 1st edn. Springer, Berlin New York Heidelberg
7. Fujii GY et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109(10):1807–1812; discussion 1813
8. Fujii GY et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109(10):1814–1820
9. Hasumura T et al (2000) Retinal damage by air infusion during vitrectomy in rabbit eyes. Invest Ophthalmol Vis Sci 41(13):4300–4304
10. Hirata A et al (2000) Effect of infusion air pressure on visual field defects after macular hole surgery. Am J Ophthalmol 130(5):611–616
11. IESNA Light Sources Committee (1998) IESNA guide to choosing light sources for general lighting. Illuminating Engineering Society of North America, New York
12. Jackson T (2000) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 129(1):116–117
13. de Juan E Jr, Hickingbotham D (1990) Refinements in microinstrumentation for vitreous surgery. Am J Ophthalmol 109(2):218–220
14. Keiser G (2000) Optical fiber communications, 3rd edn. McGraw-Hill, Boston, MA
15. Kwok AK et al (1999) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 127(6):731–733
16. Ladd BS et al (2003) Force comparison of air currents produced by a standard and modified infusion cannula. Retina 23(1):76–79
17. Lam DS et al (2000) Sutureless pars plana anterior vitrectomy through self-sealing sclerotomies in children. Arch Ophthalmol 118(6):850–851
18. López-Higuera JM (2002) Handbook of optical fibre sensing technology. Wiley, New York
19. Mohan N, Tore MU, William PR (2003) Power electronics: converters, applications, and design, 3rd edn. Wiley, Hoboken, NJ
20. Oshitari K et al (2001) Evaluation of retinal damage induced by air/fluid exchange using a trypan blue inclusion test in rabbits. Am J Ophthalmol 131(6):814–815
21. Rahman R et al (2000) Self-sealing sclerotomies for sutureless pars plana vitrectomy. Ophthalmic Surg Lasers 31(6):462–426
22. Sabersky RH (1999) Fluid flow: a first course in fluid mechanics, 4th edn. Prentice Hall, Upper Saddle River, NJ
23. Smith WJ (2005) Modern lens design, 2nd edn. McGraw-Hill, New York
24. Tomal, DR, Neal SW (2004) Electronic troubleshooting, 3rd edn. McGraw-Hill, New York
25. Vo-Dinh T (2003). Biomedical photonics handbook. CRC Press, Boca Raton, FA
26. Yonemura N et al (2003) Long-term alteration in the air-infused rabbit retina. Graefes Arch Clin Exp Ophthalmol 241(4):314–320

Chapter 3

25-Gauge, Sutureless, Trans-Conjunctival Vitrectomy

S. Charles

Core Message

- Indications for 25-gauge, trans-conjunctival vitrectomy have changed since the introduction of this technology.
- All vitreoretinal procedures and disease previously operated using 20-gauge can be operated with 25-gauge, with the proviso that one wound must be enlarged to 20-gauge for intraocular foreign bodies and fragmenter cases.
- Conjunctival displacement and angulated wound construction are essential to reduce wound leaks leading to hypotony and choroidals, vitreous wicks which are likely to result in endophthalmitis, and bleeding secondary to hypotony.
- A wide variety of 25-gauge tools are available for epiretinal membrane dissection, exchanges, internal drainage of subretinal fluid, laser photocoagulation, and illumination. Multi-functional tools are not available.
- New techniques and improvements in tool design have greatly diminished the tool flexion problem. Using non-contact wide-angle systems to view the peripheral retina is the biggest cause of tool flexion problems, which has caused some surgeons to use 23-gauge technology.
- Sutureless 25-gauge vitrectomy requires changing techniques and parameters, but offers the advantage of better fluidic stability, faster visual improvement, much better patient comfort, and much less conjunctival damage. Time savings are not the issue; the time saved by not having to suture an infusion cannula in place, make or close conjunctival incisions, and suture sclerotomies is largely offset by taking more time for the vitrectomy.

3.1 Introduction

Sutureless, trans-conjunctival 25-gauge vitrectomy was introduced by de Juan [1, 2] and colleagues, and has rapidly become an accepted part of the vitreoretinal armamentarium. Sutureless vitrectomy is made possible by smaller diameter instruments, enabling smaller sclerotomies as well as conjunctival displacement before making the trans-conjunctival sclerotomies, so that the conjunctiva covers the sclerotomy after surgery is completed. 25-gauge trocars are used to place thin-wall cannulas, resulting in 23.5-gauge sclerotomies. The cannulas are used to maintain alignment between the displaced conjunctival incision and the sclerotomy, and facilitate finding the small incisions when inserting and exchanging tools.

3.2 Surgical Indications

At the time of introduction of this new technology it was thought that 25-gauge sutureless vitrectomy was only going to be indicated for epimacular membranes, macular holes, vitreomacular traction, and surgery for retinal venous occlusion. Many surgeons thought at the time that 25-gauge surgery was inappropriate for vitreous hemorrhages, rhegmatogenous retinal detachments, PVR, diabetic traction retinal detachments, or giant breaks. Many surgeons, including the author, now believe that 25-gauge surgery is ideal for vitreous hemorrhages, rhegmatogenous retinal detachments, PVR, and giant breaks, and for diabetic traction retinal detachments with moderate amounts of epiretinal membranes. Branch vein decompression (sheathotomy) or radial optic neurotomy (RON) are no longer thought to be effective procedures, but vitrectomy alone for reduction of macular edema from venous occlusion as well as for diabetic retinopathy is effective. The probable mechanisms by which vitrectomy reduces macular edema include VEGF reduction in the macula and increased oxygen tension in the vitreous cavity.

Removal of dislocated lens material may require one 20-gauge sclerotomy, because dense lens material creates too much flow resistance for small lumen instruments.

The technique of combining two 25-gauge sutureless with one 20-gauge sutured incision has been described as 20/25 vitrectomy by the author. Initially, silicone cases required enlarging one sclerotomy to 20-gauge, but air-silicone exchange can be performed at the end of a 25-gauge case by using a MedOne VFI, short silicone injection cannula through a 25G cannula, not the infusion line. Intraocular foreign bodies can be removed using the 20/25 technique as well.

Patients with glaucoma filtering procedures or poorly controlled glaucoma are ideal candidates for 25-gauge surgery, because trauma to the conjunctiva is minimal and the small sclerotomies can be positioned away from the bleb. Patients with severe dry eyes, ocular surface disorders, and scarred conjunctiva are excellent candidates for 25-gauge surgery as well.

Summary for the Clinician

- Conventional indications include: epimacular membrane, macular hole, vitreomacular traction syndrome, mild-to-moderate vitreous hemorrhage, or opacities.
- Expanded indications include: rhegmatogenous retinal detachment, traction retinal detachment, proliferative vitreoretinopathy, giant retinal tears, silicone oil cases, and trauma.
- Enlarging on a 25-gauge port to 20-gauge enables use of intraocular foreign body forceps and the fragmenter to remove dislocated dense, lens material.

3.3 Wound Construction

The purpose of the trocar is to make a 25-gauge sclerotomy and enable simultaneous insertion of a flexible 23.5-gauge self-retaining cannula which fits over the trocar. The conjunctival incision is intentionally displaced from the scleral incision so that the two incisions will not be aligned after cannula withdrawal and the conjunctiva will cover the sclerotomy. Repeated insertion and withdrawal of tools is accomplished through the cannula, which maintains alignment of the conjunctival and scleral incisions and protects the wounds. The conjunctiva should be displaced using a cotton-tip applicator by gently moving it anteriorly or circumferentially or some combination thereof. An attempt should be made to avoid conjunctival and scleral vessels, to reduce postoperative sub-conjunctival hemorrhages. The Alcon non-coring trocar is based on a modified MVR blade, and requires less insertion force than hypodermic needle-based, coring type designs. Although a prospective, non-randomized consecutive clinical series by the author using a non-coring trocar showed that fluid air exchange results in less hypotony than published results with the coring type trocar, oblique wound construction has largely eliminated the need for fluid–air exchange. The non-coring trocar cannula usually requires no rotation when inserted. If some resistance is encountered, small-amplitude back-and-forth rotation will facilitate insertion. The cotton-tip applicator should be handed back to the scrub tech or dropped so that the forefinger of this hand can be used to guide the trocar cannula during insertion. The trocar should be aimed toward a virtual point about 2 mm anterior to the center of the eye or about 2 mm posterior to the lens. The incisions should be made 4.0 mm posterior to the limbus unless there is a pars plana abnormality from ROP, trauma, or pars planitis or a large choroidal detachment, suprachoroidal hemorrhage, or high retinal detachment, which would necessitate making the incisions through the pars plicata. 25-gauge incisions may be made 3 mm posterior to the limbus in aphakic eyes. The inferotemporal incision should be made just below the 3 or 9 o'clock position to reduce bleeding and pain, but as far as possible from the lower lid so it will not be displaced if the eye is rotated inferiorly. The superonasal incision is usually made on a virtual line from the lowest point of the bridge of the nose extending through the center of the pupil, and then plugged with a 25-gauge plug. This location reduces tool flexion issues, and facilitates peripheral and anterior access. The purpose of the plug is to prevent vitreous prolapse or fluid loss through the port while making the third incision. The superotemporal incision is usually made on a virtual line extending from the lowest point of the supraorbital rim through the center if the pupil, again to reduce tool flexion and facilitate anterior and peripheral access. The author initially utilized straight-in wound construction, but changed to angulated (oblique, near-tangential, scleral tunnel) technique for all cases. This is not a biplanar wound, as the trocar has made the cut through the sclera before the trajectory is changed to a more perpendicular or 30° angle approach. This change in trajectory, incorrectly referred to as supination by some, is performed to avoid impaling the retina with the trocar. The initial trajectory should be near-tangential to the scleral surface.

Summary for the Clinician

- Complications of wound leaks include: endophthalmitis from vitreous wicks, choroidals secondary to hypotony, bleeding secondary to hypotony, subconjunctival silicone oil, or gas.
- Best method of preventing wound leaks is to construct a scleral tunnel using oblique (angulated, near-tangential) wound construction. Wounds that appear to be leaking should be sutured with a single 8-0 Biosorb through conjunctiva and sclera.

3.4 Fluidics

Ohm's Law for fluids is directly analogous to Ohm's Law for electricity, and teaches that pressure (gradient) is equal to the resistance times the flow. Resistance to flow is proportional to the fourth power of the inner diameter of the lumen. The much higher resistance of 25-gauge cutters and infusion ports was initially thought by many to be a major disadvantage. It turns out that increasing infusion pressure to 50–60 mmHg while flow is occurring (dynamic state) and lowering it to 35–45 mmHg (static state) when using forceps, pics, scissors or the endophotocoagulator (static state) solves the infusion side problem. The Accurus Vented Gas Forced Infusion (VGFI) allows rapid and precise switching between static and dynamic infusion pressures because of direct digital infusion pressure readout and foot-pedal control without moving the bottle. Resistance is an advantage (up to a point) in the cutter fluidic circuit, while it is a disadvantage in the infusion circuit.

The cutter has more resistance than the straight extrusion cannulas, because of the smaller bore coaxial inner needle as well as the cutter intermittently closing the port during the open-close cycle, thus requiring greater compensation with respect to the vacuum settings used with 20-gauge vitrectomy. The author uses 600 mmHg vacuum and proportional (linear) control. Fast cutting with 20-gauge cutters is advantageous because of port-based flow limiting, which results in greater fluidic stability and therefore less retinal movement and pulsatile vitreoretinal traction. The smaller lumen of 25-gauge cutters also produces port-based flow limiting. A 1,500 cpm 25-gauge cutter produces one half the pulse flow of the 2,500 cpm 20-gauge cutters, and therefore half as much pulsatile vitreoretinal traction. In addition, port-based flow limiting reduces surge when dense epiretinal membrane (ERM) suddenly elastically deforms through the port, which is analogous to occlusion break surge in phaco surgery. Fast cutting has the additional advantage of reducing vitreoretinal traction by minimizing uncut collagen fiber travel through the port. The author recommends using a cutting rate of 1,500 cpm or greater for virtually all 25-gauge tasks, and has found that core vitrectomy times are very reasonable when using 600 mmHg vacuum.

Summary for the Clinician

- Initially, it was thought that smaller 25-gauge lumens would limit surgical capabilities, but experience has shown that port-based flow limiting is actually an advantage. Greater resistance to fluid flow results in greater fluidic stability and less surge after sudden elastic deformation of dense tissue through the cutter port.
- Advantages of 25-gauge lumen are similar to the advantage of high-speed cutting; namely port-based flow limiting, which decreases pulsatile vitreoretinal traction and surge.

3.5 Cutter Design Issues

Pneumatic disposable cutters weigh much less than electric cutters, thereby increasing dexterity, reducing fatigue, and reducing flexion of the shaft. Pneumatic cutters vary (optimize) the duty cycle as a function of cutting rate, which is an advantage compared to the fixed duty cycle of electric cutters, because of the wide range of materials properties encountered during vitrectomy (from air to perfluroctane to vitreous to dense epiretinal membrane and lens material).

Summary for the Clinician

- Pneumatic cutters are lighter than electric cutters, thereby increasing dexterity and decreasing fatigue and tool flex.
- Pneumatic cutters produce a variable duty cycle; in contrast, electric cutters produce a fixed 50% duty cycle. Variable duty cycle has been shown to be advantageous, because it matches the impedance of the cutter system to the mechanical properties of the tissue.

3.6 Tool and Visualization Tradeoffs

Disposable forceps and scissors are advantageous for 25-gauge surgery [3]. The advantages of disposable 25-gauge instruments include elimination of sterilization and cleaning issues and the inevitable damage that occurs to fragile reusable instruments. The author uses Alcon DSP 25 G disposable ILM forceps and curved scissors. The so-called ILM forceps are ideal for epimacular membranes, macular holes (ILM peeling), vitreomacular traction, proliferative vitreoretinopathy (PVR), and submacular surgery for inactive, non-AMD cases.

Multi-function tools such as the end-aspirating laser probe (Chang) and the disposable bipolar endoilluminator are not available in a 25-gauge diameter, but 25-gauge laser probes and bipolar diathermy tools function very well.

The author very rarely uses bimanual surgery techniques or additional illumination ports. Bimanual surgery is used to a great extent to offset dissection forces, but disposable scissors with consistent cutting have greatly reduced this problem. Tornambe Torpedos in a 25-gauge form factor can be used for sutureless 25-gauge surgery. Although wide-angle illumination systems can improve video quality because of more uniform illumination, diffuse illumination reduces the ability to see clear vitreous, ILM and thin, nearly clear epiretinal membranes. Wide-angle (panoramic) viewing is essential for removing peripheral vitreoretinal traction in rhegmatogenous retinal detachment, PVR, and giant break cases, but should not be used for macular surgery or most diabetic traction retinal detachments, because it decreases lateral and axial (depth) resolution. Contact-based wide-angle systems (Volk, AVI), have a greater field of view than non-contact systems (BIOM, EIBOS), eliminate corneal asphericity, and unlike non-contact systems do not require excessive eye rotation, which causes tool flex with 25-gauge tools.

Summary for the Clinician

- Disposable 25-gauge end-grasping forceps and curved scissors are effective for epiretinal management and avoid contamination, damage and wear issues.
- Bimanual 25-gauge surgery, although seldom necessary, can be safe and effective using 25-gauge Tornambe Torpedo.
- Focal, specular and retro illumination is preferable to diffuse illumination when viewing transparent structures. Multi-functional tools are rarely possible in a 25-gauge form factor.

3.7 Tool Flexion

Tool flexion is the most significant complaint about 25-gauge systems, but this problem can be minimized using optimized techniques and tools. The second generation Alcon endoilluminators and endolaser probes are 58% stiffer than the first generation tools. Careful positioning of the sclerotomies reduces tool flexion. The superonasal incision should be placed in alignment with the lowest point on the bridge of the nose. The super-temporal incision should be placed at a low point on the brow, typically just above the 3 or 9 o'clock meridian. The inferotemporal incision should be placed just below the 3 or 9 o'clock meridian. The patient's head can be rotated toward the target pathology during surgery to better view the periphery. The patient can cooperate when local anesthesia is used, and the anesthesiologist can help when general anesthesia is used.

Scleral depression by the scrub tech or assistant can provide peripheral access without probe-induced ocular rotation. Contact-based wide-angle visualization systems (Volk, Avi) allow the surgeon to maintain the eye near the primary position and to rotate the instruments around the sclerotomies instead of using forces on the sclerotomies to rotate the eye.

Using 23-gauge tools virtually eliminates tool flexion, but raises significant questions about wound leaks which demands more challenging wound construction.

Summary for the Clinician

- Tool flexion issues can be addressed with new techniques and technology, and by using contact-based instead of non-contact wide angle visualization.

3.8 20/25 Vitrectomy

Certain limitations of 25-gauge vitrectomy can be overcome by enlarging one port to 20-gauge for certain tasks [4]. One sclerotomy can be enlarged for phacofragmenter use, for lensectomy or removal of dislocated lens material, or use of the Machemer-Parel diamond-coated forceps for intra-ocular foreign body removal The technique varies depending on the indications previously described, but in general an 8–0 nylon sclerotomy suture cut on the knot was used for 20-gauge sclerotomy and a 6–0 plain gut conjunctival suture cut on the knot used at the inflection point of an L-shaped mini-conjunctival flap. Utilizing one 20-gauge sclerotomy with two 25-gauge sclerotomies to

address the mechanical properties of dense lens material or the physical size of intraocular foreign bodies was found to be safe and effective. The 20/25 technique can also be used for 20-gauge conformal forceps, end-gripping diamond-coated forceps, the Chang end-aspirating laser probe, the disposable bipolar endoilluminator, or certain illuminated instruments These techniques allow the advantages of 25-gauge to be combined with the advantages of one special-purpose 20-gauge sclerotomy for selected cases.

Air-silicone exchange in 25-gauge vitrectomy cases can be performed with a specialized silicone infusion cannula (MedOne) that fits in the lumen of 25-gauge cannulas. Complete silicone fill of the vitreous cavity can be performed in less than 3 min, allowing air to exit from the opposite, open cannula, when using this technique, while maintaining the sutureless benefits of 25-gauge vitrectomy. In cases of reoperation under silicone oil, a transcleral 25-gauge silicone infusion cannula directly attached to the silicone tubing can be used for silicone infusion or two-port technique, using the MedOne cannula for sequential silicone volume replacement. If a 25-gauge silicone infusion cannula is not available, a 20/25-gauge technique can be used, although less desirable.

Summary for the Clinician

- By enlarging one 25-gauge sclerotomy to 20-gauge after completing removal of the vitreous, 25-gauge technology can be applied to intraocular foreign body cases and to eyes requiring a fragmenter.
- Use of the 20/25 approach enables the benefits of 25-gauge surgery to be applied to all cases.

3.9 Visualization

Smaller diameter fibers can increase light losses which can be compensated for by using by using one of the new xenon sources such as the Alcon, Synergetics or DORC xenon illuminator sources. The Accurus Xenon Illuminator has ISO standard filtering to produce a safe, nearly white-appearing light with low aphakic hazard function (AHF). The second generation endoilluminator probes have twice as much light throughput, much larger divergence angle and are twice as stiff as the first generation tools. Care must be taken with xenon sources to reduce power after lamp change or when a 25-gauge case follows a 20-gauge case.

Summary for the Clinician

- Focal, retro, and specular illumination as used with slitlamp biomicroscopy are applicable to vitrectomy, and preferred to wide-angle diffuse illumination when visualizing transparent ILM, clear vitreous, and "glassy" epiretinal membranes.
- Colorless tissue such as clear vitreous, ILM, retina and transparent epiretinal membranes are best seen with white light, not yellow or green.
- Brighter light, xenon and mercury vapor improve visualization with small fibers, but have the potential for causing phototoxicity. Care must be taken to use the minimum light level, especially for macular surgery.

3.10 Wound Leak Issues

Postoperative wound leaks have been a concern since sutureless 25-gauge technology was introduced. Wound leaks may lead to hypotony, resulting in choroidal detachments, bleeding, vitreous volume enhancement, or reoperations to suture the wounds. Vitreous wicks increase the risk of endophthalmitis. Intraoperative wound leaks through the cannula can result in bleeding, vitreous prolapse with secondary vitreoretinal traction, miosis due to hypotony, or even retinal prolapse. The author initially raised the issue of conjunctival antibiotics gaining access to the vitreous cavity through unsutured sclerotomies, resulting in retinal toxicity, and anecdotal reports have substantiated this concern. de Juan has advocated allowing vitreous to plug the wounds, and the author subsequently introduced the idea of using fluid–air exchange to reduce wound leaks. Initially the author recommended partial fluid–air exchange, but this left the inferotemporal sclerotomy unprotected when the patient was seated or standing; total fluid–air exchange is now used for all cases not requiring gas or silicone oil with thin sclera. Many surgeons have noted the role of vitreous incarceration in 20-gauge wounds as a factor in post-vitrectomy retinal detachment. The author has emphasized that the surface tension effect of an air bubble can reduce or eliminate wound leaks and prevent vitreous wicks until fibrin seals the wound, just as gas bubbles are used to "seal" retinal breaks and macular holes. Air is also an excellent way to intraoperatively "seal" wound leaks in trauma cases. The author recommends removing as much peripheral vitreous as possible in 20-gauge as well as 25-gauge cases. Fluid–air exchange is used much less since switching to scleral tunnel wound construction The author strongly

recommends the use of sub-conjunctival antibiotics after all vitrectomies, because topical antibiotics do not achieve a minimal inhibitory concentration (MIC) in the vitreous cavity of a two-compartment eye. Broad spectrum coverage of commonly occurring pathogens requires use of an aminoglycoside (gentamycin or tobramycin) and a semi-synthetic penicillin (ceftazimidine), or vancomycin if the patient is allergic to penicillin.

Summary for the Clinician

- Endophthalmitis prevention has largely replaced hypotony as the most important wound-related issue.
- Surgeons should take care to avoid vitreous wicks, and not refrain from using sub-conjunctival antibiotics with broad coverage.

3.11 Cannula Withdrawal and Wound Closure

The cannulas should be withdrawn with near tangential trajectory to facilitate approximation of the inner and outer portion of the scleral tunnel. Intraocular pressure pushes the interior part of the scleral tunnel against the outer layer. The best approach is to press on the wound with the back of smooth forceps while removing the cannula with the infusion at about 20 mmHg. This technique is similar to applying pressure to a venipuncture site as the needle is withdrawn.

Slow withdrawal of tools from cannulas reduces acute vitreoretinal traction; think of the tool in the cannula as a syringe with the plunger being pulled back. Supporting the sclera while removing the cannulas reduces wound eversion, pressure on the globe, and the likelihood of vitreous prolapse. The wounds should not be massaged after cannula removal; the conjunctiva should be gently moved back into its original position and external pressure applied to the sceleral tunnel with a smooth forceps and pressure applied to the internal portion of the tunnel by setting the IOP at 25 mmHG. If a wound leak is detected, a single 8-0 Biosorb suture can be placed through conjunctiva and sclera to close these small wounds.

Summary for the Clinician

- Careful attention to cannula withdrawal, and especially avoidance of vitreous wicks, is essential to prevent wound leaks and endophthalmitis. If there is any concern about a wound leak, the wound should be sutured in a single layer.

References

1. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109(10):1814–1820
2. Fujii GY, De Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C, Ng E, Barnes A, Wu SL, Sommerville DN (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109(10):1807–1812
3. Capone A (2005) 25 gauge pars plana vitrectomy: advances in instrumentation and broader indications. In: Program and abstracts of the American Society of Retina Specialists 23rd Annual Meeting, Montreal, Canada, 16–20 July 2005
4. Charles ST (2005) 20/25 vitrectomy; combined 25 and 20-gauge vitrectomy. In: Program and abstracts of the American Society of Retina Specialists 23rd Annual Meeting, Montreal, Canada, 16–20 July 2005

Chapter 4

Transconjunctival 23-Gauge Vitrectomy

C. Eckardt

Core Message

- 23-gauge transconjunctival vitrectomy was developed to improve on the reported shortcomings of 25-gauge vitrectomy.
- Every large opening of the conjunctiva and sclera, and every closure with resorbable suture material is associated with greater postoperative inflammation than a single small incision requiring no suture.
- For patients, the milder inflammatory reaction and absence of astigmatism mean less postoperative irritation and speedier rehabilitation.
- 23-gauge vitrectomy is suited not only for treatment of surgically less complicated vitreoretinal pathologies, but also for even the surgically most difficult disorders.
- The indications for 25-gauge vitrectomy, by contrast, are seen by many surgeons in the repair of the less surgically complex vitreoretinal pathologies.
- The concept of 25-gauge transconjunctival vitrectomy can also be applied with the larger 23-gauge instrumentarium.
- The closure achieved by self-sealing sclerotomies is so effective as to practically eliminate the risk of postoperative hypotony.
- The stability and efficiency of the instruments allows repair not only of macular disorders but also of the surgically most complicated pathologies in all fundus regions.
- The best possible preservation of the conjunctiva and sclera, beginning with the very first operation, is of inestimable value for all subsequent interventions.

23-gauge transconjunctival vitrectomy [1] is based on the same principles as 25-gauge transconjunctival sutureless vitrectomy [3, 4]. It was developed to improve on the reported shortcomings of 25-gauge vitrectomy vis-à-vis conventional 20-gauge vitrectomy, such as the too high flexibility and poorer efficiency of the instruments as well as the associated occasional early postoperative ocular hypotony [7]. The main problem encountered in the development of 23-gauge vitrectomy was an increase in leakage from the sclerotomies for the microcannulas. This problem was finally solved by placing the sclerotomies as self-sealing tunnel incisions running tangential — not perpendicular — to the sclera. While the microcannulas were originally placed using a two-step method, a one-step technique has now been devised.

4.1 Placement of the Microcannulas: Two-Step Technique

A forceps is used to move the conjunctiva at the site of the planned sclerotomy about 2 mm laterally, i.e., parallel to the corneoscleral limbus. The displaced conjunctiva is held firmly against the sclera using a pressure plate [5]. A 1-mm diameter opening at the center of the plate ends laterally in a slit. The outer edge of the plate's underside is equipped with small teeth to prevent slippage. The pressure plate performs three functions: (1) it is used to press the conjunctiva firmly against the sclera to prevent it from moving as the scleral tunnel incision is made and following insertion of the microcannulas (this facilitates subsequent locating of the conjunctival and scleral incisions), (2) it is used to move the globe during the sclerotomy, and (3) it aids in measuring the distance between the sclerotomy and the corneoscleral limbus (placed directly on the corneoscleral limbus, the distance to the middle of the central opening in the plate is 3.5 mm).

While the conjunctiva is being securely held by the pressure plate, the scleral tunnel incision is made using a 45°-angled 23-gauge stiletto knife (Fig. 4.1). To make the incision, the knife is placed through the central opening in the pressure plate, and the blade drawn at a 30° angle tangentially through the sclera parallel to the corneoscleral limbus. During this procedure the globe

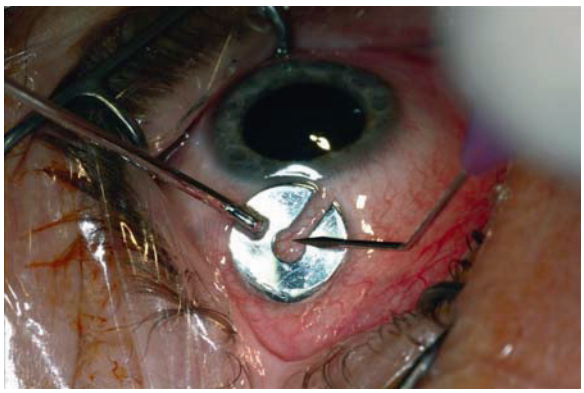


Fig. 4.1 Pressure plate for holding the conjunctiva firmly against the sclera during conjunctival and scleral incision. A 45°-angled 23-gauge stiletto knife is placed through the central opening at a 30° angle to perform the scleral tunnel incision

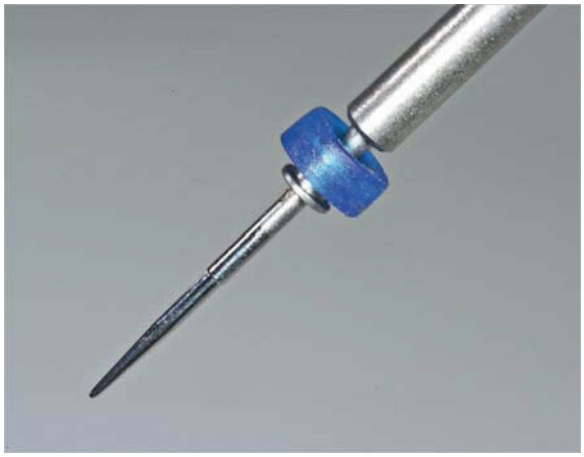


Fig. 4.2 Inserter with microcannula (DORC). The inserter possesses a probe-like blunt tip for easy insertion into the scleral tunnel

tends to rotate in the direction of the cut, despite being held by the pressure plate. This can be avoided by using an extremely sharp knife**.** Mild pressure must continue to be applied as the blade is withdrawn from the tunnel incision, to secure its position on the conjunctiva and sclera. Corresponding to the width of the stiletto blade, the cut through the sclera ranges in width from 0.72 to 0.74 mm. The microcannula is inserted into this tunnel incision using the so-called "inserter"(DORC, Zuidland, Holland), a specially constructed probe-like steel instrument (Fig. 4.2). The microcannulas (also made of steel) are 4.5 mm (instrument cannula) and 4 mm (infusion cannula) long without their heads, their lumen diameter is 0.65 mm, the outer diameter 0.75 mm. Due to its blunt tip and conic form, the inserter can almost always be easily introduced into the conjunctival incision and scleral tunnel. Only insertion of the somewhat fatter microcannula requires application of a modicum of pressure. Since the tangential position of the inserter causes the globe to rotate under pressure, pressure must be applied in the direction of the apex of the orbit. To do this, the inserter must be moved from its original tangential position to a position perpendicular to the sclera, where the resistance caused by the introduction of the microcannula can be easily overcome. Before the microcannula is inserted all the way into the sclerotomy, the pressure plate is removed. As the inserter is withdrawn from the microcannula, the cannula must be held firmly in place in the sclerotomy using a special forceps (DORC). Normally the infusion microcannula is first placed in the inferotemporal quadrant.

4.2 Placement of the Microcannulas: One-Step Technique

In the one-step technique microcannulas are not inserted with a blunt inserter as in the two-step technique, but with a sharp trocar (Fig. 4.3a,b). The width of the resulting scleral incision is somewhat less than that produced by a 23-gauge stiletto knife. It may be necessary to apply slightly higher pressure for insertion of the microcannula, occasionally causing lateral rotation of the globe. This possible shortcoming of the one-step technique is compensated by the quicker insertion of the microcannulas. Moreover, because no stiletto knife is used, the one-step technique is also less expensive.

4.3 Course of the Scleral Tunnel Incision

The two instrument microcannulas are usually placed in the superotemporal and superonasal quadrants, the infusion microcannula in the inferotemporal quadrant.

The three tunnel incisions can either run parallel to the corneoscleral limbus or they can run an anterior–posterior course, i.e, towards the posterior pole (Fig. 4.4 a,b). The course running parallel to the limbus has the advantage that the interior opening of the tunnel is located the same distance from the corneoscleral limbus as the external opening. Such an alignment of the tunnel incisions was first described as the "self-sealing sclerotomy" technique. In that procedure, however, the conjunctiva was opened and a 20-gauge instrumentarium was used [6, 9]. If the tunnel incisions ran an anterior–posterior course, there was a risk that the tunnel's interior opening could lie too close to the ora serrata. This risk could be lowered by locating the exterior opening a corresponding distance

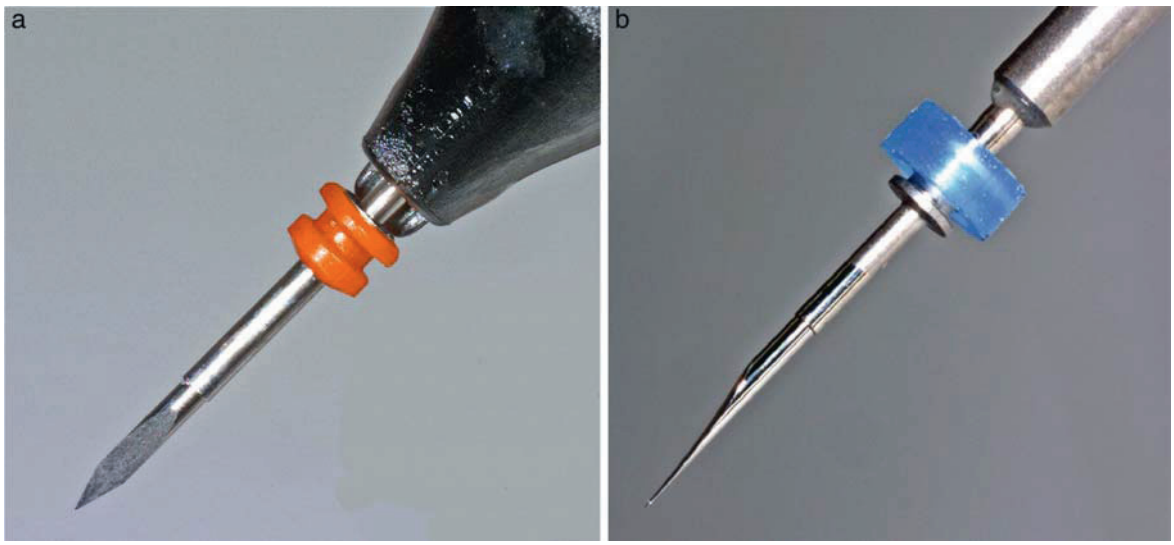


Fig. 4.3 Sharp 23-gauge trocars by Alcon (a) and DORC (b)

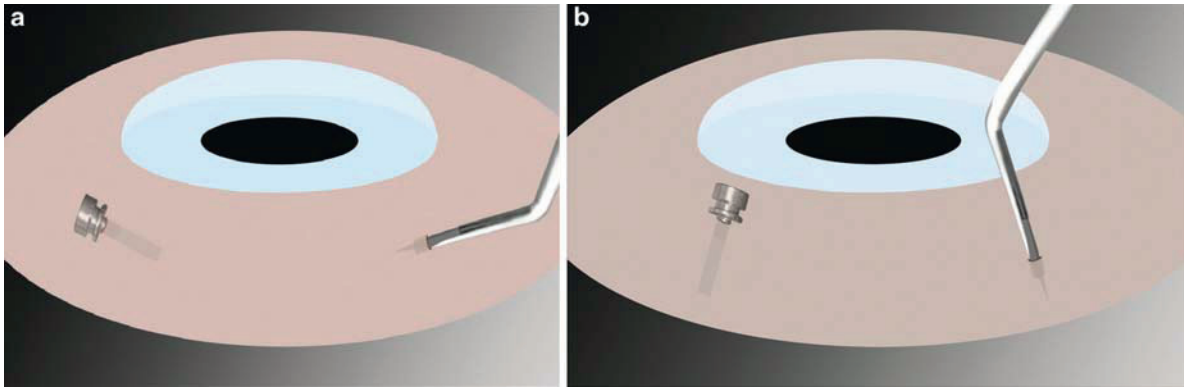


Fig. 4.4 The scleral tunnels can either run parallel to the corneoscleral limbus (**a**), or in an anterior–posterior direction (**b**)

closer to the corneoscleral limbus. But since the conjunctiva in this area can only be displaced scarcely or not at all, the result would be a scleral incision lying directly under the conjunctival incision. This possible shortcoming of an anterior-posterior tunnel is offset by the advantage of its scleral incision which runs parallel to the scleral fibers, requiring that the fibers need only be separated (not cut), thus facilitating more rapid and superior postoperative closure of the sclerotomy [8].

4.4 Instrumentarium

Some manufacturers, including DORC, Medlabs, and Synergetics, equip the microcannulas with a valve-system (Fig. 4.5) consisting of a silicone membrane mounted cap-like on or built into its head. A slot in the membrane allows insertion of the instruments. When an instrument is withdrawn, the membrane seals the cannula, preventing the escape of intraocular fluid and averting intraoperative swings in pressure. Use of the valve cannula also protects the intraocular tissue by reducing the amount of infusion and reducing the operation time.

The shafts of 23-gauge instruments are 0.64 mm in diameter, those of 20-gauge instruments 0.89 mm, and those of 25-gauge instruments 0.51 mm. The author's experience with the 23-gauge vitrectomy system has been with the DORC instrumentarium. A wide variety of 23-gauge instruments is available today, including endgripping and flatgripping forceps, various scissors, including curved scissors, endoillumination probes with different illumination angles, as well as straight and curved endolaser probes.

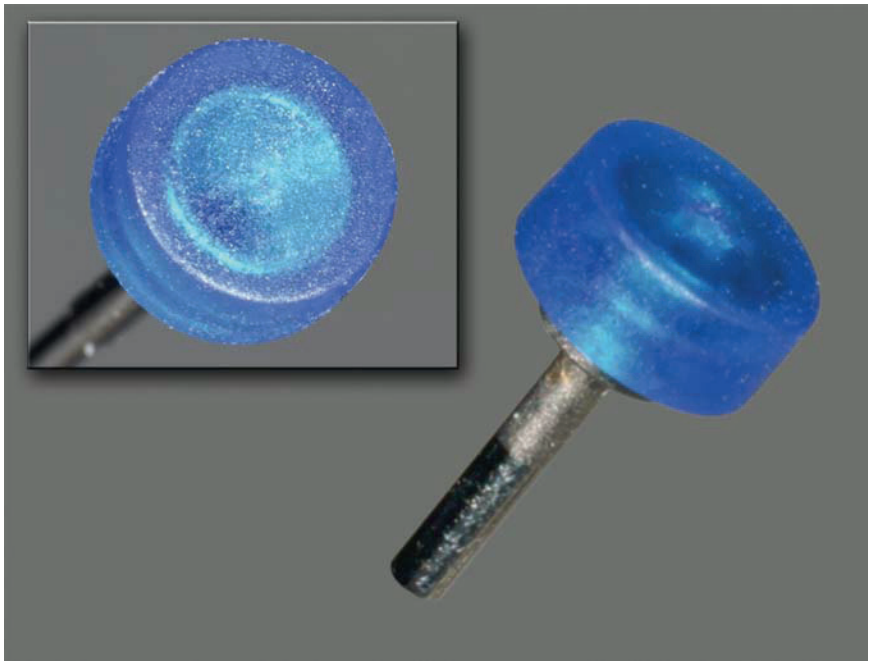


Fig. 4.5 Valve cannula (DORC). A cap-like silicone membrane is mounted on the head of the microcannula. A slot in the membrane allows the insertion of instruments

4.5 Combined Phacoemulsification/ Vitreoretinal Surgery

The placement of the microcannulas during combined cataract/vitrectomy surgery differs only slightly from that of vitrectomy surgery alone. If done after the cataract surgery, insertion of the microcannulas with the requisite pressure could cause intraocular fluid to escape from the cornea wound. Since this cannot always be avoided even by suture closure, at least one of the three microcannulas, the infusion cannula, should be placed at the outset of the procedure.

4.6 Scleral Indentation

If valve cannulas are not used, closure of one of the two instrument cannulas during the vitreoretinal surgery may be advantageous — if for example the surgeon is using the coaxial light of the microscope to work with the vitreous cutter in one hand while performing the scleral indentation with the other. The second, unused open cannula can give rise to wide swings in intraocular volume, which can complicate or impede entirely manipulation of the instruments. This problem does not arise if microcannulas with a valve are used (Fig. 4.6)

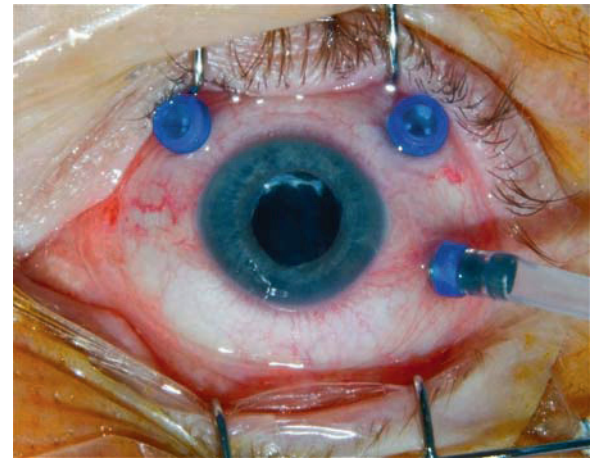


Fig. 4.6 Intraoperative situation with 3 valve cannulas (DORC) in use

4.7 Silicone Oil Injection and Removal

Silicone oil can be injected without complications using 23-gauge microcannulas. For this purpose, the infusion tube on the head of the microcannula is exchanged for a tube filled with silicone oil and attached to a syringe. The silicone oil tube is affixed to the head of the cannula.

Neither 1,000 cst nor 5,000 cst silicone oil causes the tube to detach from the cannula.

1,000 cst silicone oil is most rapidly removed by the application of pressure not by suction. The two instrument cannulas for drainage of the oil are left open so that the high pressure applied by the infusion solution will force the silicone oil out within a few minutes. This technique is not suitable for 5,000 cst silicone oil, whose higher viscosity requires a 20-gauge sclerotomy.

4.8 Removal of the Microcannulas

If microcannulas without valves are used, they should be closed with plugs at conclusion of the procedure, regardless of whether intraocular tamponade (gas, silicone oil) has been performed. The intraocular pressure is then set to about 20 mmHg, and the cannulas and their plugs are withdrawn one after the other in the direction of the scleral tunnels using special cannula forceps, the infusion cannula being removed last. Mild pressure should be applied to the scleral tunnel incisions using a cotton wool applicator for as long as subconjunctival microbleeding from the episcleral vessels is evident. This often requires the application of pressure for 30–60 s, occasionally even longer. Not only does this stop the bleeding, but it leads to complete closure of the exterior scleral tunnel opening, which is usually recognizable as a somewhat gaping wound in the sclera immediately after removal of the microcannulas.

Summary for the Clinician

- The pressure plate performs three functions: (1) it is used to press the conjunctiva firmly against the sclera to prevent it from moving as the scleral tunnel incision is made and following insertion of the microcannulas, (2) it is used to move the globe during the sclerotomy, and (3) it aids in measuring the distance between the sclerotomy and the corneoscleral limbus.
- In the one-step technique, microcannulas are not inserted with a blunt inserter as in the two-step technique, but with a sharp trocar.
- The advantage of an anterior-posterior tunnel is that its incision runs parallel to the scleral fibers, requiring that the fibers need only be separated (not cut), thus facilitating more rapid and superior postoperative closure of the sclerotomy.

Summary for the Clinician

- The placement of the microcannulas during combined cataract/vitrectomy surgery should be placed at the outset of the phaco procedure.
- Silicone oil can be injected without complications using 23-gauge microcannulas.
- If microcannulas without valves are used, they should be closed with plugs at conclusion of the procedure. The intraocular pressure is then set to about 20 mmHg, and the cannulas and their plugs are withdrawn one after the other in the direction of the scleral tunnels using special cannula forceps, the infusion cannula being removed last.

4.9 23-g Vitrectomy Compared to Conventional 20-g Vitrectomy

General Advantages

Every large opening of the conjunctiva and every closure with resorbable suture material is associated with greater postoperative inflammation than a single small incision requiring no suture. The situation is similar for scleral incisions, where suture closure can have the added side-effect of causing temporary postoperative astigmatism [2]. Both transconjunctival vitrectomy techniques, the 23-gauge as well as the 25-gauge, are therefore superior to conventional 20-gauge techniques. For patients, the milder inflammatory reaction and absence of astigmatism mean less postoperative irritation and speedier rehabilitation. Compared to these advantages, the possible shorter operation time of transconjunctival techniques is only of secondary importance.

4.9.1 Advantages in Cases Requiring Multiple Interventions

The avoidance of postoperative scar formation of the conjunctiva and sclera is an advantage of 23-gauge vitrectomy that is especially beneficial in patients requiring multiple interventions. Regardless of whether the repeat vitrectomy is undertaken in the early postoperative phase or after, a mobile conjunctiva is present. When choosing where to locate the sclerotomies, the surgeon does not have to consider the location of previous sclerotomies. Often the scleral tunnel incisions can scarcely be recognized by slit-lamp microscopy just a few days after surgery. This has several causes. For one, the incision is smaller (0.72 mm vs 1.15 mm for 20-gauge vitrectomy).

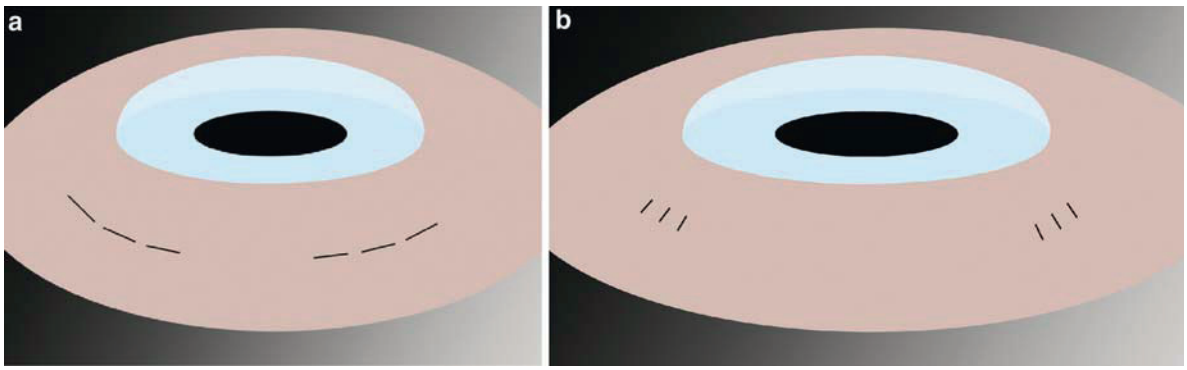


Fig. 4.7 Schematic diagram comparing the situation of the superior sclerotomies after three traditional 20-gauge vitrectomies (**a**) and three transconjunctival 23-gauge vitrectomies (**b**)

Second, the 23-gauge tunnel incision causes much less traumatization of the wound borders, the once-only placement of the microcannulas in the incision being much less traumatic to the sclera than the repeated insertion and withdrawal of instruments through a 20-gauge sclerotomy. Third, self-sealing sclerotomy closure results in less inflammation of the sclera than closure with resorbable suture material, with its risk of a suture-related inflammatory reaction and/or atrophy in the area of the sclerotomy, each commonly seen following 20-gauge vitrectomy. For revision surgery performed within a few weeks after surgery, the anatomic conditions are much more favorable following 23-gauge vitrectomy than following 20-gauge vitrectomy. The conjunctiva is less chemotic and hyperemic, and the self-sealing tunnel incision closure is clearly more stable than 20-gauge sclerotomy closure with a 7-0 or 8-0 polyglactin suture. A further advantage is that the course of the tunnel incisions radial to the corneoscleral limbus leaves more room for future sclerotomies than do conventional incisions running parallel to it (Fig. 4.7a,b).

4.9.2 Drawbacks and Shortcomings of 23-Gauge Vitrectomy

For some 23-gauge instruments, the smaller lumen is occasionally disadvantageous. A 23-gauge vitreous cutter for simple vitrectomy, for example, requires about 30% more time than does a 20-gauge cutter. The situation is similar for removal of a nonclotting intravitreal hemorrhage using a flute needle. For all other instruments we have experienced no appreciable difference in their efficacy versus 20-gauge instruments. This is true for example of the endoillumination probe and the endolaser probe, as well as for the various scissors and forceps, whose handling, function, and size are wholly adequate for even the most difficult surgical procedures. We experienced no problems with the stability of the instruments. Although by nature somewhat less stable than 20-gauge instruments, they have no appreciable drawbacks when used. Almost all techniques associated with 20-gauge vitrectomy, such as work on the periphery using scleral indentation or extreme lateral rotation of the globe, can be performed equally well with 23-gauge instruments.

For scleral indentation itself, however, transconjunctival vitrectomy sometimes only allows a minimal indentation in the nasal quadrants, due to the anatomic situation of the conjunctiva. Scleral indentation posterior to the equator, as performed in conventional vitrectomy with large conjunctival opening, is therefore not at all possible, or only to a limited extent. Also not feasible are techniques requiring special instruments not yet available in 23-gauge, such as endofragmentation needles, endocryocoagulation probes, and numerous angled instruments which by their very nature cannot be introduced through microcannulas.

4.9.3 Postoperative Hypotony, Endophthalmitis

Whereas in conventional 20-gauge vitrectomy, normotone intraocular pressure can be achieved by suture closure at conclusion of the operation, in 23-gauge vitrectomy a hypotony exists immediately after removal of the microcannulas, regardless of whether or not a gas tamponade was performed. In our experience, the pressure returns to normal in only a few hours. In a small series of 30 consecutive patients in whom we measured the intraocular pressure between 5 and 7 h after surgery, only two eyes had an intraocular pressure below 10 mm Hg (6 and 8 mm Hg); in all other eyes the pressure varied between 10 and 16 mm Hg. On the first day postoperative, i.e., about 16 h after surgery, all eyes had normal pressure. It is unclear whether the temporary hypotony immediately postoperative and/or the delayed sclerotomy closure are associated with a higher risk of intraocular hemorrhage

and/or endophthalmitis; only a large comparative study can provide the answer. Our experience does not suggest a higher incidence of hemorrhage. Of the more than 1,800 eyes we operated on using the 23-gauge technique in 2006 and 2007, fewer than 1% had hypotony on the first day postoperative. Postoperative endophthalmitis was noted in none of these eyes.

4.10 23-Gauge Vitrectomy vs 25-Gauge Vitrectomy

4.10.1 Instrument Size

With regard to both the stability and efficacy of the instruments, 23-gauge vitrectomy is suited not only for treatment of surgically less complicated vitreoretinal pathologies, but also for even the surgically most difficult disorders, such as advanced PVR or diabetic retinal detachments requiring complex surgery on the retinal periphery. The indications for 25-gauge vitrectomy, by contrast, are seen by many surgeons in the repair of the less surgically complex vitreoretinal pathologies. While it is recommended that centers offering both procedures should carry out the appropriate case selection, preoperative decisions in favor of 25-gauge for a particular case harbor the risk that the situation will turn out to be more complicated intraoperatively than originally assumed. This can have the consequence that the instrumentarium must be changed during the procedure to conventional 20-gauge with opening of the conjunctiva. To date this has not occurred in any of our cases in which the 23-gauge technique was used.

Even in surgically uncomplicated situations, such as the removal of a simple diabetic membrane or of a macular pucker, 23-gauge vitrectomy offers clear advantages. The longer forceps arms allow readier grasping of the membranes for quicker detachment from the retina than do those of 25-gauge forceps. The same is true of the scissors, namely the larger 23-gauge scissors enable more effective (fewer cuts) excision of epiretinal proliferations than do 25-gauge scissors.

4.10.2 Sclerotomies

A fundamental difference distinguishes the sclerotomies of 23-gauge vitrectomy from those of 25-gauge vitrectomy: the 23-gauge sclerotomy is a tunnel incision. Postoperative wound closure relies on the intraocular pressure to hold the wound borders together. In light of the sclera's thinness in the area of the pars plana (about 0.8 mm) and the diameter of the microcannula (0.75 mm), the tunnel must run very precisely at an angle of about 30° through the sclera with smooth wound borders to ensure self-sealing closure. After numerous trials on eyes from eye banks, we concluded that the best closure can be achieved when the tunnel is made with a blade and not with a trocar. The closure achieved by a 23-gauge tunnel incision sclerotomy is excellent (Fig. 4.8).

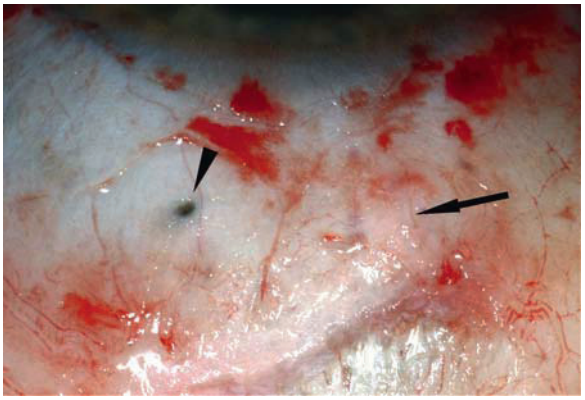


Fig. 4.8 Comparison of two sclerotomies in an enucleated eye, one done with the 23-gauge technique (*arrow*), the other with the 25-gauge technique (*arrowhead*). The photo was taken immediately after removal of the microcannulas. The wound edges of the 23-gauge tunnel incision lie so closely together that the tunnel opening is scarcely recognizable. By contrast, the rough borders of the 25-gauge sclerotomy are wide apart, and have the appearance of a hole

In 25-gauge vitrectomy, by contrast, the sclerotomy is performed with a trocar, i.e., a round sharp needle, at a right angle through the sclera. This does not create a split or slit in the sclera but an irregular, crescent-shaped-to-round opening. Postoperatively, the intraocular pressure tends to keep this sclerotomy open rather than closed, but due to its small size closure usually occurs within a short time due to normal wound healing, often but not always within a single day.

Summary for the Clinician

- The avoidance of postoperative scar formation of the conjunctiva and sclera is an advantage of 23-gauge vitrectomy that is especially beneficial in patients requiring multiple interventions.
- Self-sealing sclerotomy closure results in less inflammation of the sclera than closure with resorbable suture material, with its risk of a suture-related inflammatory reaction and/or atrophy in the area of the sclerotomy, each commonly seen following 20-gauge vitrectomy.

Summary for the Clinician

- Not feasible are techniques requiring special instruments not yet available in 23-gauge, such as endofragmentation needles, endocryocoagulation probes, and numerous angled instruments which by their very nature cannot be introduced through microcannulas.
- In 23-gauge vitrectomy, a hypotony exists immediately after removal of the microcannulas, regardless of whether or not a gas tamponade was performed. The pressure returns to normal in only a few hours.
- A fundamental difference distinguishes the sclerotomies of 23-gauge vitrectomy from those of 25-gauge vitrectomy: the 23-gauge sclerotomy is a tunnel incision. The best closure can be achieved when the tunnel is made with a blade and not with a trocar.
- In light of the sclera's thinness in the area of the pars plana, the tunnel must run very precisely at an angle of about 30° through the sclera with smooth wound borders to ensure self-sealing closure.

4.11 Conclusion

The concept of 25-gauge transconjunctival vitrectomy can also be applied with the larger 23-gauge instrumentarium, if the sclerotomies for the microcannulas are made as tunnel incisions using the special technique described above. The closure achieved by these self-sealing sclerotomies is so effective as to practically eliminate the risk of postoperative hypotony. The stability and efficiency of the instruments allows repair not only of macular disorders but also of the surgically most complicated pathologies in all fundus regions. We regard the repair of surgically complicated cases as an excellent indication for 23-gauge transconjunctival sutureless vitrectomy. Since complicated cases must often undergo multiple interventions, the best possible preservation of the conjunctiva and sclera, beginning with the very first operation, is of inestimable value for all subsequent interventions. For medical reasons, for economical reasons, and for logistical reasons it is a great advantage to have a single instrumentarium suitable for all cases. In the author's clinic, the 23-gauge system has proved over the past 3 years to be just such a system, almost completely replacing conventional 20-gauge vitrectomy.

References

1. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
2. Eckert T, Eckardt C (1996) Verhalten des Hornhautastigmatismus nach Pars-plana Vitrectomy mit und ohne gleichzeitiger Kataraktoperation. Ophthalmologe 93:38–44
3. Fujii GY, de Juan E Jr, Humayun MS, et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1813
4. Fujii GY, de Juan E Jr, Humayun MS, et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
5. Hilton FG, Josephberg RG, Halperin LS, et al (2002) Office-based sutureless transconjunctival pars plana vitrectomy. Retina 22:725–732
6. Kwok AK, Tham CC, Lam DS, et al (1999) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 127:731–733
7. Lakhanpal RR, Humayun MS, de Juan E Jr, et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
8. Rizzo S, Genovesi-Ebert F, Vento A et al (2007) Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicrosopic study. Graefes Arch Clin Exp Ophthalmol 245:1281–1288
9. Theelen T, Verbeek A, Tilanus MAD, von den Biesen PR (2003) A novel technique for self-sealing, wedge-shaped pars plana sclerotomies and its features in ultrasound biomicroscopy and clinical outcome. Am J Ophthalmol 136:1085–1092

Chapter 5

23-Gauge One-Step Instrumentation

S. Rizzo, M. Palla

Core Messages

- 23-gauge surgery reunites the advantages of both classical vitreoretinal surgery and 25-gauge surgery
- The transition to a "one step" technique makes this surgery even more versatile
- 23-gauge surgery provides enhanced and in some cases superior performance in comparison with traditional vitreoretinal surgery, thanks to the evolution in surgical instruments

5.1 Introduction

Over the past few years, the manufacturers of surgical instruments have tried to combine 25-gauge user-friendliness and micro-invasiveness with 20-gauge performance when creating 23-gauge surgery.

5.2 Trocar

We have made the transition from a "two step" surgery, which required sclerotomy followed by trocar insertion, to a "one step" surgery with direct trocar insertion into the sclera as done in 25-gauge surgery.

Alcon proposes a "one step" device consisting of a solid stiletto with a trapezoidal cutting section and a cutting diameter of 0.74 mm compared with 0.61 mm for the 25-gauge. The cutting shape was optimized to obtain a better resealing of the edges.

The length of the stiletto is 9.6 mm compared with 9 mm for the 25-gauge. The trocar is in titanium and not in polyamide as is the case for the 25-gauge, and is subdivided into the part out of the sclera, block length 1.5 mm, and a bulbar part of 4 mm compared with 3.51 mm in the 25-gauge, which facilitates a safer oblique insertion. The titanium trocar causes less friction between the surgical instrument and the wall of the trocar itself, which ensures more precise control; the opening of the trocar is funnel-like to facilitate the introduction of the instruments. The trocar section measures 0.75 mm, with an internal lumen of 0.65 mm (Fig. 5.1).

DORC offers a "two-step" to "one-step" device which consists of three stilettos with a closing valve (Fig. 5.2); the valve mechanism prevents vitreous leakage out of the trocar, thereby reducing the possibility of entrapment in sclerotomy, and at the same time the possibility of contamination of the internal part of the bulb by external pathogenous agents. DORC proposes a stiletto with an elliptic section tip (Fig. 5.3) on which a metallic trocar has been fixed to reduce friction.

The universal infusion cannula has an internal diameter of 0.56 mm, compared with 0.42 mm in the 25-gauge, and can be used, like the Alcon infusion cannula, indifferently with any of the three trocars; the insertion of the tube is facilitated by the presence of a central guiding tube (Fig. 5.4).

5.3 Vitrectome

The new 23-gauge Alcon vitrectome functions with a pneumatic mechanism which is based on the pressure difference created on a diaphragm positioned within the instrument, which compresses and decompresses a control spring in the blade in a cyclic manner (Fig 5.5).

Maximum cutting rate equals 2,500 cuts per minute with enhanced performance compared to a 20-gauge, and compared to 1,500 cuts per minute with a 25-gauge. A high cutting rate reduces the possibility of retinal traction caused by the instrument.

The 23-gauge entry port lies closer to the tip of the instrument than is the case with the 20- or 25-gauge (0.229 mm 23-gauge, 0.356 mm 25-gauge, 0.457 mm 20-gauge), which facilitates a safer and more efficient approach of the retinal surface (Fig. 5.6). Moreover, by adjusting the vacuum parameters appropriately, we can

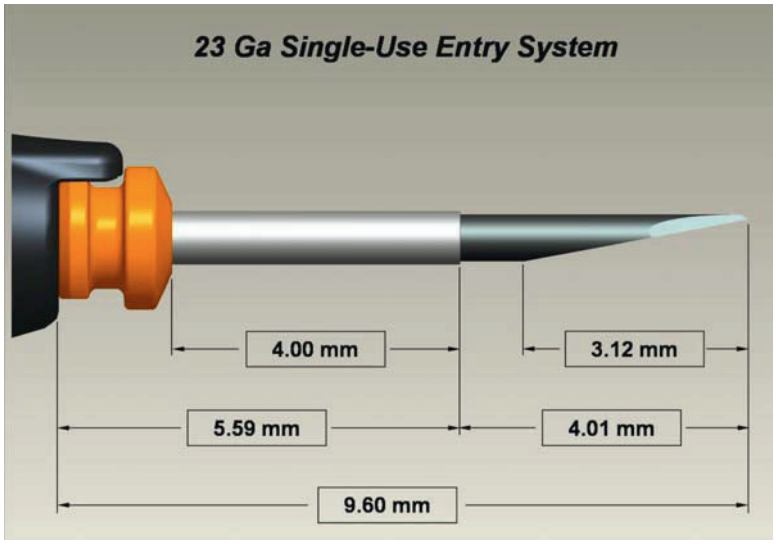


Fig. 5.1 Measure characteristics of 23 gauge alcon trocar and stiletto

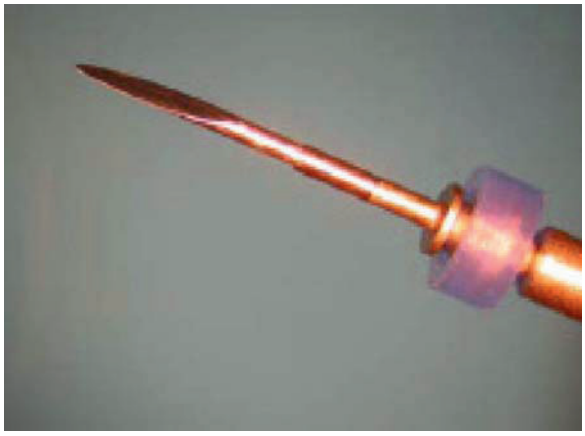


Fig. 5.2 The one-step Dorc stiletto with closing valve

Fig. 5.4 The 23 gauge alcon infusion cannula can be used for all the 3 trocars

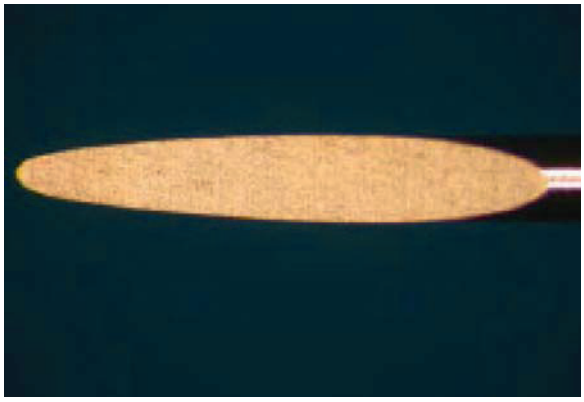


Fig. 5.3 The elliptic section tip of Dorc one-step stiletto

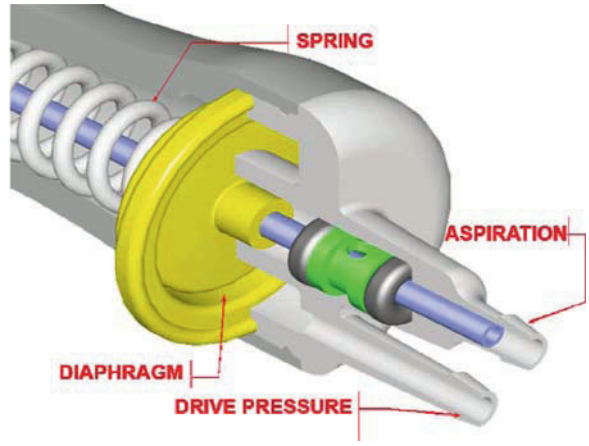


Fig. 5.5 The pneumatic mechanism of Alcon 23 gauge vitrectome

Fig. 5.6 The difference between 20 gauge (*left*) and 23 gauge (*right*) Alcon vitrectome probe. The vitrectome port is 50% closer to the tip in 23 gauge probe

achieve, at maximum cutting rate, a flow superior to that for 20-gauge (3.2 ccmin^{-1} @ 2,500 cpm with vacuum 150 mmHg. for 20-gauge, and 4.6 cc min^{-1} @ 2,500 cpm with vacuum 600 mmHg for 23-gauge) — this is because the pneumatic system is a dynamic system that allows for a variable opening time of the vitrectome opening, which is not the case with the traditional electro-static system.

The big advantage of having a variable duty cycle (port opening/closing time) is that the performance of the vitrectome can be adjusted to the density of whichever medium it finds itself in (Table 5.1).

The rigidity of a 23-gauge vitrectome registers below that of a 20-gauge,but is double that of a 25-gauge and therefore enables the surgeon to use the instrument to move the eye.

DORC allows the choice between two vitrectomy units: 1,500 and 2,500 cpm.

Moreover, DORC vitrectomy units are universal, and can be used both dealing with Associate 2500 and with Accurus.

5.4 Endoilluminator and Endolaser

The new 23-gauge Alcon Xenon light endoilluminator pairs an optic fibre 20-gauge with a diameter of 750 Mμ with a 23-gauge diameter 425 Mμ in such a way that a maximal illumination of 78° arch is obtained. The endoilluminator is equipped with a cut-off filter for ultraviolet rays to give maximum retina protection.

As far as endolasers are concerned, both Alcon and DORC have perfected a flexible curved fibre. The fibre

Table 5.1 Differences between 20-, 23- and 25-gauge Alcon pneumatic vitrectome

Port dimensions (mm)	20-gauge	23-gauge	25-gauge
Needle OD	0.908	0.641	0.514
Needle ID	0.516	0.358	0.264
Cutter stroke	1.016	1.016	1.016
Lumen area (mm^2)	0.209	0.101	0.055
Port length	0.434	0.343	0.236
Port depth	0.287	0.229	0.147
Port area (mm^2)	0.254	0.183	0.083
Port distance to end	0.457	0.229	0.356
Ratio of port/Lumen area	1.217	1.819	1.514
Cut rate (cuts per min)	100–2,500	100–2,500	100–1,500
Duty cycle	97% @ 100	97% @ 100	96% @ 100
Flow (cc min^{-1}) [*measured in a closed system with 30 mm Hg infusion*]	31% @ 2,500 @ 150 mmHg Vacuum 17.3 @ 0 cpm 3.2 @ 2,500 cpm	42% @ 2,500 @ 350 mmHg Vacuum 15.4 @ 0 cpm 4.6 @ 2,500 cpm	38% @ 1,500 @ 600 mmHg Vacuum 8.6 @ 0 cpm 3.8 @ 1,500 cpm

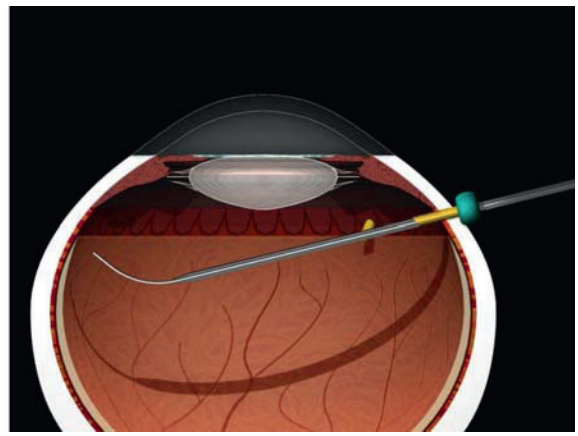


Fig. 5.7 Flexible endolaser fiber can reach the extreme periphery

can be retracted in the instrument's lumen to facilitate its introduction within the eye. Once inserted, the fibre is removed by manoeuvring the appropriate cursor of the handle; once out, the fibre retakes its original curve and enables laser treatments which are more peripheral than those of a standard endolaser (Fig. 5.7).

The fiber also ensures co-axial illumination compared with a laser beam.

5.5 Summary

- Thanks to new instruments, 23-gauge surgery can be used in almost all cases in retinal surgery.
- The continuous evolution of surgical instruments enables an ever easier approach to this type of surgery.
- Wide range of application, fast execution and micro-invasiveness are the strong points of this surgery.

Chapter 6

Small Gauge Vitrectomy: Anesthesia, Incision Technique and Cannula Removal

S. Rizzo, F. Genovesi-Ebert, F. Patelli

Core Message

- Sub-tenon anesthesia can be performed in order to perform small-gauge vitrectomy with less invasive modality than peribulbar needle injection, and is more efficient than topical anesthesia as it allows akinesia as well.
- Hypotony is a complication related to postoperative wound leakage, so incision construction is critical.
- Oblique parallel incisions achieve airtight sclerotomies in 25- and in 23-gauge vitrectomy.
- Shaving the cannula from the inside and removing the cannulas with low IOP pressure using a fiberlight are mandatory to avoid vitreous incarcerations.
- Endophthalmitis risk is greater in 25-gauge vitrectomy than in 25-gauge, and can be avoided by performing careful patient preparation, by modifying incision construction, and by avoiding vitreous incarceration in the sclerotomies.

6.1 Introduction

Making incisions smaller without sutures and achieving the same or better outcomes has long been the goal of modern surgeons. The recent development of 25-gauge (25-g) instrumentation for vitreous surgery, introduced by Fujii et al., has promoted great interest in the transconjunctival sutureless vitrectomy system [1] and has found a rapid acceptance; in fact, the 2006 ASRS PAT survey showed 70% penetrance for routine ERM. Recently small-gauge vitrectomy has been advocated for more complex vitreoret2inal pathology, due to the development of technology such as the increased stiffness of 25-gauge instruments and the new 25-gauge light sources available.

Because the 25-gauge instruments are smaller (0.5 mm) compared to the 20-gauge ones (0.9 mm) there is no significant disruption of the conjunctiva, and the incisions left in the sclera usually do not require sutures. 23-gauge vitrectomy has been introduced by Eckardt [2], and currently the chance for choosing between two different callipers allows us to deal with the majority of vitreoretinal diseases using small-gauge vitrectomy.

The main drawback is that an unsutured wound won't hold IOP at the end of the surgery and may leak postoperatively, causing hypotony [3].

Especially if a more extensive vitrectomy with air–fluid exchanges and air-gas endotamponade is required, sutureless sclerotomies performed with the tradictional modality are not completely airtight. The traditional incision construction [4] is straight and perpendicular to the scleral surface; therefore the displaced fibers do not realign immediately at the end of 25-gauge surgery, and open sclerotomies have been frequently observed. As the sclerotomy could remain open for some time or require a vitreous plug to seal the eye, postoperative hypotony has been described with different incidence rate [3, 5]. Moreover, since the conjunctiva is covering the incision it is difficult to visualize if some vitreous fibers are trapped inside the scleral opening, thus increasing the risk of endophtalmitis [6].

During the last AAO Retina Subspeciality Day, Bascom Palmer Multicenter Analysis reported an 1% incidence of endophthalmitis after 25-gauge (via verbal correspondence, pubblication pending) and the Wills Vitrectomy Series reported one out of 443 cases with 25-gauge and one out of 5,498 cases with 20-gauge. The risk appeared to be 12.4 times greater with 25-gauge [6].

Potential sources of infection are conjunctiva and sutureless sclerotomy. Therefore as well as patient preparation, wound construction is a critical point in small-gauge pars plana vitrectomy.

This chapter outlines how to construct quick self-sealing airtight incisions and how to achieve safe cannula removal. Moreover, current anesthesia techniques have also been stressed.

6.2 Anesthesia

Anesthesia for small-gauge vitrectomy is similar to the 20-gauge approach. Peribulbar or retrobulbar local anesthesia is the commonly used method.

Topical anesthesia may be chosen for minimal 25-gauge vitrectomy, and Lidocaine 2% jelly, with or without sedation, offers adequate analgesia. Lack of akinesia does not prevent a successful surgical result, even if 25-gauge was more challenging than 23-gauge due to the tool flexibility [7].

Sub-tenon anesthesia [8] can be performed in order to perform small-gauge vitrectomy with a less invasive modality than peribulbar needle injection, and is more efficient than topical anesthesia as it allows akinesia as well. Ophthalmic regional anesthesia (analgesia and akinesia) can be obtained by instilling local anesthetics in the episcleral space below Tenon's capsule employing either needles or cannulae, but use of cannulae may reduce or eliminate some of the rare adverse sequelae associated with traditional needle-based blocks.

Tenon's capsule is a fascial layer of connective tissue that surrounds the globe and invests into the extraocular muscles. Anteriorly, it is fused to the conjunctiva a few millimeters posterior to the limbus. Behind the eye, it terminates near the optic nerve insertion into the globe.

The potential space between the rigid sclera and the capsule is the sub-Tenon's or episcleral space. Sensory innervations in the form of short ciliary nerves from the ophthalmic branch of the trigeminal nerve penetrate the posterior capsule en route to the globe. Injection of anesthetic under Tenon's capsule will thus produce analgesia. Akinesia occurs due to blockade of motor nerve branches as they travel through the space on course to the extraocular muscles. The fascial sheath of the globe guides the anesthethic to the lids and to orbicularis muscle, thus preventing blinking.

Amaurosis may ensue when anesthetic bathes the anterior portion of the optic nerve.

The technique is the following: surface analgesia is obtained with topical agents on the eye, then the patient is asked to gaze in the direction diagonally opposite from the intended incision site, in order to broadly expose the access area. A mild cauterization is performed about 6 mm from the inferior/nasal limbus because this quadrant is closest to the posterior pole. Vannas Scissors are used to punch a tiny hole through the conjunctiva, and to dissect down through Tenon's to the bare sclera. It's very important to get the cannula under all layers of Tenon's capsule; this virtually guarantees that the anesthetic will end up in the muscle cone and provide an excellent block. Following dissection, the cannula is inserted through the opening. The syringe should be positioned straight up, so that it's essentially parallel to the optic nerve. Positioning the cannula in this way ensures that the anesthetic will encircle the globe. Then slowly inject all the anesthetic (3–5 cc), remove the cannula, and after 5–7 min the trocar insertion and 25-gauge vitreoretinal surgery are safely and easily performed.

Commonly encountered complications of sub-Tenon's anesthesia are mostly minor, and include pain upon injection, reflux of local anesthetic, chemosis, bleeding, and retained visual sensations. Anterograde reflux and loss of local anesthetics upon injection occurs if the dissection is oversized relative to the gauge of the cannula. Inadequate access into the episcleral space can also promote chemosis. Bleeding and subconjunctival haemorrages are reduced by a mild localized cauterization.

Here is a little tip: following the injection, keep an eye on the conjunctiva. No chemosis means that you've injected under all layers of Tenon's. Conjunctival swelling may occur also with peribulbar or retrobulbar anesthesia, and indeed makes it difficult to assess precisely the entrance sites for both the –25- and 23-gauge trocars; the swelling can push the cannula out, but the main problem is that the surgeon at the end of the operation cannot assess the complete closure of the wounds, and can miss recognising the leakage from an incompetent sclerotomy.

Summary for the Clinicians

- Anesthesia for small-gauge vitrectomy is similar to the 20-gauge approach.
- Peribulbar or retrobulbar local anesthesia is the commonly used method, while topical anesthesia may be chosen for minimal 25-gauge vitrectomy. Currently, sub-tenon anesthesia performed with a blunt cannula can be safely used for small-gauge vitrectomy, as it is less invasive than traditional needle-based blocks and more efficient than topic instillation because it also allows akinesia.

6.3 Surgical Technique

6.3.1 25-Gauge Trocar Insertion Techniques

Conjunctiva is displaced while holding the tenon to avoid rotation of the globe, then trocars are positioned first in the infero-temporal quadrant for the infusion line, then in the supero-temporal and supero-nasal quadrants. We can

displace the conjunctiva and hold the eye using forceps, cotton tip, or Thorton ring. The correct positioning of the cannulas in the vitreous chamber has to be checked holding a fiberoptic on the corneal surface with one hand, and indenting the cannula with the other. Then the orifice of the infero-temporal microcannula is connected to an infusion line and vitrectomy is started.

Hagemann's Incision. In order to achieve a completely airtight incision, oblique insertion of the trocars, modifying the technique proposed by Eckardt for transconjunctival sutureless 23-gauge vitrectomy [2] has been suggested by Hagemann (ARVO poster n 4661 2006) and Lopez-Guajardo [9]. The straight 25-gauge system (Baush & Lomb or Alcon) is thus inserted obliquely perpendicular to the scleral fibers.

Hagemann's incision is performed by inserting trocars first at an oblique angle of 30°, tangential to the scleral surface, 3.5 mm to the corneoscleral limbus; then the port is screwed. The blade, positioned perpendicular to the cornea, is directed towards the 12 o'clock position. The sclerotomy so achieved is airtight, but the scleral fibers, arranged in concentric circles near the cornea, are dissected, and the sealage of the wound could be delayed.

Rizzo's Incision. We have therefore hypothesized that incisions running parallel to the scleral fibers may seal quicker, as the majority of the fibers should have been separated, but not cut. So we have developed a further insertion technique [10] in order to create a quicker self-sealing airtight entry to expand 25-gauge indications more safely. Taking the arrangement of scleral structure into consideration, the incision is made parallel to the limbus and to the scleral fibers, using the same modality as for the 20-gauge incision.

The Rizzo's modified oblique-parallel sclerotomy is performed by inserting trocars at an oblique angle of 30° tangential to the scleral surface; then the port is screwed in order to exert the necessary pressure for inserting the cannula. The blade, positioned parallel to the cornea, enters the sclera directed towards the posterior pole, in phakic eye at 3 mm from the limbus, and exits in the vitreous chamber at 4 mm; then the system is straightened.

Thus, scleral fibers are spread apart but not completely torn (Fig. 6.1).

We compared the effectiveness of the different incisions (straight, oblique-perpendicular and oblique-parallel) in 25-gauge vitrectomy for macular hole repair, and investigated their behaviour with the UBM.

We demonstrated that all the oblique-parallel incisions were airtight after the removal of 25-gauge cannulas, and that the sclerotomy was much narrower compared to the oblique-perpendicular one.

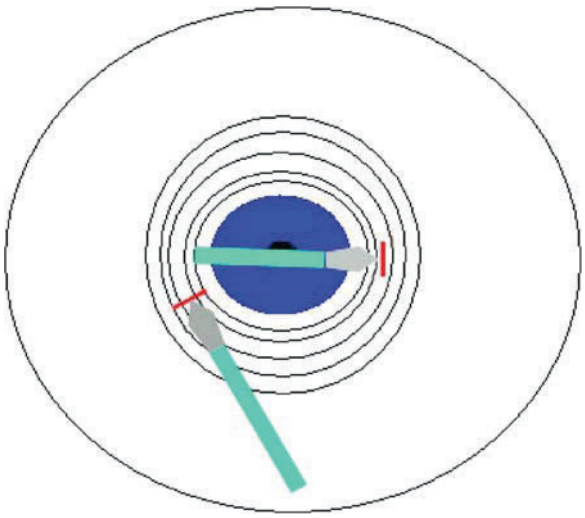


Fig. 6.1 (*Above*) The blade enters the sclera parallel to the scleral fibers. (*Below*) The incision is made perpendicular to the scleral fibers

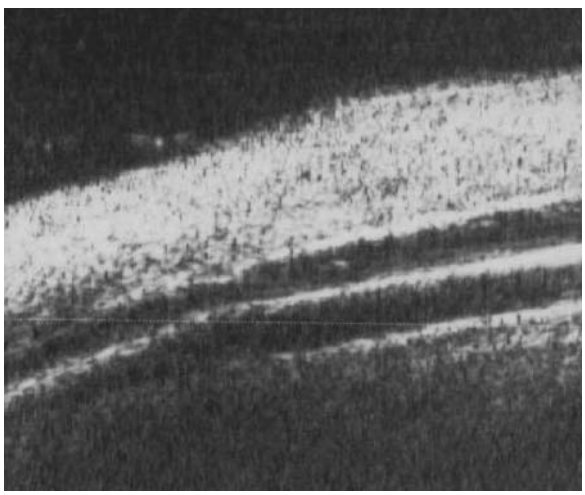


Fig. 6.2 Oblique-parallel incision is well healed, with perfect apposition of the internal wound lips. No scleral defect is evident in the sclerotomy sites. The *hyperreflective line* evident in the vitreous chamber is the gas bubble interface

UBM examination 1 day postoperatively showed all sclerotomies well-healed, with perfect apposition of the internal wound lips (Fig. 6.2).

In addition, the oblique-perpendicular incisions were airtight at the end of the surgery. At 1 day p.o. UBM examination, the majority of sclerotomies were well-healed, but in all a minimal gape was clearly visible (Fig. 6.3), 1.4% of eyes showed peripheral cilio-choroidal detachment that was resolved at the 7 days UBM, while the gape was still evident.

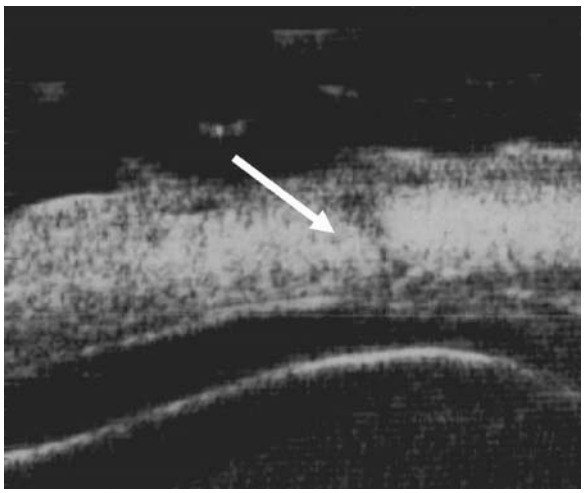


Fig. 6.3 Oblique perpendicular incision. The scleral defect is clearly visible with a minimal gape (*arrow*)

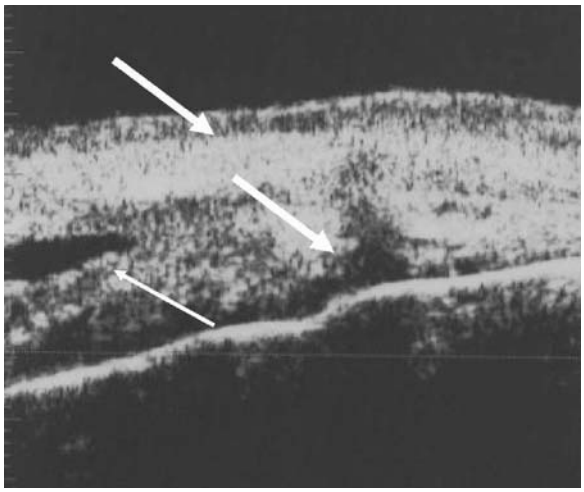


Fig. 6.4 Straight incision shows a significant gape (*arrow*) and subconjunctival fluid

With straight incision at the end of the surgery conjunctival bleb formation was detected in 4.5% of cases, and 15% sclerotomy was sutured. At 1 day p.o., hypotony was recorded in 2.25% of patients. The 1-day p.o. UBM examination showed a significant gape in all sites (Fig. 6.4); weak vitreous entrapment was shown in 16.2%, subconjunctival fluid in 1.8%, cilio-choroidal detachment in 3.5%. At 1 month p.o., the sclerotomy defect was still detectable; other complications were no longer evident.

We concluded that Rizzo's incision achieved the quickest and most complete sealing from the first day p.o. without complications. Oblique-perpendicular incision is satisfactory, but may allow episodes of hypothony, resulting in ciliochoroidal detachment; standard incision is less safe because it may leak at the end of the surgery, and seems to seal slower.

The current studies in the literature cannot comment adequately on whether standard straight insertion may or not require suture in case of air or gas tamponade [3, 5, 11]. It has been postulated that a stable and properly inserted microcannula may become lax and deformed with time, due to pivoting motions of the instruments during peripheral vitrectomy. Moreover, extensive manipulation may cause wound extension, thus requiring suture placement. The advantage of these modified techniques or this modified technique may be clinically irrelevant if vitrectomy requiring minimal intraocular manipulation and tissue dissection is performed. In contrast, it could be critical in complicated vitrectomy, where the use of multiple intraocular instruments with several tool exchanges is required.

6.3.2 23-g Trocars Insertion Techniques

Eckard's Two-Step Incision. The first 23-gauge vitrectomy system used was the 23-gauge DORC with a two-step incision.

Eckard's two-step incision consists of the following procedure; the stiletto blade enters the vitreous chamber at an oblique angle of 30°, then the cannula–trocar system is inserted tangential to the scleral surface, 3.5 mm to the corneoscleral limbus, then the port is screwed. (see Chapter 4)

There are some problems related to the two-step incision, making it difficult. In particular, it can be difficult to recognise the stiletto cut, and double incision may occur when inserting the cannula system. (see Chapter 4)

Recently a new 23-gauge one-step system has been developed by Alcon. The system is designed like the 25-gauge ones, with the blade and the cannula all together, and allows a quicker one-step manouvre, but the modified incision oblique parallel used for the 25-gauge system doesn't suit 23-gauge due to the larger dimension of the 23-gauge trocars, so we had to create an incision suitable for the 23-gauge One-Step System.

Zorro's Incision. Therefore, in order to achieve a tunnel-like effect, the incision construction has to be as oblique as possible and as long as possible [12]. In order to achieve an optimal water/airtight sclerotomy, the first thing to do is to modify the incision angle. With an incision angle of 45°, we achieve in fact a tunnel of 1.154 mm (Fig. 6.5). By reducing the incision angle by 15° and using an angle of 30°, the length of the tunnel increases by 30%, as the tunnel is 1.414 mm; therefore it is more airtight (Fig. 6.6).

The second trick is to modify the incision direction by inserting the system obliquely without straightening. The blade is inserted at 3.2 mm from the limbus, at an oblique angle of 10–15°, and enters the vitreous without straightening (Fig. 6.7).

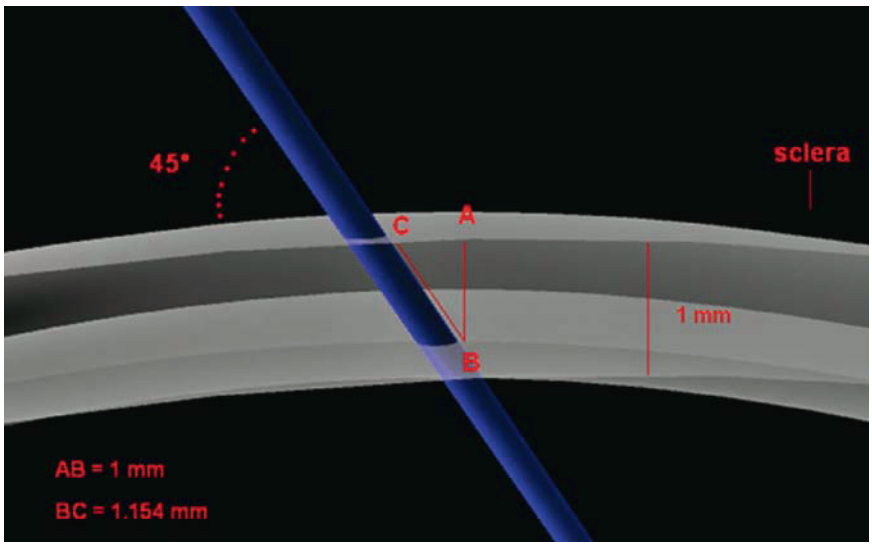


Fig. 6.5 An incision angle of 45° achieves a tunnel of 1.154 mm

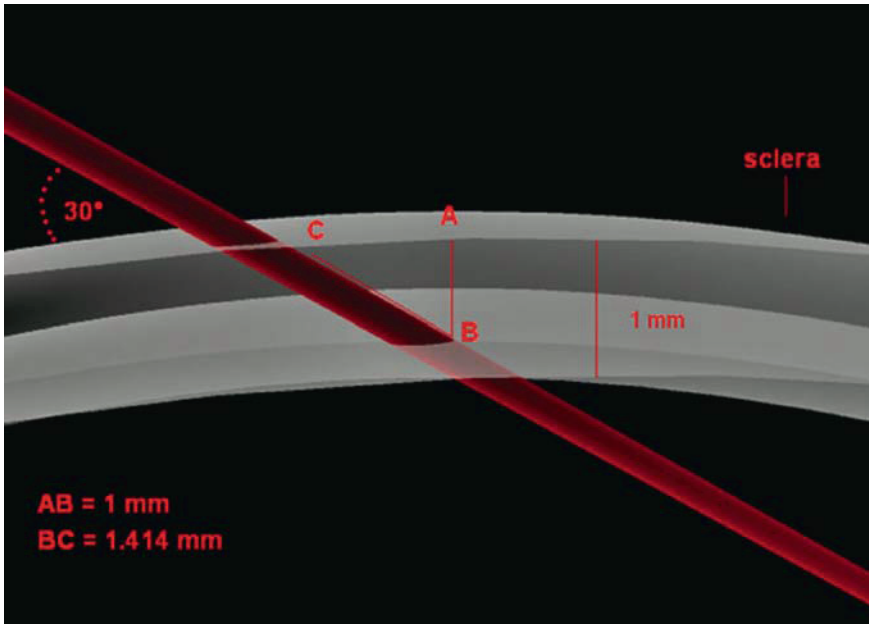


Fig. 6.6 By reducing the incision angle by 15°, and using an angle of 30°, the length of the tunnel increases by 30%, as the tunnel is 1.414 mm ; therefore it is more airtight

At the day 1 UBM, the incision is completely sealed, and barely detectable. In endoscopic view (Fig. 6.8) the Zorro incision is narrower and smaller than the standard incision.

We have demonstrated that this incision is airtight and safe in complicated vitrectomy [13].

Pollack's Incision. Recently, Pollack has improved Zorro's direct and oblique technique by suggesting a biplanar insertion modality. The technique is the following: hold trocar bevel up with the tip at approximately 5° to the sclera, then insert trocar to 50% of the scleral depth, until just past end of bevelled tip. Raise handle until trocar shaft is at about 30° angle to sclera and complete the insertion [14].

- *Rizzo's Parallel Incision*. We demonstrated the efficacy of oblique-parallel insertion for 25-gauge vitrectomy but even more so for 23-gauge vitrectomy, due to the larger diameter and to the more extensive vitrectomy performed with 23-gauge, for instance in retinal detachment repair. In pseudophakic patients

the incision is performed by inserting the system parallel to the limbus, 5° tangential to the sclera; then when we straightened, at a 30° angle in order to enter the vitreous chamber avoiding the IOL. In phakic eyes we could hurt the lens, so we usually perform a Zorro or a Pollack incision. It is well-known that the sclera heals with a fibrin plug within 6–12 h, so it is critical to assess if the incision is closed in the early postoperative period. UBM performed 4 h postoperatively showed that the 23-gauge oblique-parallel incision was already sealed (Fig. 6.9) [15].

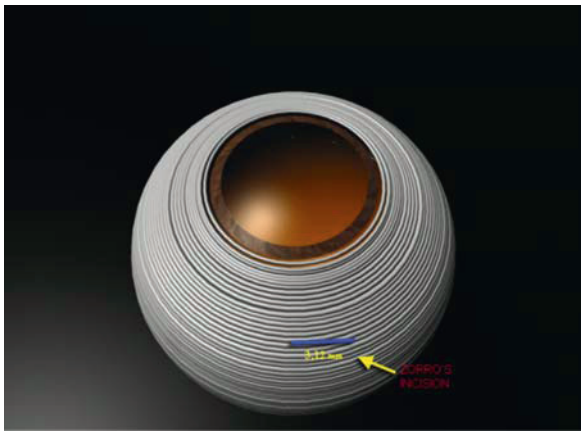


Fig. 6.7 Zorro's Incision. The blade is inserted at 3.2 mm from the limbus, at an oblique angle of 10–15°, and enters the vitreous without straightening

6.3.3 Insertion of the 25–23-Gauge Chandelier

If bimanual technique is required, we can insert one or more chandelier fiberlights.

Technique: Shift the conjunctiva with a swab and make an entry hole with the naked trocar or with a needle at 12 or 6 o'clock, perpendicular to the sclera. Hold the conjunctiva aside to align the conjunctival and scleral holes, and press the chandelier light in order to insert it.

6.3.4 Complications of Trocar Insertion

In a very hypotonic eye, insertion may be difficult. If the vitreous is very fluid (for example in high myopia,) or the eye has already been vitrectomized, it may become hypotonic after the first trocar has been inserted. Tips: turn on the irrigation immediately and place the other two trocars with the irrigation going.

Summary for the Clinician

- 25–23-gauge incisions performed at an oblique angle to the sclera and in accordance with the direction of the scleral fibers (parallel to the limbus) are airtight at the end of the surgery.

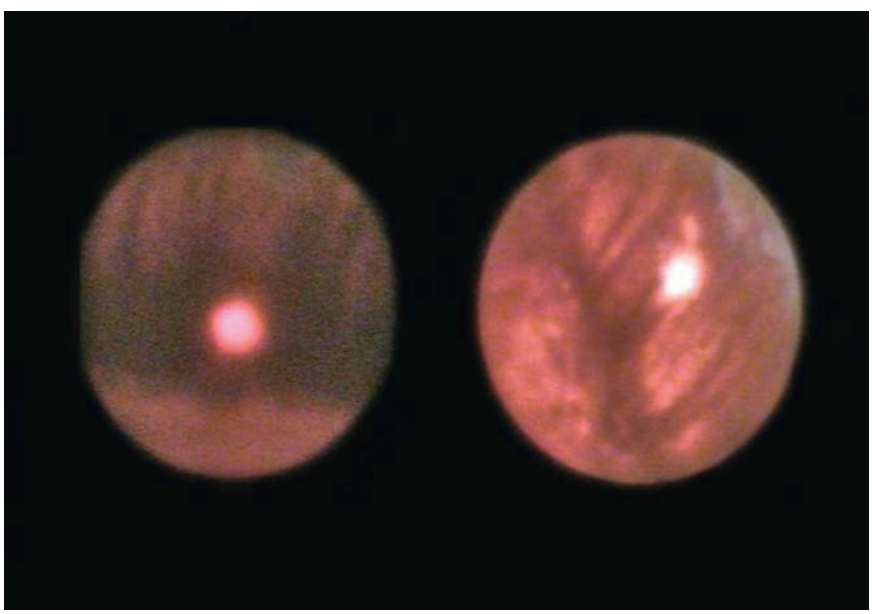


Fig. 6.8 In endoscopic view, the Zorro incision (*right*) is narrower and smaller than the standard incision (*left*)

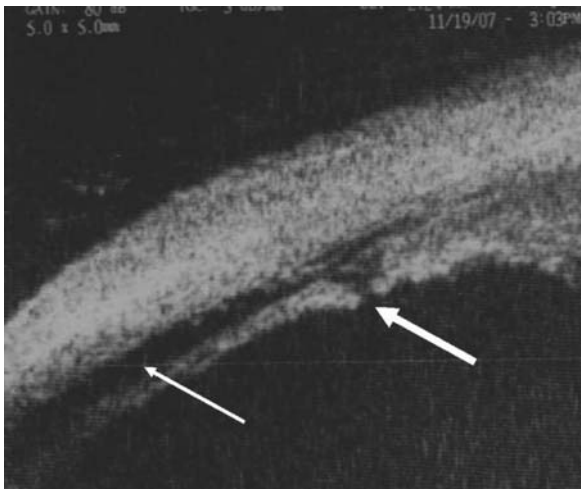


Fig. 6.9 4 h postoperatively UBM. 23-gauge oblique-parallel incision is already sealed. No scleral defect is visible. Only the choroidal entry is evident (*thick arrow*). A small ciliochoroidal effusion is also evident, due to the pressure exerted during the trocar insertion (*thin arrow*)

6.3.7 Cannula Removal

Before removal, always clear the cannulas from inside, because shaving the vitreous from the cannula is mandatory. Clamp the infusion cannula before removing the surgical instruments: if we remove cannulas with infusion on, we can create a vitreous wick.

In order to avoid vitreous incarceration in the sclerotomy, a fiber light may be used when pulling the cannulas. We suggest a solid light probe into vitreous cavity, then slowly pull out cannula over the light probe, and keep the smaller diameter light in the vitreous cavity because the solid probe keeps vitreous out of the cannula. During the fiberlight withdrawal, the infusion pressure has to be lowered to 5 mmHG. We press and massage the sclera with a cotton tip to close the wound, then we raise the infusion pressure to 25–30 mmHG in order to check if the sclerotomy is airtight. Afterwards we remove the infusion cannula, and we check the final IOP: if there is a pressure drop, we perform an air or BSS refilling (depending on what we have used at the end of the surgery) with a 30-gauge needle. If the leakage persists, we suture the sclerotomy. How can we recognize wound leaks? If we detect a bleb that continues to grow, a scleral suture is required, and a single trans-conjunctival vicryl suture allows best patient comfort.

We have to check IOP also in the early postoperative period (about 6 h p.o) in order to prevent more severe complications as well as hypotony, such as choroid detachment and endophthalmitis.

Summary for the Clinician

- Avoid vitreous incarceration in the sclerotomies.
- Always check the sclerotomies at the end of the surgery in direct or indirect visualization because sometimes, despite our efforts, sclerotomies may leak.
- Hypotony is a complication related to postoperative wound leak, and can be eliminated by modifying the incision construction and by suturing any questionable sclerotomies in order to prevent subsequent endophthalmitis.

References

1. Fujii GY, de Juan E Jr, Humayun MS, Chang T, Pieramici DJ, Barnes A, Kent D (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophtalmology 109:18107–18134
2. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
3. Byeon S, Chu YK, lee SC, Koh HJ, Kim SS, Kwon OW (2006) Problems associated with the 25-gauge transconjunctival sutureless vitrectomy system during and after surgery. Ophthalmologica 220:259–265
4. Fujii GY, de Juan E, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
5. Lakhanpal RR, HumayunMS, de Juan E Jr, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou BA (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
6. Kunimoto DY, Kaiser RS (2007) Wills Eye Retina Service. Incidence of Endophtalmitis after 20-gauge and 25-gauge vitrectomy. Ophthalmology 114(12):2133–2137. Epub 4 October 2007
7. Theocharis IP, Alexandridou A, Tomic Z (2007) A two-year prospective study comparing lidocaine 2% jelly versus peribulbar anaesthesia for 25 G and 23 G sutureless vitrectomy. Graefes Arch Clin Exp Ophthalmol 245(9):1253–1258. Epub 7 March 2007
8. Kwok AK, Van Newkirk MR, Lam DS, Fan DS (1999) Sub-Tenon's anesthesia in vitreoretinal surgery: a needleless technique. Retina 19(4):291–296
9. Lopez-Guajardo L, Parejra-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25 g vitrectomy. Am J Ophthalmol 141:1154–1156
10. Rizzo S, Genovesi-Ebert F, Vento A et al (2007) Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicroscopic study.

Graefes Arch Clin Exp Ophthalmol 245(9):1281–1288. Epub 21 February 2007. PMID: 17318571

11. Ibarra M, Hermel M, Prenner JL et al (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
12. Rizzo S, Genovesi-Ebert F (2007) Angled incision techniques for 25-g and 23-g surgery. Euretina, Montecarlo
13. Rizzo S, Genovesi-Ebert F, Vento A et al (2007) New "single step entry" system for 23-gauge vitrectomy poster: poster 20072217/B826 presented at ARVO, May, Fort Lauderdale, Florida
14. Pollack J (2007) Micro-incision vitrectomy surgery transitional course, AAO, 8 November, New Orleans
15. Rizzo S, Genovesi-Ebert F et al (2007) 23-Gauge One-Step Vitrectomy: the extreme end of wound contruction. Paper presented at ASRS Meeting, December, Palm Springs, California

Chapter 7

Comparison of 25-Gauge Trocar/Cannula Wound Healing and Remodeling with In Vivo Vitrector Flow Analysis

P.J. Ferrone

Core Messages

- Microsurgical techniques have advanced to allow for smaller, effective instrumentation. This instrumentation has decreased in size from the standard 20-gauge (1.1 mm) size to the 25-gauge (0.5 mm size) instrumentation.
- Transconjunctival wounds made with this smaller gauge surgery do not require a conjunctival peritomy.
- 25-gauge instrumentation produces less external ocular trauma, and allows for a more rapid recovery after surgery.
- Most retinal pathology can be dealt with effectively using 25-gauge instrumentation.
- There is a low incidence of postoperative short-term hypotony in some 25-gauge cases, and there may be a slightly higher incidence of endophthalmitis with these procedures compared to standard (suture closed) 20-gauge surgery.
- Trocar/cannula (T/C) design may be important in optimizing wound construction and healing.
- There are differences in flow between the different 25-gauge vitrectomy systems
- These differences are in part due to vitrector port open/closed ratios at given cut rates. This ratio is influenced by cutter design and tubing internal diameter.
- Spring-loaded pneumatic cutters, such as the Accurus 25 gauge cutter, are tuned to an optimal cut rate for a 50/50 open/closed port time. As cut rate increases with these cutters, flow can decrease significantly.
- When varying from the optimal cut rate with these spring-loaded pneumatic cutters, the flow rate of the cutter can be unintentionally affected, i.e., increased with more open port time (lower cut rate) and decreased with more closed port time (higher cut rate), despite being set at the same vacuum setting.
- Electric cutters have an equal port open–closed time independent of a change in cut rate settings, and therefore have more predictable flow at the same vacuum setting across different cut rates. This is not the case with the standard spring-loaded pneumatic cutters.

Vitrectomies with 20-gauge instruments require a conjunctival peritomy, three 1-mm scleral incisions and multiple sutures. They subject the globe to surgical trauma and necessitate a difficult rehabilitation course, including postoperative inflammation, astigmatism, and ocular irritation from the sutures, and a more difficult rehabilitation course before the patient's eye heals enough to recover visual acuity. Consequently, vitreoretinal specialists have looked for smaller, self-sealing incisions that would make vitrectomy easier and better for doctor and patient alike.

In 1996, Chen reported successful use of scleral tunnel incisions for sutureless vitrectomy [1], and modifications of this technique remain in use today [2–7]. However, there were reports that up to 20% of such sclerotomies required suturing because of leakage [8], and that the tunnels made it difficult to insert instruments into the eye [7].

After more than a decade of research on reducing vitrectomy instruments to 25-gauge size [9], de Juan et al. developed an alternative approach to self-sealing incisions: a three-port, 25-gauge (0.5 mm) microcannulated vitrectomy system. Their method of closed intraocular microsurgery used offset, transconjuctival stab wounds, microcannulas to keep the incisions open and provide ocular access, and a high-speed electric vitreous cutter. In 2001, this system was made available for use by other vitreoretinal surgeons, and other 25-gauge vitrectomy systems have been introduced since.

Clinical studies have demonstrated that, compared to standard 20-gauge surgery, 25-gauge vitrectomy reduces

the time it takes to open and close the eye [10–12]; does not significantly change total surgical time or increase complications [13–18]; rarely requires sutures [15, 19]; and produces less ocular trauma, leading to clear corneas and a normal-appearing eye sooner after surgery [10, 14, 15]. The technique has been used clinically for a wide variety of conditions, including macular holes, puckers, retinal detachments, macular epiretinal membranes, and pediatric retinal pathology [10–12, 15, 20, 21], as well as for vitreous loss after cataract surgery [16, 17] and to relieve positive vitreous pressure before phacoemulsification [22]. However, most of the published literature on this method for vitreoretinal surgery concerns the original 25-gauge system, the Millennium™ Transconjunctival Sutureless Vitrectomy System (TSV25, Bausch & Lomb).

Wound healing has been studied, and ocular healing progression after simulated vitrectomy with TSV25 and the Accurus Surgical System (Alcon Laboratories, Ft. Worth, TX, USA), in comparison to 20-gauge sutured and 23-gauge needle wounds has been evaluated. A study was performed in which four young-adult New Zealand albino rabbits were used, with each animal serving as its own control because of the bilateral design. Four wounds were made in each eye: a 25-gauge TSV25 trocar/cannula (T/C) wound; a 25-gauge wound from the T/C assembly in the Accurus Surgical System; a 23-gauge hypodermic needle-stick wound; and, after peritomy, a wound with a standard 20-gauge micro-vitroretinal (MVR) blade. The wounds were physically separated, one in each quadrant.

The 25-gauge entry wounds were made using the manufacturer's standard equipment for sutureless vitrectomy. Both systems have similar specifications and characteristics. They produce stab incisions of approximately 0.5 mm, with the incision offset between conjunctiva and sclera to facilitate self-sealing after surgery. After the trocar (attached to a polymer microcannula/polyimide tubing assembly) penetrates the eye, it is withdrawn and the microcannula assembly left in place to hold the wound open. (An infusion cannula, light pipe, vitreous cutter and other instruments are inserted interchangeably through three wounds to perform the vitrectomy. A two-port technique sometimes is used.)

Both models of trocar/cannula units contain an anti-rotation feature to prevent movement of the cannula assembly relative to the trocar during insertion. The Millennium TSV25 uses a hollow, tri-bevel needle to produce a linear wound measuring 0.020' (0.5 mm, or 25-gauge). The Accurus trocar's tri-bevel needle is solid and slightly larger (0.021'). It produces a chevron-shaped wound. (Fig. 7.1)

To simulate vitrectomy, each wound was stretched for 15 min with a vitreous cutter that was appropriate to the wound size. Vitreous was cut for part, but not all, of the 15–min period. Normal IOP was verified at the conclusion of the procedure.

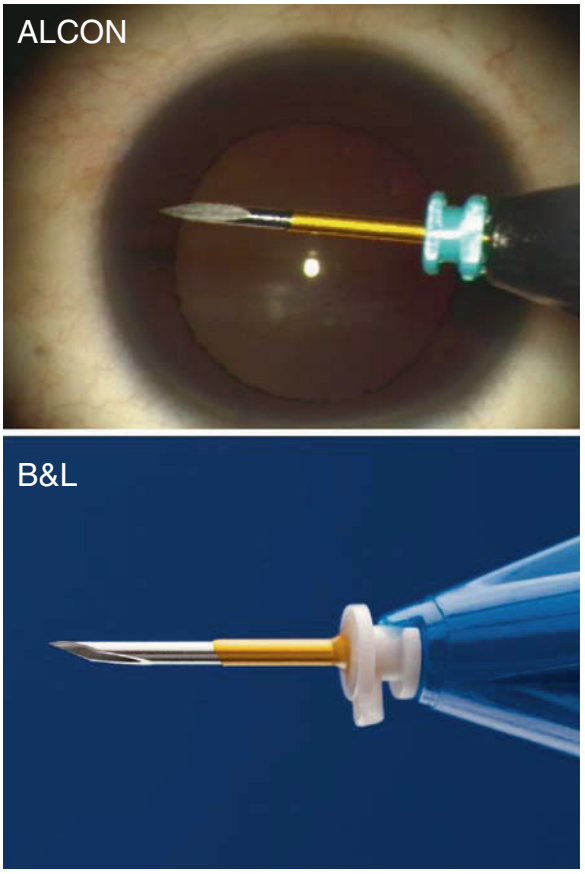


Fig. 7.1 Alcon trocar/cannula above, and Bausch and Lomb trocar/cannula below

At 1, 2, 3 and 6 weeks after surgery, one animal was sacrificed and histologic sections of the eight ocular wounds were prepared for analysis. The sections were also photographed with a standard biomicroscope imaging system. These photos were reviewed independently by four masked vitreoretinal specialists and an ocular pathologist.

The 25-gauge T/C wounds from both systems measured approximately 23.5-gauge in external diameter; however, wound architecture differed. The TSV25 wounds were linear, and the Accurus wounds had a chevron shape. The latter had a tendency to gape after 15 min of stretching with the surgical instrument.

The 25-gauge wounds, as well as the 23-gauge hypodermic needle wounds, were fairly well-healed by 3 weeks in most cases, and some variation in wound healing was

noted over that time period, even using the same entry system. Fibroblast migration occurred soon after surgery. At 1 week, loose collagen could be seen in the wounds.

The 20-gauge standard sutured wound also healed well at 1 week. At 2 weeks, a few of the T/C wounds were well vascularized, and this process was more notable for all the small-gauge wounds by 3 weeks post-surgery. A tight collagen plug with fewer fibroblasts formed by 2–3 weeks. (Fig. 7.2)

Beyond 3 weeks, collagen reorganized into a more lamellar type orientation in a superficial-to-deep progression. This process, as well as overall healing, occurred at varying rates in the T/C wounds, and the five observers agreed that it appeared to proceed more quickly in the TSV25 wounds. Collagen reorganization was seen at 6 weeks in the TSV25 wounds, as well as in the 25-gauge Accurus wounds. (Fig. 7.3)

Most 25-gauge wounds showed some degree of internal vitreous tamponade as healing began. Observers agreed that the amount of vitreous visible in the wound appeared to be greater in the Accurus wounds than in the TSV25 wounds. (Fig. 7.4)

Most of the connective tissue response around the small-gauge wounds appeared to be from the episclera. Initially, the wounds were plugged with a fibrin clot. This was followed by the collagen deposition from fibroblasts, and vascularization of the wound.

In some of the Accurus wounds at 2–3 weeks, fibrous ingrowth was seen, indicating less optimal wound healing (Fig. 7.5).

The 23-gauge needle wounds followed a healing path similar to that displayed by the 25-gauge wounds. Because they were sutured, the 20-gauge wounds also healed well by 3 weeks after surgery.

More than 3 decades ago, vitrectomy was performed with the "open sky" technique, a procedure so invasive that ophthalmologists limited it to very few indications. The advent of the closed, pars plana method in 1971 [23] represented a welcome opportunity to use vitrectomy in treating a wider variety of vitreoretinal pathologies. The 19- and 20-gauge systems that developed from this initial breakthrough remain in use today, and are used for the large majority of the three-port, pars plana vitrectomies performed worldwide.

However, 20-gauge vitrectomy causes surgical trauma from a conjunctival peritomy, and subjects patients to the discomfort of multiple sutures. Patients experience a "red eye," postoperative inflammation, astigmatism, poor

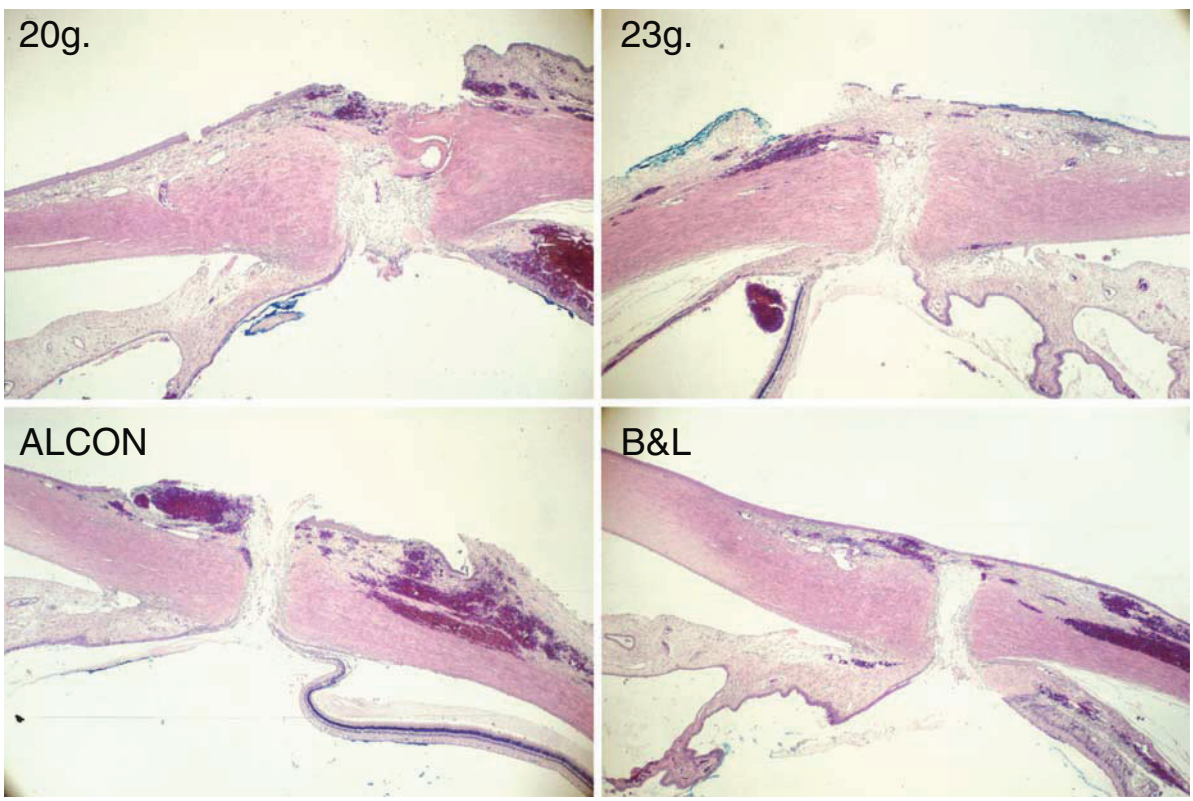


Fig. 7.2 Healing of the various wounds at 1 week (20- gauge sutured; 23- gauge hypodermic needle not sutured; Alcon 25- gauge TC; and B&L TSV 25 TC)

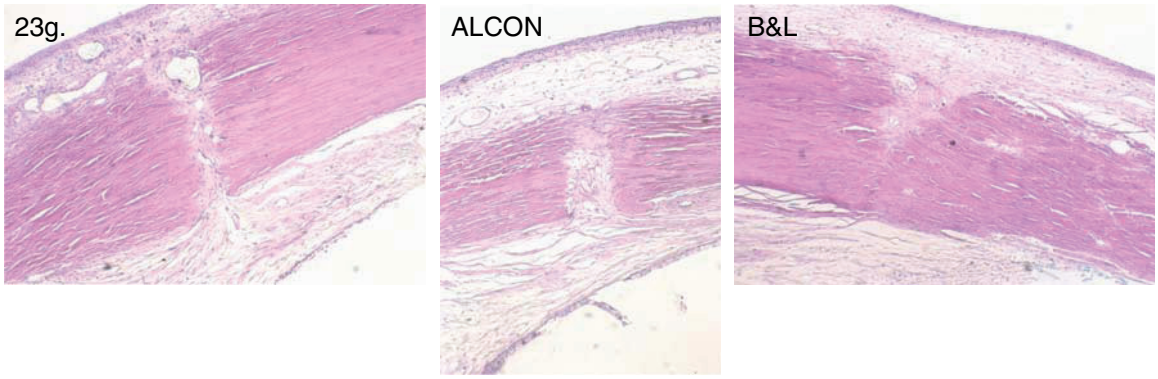


Fig. 7.3 6-week data

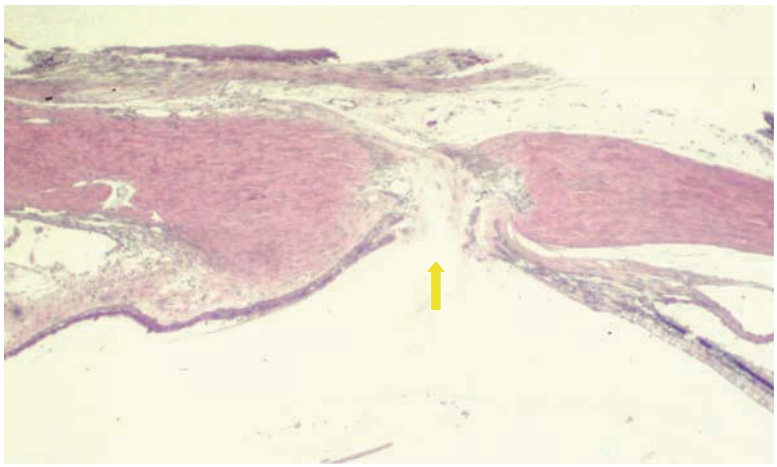


Fig. 7.4 Vitreous into 25-gauge Alcon wound at 3 weeks

visual acuity and ocular irritation from the sutures. By eliminating the peritomy and keeping the incisions small and sutureless, 25-gauge vitrectomy avoids such surgical sequelae [10–22].

One problem reported with 25-gauge vitreous surgery included some transient postoperative hypotony, which in most cases resolves without further complication. In pseudophakic children in whom 25-gauge surgery was used for removal of posterior capsular membrane, Lam et al. reported that four of ten eyes had hypotony (IOP: 3–10 mmHg). The condition resolved for all but one eye, which had hypotony before surgery and returned to the preoperative level [21]. In adults, Shimada et al. reported a series of 169 eyes undergoing 25-gauge vitrectomies, in which there was a 9% rate of hypotony, which resolved in 2–4 days [23]. Liu et al. published a case report in which an IOP of 5 mmHg on postoperative day 1 was followed by a choroidal fold. Though IOP began rising on day 6 and the choroidal detachment resolved, fold marks and metamorphosia persisted at 3 months, and BCVA was 20/40 [24].

Instrument fragility has also been reported. In 2004, Inoue et al. reported a case in which the vitreous cutter's tip broke during epiretinal membrane removal and was aspirated [25].

The increase in endophthalmitis after institution of no-stitch cataract surgery [26–29] has caused some concern about the risk of such infections after sutureless vitrectomy. In 20-gauge vitrectomy, Cohen et al. reported an endophthalmitis rate of 0.07% in their 10-year study involving 12,216 vitrectomies [30]. Theoretically, the risk in 25-gauge procedures might be lower because of the smaller incisions and shorter operating time, or larger because of the lower flow rates and occasional hypotony. Greater clinical experience and research will be required to determine the true incidence. So far, only a single case of postoperative endophthalmitis after 25-gauge vitrectomy has been reported in the literature [31], out of clinical reports on more than 450 patients [10, 13, 15–21, 25].

The animal study described above demonstrates that the unsutured trocar/cannula incisions heal very quickly,

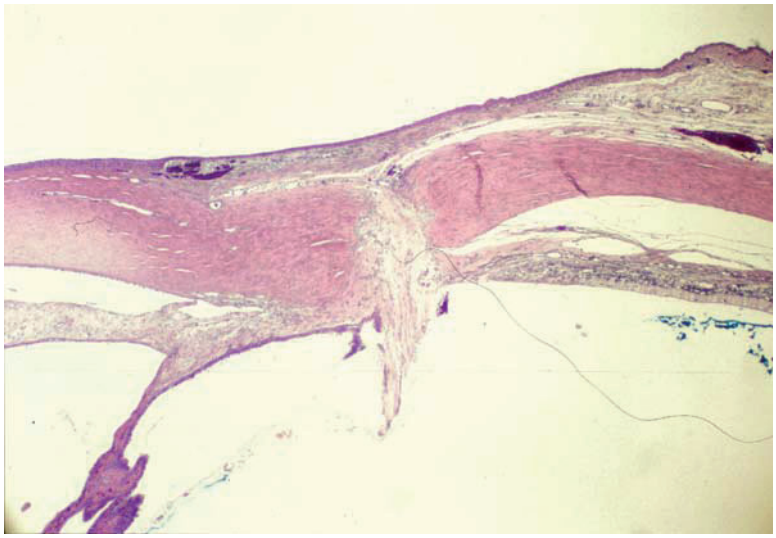


Fig. 7.5 Alcon 3 week wound with fibrous in growth

perhaps suggesting an explanation for the paucity of endophthalmitis cases reported for this technique. The 25-gauge incisions healed as well as did sutured, 20-gauge vitrectomy wounds. With a comparable diameter to the 23-gauge needle, the 25-gauge wounds also followed a healing pattern similar to that observed after the hypodermic needle-stick.

Both the B&L TSV25 and the Alcon Accurus 25-gauge trocar/cannula systems produced wounds that healed well by 3 weeks after surgery. There was some variation in the wound healing, even with the same 25-gauge entry system. However, the five independent observers agreed that the TSV25 trocar/cannula wounds healed better overall.

Healing followed this general course. Fibroblast migration occurred soon after the 25-gauge wounds were made. Loose collagen could be seen bridging the wounds by 1 week out. Wounds were well vascularized by 2–3 weeks post-surgery, and a tight collagen plug with fewer cells also formed by that time. Finally, collagen assumed a more lamellar type orientation, in a superficial-to-deep progression. This reorganization was notable by 6 weeks in the TSV25 wounds and in the Accurus wounds.

Both systems use a tri-bevel needle, creating wounds that measured approximately 23.5-gauge in external diameter during this study. However, at all time points after surgery, the TSV25 wounds appeared smaller in histologic section than did the Accurus wounds, despite having a similar external diameter. This apparent size differential, as well as the observation of small differences in wound healing, could be attributed to the differing trocar needle designs.

The Accurus trocar needle is slightly thicker than the TSV25 needle (0.021' vs 0.020'), and the TSV25 needle is hollow while the Accurus needle is solid. TSV25 wounds appeared linear on the scleral surface; the Accurus wounds had a chevron shape. Thus, the wounds spanned a similar linear distance across the sclera, but the bent trajectory of the Accurus wounds produced a larger total wound area, independent of the needle's outer diameter. (Fig. 7.6) This appeared to make the wound more prone to gaping.

The conclusions in the study described had two limitations: its small size, with only two wounds of each type examined for each time point in the healing process, and the subjective nature of the observers' inspection of the histological sections of the wounds. Further research will be needed to determine if the observed differences persist with greater numbers and further refinements of 25-gauge vitrectomy systems. Clinical studies also are needed to compare rates of endophthalmitis between 25-gauge vitrectomy and conventional surgery.

After instrument manipulation that mimicked surgery, the 25-gauge vitrectomy system wounds underwent a healing process similar to that seen after a 23-gauge hypodermic needle-stick. The wounds were well-healed by 3 weeks in most cases. All were very well-healed by 6 weeks, with some remodeling of the collagen by that time.

The T/C entry wounds healed as well, without sutures, as did the sutured 20-gauge vitrectomy wounds. The most variability in healing occurred during the first 3 weeks after surgery, even among wounds created by the same trocar/cannula entry system.

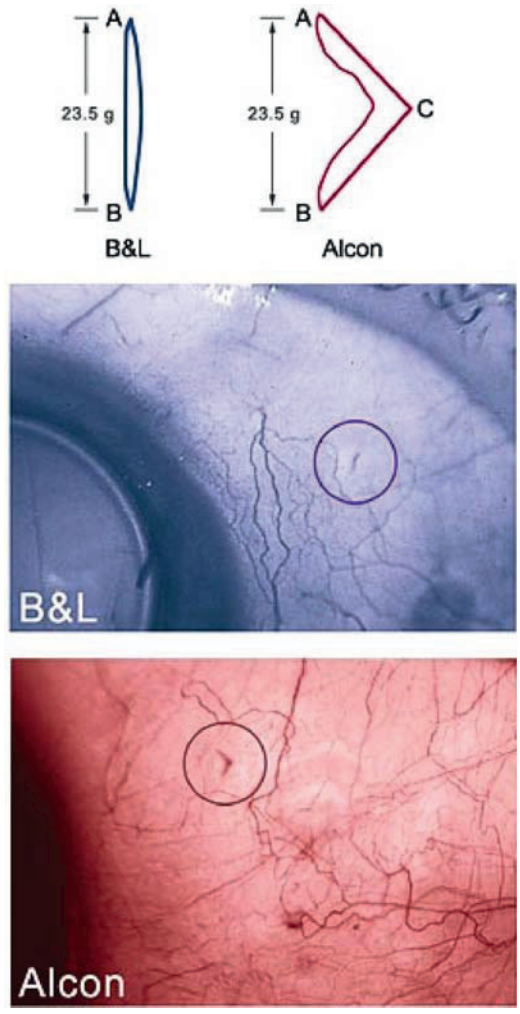


Fig. 7.6 Wound architecture at 3 weeks old in a human. The Bausch & Lomb 25-gauge vitrectomy wound (top photo, circled) is linear while the Alcon wound is chevron shaped. This produces a longer total wound length [in diagram, (A to C) + (C to B)] even though the chord length (A to B) measures 23.5 gauge for both wounds. In this study, the Alcon chevron-shaped wounds also appeared more apt to gape than the linear B&L wounds. (Photos by Phillip J. Ferrone, MD)

Healing followed a similar course in both types of 25-gauge wounds, but was slightly delayed overall in the Accurus wounds. Larger amounts of vitreous could be seen in the Accurus wounds in the early stages, followed by fibrous in-growth indicating less optimal wound healing. Overall, the 25-gauge B&L TSV25 wounds healed better than the Alcon Accurus wounds. The linear TSV25 wounds were less likely to gape, and appeared smaller in histologic section than the chevron-shaped Accurus wounds. This was despite the fact that the T/C external diameter of each system was similar.

There are other variations to the observed wound healing found in the above-mentioned study, such as oblique wound construction which is useful in some circumstances; (Fig. 7.7) and cleaning vitreous from a wound when finishing surgery with the eye at a normal intraocular pressure or with a partial gas fill in order to avoid vitreous prolapse, which can cause wounds to heal poorly by allowing the vitreous gel to obstruct the edges of the healing wound tissues. (Fig. 7.8)

In vivo flow analysis of different 25-gauge vitrectomy systems has been performed to determine if there is a difference in flow between different vitreous cutters at standard vitrectomy parameters in vivo. The flow and cutting efficiency for the Alcon and B&L 25-gauge systems at standard parameters in vivo were compared. In the aforementioned study, fresh pig eyes were used with six eyes in each group (except for the two standard vitrector samples, for which there were four eyes in these groups). Measurements were made in consecutive series and compared the various Alcon Accurus and B&L Millennium systems. As a standard for 20-gauge systems, the parameters for the standard pneumatic cutters from both companies had an aspiration setting of 150 mm Hg and 600 cpm. The bottle height was set at 48 cm to gravity on both systems (equivalent to 35 mm Hg on the Alcon VGFI set up). For the 25-gauge systems, the parameters for aspiration were 550 mm Hg and a cut rate of 1,000 and 1,500 cpm for each system. The Alcon pneumatic (spring-loaded), and B&L electric 25-gauge cutters were used. The bottle height was set to 70 cm to gravity on both systems. A new cutter and eye were set up for each data point. Each eye had an infusion cannula placed in it. Flow was measured in a standardized way with fluorescein-stained vitreous and primed machines. A standardized surgical technique was used, and cutting was done in the central vitreous cavity, moving the probe in an orbital pattern. The time for the fluid to travel 30 cm in the tubing was recorded. (Fig. 7.9) The different internal diameter of the tubing for each system was taken into account. Statistics were performed using a one-tailed *t*-test for differences between population means, designed for small sample sizes with unequal variances. The results showed flow rates under the above stated in vivo conditions were as follows: 20-gauge Alcon standard pneumatic cutter = 2.48 cc min^{-1}; 20-gauge B&L standard pneumatic cutter = 2.44 cc min^{-1}. For the 25-gauge Alcon cutter at 1,500 cpm = 1.92 cc min^{-1}; 25-gauge B&L cutter at 1,500 cpm = 2.91 cc min^{-1}; 25-gauge Alcon cutter at 1,000 cpm = 3.31 cc min^{-1}; and the 25-gauge B&L cutter at a flow rate for 1,000 cpm = 3.17 cc min^{-1}. (Table 7.1)

The statistically significant differences in flow (25-gauge) were between: the Alcon 1,500 cpm and the Alcon

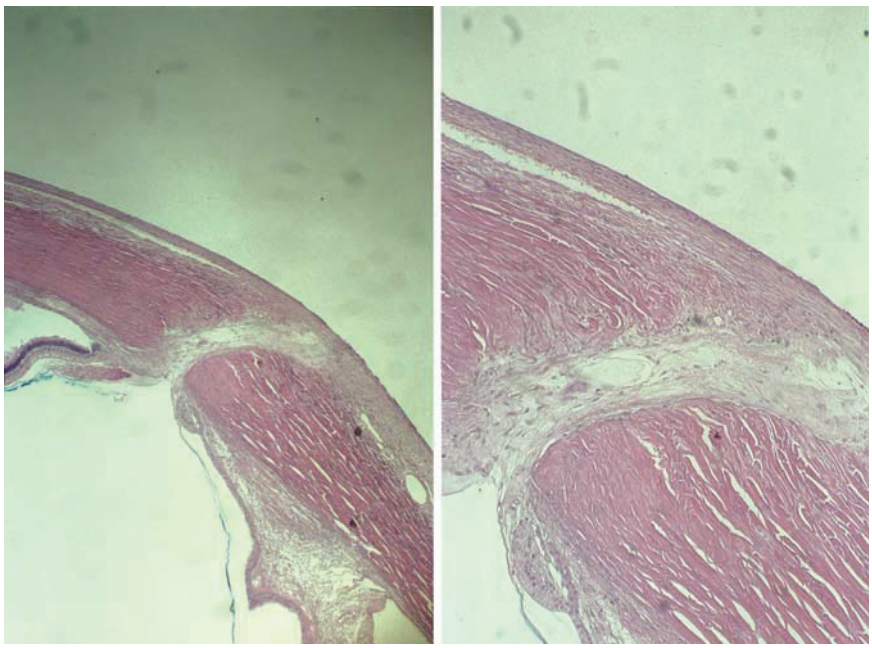


Fig. 7.7 Examples of oblique wounds made with the B&L TSV 25 TC at 3 weeks

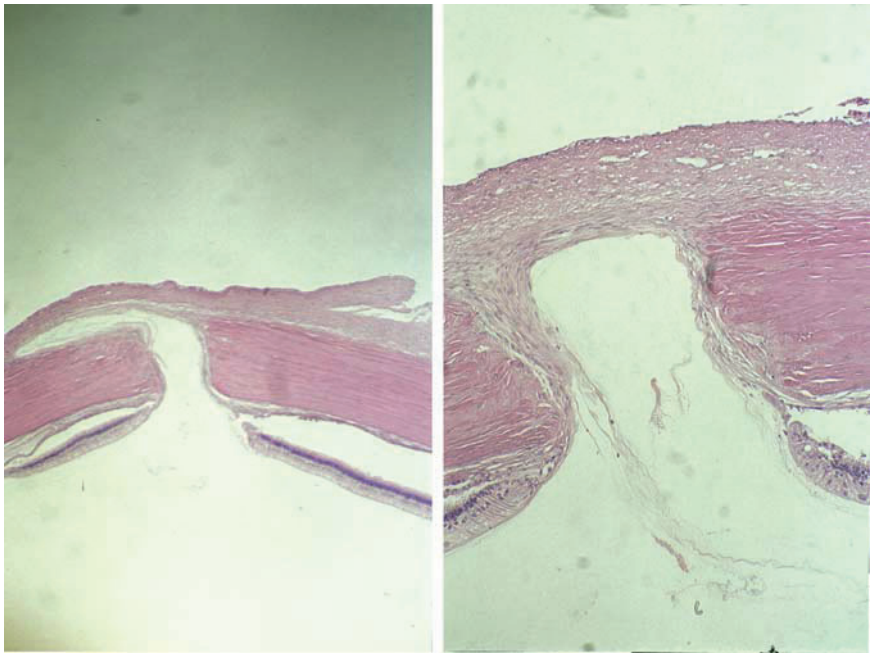


Fig. 7.8 Examples of poorly healed 25–gauge wounds with vitreous still obstructing wound healing at 3 weeks

1,000 cpm, 1.9 vs 3.3 cc min^{-1}, $p = 0.0007$; and between the Alcon 1,500 cpm and the B&L 1,500 cpm, 1.9 vs 2.9 cc min^{-1}, $p = 0.0235$. Comparing the Alcon 1,500 cpm (25 g) to the Alcon 600 cpm (20 g), there was a statistically significant difference in flow, 1.9 vs 2.5 cc min^{-1}, $p = 0.0084$. There was no statistically significant difference in flow when comparing the B&L 1,500 cpm (25 g) to the B&L 600 cpm (20 g), 2.9 vs 2.4 cc min^{-1}, $p = 0.2778$.

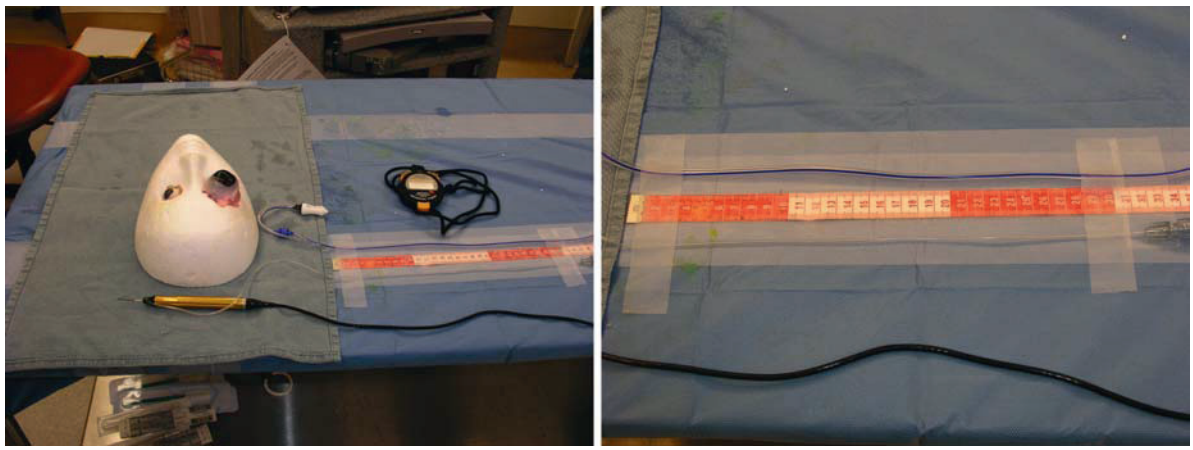


Fig. 7.9 Standardized experimental set-up for the flow experiment performed on pig eyes

In conclusion, there are differences in flow and cutting efficiency in vivo between the various systems at common surgical settings. Some of these differences may be due to duty cycle (duty cycle is cutter port open/closed time) variations especially with the spring-loaded pneumatic cutters at different cut rates. (Fig. 7.10) The difference in flow with the electrically driven cutters at the different cut rates is not significant (flow is cut rate independent) due to the constant open/closed port time, even when comparing 20- vs 25-gauge at the above settings, whether in pig vitreous or saline. (Fig. 7.11) However, the spring-loaded pneumatically driven cutters have a significant difference in flow at the various cut rates (flow is cut rate dependent), due to their variable open/closed cutter port time, whether in pig vitreous or saline, thereby influencing tissue turbulence and possibly "tissue jump" into the vitrectomy cutter opening. By understanding the differences and characteristics between the different vitrectomy machines and cutters, the surgeon can maximize the performance of the equipment and use it to the patient's full benefit.

The flow rates of the Bausch and Lomb 25-gauge electric cutters are significantly higher than the Alcon 25-gauge cutters at 1,500 cuts per minute, when comparing the Accurus and Millennium machines.

Table 7.1 Summary of Flow Data (cc min^{-1})

Cutter	Mean	Variance	Standard deviation	Coefficient of variation
25-gauge Alcon pneumatic 1,500 cpm	1.9	0.06	0.24	0.12
25-gauge B&L electric 1,500 cpm	2.9	0.79	0.89	0.31
25-gauge Alcon pneumatic 1000 cpm	3.3	0.31	0.56	0.17
25-gauge B&L electric. 1,000 cpm	3.2	0.28	0.53	0.17
20-gauge Alcon standard 600 cpm	2.5	0.06	0.25	0.10
20-gauge B&L standard 600 cpm	2.4	0.58	0.75	0.31

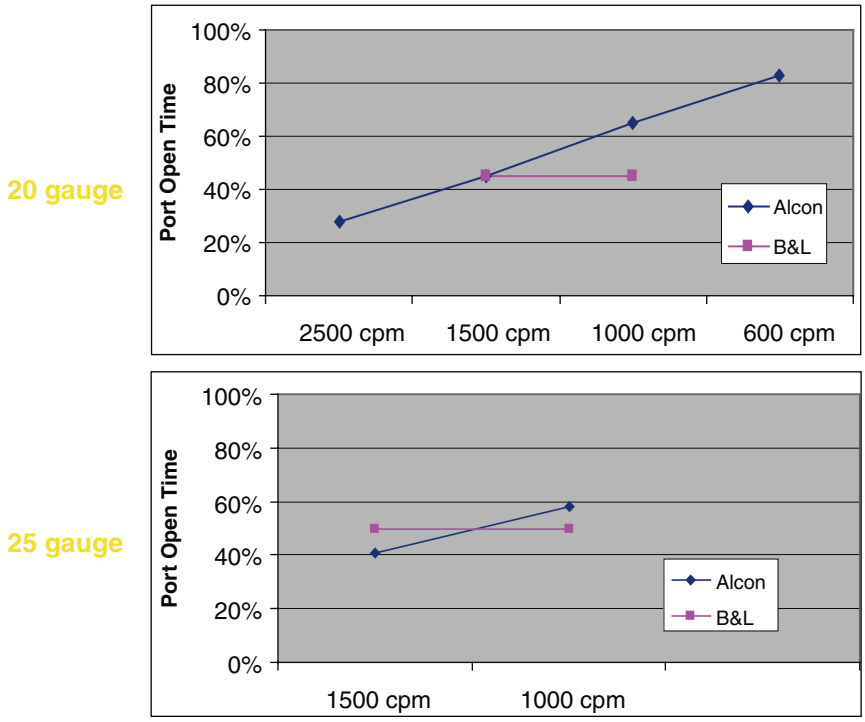


Fig. 7.10 Duty cycles of the various vitreous cutters

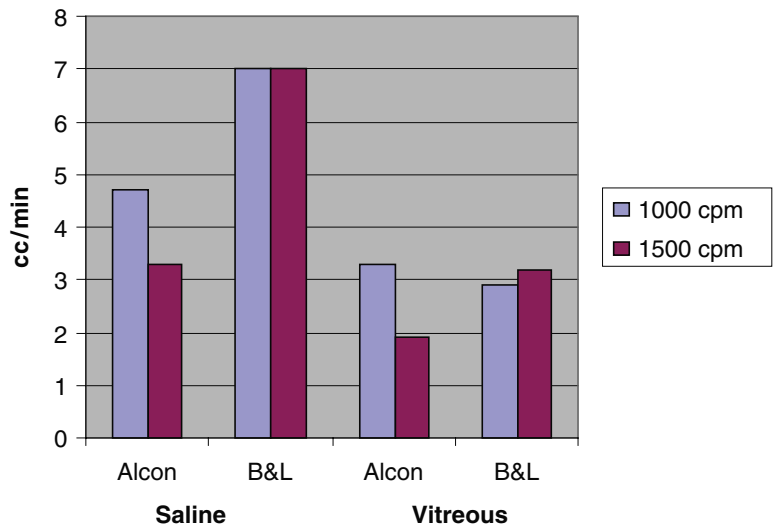


Fig. 7.11 25-gauge flow in pig vitreous as compared to saline

Summary for the Clinician

- Wounds from the 25-gauge trocar/cannula (T/C) systems produce approximately a 23.5-gauge wound when the T/C is removed.
- The design of the Alcon T/C creates a larger wound than the Bausch and Lomb TSV 25 T/C.
- Wounds from both 25-gauge T/C systems heal well without the use of sutures by 3 weeks after surgery.
- There is reorientation of the lamellar scleral collagen by 6 weeks after surgery.
- There are differences between the flow-rate characteristics of the Bausch and Lomb and Alcon 25-gauge cutters

References

1. Chen JC (1996) Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 114(10):1273–1275
2. Kwok AK, Tham CC, Lam DS, Li M, Chen JC (1999) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 127(6):731–733
3. Schmidt J, Nietgen GW, Brieden S (1999) [Self-sealing, sutureless sclerotomy in pars plana vitrectomy] [Article in German]. Klin Monatsbl Augenheilkd 215(4):247–251
4. Assi AC, Scott RA, Charteris DG (2000) Reversed self-sealing pars plana sclerotomies. Retina 20(6):689–692
5. Jackson T (2000) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 129(1):116–117
6. Rahman R, Rosen PH, Riddell C, Towler H (2000) Self-sealing sclerotomies for sutureless pars plana vitrectomy. Ophthalmic Surg Lasers 31(6):462–466
7. Yeshurun I, Rock T, Bartov E (2004) Modified sutureless sclerotomies for pars plana vitrectomy. Am J Ophthalmol 138(5):866–867
8. Milibak T, Suveges I (1998) Complications of sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 116(1):119
9. de Juan E Jr, Hickingbotham D (1990) Refinements in microinstrumentation for vitreous surgery. Am J Ophthalmol 109(2):218–220
10. Fujii GY, de Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C, Ng E, Barnes A, Wu SL, Sommerville DN (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109(10):1807–1812; discussion 1813
11. Chang CJ, Chang YH, Chiang SY, Lin LT (2005) Comparison of clear corneal phacoemulsification combined with 25-gauge transconjunctival sutureless vitrectomy and standard 20-gauge vitrectomy for patients with cataract and vitreoretinal diseases. J Cataract Refract Surg 31(6):1198–1207
12. Rizzo S, Genovesi-Ebert F, Murri S, Belting C, Vento A, Cresti F, Manca ML (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol 19:1–8 [Epub ahead of print].
13. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109(10):1814–1820
14. Chalam KV, Gupta SK, Vinjamaram S, Shah VA (2003) Small-gauge, sutureless pars plana vitrectomy to manage vitreous loss during phacoemulsification. J Cataract Refract Surg 29(8):1482–1486
15. Chalam KV, Shah VA (2004) Successful management of cataract surgery associated vitreous loss with sutureless small-gauge pars plana vitrectomy. Am J Ophthalmol 138(1):79–84
16. Cho YJ, Lee JM, Kim SS (2004) Vitreoretinal surgery using transconjunctival sutureless vitrectomy. Yonsei Med J 45(4):615–620
17. Lakhanpal RR, Humayun MS, de Juan Jr E, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou TJ (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112(5):817–824
18. Yanyali A, Celik E, Horozoglu F, Nohutcu AF (2005) Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. Am J Ophthalmol 140(5):939–941
19. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139(5):831–836
20. Shimada H, Nakashizuka H, Mori R, Mizutani Y (2005) Expanded indications for 25-gauge transconjunctival vitrectomy. Jpn J Ophthalmol 49(5):397–401
21. Lam DS, Fan DS, Mohamed S, Yu CB, Zhang SB, Chen WQ (2005) 25-gauge transconjunctival sutureless vitrectomy system in the surgical management of children with posterior capsular opacification. Clin Experiment Ophthalmol 33(5):495–498
22. Chalam KV, Gupta SK, Agarwal S, Shah VA (2005) Sutureless limited vitrectomy for positive vitreous pressure in cataract surgery. Ophthalmic Surg Lasers Imag 36(6):518–522
23. Machemer R, Buettner H, Norton EW, Parel JM. Vitrectomy (1971) A pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 75(4):813–820
24. Liu DT, Chan CK, Fan DS, Lam SW, Lam DS, Chan WM (2005) Choroidal folds after 25 gauge transconjunctival sutureless vitrectomy. Eye 19(7):825–827

25. Inoue M, Noda K, Ishida S, Nagai N, Imamura Y, Oguchi Y (2004). Intraoperative breakage of a 25-gauge vitreous cutter. Am J Ophthalmol 138(5):867–869
26. Lundstrom M, Montan P, Stenevi U, Thorburn W Postoperative endophthalmitis related to type of incision in cataract surgery. Presented at the April 2005 meeting of the American Society of Cataract & Refractive Surgery
27. Miller JJ, Scott IU, Flynn HW Jr, Smiddy WE, Newton J, Miller D (2005) Acute-onset endophthalmitis after cataract surgery (2000–2004): incidence, clinical settings, and visual acuity outcomes after treatment. Am J Ophthalmol 139(6):983–987
28. West ES, Behrens A, McDonnell PJ, Tielsch JM, Schein OD (2005) The incidence of endophthalmitis after cataract surgery among the U.S. Medicare population increased between 1994 and 2001. Ophthalmology 112(8):1388–1394
29. Lundstrom M (2006) Endophthalmitis and incision construction. Curr Opin Ophthalmol 17(1):68–71
30. Cohen SM, Flynn HW Jr, Murray TG, Smiddy WE (1995) Endophthalmitis after pars plana vitrectomy. The Postvitrectomy Endophthalmitis Study Group. Ophthalmology 102(5):705–712; Review
31. Taylor SR, Aylward GW (2005) Endophthalmitis following 25-gauge vitrectomy. Eye 19(11):1228–1229

Chapter 8

25-Gauge Vitreous Surgery: Getting Started

C.C. Awh

Core Message

- 25-gauge vitrectomy simplifies and shortens many of the cases performed by the typical vitreoretinal surgeon.
- The 25-gauge system has been demonstrated to improve patient outcomes, in the form of more rapid recovery of vision and decreased postoperative discomfort.
- The specific complications to watch for in the immediate postoperative period are those of infection and hypotony.
- Differences in instrument performance and surgical techniques make case selection particularly important for surgeons learning 25-gauge vitrectomy.

8.1 Introduction

The "early" days of 25-gauge vitrectomy were not so long ago. The concept of sutureless, transconjunctival cannulas, developed by Eugene de Juan, Jr. and co-workers around the year 2000 [1], was rapidly adopted for commercial use by 2001 [2]. Bausch and Lomb produced the first commercially available 25-gauge vitrectomy system, combining de Juan's microcannulas with a 25-gauge version of a high-speed electric vitreous cutter that proved outstanding for this application. Soon, other companies followed with pneumatic 25-gauge cutter systems. Continual improvements in cannula designs, illumination devices, and instrumentation now allow surgeons to effectively address a broader spectrum of vitreoretinal pathology [3, 4], and most would agree that 25-gauge vitrectomy has taken a permanent place in our surgical armamentarium.

This chapter is primarily directed toward surgeons with little to no experience with 25-gauge vitrectomy, although the more experienced surgeon may find some useful tidbits. I will assume that the reader is already an experienced vitreous surgeon, and will not elaborate on issues that are common to all types of vitrectomy. My suggestions are based on my personal experience in over one thousand 25-gauge vitrectomy cases. Like many surgeons, my techniques are a combination of the evolutionary and the archaic, and the reader should be quick to reject these suggestions as his or her experience dictates.

Perhaps the first issue to address for the prospective 25-gauge vitrectomy surgeon is this: "why?" Given our ability to effectively address virtually all vitreoretinal surgical problems with 20-gauge instruments, and the recent advent of 23-gauge vitrectomy [5] instrumentation, this is an important question. The answer, in my opinion, is this: 25-gauge vitrectomy simplifies and shortens many of the cases performed by the typical vitreoretinal surgeon, is a more proven technology than 23-gauge vitrectomy (at least at the time of this writing), and has been demonstrated to improve patient outcomes, in the form of more rapid recovery of vision [6] and decreased postoperative discomfort. The techniques necessary to perform safe and effective 25-gauge vitrectomy are easily mastered by the experienced surgeon, and the wounds caused by the transconjunctival microcannulas differ primarily in scale from the wounds caused by conventional sclerotomies, as opposed to the longer, oblique incisions necessary to create sutureless wounds with larger-gauge instruments. The issues of patient outcome and wound healing, so relevant to this discussion, are reviewed elsewhere in this book.

Keep in mind the goals of your initial 25-gauge cases. In addition to the obvious, i.e., addressing the patient's eye problem, the beginning 25-gauge surgeon should concentrate upon the following issues:

- Preoperative Considerations
  - Case selection
  - Preoperative preparation

- Intraoperative Considerations
  - Cannula insertion
  - Instrument insertion, manipulation, and removal
  - Visualization and illumination
  - Cannula removal
- Postoperative management

8.2 Case Selection

Differences in instrument performance and surgical techniques make case selection particularly important for surgeons learning 25-gauge vitrectomy.

A well-defined macular epiretinal membrane or a simple non-clearing vitreous hemorrhage in a pseudophakic patient is an ideal first case, although other types of pathology are also suitable. In general, select eyes with healthy sclera and conjunctiva, a clear anterior segment, and with intraocular pathology that will not require peripheral dissection or multiple instrument exchanges. Surprisingly, eyes that have undergone previous pars plana vitrectomy can be excellent surgical candidates if they meet these criteria.

8.3 Preoperative Preparation

8.3.1 Anesthesia

Although 25-gauge vitrectomy can be performed with peribulbar and even with topical anesthesia, retrobulbar anesthesia is preferable for several reasons. The mild proptosis of the globe improves surgical access, and the volume effect of the anesthetic bolus makes it easier to insert the cannulas by minimizing retropulsion of the globe. The akinesia achieved by retrobulbar anesthesia is also desirable, given the more flexible nature of 25-gauge instruments.

In cases where the block is incomplete, it is often possible to achieve adequate patient comfort with supplemental topical anesthetic drops. If an additional injection is necessary, use the smallest volume possible, in order to minimize conjunctival chemosis. I use a 30-gauge needle to inject a small amount of subconjuntival 2% lidocaine in one quadrant of the eye, then gently "roll" the anesthetic agent to other quadrants of the subconjunctival space with a cotton-tipped swab, taking care to avoid conjunctival tears.

8.3.2 Patient Position

Because the more flexible nature of 25-gauge instruments can make manipulation of the globe more difficult, careful attention should be given to the patient's head and body position prior to the start of surgery. The patient's head should be positioned such that the visual axes of the eye and of the operating microscope are coaxial. It is particularly important for the eye to be pointed straight upward in cases where a non-sutured contact lens or sutureless lens ring will be utilized — this will minimize the tendency for the lens to slide off-axis during surgery. The exception to this rule is in patients with protruding brows or particularly deep-set eyes. In these cases, it can be helpful to slightly retroflex the patient's neck and head to improve access to the eye.

8.3.3 Surgical Prep

There are theoretical reasons that eyes undergoing 25-gauge vitrectomy may be more susceptible to endophthalmitis. Pathogens on the surface of the conjunctiva may be introduced into the vitreous cavity by the trocar/cannula during insertion. The decreased amount of infusion (compared to conventional 20-gauge vitrectomy) may reduce dilution or efflux of intraocular pathogens. Postoperatively, the sutureless sclerotomies may provide access for pathogens, particularly in hypotonus eyes.

Careful preparation of the ocular surface is essential to minimize the possibility of endophthalmitis. Active surface infections, such as conjunctivitis or blepharitis, should be treated preoperatively. Even in the absence of preoperative infection, some surgeons prescribe several days of preoperative topical antibiotics, although there are no data to support this. I typically instill a drop of topical 5% povidone-iodine immediately after administering the anesthestic injection, allowing this to bathe the ocular surface during the surgical prep of the eyelids and periorbital skin with povidone-iodine. The eye is then copiously irrigated with a dilute solution (around 1%) of povidone-iodine in saline. The surgical drape and eyelid speculum should then be placed in a manner that prevents the cannulas and instruments from contacting the eyelashes.

Summary for the Clinician

- A well-defined macular epiretinal membrane or a simple non-clearing vitreous hemorrhage in a pseudophakic patient is an ideal first case.
- Retrobulbar anesthesia is preferable.
- Because the more flexible nature of 25-gauge instruments can make manipulation of the globe more difficult, careful attention should be given to the patient's head and body position prior to the start of surgery.
- Careful preparation of the ocular surface is essential to minimize the possibility of endophthalmitis.

8.4 Intraoperative Considerations

8.4.1 Cannula Insertion

The transconjunctival cannulas are pre-loaded on 25-gauge trocars (Fig. 8.1). The surgeon or assistant should ensure that the cannulas are firmly seated on the trocars prior to insertion, to reduce the possibility of the cannula collapsing or buckling as it is driven through the sclera.

I typically insert the cannulas 3.0 mm posterior to the corneoscleral limbus in aphakic or pseudophakic eyes, or 3.5 mm in phakic eyes. The entry point can be determined with calipers or a scleral marker. One trocar design incorporates a marker at its proximal end (Fig. 8.2). I use a cotton-tipped applicator to displace the conjunctiva prior to cannula insertion, so that the conjunctival wound will slide away from the scleral wound when the cannulas are removed at the conclusion of surgery. Avoid grasping the conjunctiva with toothed forceps, to minimize conjunctival laceration.

I insert the cannulas tangential to the globe, although some surgeons prefer to insert them at a more acute angle to create a longer intrascleral wound. The first action should be a firm push through the conjunctiva and into the sclera. As the trocar penetrates the sclera, slight resistance may be encountered as the larger diameter cannula contacts the scleral wall. At this stage, gentle back and forth twisting can ease insertion of the cannula.

Insert the infusion line into the first cannula to maintain normal intraocular pressure during insertion of subsequent cannulas. The infusion line should be affixed to the sterile drape to direct the infusion flow toward the center of the vitreous cavity. I use a spring-loaded drape clip, not tape, for this purpose (Fig. 8.3). The clip allows me to more easily move the infusion line from cannula to cannula if needed. I typically insert the superior cannulas at about the ten o'clock and two o'clock meridians, because I rely on the cannula hubs to stabilize a sutureless silicone lens ring. If the cannulas are placed too close to the horizontal meridian, the lens ring will tend to drift during surgery. Sometimes the condition of the eye or the target pathology will dictate a major deviation from the typical sclerotomy sites. One example of this, not recommended as an initial case, is the use of 25-gauge cannulas for vitrectomy in eyes with functioning glaucoma filtering blebs.

Fig. 8.1 B&L 25-gauge cannula loaded on trocar

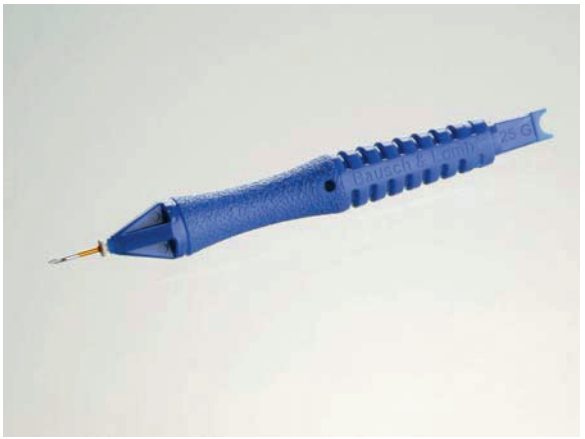


Fig. 8.2 B&L trocar with integrated scleral marker

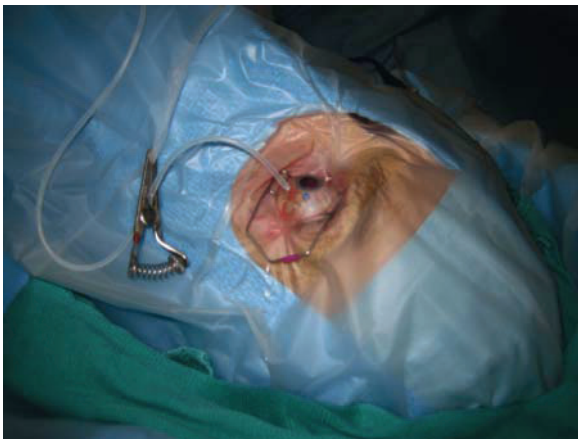


Fig. 8.3 Surgical drape clip for infusion line

8.4.2 Instrument Insertion, Manipulation, and Removal

It is easier to insert instruments into the eye through cannulas than through conventional sclerotomies. This is particularly true of flexible instruments, such as soft-tipped

cannulas or diamond-dusted membrane scrapers. However, there is minimal clearance between the instrument shaft and the inner wall of the cannula, and the resulting friction can loosen the cannulas during surgery. This is particularly relevant as instruments are being removed from the eye. While extracting an instrument, make sure to align the axis of the instrument with the axis of the cannula to minimize friction. If the cannula appears loose, use a forceps to stabilize the cannula hub, a task that must sometimes be performed by the surgical assistant if the surgeon's fellow hand is holding a second instrument in the eye.

If a cannula comes loose during surgery, the surgeon has several options. If the problem is recognized before the instrument (e.g., the vitreous cutter) has been fully removed from the eye, keep the instrument tip within the vitreous cavity and use the instrument shaft as a guide to slide the cannula back into place. If the instrument has already been removed from the eye and if the cannula remains on the instrument shaft, locate the conjunctival incision (which will be displaced from the scleral incision) and reinsert the instrument through the conjunctiva and sclera, using it as a cannula guide. If neither of these options exists, then reload the cannula on the trocar and insert it in a new location. Plug the fellow cannula during these efforts. If the cannula has come free near the conclusion of the case, it is sometimes easiest to insert the instrument directly through the sclerotomy without using a cannula, although this technique is more likely to result in a wound leak.

8.4.3 Instrument Manipulation

The more flexible nature of 25-gauge surgical instruments requires other modifications in technique. Even though the newer generations of instruments are stiffer, they will flex during attempts to forcibly rotate the globe. Therefore, surgery of the peripheral and anterior retina is ideally accomplished with a panoramic viewing system. With such a system, the eye can be left in a relatively stable upright position, and an instrument can be manipulated with the cannula as its pivot point, similar to a rowboat oar in its oarlock.

The tendency of the instruments to flex is relevant to the location and angle of cannula insertion at the start of the case. If the surgery will require a significant amount of work in the anterior portion of the globe (e.g., vitreous incarceration and retained intracapsular lens cortex following complicated cataract surgery) the cannulas should be inserted in a direction toward the target pathology. The patient's nose may limit access from the nasal quadrants. In such cases, it is sometimes necessary to place the infusion line nasally and to shift the surgeon's position to the temporal side of the patient.

8.4.4 Visualization

Although I have mentioned the value of panoramic viewing systems for 25-gauge vitrectomy, I use a flat contact lens for detailed macular surgery. The most stable system for securing contact lenses is a sew-on lens ring. However, to avoid the need for sutures, I typically use a silicone lens ring that is stabilized by three-point contact with the cannula hubs (Fig. 8.4). This allows me to use a flat quartz or sapphire lens, which provides a stable high-resolution view. Other options include a low-mass reusable plastic lens with stabilizing feet (Fig. 8.5), or disposable silicone lenses.

8.4.5 Illumination

Available higher-output light sources and their compatible fiberoptic devices have eliminated inadequate illumination (compared to 20-gauge vitrectomy) as a problem during the 25-gauge vitrectomy. A variety of diffusion light pipes, chandeliers (Fig. 8.6), and even illuminated infusion cannulas are available, allowing bimanual surgery and surgeon-performed scleral depression during vitrectomy. However, for the initial cases, I recommend a standard non-diffusion light pipe. The discrete beam is better for identifying clear vitreous, epiretinal membranes and internal limiting membrane. If you have wisely selected a pseudophakic or aphakic patient, the standard light pipe should provide excellent illumination of the vitreous in all areas of the posterior segment.

Chandelier illumination is invaluable for cases that benefit from a comprehensive view of the retina (e.g., giant retinal tear detachment repair), bimanual technique, or surgeon-performed scleral depression. Although these

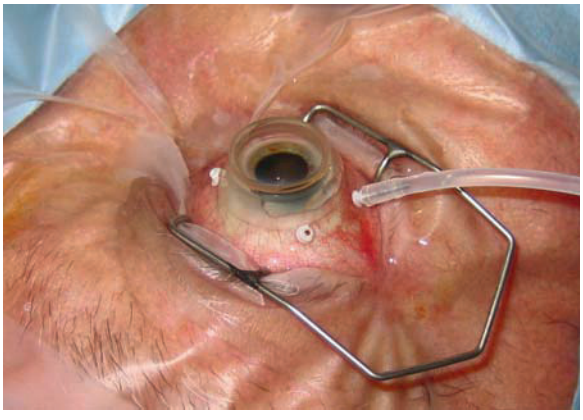


Fig. 8.4 Silicone lens ring, stabilized by cannula hubs

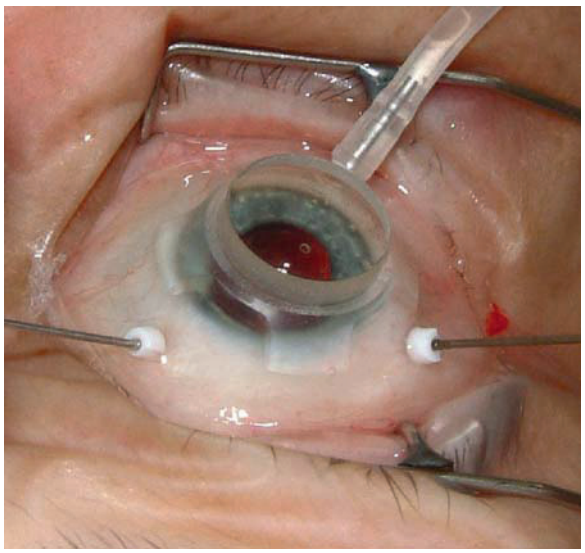


Fig. 8.5 Volk Self-Stabilizing Vitrectomy "SSV" contact lens

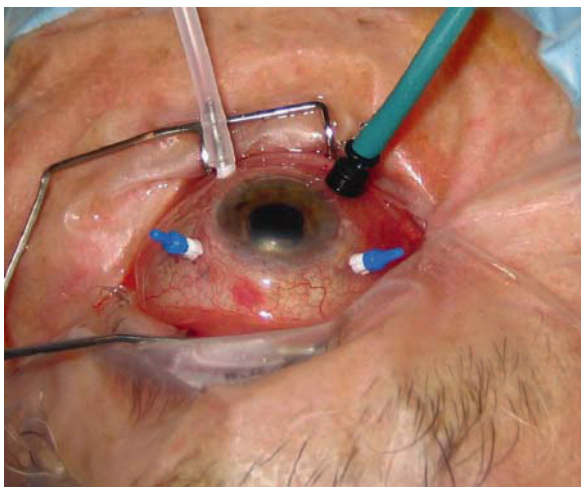


Fig. 8.6 25-gauge chandelier

types of cases are not suggested for the beginning surgeon, I offer a few suggestions for future reference:

1. Insert the chandelier before inserting the 25-gauge cannulas. The two-step technique necessary to insert the currently available chandeliers is more easily performed without the infusion line in place. Active infusion can cause chemosis after the initial stab incision, and makes insertion of the chandelier more difficult.
2. Direct the chandelier more posteriorly than the typical entry angle for the cannulas. This reduces glare.
3. Clear vitreous is difficult to visualize with diffuse illumination. A small amount of triamcinolone acetonide injected into the vitreous cavity makes the vitreous much easier to identify. However, the use of intraocular steroids may theoretically increase susceptibility of the eye to infection, and I do not use this technique routinely.
4. At the conclusion of surgery, I usually remove the chandelier before removing the cannulas. Wound leaks are rare, since there are no instrument exchanges and usually relatively little removal of peripheral vitreous in the region of the chandelier.

8.4.6 Fluidic Considerations

The smaller lumen of the vitreous cutter and infusion line results in reduced flow compared to 20-gauge vitreous cutters. This can be partially overcome by increasing infusion pressure. A typical working infusion pressure with the high-speed electric cutter system is around 35–40 mm Hg (equivalent to 70 inches of water). The pneumatic cutter, due to its lower maximum flow, typically requires a higher infusion pressure of 50–60 mm Hg. Because the fluidics of the electric cutter allows maximum flow at its maximum cut rate, flow can be regulated simply by varying the vacuum level. Maximum flow with the current generation of pneumatic cutter requires a combination of high vacuum and low cut rate, which can result in increased vitreous traction and is not recommended. Lower cut rates should be used primarily to allow the cutter to engage thicker or stiffer material (e.g., organized hemorrhage, lens capsule). The ability of 25-gauge cutters to effectively remove vitreous at high cut rates with low flow, combined with the smaller tip geometry compared to larger-gauge cutters, are an advantage when dissecting vitreous or membranes close to the retinal surface. This reduces the need for intraocular scissors or blades, and thus reduces the number of associated instrument exchanges.

The smaller port and reduced flow of the vitreous cutter makes it essential that the cutter tip be brought to the target tissue. A thorough vitrectomy is much more easily performed if the cutter is systematically and continually moved to engage the vitreous at its cut boundary. Temporary elevation of the infusion pressure can allow the surgeon to more rapidly perform the "core" vitrectomy or to engage the posterior cortical vitreous to create a posterior vitreous detachment. However, significant elevation of the infusion pressure should only be performed during periods of active aspiration or for temporary hemostasis. The cannulas allow much less flow of fluid around instrument shafts than do conventional sclerotomies, and the intraocular pressure can remain dangerously elevated during prolonged intraocular manipulations with non-aspirating instruments (e.g., forceps, laser probes, scissors) if the infusion pressure is not appropriately monitored and adjusted.

8.4.7 Membrane Peeling

The most significant adjustment for most surgeons learning 25-gauge vitrectomy is in the feel and performance of intraocular forceps. Epiretinal membrane peeling is one of the most technically demanding requirements of any surgical procedure, and the slightly more flexible instrument shaft is noticeable to most experienced surgeons. This has no material effect on my ability to work in the posterior pole, but can make peripheral dissections difficult.

During your first cases of peeling epiretinal or internal limiting membrane, you will discover that the tips of 25-gauge instruments, although precise by virtue of their smaller size, are also more likely to tear the edge of an elevated membrane. After identifying and elevating the membrane edge, re-grasp the membrane with the entire opposing surfaces of the forceps jaws. Turn the forceps tip so that its broadest and most blunt surface is perpendicular to the direction of membrane peeling. This will reduce the tendency of the tip of the instrument to tear the membrane.

8.4.8 Concluding the Case

8.4.8.1 Peripheral Retina Inspection

As with larger-gauge vitrectomy, it is important to inspect the peripheral retina for iatrogenic retinal breaks near the conclusion of surgery. I inspect the retina prior to any planned fluid-air exchange; otherwise it is my final act prior to removing the cannulas. Some surgeons use a panoramic viewing system to inspect the retinal periphery, but I typically use the indirect ophthalmoscope, with a cotton-tipped applicator as a scleral depressor. Take care to depress gently in the region of the cannulas to avoid tearing the conjunctiva, which is anchored to the sclera at these locations.

8.4.8.2 Cannula Removal

I remove the cannulas with a heavy blunt forceps. I plug the cannulas to allow the intraocular pressure to normalize, and I clamp the infusion line before I remove the superior two cannulas. This may reduce the tendency of infusion fluid to force itself through the vitreous skirt and the sclerotomy, and reduce the chance of wound leakage. After removing a cannula, I apply brief gentle pressure to the region of the sclerotomy with a cotton-tipped applicator. I do not vigorously "massage" the conjunctiva. I then open the infusion line to ensure that the eye maintains a normal pressure, and to check for sclerotomy site leaks. If a suture seems necessary, this should be placed prior to removing the final cannula and infusion line. When satisfied with the appearance of the eye, I remove the final cannula and infusion line as a single unit.

8.4.8.3 Wound Leaks

Wound leaks occur in around one percent of sclerotomies [7], and are more common in fluid-filled eyes. The surface tension of an intraocular gas bubble will effectively tamponade a minimally-leaking sclerotomy. Because of this, some surgeons advocate a fluid–air exchange at the conclusion of every 25-gauge vitrectomy. Given the relative infrequency of wound leaks, I find this unnecessary. If a sclerotomy site is leaking, I typically recommend the following steps:

1. Apply gentle constant pressure over the sclerotomy with the infusion line open. After 10–15 s, many small leaks will seal.
2. Inject a bubble of filtered air into the vitreous cavity with a 30-gauge needle to restore normal intraocular pressure and tamponade the sclerotomy. This will control all but the largest wound leaks.
3. Finally, suture the sclerotomy. The wound is simply a slightly stretched 25-gauge needle puncture. A single absorbable suture is sufficient to close the wound. Because only a small incision in the conjunctiva is necessary to expose the sclerotomy, conjunctival sutures are usually unnecessary. The avoidance of conjunctival sutures helps to minimize postoperative patient discomfort.

When in doubt, suture! It is far better to leave the operating room confident in the wound integrity than with worries about postoperative hypotony. As your experience and confidence grow, you will find that sutures are rarely necessary.

Summary for the Clinician

- It is easier to insert instruments into the eye through cannulas than through conventional sclerotomies.
- The more flexible nature of 25-gauge surgical instruments requires other modifications in technique. Even though the newer generations of instruments are stiffer, they will flex during attempts to forcibly rotate the globe.
- The tendency of the instruments to flex is relevant to the location and angle of cannula insertion at the start of the case.
- The most stable system for securing contact lenses is a sew-on lens ring.
- Available higher-output light sources and their compatible fiberoptic devices have eliminated inadequate illumination as a problem during 25-gauge vitrectomy.

Summary for the Clinician

- The smaller port and reduced flow of the vitreous cutter makes it essential that the cutter tip be brought to the target tissue.
- It is easier to insert instruments into the eye through cannulas than through conventional sclerotomies.
- The more flexible nature of 25-gauge surgical instruments requires other modifications in technique. Even though the newer generations of instruments are stiffer, they will flex during attempts to forcibly rotate the globe.
- The tendency of the instruments to flex is relevant to the location and angle of cannula insertion at the start of the case.
- The most stable system for securing contact lenses is a sew-on lens ring.
- Available higher-output light sources and their compatible fiberoptic devices have eliminated inadequate illumination as a problem during 25-gauge vitrectomy.
- The smaller port and reduced flow of the vitreous cutter makes it essential that the cutter tip be brought to the target tissue.
- The finer tips of 25-gauge instruments are more likely to tear the edges of a membrane during stripping or peeling maneuvers, requiring modifications in surgical technique.
- It is important to inspect the peripheral retina for iatrogenic retinal breaks near the conclusion of surgery.
- Clamp the infusion line before removing the superior two cannulas.
- At the end of the surgery if a sclerotomy site is leaking:
  - Apply gentle constant pressure over the sclerotomy with the infusion line open.
  - Inject a bubble of filtered air into the vitreous cavity with a 30-gauge needle to restore normal intraocular pressure and tamponade the sclerotomy.
  - If all else fails, suture the sclerotomy.

8.5 Postoperative Management

8.5.1 Postoperative Antibiotics and Dressing

I typically administer a small amount of subconjunctival antibiotic and steroid at the conclusion of surgery, although there are no supporting data for this. I do not use aminoglycoside antiobiotics because of the possibility of inadvertent retinal exposure and toxicity. I create a subconjunctival bleb of antibiotic over each sclerotomy. This further separates the conjunctival incision from the sclerotomy, and also serves to retract any vitreous wicks from the conjunctival surface.

I typically instill a drop of long-acting cycloplegic and a combination antibiotic/anti-inflammatory ointment before applying a relatively firm patch over the closed eyelids. The patch is left in place until the postoperative examination the next morning.

8.5.2 Postoperative Examination

It is at the first postoperative examination that the benefits of 25-gauge vitrectomy are often most apparent to the surgeon and patient. The eye is typically comfortable and normal in appearance, with significantly less conjunctival hemorrhage and chemosis than is typically present after conventional sutured vitrectomy.

The specific complications to watch in the immediate postoperative period are those of infection and hypotony.

Endophthalmitis is rare, and should be managed in the typical fashion [8].

If appropriate caution has been used in the operating room, damaging postoperative hypotony should be exceedingly rare. Even if the intraocular pressure is lower than normal, treatment is not indicated if the anterior chamber is formed and there are no large choroidal effusions. In most cases, the intraocular pressure will return to the normal range within 1 week. I have not found patching the eye helpful in cases of mild-to-moderate hypotony, and I prefer to leave the eye unpatched to allow the patient to recognize any worrisome changes in visual acuity.

In the rare case of a persistent unacceptably low intraocular pressure, consider injecting a small bubble of filtered air or expansile gas if the leak is in the superior half of the eye and an adequate tamponade is possible. If this is not possible, return to the operating room and suture all potential leaking sclerotomies.

Summary for the Clinician

- Administer a small amount of subconjunctival antibiotic and steroid at the conclusion of surgery. Do not use aminoglycoside antiobiotics because of the possibility of inadvertent retinal exposure and toxicity. Inject a blister of subconjunctival antibiotic over each sclerotomy.
- The postoperative eye is typically comfortable and relatively normal in appearance.
- The specific complications to watch for in the immediate postoperative period are those of infection and hypotony. Endophthalmitis is rare, and should be managed in the typical fashion.

8.6 Conclusion

25-gauge vitrectomy is currently the smallest of the "small-incision" sutureless vitrectomy techniques. The wounds are therefore the least traumatic to the eye and the most rapidly healing. Ever-improving instruments and techniques now allow surgeons to address the majority of intraocular surgical problems with 25-gauge techniques.

References

1. Fujii GY, de Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1812
2. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
3. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
4. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
5. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
6. Awh CC (2003) Rate of visual acuity improvement after transconjunctival sutureless 25-gauge vitrectomy. The Annual Meeting of the American Society of Retina Specialists, New York, 142(3):513–515
7. Awh CC, Hassan TS, Heier JS, Schwartz S, Trese MT (2002) Transconjunctival 25-gauge vitrectomy: a multi-center study. Retina Congress: the Combined Annual Meeting of the Vitreous and Retina Societies. San Francisco, CA. September, 2002
8. Faia LJ, McCannel CA, Pulido JS, Hatfield RM, Hatfield ME, McNulty VE (2007) Outcomes following 25-gauge vitrectomies. Eye [Epub ahead of print 20th April 2007]

Chapter 9

25-Gauge Macular Surgery: Principles and Instrumentations

Y. Oshima, Y. Tano

Core Message

- Transconjunctival sutureless 25-gauge vitrectomy has demonstrated favorable anatomic results and long-term stable visual rehabilitation with minimal surgically induced complications in a variety of vitreoretinal pathologies.
- This system is especially useful for macular surgery without complicated and peripheral pathology.
- Recent developments of a variety of 25-gauge instruments and endoillumination devices make macular surgery much easier and faster to perform using the 25-gauge system.

9.1 Introduction

As the safety and efficacy of vitreous surgery have improved and surgical instrumentation has become more advanced, the surgical indications for macular diseases, which have traditionally been managed with observation or laser treatment only, have expanded greatly and rapidly. Recent studies in macular surgery have moved towards determining how to obtain early visual rehabilitation with less invasive and more effective surgical techniques.

The recent development of 25-gauge instrumentation for vitreous surgery has promoted great interest in transconjunctival sutureless vitrectomy systems [1, 2]. Similar to the trend toward minimally invasive surgical intervention in the case of current cataract surgery, smaller incisions with self-sealing wounds in vitrectomy might decrease surgical trauma and operating time, possibly resulting in surgical outcomes comparable or superior to conventional 20-gauge vitrectomy [1–5]. The nature of sutureless small-gauge vitrectomy leads to less traumatic conjunctival and scleral manipulation, less surgically induced astigmatism, and less postoperative patient discomfort, and theoretically facilitates early visual recovery [6, 7]. Therefore, 25-gauge vitrectomy seems to be one of the best systems for the management of macular diseases. The theoretical concerns surrounding the 25-gauge system are the decreased efficiency for vitrectomy, the extreme flexibility of the instruments, and the difficulty to manipulate the peripheral retina. However, when performing macular surgery using 25-gauge instrumentation these concerns are much less applicable, because most macular surgery does not require extensive vitrectomy or peripheral manipulation.

The current surgical indications for 25-gauge macular surgery are listed in Table 9.1.

9.2 Principles of 25-Gauge Macular Surgery

9.2.1 Preoperative Examination, Considerations, and Informed Consent

Preoperative evaluation of patients undergoing macular surgery should include measurement of the preoperative visual acuity, a stereoscopic fundus examination using a contact or noncontact lens, and optical coherence tomography, if available. Fluorescein and indocyanine green angiography are necessary in cases with vascular diseases. Factors that might affect intraoperative manipulation at

Table 9.1 Indications for 25-gauge macular surgery

- Macular pucker (epimacular proliferation)
- Macular hole
- Vitreomacular traction syndrome
- Optic-pit maculopathy
- Macular edema associated with
  - diabetic retinopathy, retinal vein occlusion, juxta telangiectasis
- Premacular and submacular hemorrhage
- Foveoschisis, macular detachment secondary to pathologic myopia

the macula include the pupil diameter and the status of the lens (phakia, pseudophakia, or aphakia); the corneal transparency should be evaluated thoroughly before surgery. Attention should also be paid to the patients' general medical conditions and anesthetic risk.

The preoperative visual acuity is an important factor for predicting visual outcomes in most macular diseases [8]. In some macular diseases, limited visual recovery is expected even with successful surgical intervention. Therefore, patients must be counseled regarding the expected surgical results, and written informed consent should be obtained before surgery.

9.2.2 Surgical Procedures for 25-Gauge Macular Surgery

9.2.2.1 Anesthesia

Most 25-gauge macular surgery can be performed using local anesthesia with monitored anesthetic care. The exceptions to this are patients who are apprehensive or unable to cooperate during surgery. However, surgeons should be aware that even the smallest movements made by patients during macular manipulations can lead to serious complications. For local anesthesia, retrobulbar or peribulbar injection of a mixture of 2% lidocaine and 0.75% bupivacaine is recommended and sufficient in most cases. If necessary, supplemental local anesthesia using 2% lidocaine can be administered topically, or administered by sub-Tenon's injection using a blunt cannula during surgery.

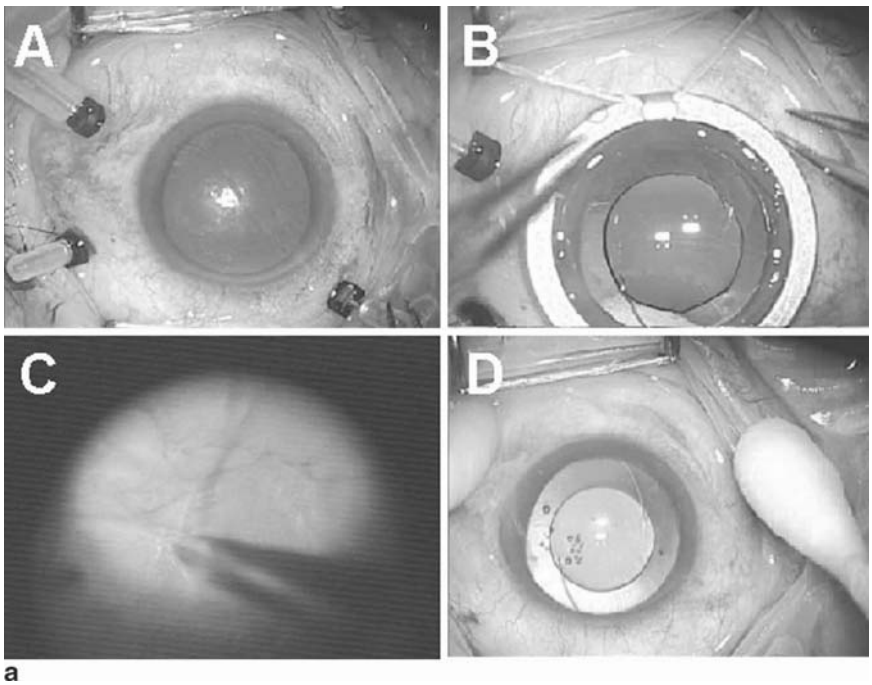
9.2.2.2 Transscleral Cannula Placement

The standard surgical protocols for transconjunctival 25-gauge vitrectomy are shown in Fig. 9.1. The trocars for transscleral cannulas are placed through the pars plana in the superonasal, superotemporal, and inferotemporal quadrants for infusion and insertion of intraocular instruments, after conjunctival displacement to purposely misalign the conjunctiva and scleral incisions. These insertions generally are located 3.5–4.0 mm posterior to the limbus. To prevent leakage from the scleral wound after removal of the cannulas, oblique insertion or microvitreoretinal (MVR) blade-guided insertion may be elected [9, 10]. In combined cataract surgery, insertion of beveled trocars before the creation of a clear corneal wound for cataract surgery is recommended, because inserting the trocars after creating the clear corneal incision may result in iris incarceration in the corneal wounds. After setting the microcannulas with trocars, phacoemulsification and intraocular lens implantation can be performed using a standard technique.

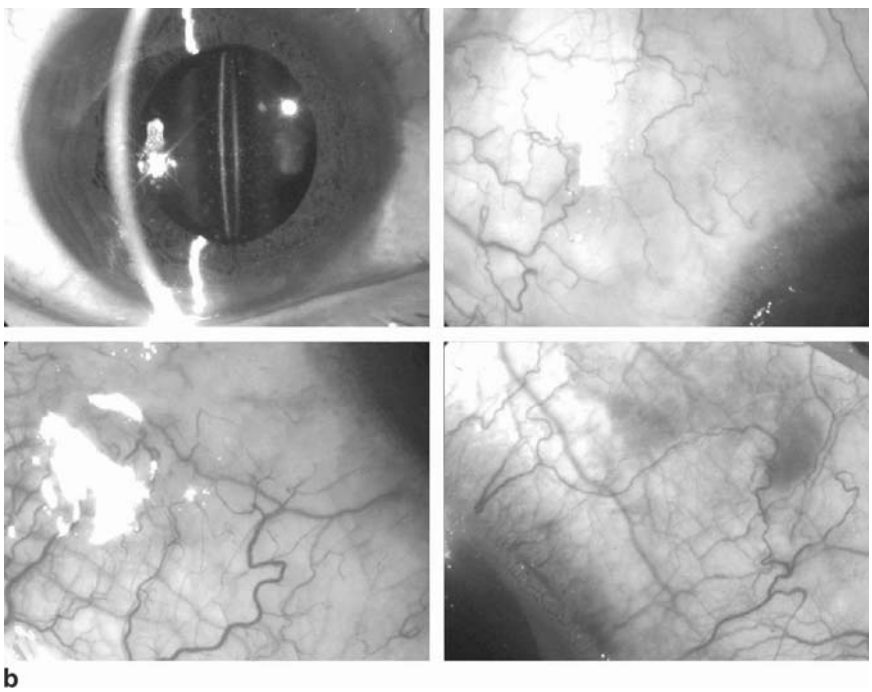
9.2.2.3 Core Vitrectomy and Posterior Hyaloid Separation (if Uncompleted)

Core vitrectomy is the first step in most vitreous surgeries, with the exception of nonvitrectomizing vitreous surgery for epiretinal membrane (ERM) removal. During 25-gauge vitrectomy, the tip of the vitrectomy probe should be inserted first in the central vitreous cavity and kept in the center of the surgical field under direct microscopic observation, to allow the surgeon to follow the movement of the tip. A vitreous gel must be engaged directly through the port of the probe for efficient vitrectomy in the 25-gauge system. For macular surgery, extensive vitrectomy to the periphery is unnecessary in most cases. However, attention should still be paid to avoid inadvertent retinal tears in the periphery. Scleral indentation to check for the development of retinal tears at the end of surgery is recommended.

Posterior hyaloid separation, if incomplete or absent, is the second step. Posterior hyaloid adherence to the macula may provide a bed for cellular proliferation or contribute to subsequent membrane traction to the macula, leading to secondary visual disturbance. Intravitreal injection of triamcinolone acetonide to visualize the vitreous gels sometimes makes it easy to detect a vitreoretinal adhesion (Fig. 9.2). There are several techniques for achieving posterior hyaloid separation. When using a vitreous cutter or a soft-tip cannula, it is recommended that the active suction in the 25-gauge system is set to 400–500 mmHg, with sufficient intraocular infusion. The active suction in the 25-gauge system is much higher than that in the 20-gauge system (200–300 mmHg). If the posterior hyaloid is strongly adhering to the retina, such as in patients with diabetic macular edema and age-related macular degeneration, a 45–90°-angled pick, a barbed 25-gauge needle, or an MVR blade can be introduced gently into the posterior hyaloid space around the disc margins to carefully incise and separate the posterior hyaloid membrane from the retinal surface. After circumferentially separating the posterior hyaloid from the disc margin, gently lifting the posterior hyaloid membrane anteriorly can easily lead to complete posterior hyaloid separation. In patients with diabetic retinopathy, care should be taken to identify the abnormal vitreoretinal adhesions on the retinal vessels, because inadvertent suction and membrane lifting may cause retinal breaks, bleeding, or both in the area of adhesion. These adhesions in patients with diabetes should be released using a vitreous cutter, a curved scissors, or both.



a



b

Fig. 9.1 (**a**) Surgical procedures of clear corneal phacoemulsification combined with 25-gauge transconjunctival sutureless vitrectomy. **A** Placement of the transscleral microcannulas through the pars plana in the superornasal, superotemporal and inferotemporal quadrants. **B** Sutureless contact lens ring is placed for vitrectomy. **C** Intravitreal manipulation using 25-gauge micro-hooked needle under endoillumination with xenon light source. **D** The eye immediately after removal of all microcannulas. The sutureless and self-sealing of the temporal corneal incision and three scleromies are completely achieved. (**b**) Slit-lamp anterior examination of scleral wounds one day after surgery. Sclera is smoothly covered with the conjunctiva, and the sclerotomies were undetectable

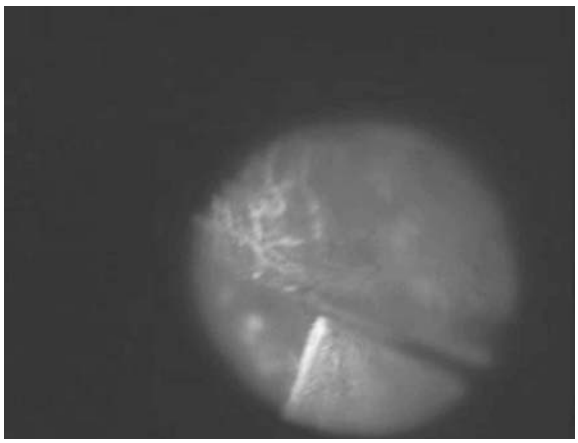


Fig. 9.2 Posterior hyaloid membrane is clearly visualized by the triamcinolone staining. The vitreoretinal adhesion is gently released by the active suction of 25-gauge vitreous cutter

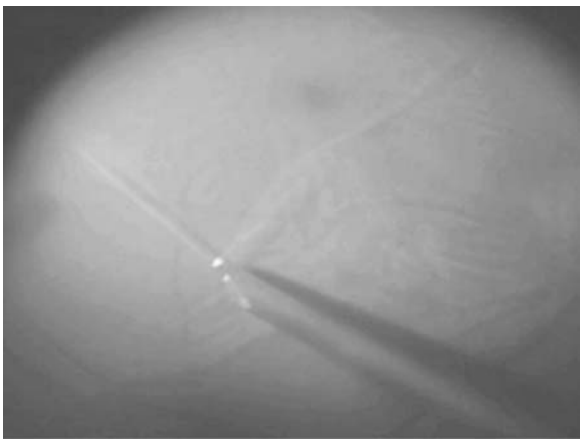


Fig. 9.3 Epiretinal membrane peeling by the use of 25-gauge micro-hooked needle

9.2.2.4 Specific Manipulation for Macular Disease

Epiretinal Tissue Removal

During macular surgery, epiretinal tissue removal from the retinal surface is essential. Various types of epiretinal tissues include residual vitreous cortex, cellophane-like thin ERMs, and thick proliferative membranes. For membrane tissue removal, several types of 25-gauge forceps are commercially available. An extendible membrane pick was developed especially for insertion through the 25-gauge trocars. The conventional method using a barbed-tip disposable needle, a so-called micro-hooked needle, or an MVR blade with a bent tip is also useful in the 25-gauge system. The desirable angle of the tip can be created by pressing the tip obliquely against another instrument. To remove membrane-type epiretinal tissues, once the membrane edge is lifted by the angled tip (Fig. 9.3) the membrane can be easily grasped using a membrane forceps and stripped from the retinal surface. Normally, gentle and smooth traction force is applied with unhurried movement of a forceps. During this maneuver, care should always be taken to watch for subtle movement or any distortion of the retinal surface and/or tiny retinal bleeding, in order to avoid possible iatrogenic retinal tear or large retinal hemorrhage. Unexpected inadvertent motion is more prone to take place with a 25-gauge instrument, due to its high flexibility. If the membrane is fragile or too thin a diamond-dusted membrane scraper is useful to gently apply to the retinal surface in order to give firm purchase on the tissue [11]. A thin layer of residual cortical vitreous can be lifted either by diamond-dusted membrane scraper or gentle aspiration from a silicone-brushed aspirating needle.

9.2.3 Nonvitrectomizing Vitreous Surgery for ERM Removal Using the 25-Gauge System

Cataract progression is a major complication of vitrectomy, which has been well-documented in previous studies of the conventional 20-gauge system for macular surgery [12, 13]. The progression of nuclear sclerosis is high (79%), despite using the 25-gauge system [4]. Nonvitrectomizing vitreous surgery has been reported to effectively prevent cataract progression in cases with ERM removal [14–16]. This procedure seems to be more suitable for small-gauge surgery using 25-gauge instruments. After transconjunctival insertion of two trocars superonasally and superotemporally for insertion of a light pipe and intraocular instruments, the ERM can be directly grasped by the membrane forceps in 25-gauge surgery without performing a vitrectomy. In order to efficiently hold membrane through unseparated posterior hyaloid, a pointed membrane forceps such as an asymmetrical forceps is preferred to end-gripping forceps. To reduce the sclerotomy-related vitreous loss, 27-gauge chandelier illumination can be employed instead of ordinary light-pipe endoillumination (Fig. 9.4) [17]. After peeling the membrane from the retinal surface, the membrane remnant, along with attaching vitreous, is removed through the transscleral cannula and excised at the sclerotomy site.

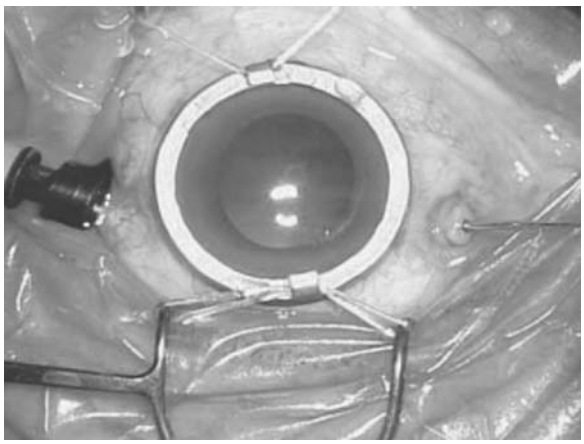


Fig. 9.4 Non-vitrectomizing vitreous surgery for epiretinal membrane removal is performed with 25/27-gauge system. A 27-gauge chandelier illuminator is inserted in the superornasal site, and a 25-gauge transscleral microcannula is set at the superotemporal quadrant for the insertion of membrane-peeling forceps

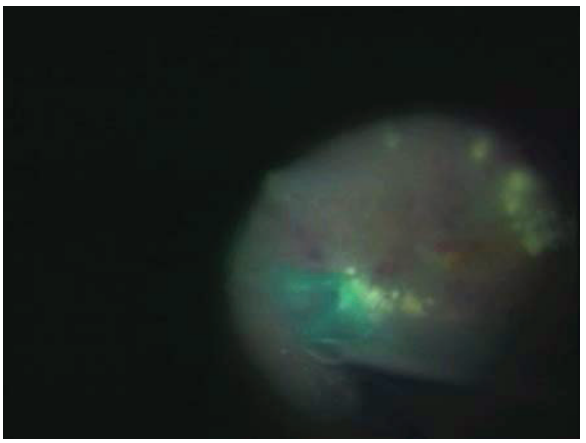


Fig. 9.5 Indocyanine green (ICG) assisted ILM peeling. The ILM is clearly stained by 0.125%-ICG saline solution and engaged by the use of 25-gauge membrane forceps

9.2.4 Internal Limiting Membrane (ILM) Peeling

Previous studies have shown that removal of the ILM improves the anatomical success rate and visual outcomes in several macular diseases, such as idiopathic macular hole, macular edema, and foveoschisis [18–22]. Presence of ILM can be interpreted by shiny reflection of the retina. However, it is virtually impossible to identify ILM only from the appearance of the retinal surface. The surgeon has to anticipate or to "suspect" its presence. When peeling the ILM, a sharp disposable needle or MVR blade can be used to puncture and peel a small area of the ILM at the temporal raphe about 3–5 mm from the fovea, in order to minimize the risk of visual field defect related to the surgical damage to the retina. Alternatively, a diamond-dusted membrane scraper can be employed to create the initial ILM flapped tear. The peeled edge of the ILM then can be lifted using an ILM elevator, or grasped directly using an ILM forceps. Finally, an ILM forceps is used for ILM maculorrhexis.

For clear visualization and safer manipulation of the transparent ILM during surgery, indocyanine green saline solution (0.125–0.5%) or trypan blue solution (0.4%) are often used as adjunctive agents to stain the ILM (Fig. 9.5). After core vitrectomy and completion of the posterior hyaloid separation, the dye can be injected intravitreally, and removed immediately by aspirating through a vitreous cutter. A small bolus of the dye is sufficient to visualize the ILM before peeling. Care must be taken during the off-label intravitreal injection of these adjuncts because of the potential risk for tissue toxicity [23–25]. Alternatively, particles of triamcinolone acetonide can be scattered on the retinal surface in order to facilitate the discrimination of ILM. As soon as the ILM is removed from the retinal surface, area of ILM defect can be delineated by subtle superficial retinal edema.

9.2.5 Submacular Surgery

Extensive submacular hemorrhage (SMH) is often complicated by age-related macular degeneration, polypoidal choroidal vasculopathy, and rupture of macroaneurysms, and sometimes requires surgery for visual recovery [26–29]. The recent trend toward small-incision surgery makes 25-gauge instruments suitable for removing submacular hemorrhages. After core vitrectomy and artificial separation of the posterior hyaloid, a small retinotomy can be created using a 25-gauge MVR blade, as described previously. The location for the retinotomy should depend on the location, size, and extent of the SMH. After creating the retinotomy, tissue plasminogen activator can be injected into the subretinal space using a 27-gauge needle for clot liquefaction. Perfluorocarbon liquid (PFCL) then is dropped on the posterior retina to form a single bubble; the enlarging bubble displaces the liquefied subretinal blood into the vitreous cavity through a small retinotomy if the eyeball is gently rocked. Extensive subretinal manipulation to completely evacuate the SMH should be avoided to prevent damaging the overlying photoreceptors and retinal pigment epithelium. After

removing the PFCL using a 25-gauge silicone-tipped needle (back-flush brush needle), fluid–air exchange is recommended for subsequent pneumatic displacement of the residual SMH after surgery. In general, neither diathermy nor laser photocoagulation is required to seal the retinotomy.

Summary for the Clinician

- Core vitrectomy is the first step in most vitreous surgeries. A vitreous gel must be engaged directly through the port of the probe for efficient vitrectomy in the 25-gauge system.
- For macular surgery, extensive vitrectomy to the periphery is unnecessary in most cases. However, scleral indentation to check for the development of retinal tears at the end of surgery is recommended.
- Posterior hyaloid separation, if incomplete or absent, is the second step.
- For achieving posterior hyaloid separation, it is recommended that the active suction in the 25-gauge system is set to 400–500 mmHg, with sufficient intraocular infusion. The active suction in the 25-gauge system is much higher than that in the 20-gauge system (200–300 mmHg).
- If the posterior hyaloid is strongly adhering to the retina a 45–90°-angled pick, a barbed 25-gauge needle, or an MVR blade can be introduced gently into the posterior hyaloid space around the disc margins to carefully incise and separate the posterior hyaloid membrane from the retinal surface.
- To remove membrane-type epiretinal tissues, once the membrane edge is lifted by the angled tip, the membrane can be easily grasped using a membrane forceps and stripped from the retinal surface. Unexpected inadvertent motion is more prone to take place with a 25-gauge instrument due to its high flexibility.
- Nonvitrectomizing vitreous surgery has been reported to effectively prevent cataract progression in cases with ERM removal. This procedure seems to be more suitable for small-gauge surgery using 25-gauge instruments. The ERM can be directly grasped by the membrane forceps in 25-gauge surgery without performing a vitrectomy.
- The peeled edge of the ILM then can be lifted using an ILM elevator or grasped directly using an ILM forceps. Finally, an ILM forceps is used for ILM maculorrhexis.

Summary for the Clinician

- For clear visualization, indocyanine green saline solution (0.125–0.5%) or trypan blue solution (0.4%) are often used as adjunctive agents to stain the ILM. Alternatively, particles of triamcinolone acetonide can be scattered on the retinal surface in order to facilitate the discrimination of ILM.
- 25-gauge surgery is useful to remove SMH. After creating the retinotomy, tissue plasminogen activator can be injected into the subretinal space. Extensive subretinal manipulation to completely evacuate the SMH should be avoided. Fluid–air exchange is recommended for subsequent pneumatic displacement of the residual SMH after surgery.

9.3 25-Gauge Instrumentation and Devices for Macular Surgery

9.3.1 Basic Instruments

A 25-gauge vitrectomy is performed using a system similar to conventional 20-gauge vitrectomy that includes a vitreous cutter, infusion, endoillumination, and several types of lenses for visualization. The specialized instrumentation required for 25-gauge transconjunctival surgery includes only the trocars and transscleral cannulas (Fig. 9.6).

9.3.2 Special Instruments and Devices for Macular Surgery

9.3.2.1 Xenon Light Source

With recent technological advances and widespread use of 25-gauge instrumentation for vitrectomy, the availability of sufficient light with adequate wide-angle endoillumination from a small-gauge endoilluminator has become more important for achieving clear fundus views. Because of the small gauge size, light-probe endoillumination used with a conventional halogen or metal-halide light source is sometimes insufficient to illuminate the vitreous cavity for delicate manipulation in the macular area. Recently, xenon light devices (Fig. 9.7) have been developed which generate much brighter illumination and eliminate the toxic light wavelength (Fig. 9.8).

9.3.2.2 Chandelier Style Endoilluminating Light Fibers

In combination with a xenon light source, several types of 25-gauge light probes for wide-angle endoillumination

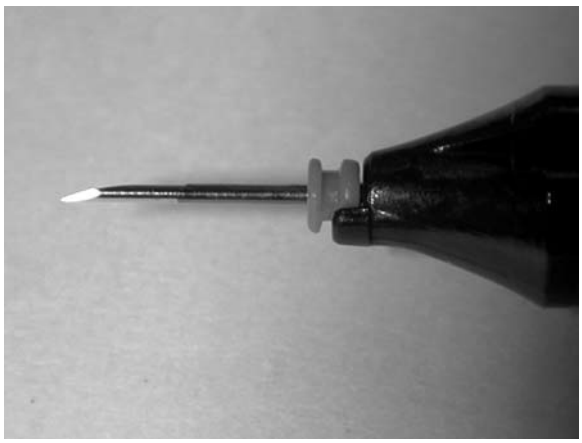


Fig. 9.6 25-gauge transscleral microcannula with a sharp tip trocar (courtesy of Alcon, Inc., USA.)

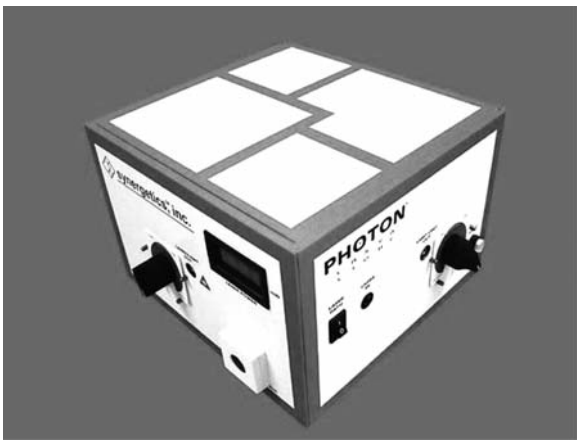


Fig. 9.7 Xenon laser light device (courtesy of Synergetics, Inc., USA.)

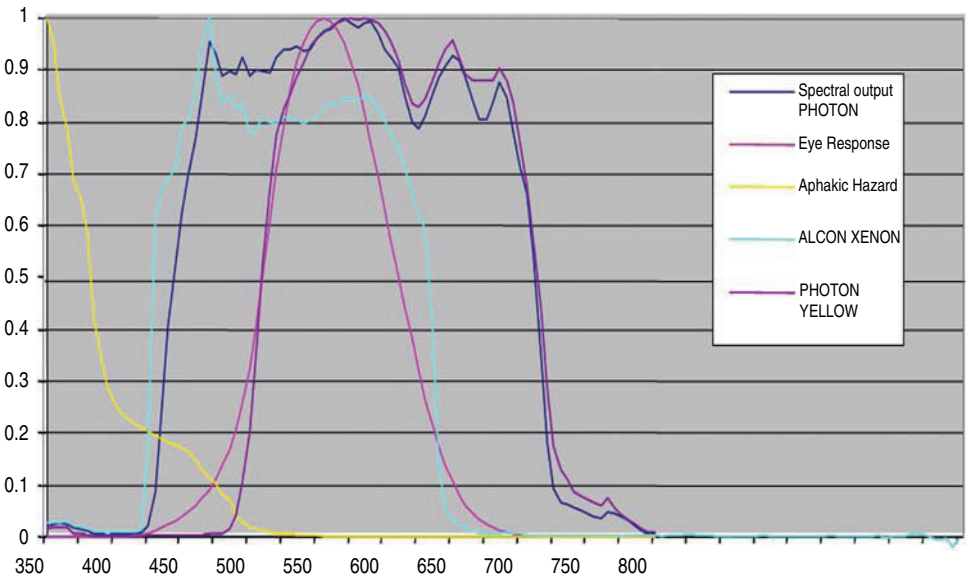


Fig. 9.8 The light wavelength under 400 nm, which is toxic to the macular, is cut off by the specific filter in the xenon laser light device (courtesy of Synergetics, Inc., USA.)

are currently available. A chandelier-style illuminator produces homogeneous and wide-angle endoillumination, making it suitable for use in combination with a panoramic-viewing system for obtaining a glare-free, wide-field fundus view and avoiding potentially dangerous localized increases in light intensity that occur using light probes (Fig. 9.9a,b). Because of its hands-free and self-retaining design, bimanual manipulation is possible during removal of strongly adherent ERMs in patients with diabetic retinopathy and proliferative vitreoretinopathy (Fig. 9.10). An illuminated 25-gauge infusion cannula is also useful to perform two-port macular surgery (Fig. 9.11). A much smaller 27-gauge endoilluminator has been developed, and will be commercially available soon (Fig. 9.12).

9.3.2.3 Microscope and Fundus Viewing System

The microscope that can be used for macular surgery includes the functions of *X*-*Y* control, automatic focusing, zoom magnification, and coaxial illumination. If a wide-angle viewing system is used, a stereoscopic inverter should be mounted on the microscope, and if endolaser photocoagulation is necessary, a laser filter also is required.

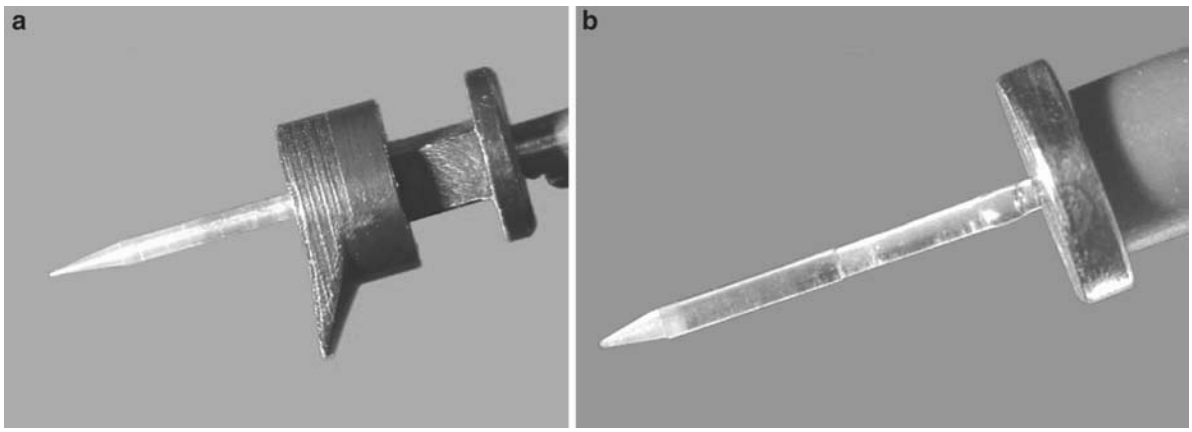


Fig. 9.9 25-gauge chandelier style endoilluminator compatible with the xenon light device (courtesy of Synergetics, Inc., USA.). (**a**) 25-gauge chandelier illuminator with a tip designed for transscleral insertion. (**b**) 25-gauge chandelier illuminator with a tip designed for insertion through the transscleral microcannula

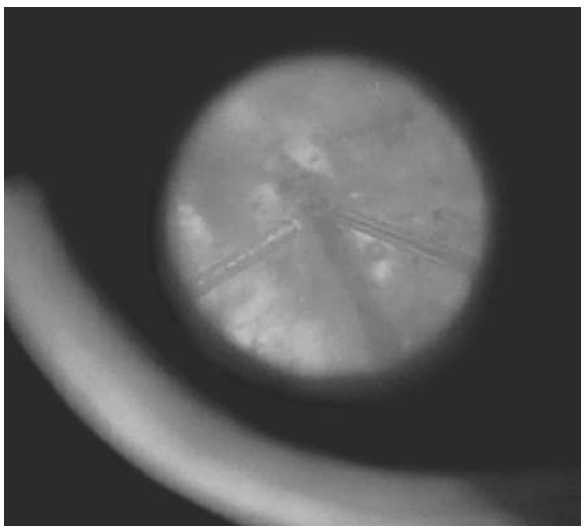


Fig. 9.10 Bimanual manipuration for membrane dissection by use of 25-gauge instruments under chandelier endoillumination

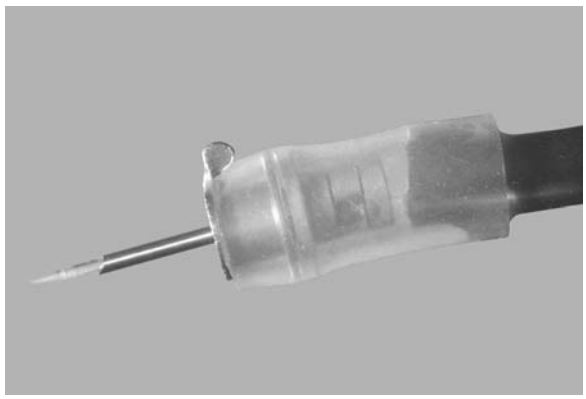


Fig. 9.11 25-gauge illuminated infusion cannula (courtesy of Synergetics, Inc., USA.) The illumination and sufficient infusion are provided through a single port. This dual function device enables two-port macular surgery in 25-gauge system

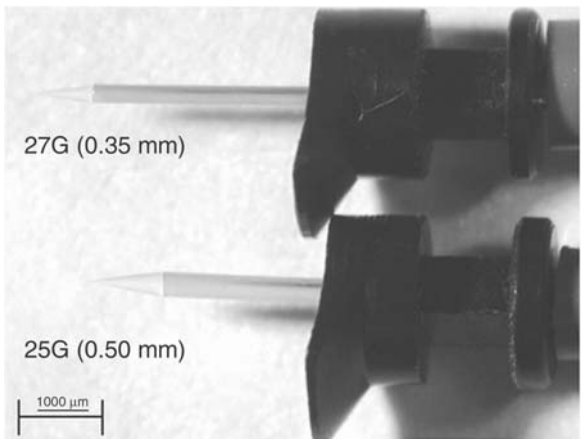


Fig. 9.12 The 27-gauge chandelier endoilluminator. The tip of the light fiber is much thinner than that of 25-gauge chandelier fiber

Most macular surgery procedures require sufficient stereoscopic viewing, i.e., adequate focus depth, wide-angle viewing, and good magnification. For clear macular viewing and surgical manipulation, a magnified reusable contact lens with a sutureless lens-fixation ring or disposable silicone contact lens is convenient, and neither requires suture placement for lens fixation [30]. For panoramic viewing and peripheral manipulation, both a panoramic contact lens and a noncontact wide-angle system are effective and convenient [31, 32].

A system for wide-angle viewing through the surgical microscope has been developed. A stereoscopic inverter incorporated into the microscope enables the

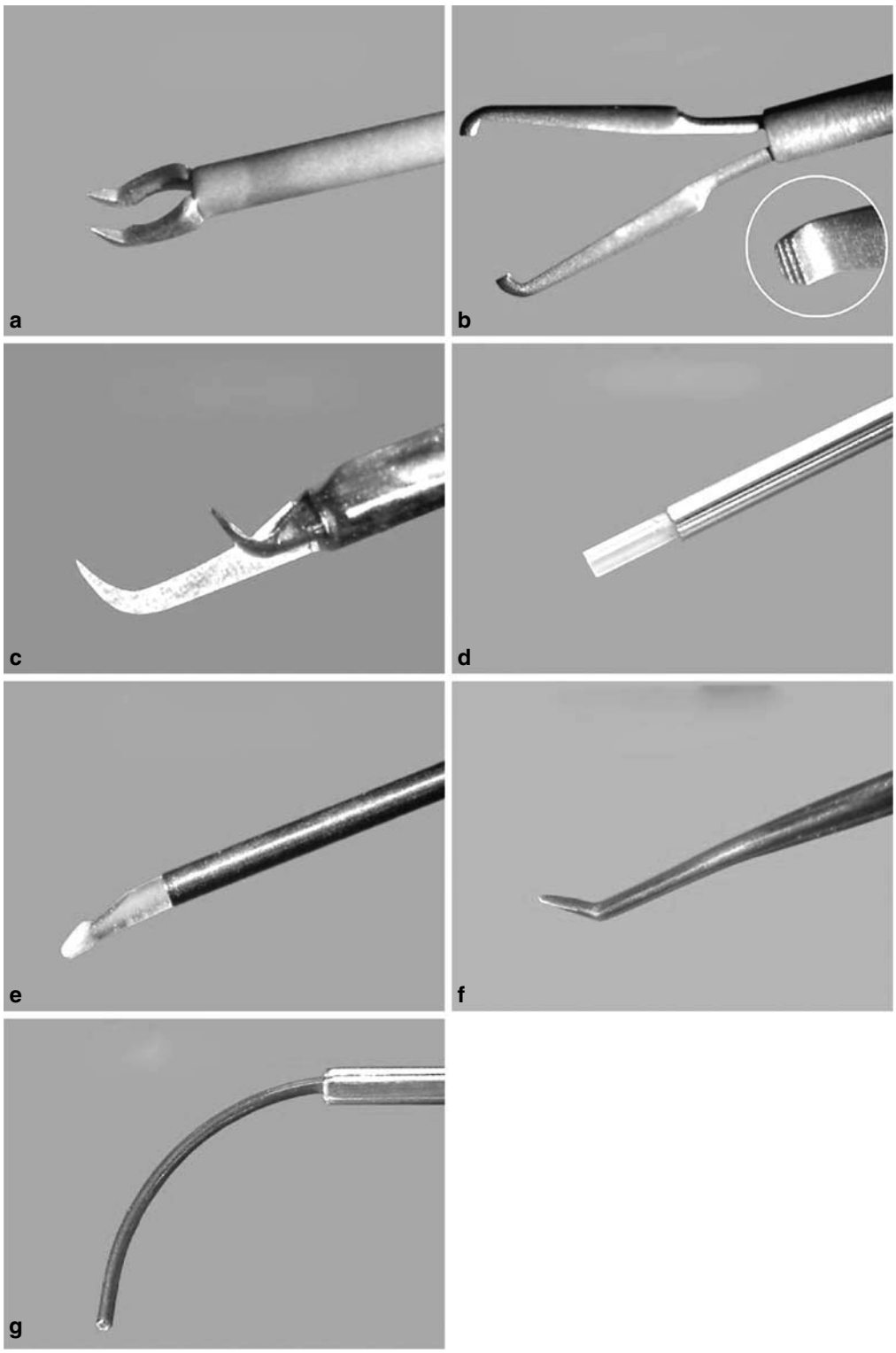


Fig. 9.13 25-gauge instruments vary in structure, shape and composition for macular surgery, dependent on the surgeon's preferences (courtesy of Synergetics, Inc., USA). (**a**) Tano asymmetric micro forceps for epiretinal membrane or ILM peeling. (**b**) Eckardt micro forceps for epiretinal membrane or ILM peeling. (**c**) Vertical scissors for membrane dissection. (**d**) Silicone-tipped backflash brush needle. (**e**) Diamond-dusted membrane scraper for removal of posterior vitreoretinal adhesion. (**f**) Rice ILM elevator for ILM peeling or posterior vitreous hyaloid separation. (**g**) Extendable endo-laser probe

use of either a pan funduscope wide-angle viewing contact lens or a noncontact panoramic system such as the binocular indirect ocular microscope for modern wide-angle viewing during vitreous surgery [31]. Generally, the wide-angle viewing system provides a 130–150° observation angle. Although 25-gauge macular surgery does not require extensive peripheral vitreous removal, vitrectomy performed with wide-angle viewing is more effective and safer for confirming the presence of peripheral vitreous traction and retinal breaks during surgery.

9.3.2.4 25-Gauge Forceps and Picks for Macular Surgery

Several types of 25-gauge membrane forceps, pick, and other instruments for macular surgery are commercially available (Fig. 9.13).

Summary for the Clinician

- Because of the small gauge size, light-probe endoillumination used with a conventional halogen or metal-halide light source is sometimes insufficient. Xenon light devices generate much brighter illumination, and eliminates the toxic light wavelength.
- A chandelier-style illuminator produces homogeneous and wide-angle endoillumination, making it suitable for use in combination with a panoramic-viewing system.
- Several types of 25-gauge membrane forceps, pick, and other instruments for macular surgery are commercially available.

9.4 Prevention and Management of Complications Related to 25-Gauge Macular Surgery

Postoperative transient hypotony, defined as intraocular pressure less than 7 mmHg, is a major concern related to self-sealing sclerotomy. The incidence of postoperative hypotony might decrease as surgeons master the learning curve associated with the procedure [5, 9]. Since the incidence of postoperative hypotony in eyes with gas tamponade is significantly lower than in those without gas tamponade, intravitreal injection of sterile air might be a useful technique to prevent postoperative hypotony [5]. To prevent leakage from the scleral wound after removal of the cannulas, oblique or guided insertion of an MVR blade can be employed [9, 10]. Other theoretical concerns related to self-sealing sclerotomy, such as vitreous incarceration in the scleral wound and retinal detachment, are reported to be less than expected [3–6]. However, the incidence of endophthalmitis seems to be a little higher in cases with 25-gauge instrumentation than in those with the conventional 20-gauge system [33].

Summary for the Clinician

- Postoperative transient hypotony, defined as intraocular pressure less than 7 mmHg, is a major concern related to the self-sealing sclerotomy.
- Intravitreal injection of sterile air might be a useful technique to prevent postoperative hypotony.
- Other theoretical concerns, such as vitreous incarceration in the scleral wound, retinal detachment, and endophthalmitis, are reported to be less than expected.

References

1. Fujii GY, de Juan E Jr, Humayun MS et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1812
2. Fujii GY, de Juan E Jr, Humayun M Set al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
3. Lakhanpal RR, Humayun MS, de Juan E Jr et al. (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
4. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
5. Oshima Y, Ohji M, Tano Y (2006) Surgical outcomes of 25-gauge transconjunctival vitrectomy combined with cataract surgery for vitreoretinal diseases. Ann Acad Med Singapore 35:175–180
6. Yanyali A, Celik E, Horozoglu F, Nohutcu AF (2005) Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. Am J Ophthalmol 140:939–941
7. Kadonosono K, Yamakawa T, Uchio E et al (2006) Comparison of visual function after epiretinal membrane removal by 20-gauge and 25-gauge vitrectomy. Am J Ophthalmol 142:513–515
8. Yamanishi S, Oshima Y, Emi K, Motokura M (2000) Optical cross-sectional evaluation of successfully repaired idiopathic macular holes by retinal thickness analyzer. Retina 20:450–458
9. Lopez-Guajardo L, Pareja-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 141:1154–1156

10. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
11. Oshima Y, Ikuno Y, Motokura M et al. (1998) Complete epiretinal membrane separation in highly myopic eyes with retinal detachment resulting from a macular hole. Am J Ophthalmol 126:669–676
12. de Bustros S, Thompson JT, Michels RG et al (1988) Nuclear sclerosis after vitrectomy for idiopathic epiretinal membranes. Am J Ophthalmol 105:160–164
13. Thompson JT, Glaser BM, Sjaarda RN, Murphy RP (1995) Progression of nuclear sclerosis and long-term visual results of vitrectomy with transforming growth factor beta-2 for macular holes. Am J Ophthalmol 119:48–54
14. Saito Y, Lewis JM, Park I et al (1999) Nonvitrectomizing vitreous surgery: a strategy to prevent postoperative nuclear sclerosis. Ophthalmology 106:1541–1545
15. Sawa M, Saito Y, Hayashi A, et al (2001) Assessment of nuclear sclerosis after nonvitrectomizing vitreous surgery. Am J Ophthalmol 132:356–362
16. Sawa M, Ohji M, Kusaka S et al (2005) Nonvitrectomizing vitreous surgery for epiretinal membrane long-term follow-up. Ophthalmology 112:1402–1408
17. Oshima Y, Awh C, Tano Y (2007) Self-retaining 27-gauge transconjunctival chandelier endoillumination for panoramic viewing during vitreous surgery. Am J Ophthalmol 143:166–167
18. Brooks HL Jr (2000) Macular hole surgery with and without internal limiting membrane peeling. Ophthalmology 107:1939–1948
19. Kadonosono K, Itoh N, Uchio E et al (2000) Staining of internal limiting membrane in macular hole surgery. Arch Ophthalmol 118:1116–1118
20. Kusaka S, Hayashi N, Ohji M et al (2001) Indocyanine green facilitates removal of epiretinal and internal limiting membranes in myopic eyes with retinal detachment. Am J Ophthalmol 131:388–390
21. Ikuno Y, Sayanagi K, Ohji M et al (2004) Vitrectomy and internal limiting membrane peeling for myopic foveoschisis. Am J Ophthalmol 137:719–724
22. Ikuno Y, Tano Y (2006) Vitrectomy for macular holes associated with myopic foveoschisis. Am J Ophthalmol 141:774–776
23. Haritoglou C, Gandorfer A, Gass CA et al (2002) Indocyanine green-assisted peeling of the internal limiting membrane in macular hole surgery affects visual outcome: a clinicopathologic correlation. Am J Ophthalmol 134:836–841
24. Ando F, Sasano K, Suzuki F, Ohba N (2004) Indocyanine green-assisted ILM peeling in macular hole surgery revisited. Am J Ophthalmol 138:886–887
25. Haritoglou C, Eibl K, Schaumberger M et al (2004) Functional outcome after trypan blue-assisted vitrectomy for macular pucker: A prospective, randomized, comparative trial. Am J Ophthalmol 138:1–5
26. Bennett SR, Folk JC, Blodi CF, Klugman M (1990) Factors prognostic of visual outcome in patients with subretinal hemorrhage. Am J Ophthalmol 109:33–37
27. Lewis H (1994) Intraoperative fibrinolysis of submacular hemorrhage with tissue plasminogen activator and surgical drainage. Am J Ophthalmol 118:559–568
28. Kamei M, Tano Y, Maeno T et al (1996) Surgical removal of submacular hemorrhage using tissue plasminogen activator and perfluorocarbon liquid. Am J Ophthalmol 121: 267–275
29. Shiraga F, Matsuo T, Yokoe S et al (1999) Surgical treatment of submacular hemorrhage associated with idiopathic polypoidal choroidal vasculopathy. Am J Ophthalmol 128:147–154
30. Ikuno Y, Ohji M, Kusaka S et al (2002) Sutureless contact lens ring system during vitrectomy. Am J Ophthalmol 133:847–848
31. Nakata K, Ohji M, Ikuno Y et al (2004) Wide-angle viewing lens for vitrectomy. Am J Ophthalmol 137:760–762
32. Spitznas M (1987) A binocular indirect ophthalmomicroscope (BIOM) for non-contact wide-angle vitreous surgery. Graefes Arch Clin Exp Ophthalmol 225:13–15
33. Kunimoto DY, Kaiser RS, Willis Eye Research Service (2007) Incidence of endophthalmitis after 25- and 20-gauge vitrectomy. Ophthalmology 114:2133–2137.

Chapter 10

25-Gauge Sutureless Vitrectomy for Diabetic Retinopathy

T.S. Hassan

Core Message

- 25-gauge vitrectomy has emerged as a treatment approach for the following indications:
  - Nonclearing VH,
  - Tractional retinal detachment,
  - Refractory diabetic macular edema,
  - Combined tractional and rhegmatogenous retinal detachment,
  - High risk PDR with anterior segment neovascularization
  - Severe premacular subhyaloid hemorrhage,
  - Vitreopapillary traction
  - Ghost-cell glaucoma
- Vitrectomy has the potential to lead to long-lasting good outcomes for some eyes with refractory CSDME, and should be in the armamentarium of all vitreoretinal surgeons.
- Proliferative pathology posterior to the equator, with or without tractional retinal detachment, has become significantly easier to approach, and may become another indication for which 25-gauge vitrectomy is the preferred technique as newer peripheral light sources and wide-field viewing systems become more ubiquitously available.
- The majority of diabetic eyes that require vitrectomy may now be approached with the 25-gauge surgical technique.

10.1 Introduction

Machemer first described vitrectomy in 1971 when he reported the successful treatment of a 5-year-old nonclearing vitreous hemorrhage (VH) and saw visual improvement from 2/200 to 20/50 [1]. Since then, quantum leaps in technology, surgeon experience, and the understanding of diabetic pathoanatomy have led to the development of increasingly safer and effective vitrectomy. Dramatic improvements in surgical instrumentation and techniques have expanded diabetic surgical indications, and changed the goals of surgery from the reduction of vision loss or visual stabilization to visual improvement and long-term anatomic stability.

In recent years, small-incision surgical procedures have been developed in many disciplines, driven by surgeons' desire to perform less traumatic operations that result in less postoperative inflammation, less patient morbidity, and faster postoperative recovery [2–5]. These patient advantages have been gained in ophthalmology, first as phacoemulsification supplanted extracapsular cataract extraction in the past 2 decades, and more recently, as phacoemulsification with small self-sealing sutureless corneal wounds supplanted previous techniques. Since Machemer's original description of vitrectomy with a 17-gauge multifunction instrument, numerous investigators have sought to develop a smaller, sutureless vitrectomy system to gain similar advantages and minimize iatrogenic damage to eyes with posterior segment pathology. These efforts led to the development of the 25-gauge transconjunctival sutureless vitrectomy system by de Juan and coworkers, first described by Fujii in 2002 [6, 7]. This original report, and several others published in the past few years, describe successful visual and anatomic outcomes following 25-gauge vitrectomy for a number of surgical indications, including both nonproliferative (NPDR) and proliferative diabetic retinopathy (PDR) [7–10].

Other chapters in this text describe the development of 25-gauge vitrectomy, general 25-gauge surgical techniques, and methods of transitioning from 20- to 25-gauge vitrectomy. This chapter will focus on the specific application of 25-gauge vitrectomy techniques to the management of diabetic retinopathy.

10.2 25-Gauge Surgical Indications

Though an in-depth analysis of all vitrectomy techniques for diabetic retinopathy is beyond the scope of this chapter, herein will be a discussion of those performed with 25-gauge vitrectomy.

In the past 35 years, many improvements in vitrectomy technique and instrumentation have occurred, primarily with the use of 19 and 20-gauge systems, while a greater understanding of the pathobiology of diabetic retinopathy has led to the evolution of numerous surgical indications for diabetic vitrectomy. Currently, the most common indications are: nonclearing VH, tractional retinal detachment, refractory diabetic macular edema, combined tractional and rhegmatogenous retinal detachment, high risk PDR with anterior segment neovascularization and opaque media, severe premacular subhyaloid hemorrhage, vitreopapillary traction, and ghost-cell glaucoma [11–26]. 25-gauge vitrectomy has emerged as a treatment approach for all of these indications in some settings, and has now become the method of choice for several of them.

For both NPDR and PDR, the main surgical goals for all indications are to: (a) clear media opacities, and (b) remove or relieve anteroposterior and tangential vitreoretinal traction — while maintaining hemostasis, avoiding or minimizing retinal breaks, and ultimately, controlling future disease progression.

10.3 Instrumentation

The development of new surgical instrumentation over the past several years has allowed 25-gauge vitrectomy for diabetic retinopathy to progress from a procedure only used for post-equatorial pathology to one used for more widespread indications, including those with more peripheral pathologic changes to at least the posterior vitreous base.

The original 25-gauge vitrectomy instruments were introduced by Bausch & Lomb (Rochester, NY, USA) and included a high-speed vitreous cutter (1,500 cuts/minute), endoilluminating light pipe, endolaser probe, extendable aspirating pick, and several intraocular forceps. The initial use of these instruments was not coupled with wide-field viewing, and the intraocular light was poor in both intensity and width of field. Refractory clinically significant diabetic macular edema (CSDME) and nonclearing VH in eyes without significant peripheral pathology were the main diabetic indications for surgeons gaining early experience with 25-gauge vitrectomy. In the past couple of years, several instrument manufacturers have developed stiffer-shafted light pipes, laser probes, and forceps that now allow the eye to be moved with greater excursions and without significant bending of the instruments. There are vitreous cutters that can now even reach speeds of 2,500 cuts/minute, with improvements in their flow characteristics that have expanded indications for 25-gauge vitrectomy. A greater variety of instruments are now available, such as vertical and horizontal scissors, forceps with many tip styles, tissue manipulators, intraocular diathermy, extendable and angled laser probes, soft-tipped extrusion cannulas, lighted picks and forceps, and even a silicone oil cannula. Wide-field viewing systems and new peripheral lighting, such as provided by chandeliers or lighted infusion cannulas powered by high-output xenon light sources, now allow surgeons to approach essentially all PDR, other than combined rhegmatogenous/tractional retinal detachments, with 25-gauge vitrectomy.

10.4 25-Gauge Vitrectomy for Nonproliferative Diabetic Retinopathy

The most common cause of visual loss in diabetic patients is CSDME, occurring in 29% of diabetics that have had the disease longer than 20 years [27]. Two or more lines of vision are lost in more than half of affected patients after 2 years follow-up [28]. Focal macular laser, applied by guidelines set forth by the Early Treatment Diabetic Retinopathy Study (ETDRS), is known to reduce persistence of CSDME and associated moderate visual loss by 50%. Some eyes are poorly responsive, however, and this same series showed that 15% of treated eyes lost three or more lines of vision during follow-up [29]. Lee and Olk found that 25% of eyes lost vision over 3 years follow-up after receiving standard macular laser treatment [30]. Unlike eyes with focally leaking microaneurysms that typically respond well to macular laser, eyes with diffuse macular edema from widespread blood-retinal barrier dysfunction and abnormally increased macular vascular permeability generally respond poorly to focal and grid laser treatment. Clinical characteristics of these eyes include: diffuse retinal thickening, few visible microaneurysms, intraretinal cystoid spaces, macular ischemia, submacular detachment, subretinal hard exudates, and possibly an attached and taut posterior hyaloid membrane (Fig. 10.1a). These features may be well seen with slit-lamp biomicroscopy, and can be further evaluated with optical coherence tomography (OCT) (Fig. 10.1b). Fluorescein angiography (FA) generally demonstrates some macular ischemia and a diffuse nearly arcade vessel to arcade vessel, petalloid pattern of hyperfluorescence. Distinct leaking microaneurysms are only infrequently seen (Fig. 10.2).

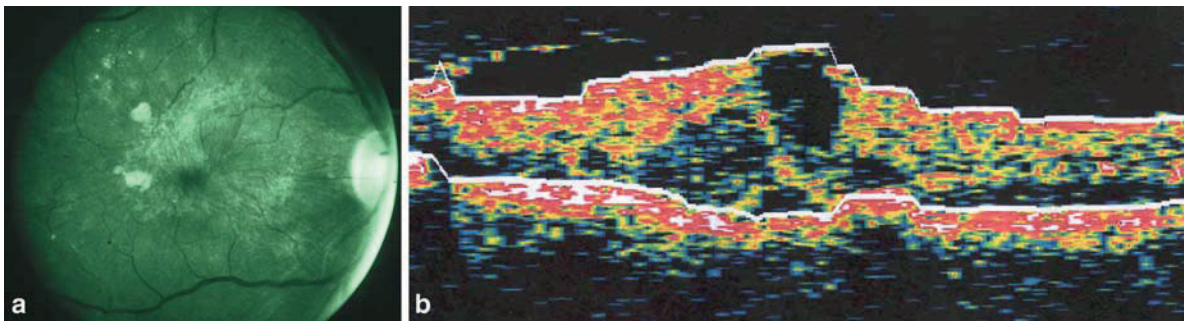


Fig. 10.1 (**a**) Red-free fundus photograph illustrating visibly taut and opacified posterior hyaloidal membrane and underlying CSDME. VA = 20/100. (**b**) OCT illustrating refractory CSDME, taut posterior hyaloidal membrane, and VA = 20/100

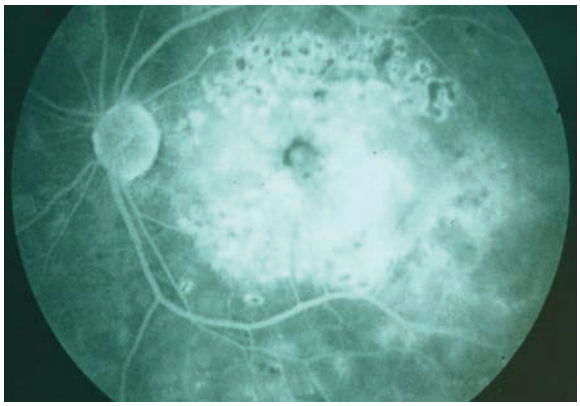


Fig. 10.2 FA demonstrating refractory CSDME with diffuse leakage and VA = 20/200

Recent diagnostic, pharmacologic, and surgical advancements have spurred the development of alternative treatments to better resolve refractory CSDME and improve vision in these poor prognosis eyes. These include the use of intravitreally-injected corticosteroids and anti-vascular endothelial growth factor (VEGF) agents, and vitrectomy. The aim of surgeons over the next several years is likely to be to determine how each treatment fits into the ever-changing algorithm of the management of diabetic macular edema.

10.4.1 Why Vitrectomy?

The role of the vitreous in the development or progression of macular edema has been evaluated for over 2 decades. Initially, Schepens suggested that vitreous traction to the macula may play a role in the cystoid macular edema associated with retinitis pigmentosa, aphakia, and uveitis [31]. Nasrallah later reported that eyes with CSDME were less likely to have a posterior vitreous detachment (PVD) than those without CSDME, which suggested a possible role for the vitreous in the development of CSDME [32]. Hikichi reported the spontaneous resolution of CSDME in 55% of eyes that developed a PVD versus 25% of eyes that did not [33]. Beyond such published reports, there has long been anecdotal evidence of CSDME resolution following vitrectomy for complications of PDR.

Vitrectomy has been investigated as a treatment alternative for refractory CSDME for approximately 15 years. Shortly after Kelly and Wendel described the successful manipulation of the vitreomacular interface to close macular holes [34], early reports suggested that the vitreomacular interface could be surgically manipulated to treat CSDME as well. Lewis et al. showed visual acuity (VA) improvement following vitrectomy and membrane peeling of a visibly taut, opacified posterior hyaloid in eyes with diffuse CSDME [24]. Since then, multiple authors have retrospectively reported that vitrectomy and separation of both *visibly taut* (and presumably *invisibly taut)* attached posterior hyaloid membranes resolved CSDME in 43–100% of eyes, and resulted in VA improvement of ≥2 lines in 38–92% of eyes [35–46]. Otani and Kishi, in a small, prospective, controlled trial, demonstrated statistically significant VA improvement and decreased macular thickness (by OCT) in vitrectomized eyes compared to a control group of observed matched fellow eyes [47]. In all series, resolution of CSDME has been shown to occur between 3 and 6 months postoperatively in most eyes, though improvement has been seen to begin earlier [38, 40]. Examples of outcomes of vitrectomy for refractory CSDME from our series are shown in Figs. 10.3 and 10.4

10.4.2 Procedure

Eyes with refractory CSDME are ideal candidates for 25-gauge vitrectomy, as they generally do not have extensive peripheral vitreoretinal traction. Surgeons

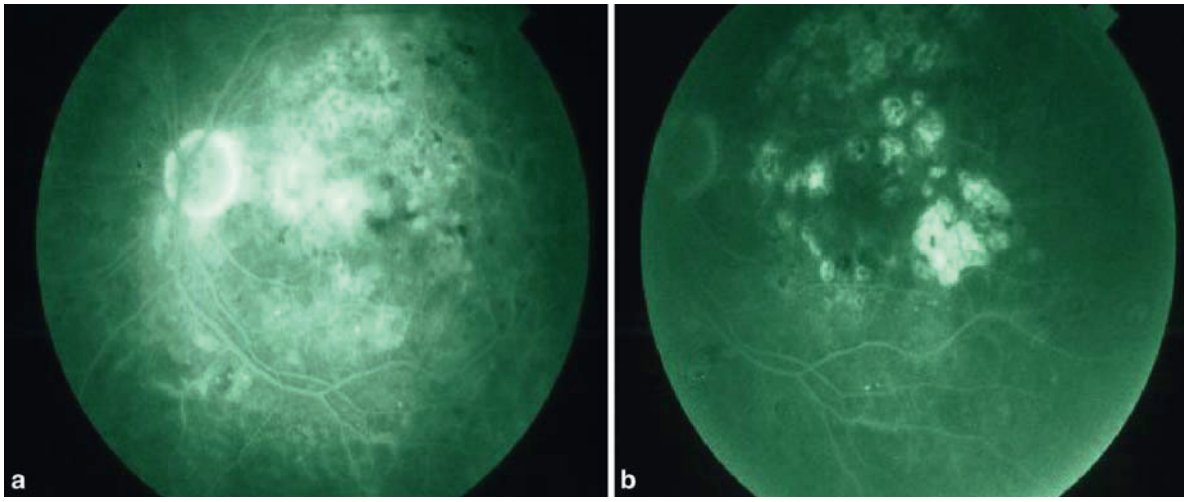


Fig. 10.3 (**a**) Pre-vitrectomy FA, Visibly opacified, taut posterior hyaloidal traction, diffuse leakage, and VA = 20/100. (**b**) Three-month post-vitrectomy FA, with resolved leakage, more visible preoperative laser scars, and VA = 20/50

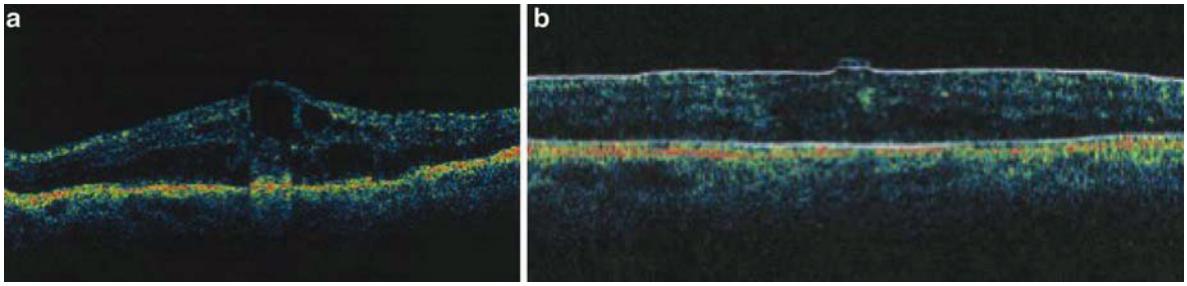


Fig. 10.4 (**a**) Pre-vitrectomy OCT demonstrating large intraretinal cystic spaces and foveal hard exudates, VA = 20/200. (**b**) Six weeks post-vitrectomy OCT; improved CSDME VA = 20/60. CSDME, clinically significant diabetic macular edema; VA, visual acuity; OCT, optical coherence tomography

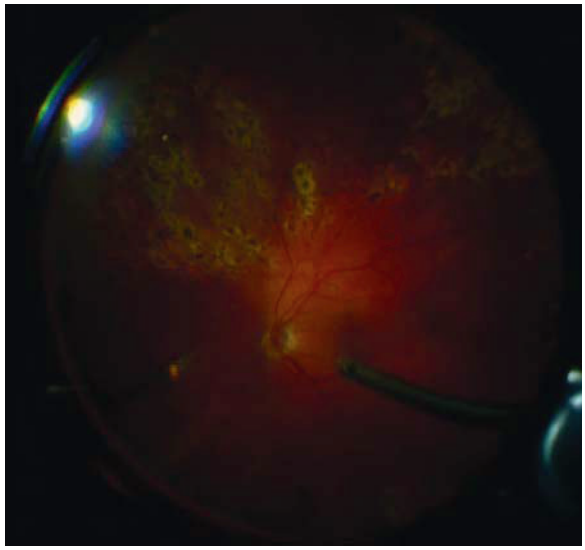


Fig. 10.5 Intraoperative view using a wide-field viewing system and lighted infusion powered by a xenon light source

currently find that available 25-gauge instrumentation is sufficient to allow achievement of all surgical goals. After introduction of the three cannulas, infusion line, vitreous cutter, and endoilluminator as described in earlier chapters of this text, vitrectomy is performed for 360 degrees. It may be carried out beyond the equator to near the vitreous base with the aid of a wide-field viewing system and high-intensity peripheral lighting such as from a xenon chandelier light or lighted infusion cannula (Fig. 10.5). The separation and removal of the posterior hyaloid membrane from the retina, particularly the macula, and of any fibrovascular proliferation is the ultimate goal of this procedure. Suction techniques are usually successful for elevating the posterior hyaloid but if it is too firmly adherent, sharp dissection with an MVR blade may be required. Every attempt is made to remove the posterior hyaloid as far beyond the equator as safely possible. Its removal, and that of the underlying internal limiting membrane, from the macula can be

challenging, particularly if there has been extensive preexisting focal laser. As discussed below, vitreoschisis is common in such eyes. Stripping of the internal limiting membrane ensures removal of all posterior hyaloidal elements from the macula, and thereby maximizes the likelihood that the CSDME will clear. Panretinal photocoagulation, delivered by straight, angled, or extendable endolaser probes or by an indirect laser system, is then added to reduce the likelihood of postoperative anterior segment neovascularization and potentially reduce vascular endothelial growth factor (VEGF) levels in the posterior segment. In eyes with no known contraindications such as glaucoma or prior history of intraocular pressure rise after steroid application, 4 mg of triamcinolone acetonide may be injected intravitreally at the completion of the case to help reduce the macular swelling early in the postoperative period.

10.4.3 Why Does Vitrectomy Work?

Several mechanisms likely play a role in the beneficial effects of vitrectomy on CSDME. Separation of the posterior hyaloid relieves vitreomacular traction in both the anteroposterior and tangential dimensions by creating a PVD. The premacular cortical vitreous is known to contain fibroblasts, astrocytes, and macrophages, and traction to the macula is relieved with removal of this potentially contractile tissue [48]. Vitreoschisis — or a split hyaloid — is frequently seen in eyes with refractory CSDME. Faulborn demonstrated that eyes with early PDR and macular traction have a high rate of vitreoschisis and histologic evidence of potentially contractile neovascularization into the posterior vitreous cortex [49]. Schwartz et al. later described a similar high rate of vitreoschisis in PDR eyes with traction [50]. Eyes with refractory CSDME likely have similar rates of vitreoschisis. Electron microscopy has shown multilayered sheets of potentially contractile vitreous and RPE cells in the epimacular posterior hyaloid tissue removed from CSDME eyes, and OCT studies have shown the reduction of edema following the relief of this tangentially oriented macular traction [51, 52].

Several authors have demonstrated the benefits of removing the internal limiting membrane (ILM) during vitrectomy for CSDME, without deleterious effects. Gandorfer et al. reported better VA and anatomic outcomes, faster CSDME resolution, and fewer recurrences of CSDME with ILM peeling than all previously published series that evaluated vitrectomy without specific ILM removal [39]. Kimura showed that ILM peeling led to resolution of CSDME and VA improvement in 100% of eyes that failed previous vitrectomy without ILM peeling for CSDME [53]. Because successful ILM removal *ensures* complete removal of the posterior hyaloid from the macula – a surgical endpoint that can be unknowingly elusive, particularly in cases of vitreoschisis – we feel ILM peeling should be safely attempted in all cases of vitrectomy for CSDME. Peeling of the ILM may also remove its intrinsic pathologic effects on the macula. The ILM in diabetic eyes contains increased levels of fibronectin, laminin, and collagen [54, 55], and peeled ILM specimens from CSDME eyes have been shown to be several times thicker than normal ILM, possibly contributing to pathologically altered fluid shifts between the vitreous and retina [56].

Vitrectomy may treat CSDME by other mechanisms as well. Higher vitreous levels of VEGF, intercellular adhesion molecule-1 (sICAM-1), interleuken-6 (IL-6), and other vasopermeable factors are seen in diffuse CSDME eyes than in control eyes, and their levels correlate with the severity of diabetic retinopathy, degree of angiographic hyperfluorescence, and central foveal thickness [57, 58]. Removal of vitreous filled with these permeability factors may contribute to the reduction of CSDME. Vitrectomy has also been shown to lead to an approximately ten-fold increase in postoperative vitreous cavity oxygenation [59], which may in turn improve oxygenation and perfusion of the retina and potentially aid in decreasing CSDME.

Vitrectomy has the potential to lead to long-lasting good outcomes for some eyes with refractory CSDME, and should be in the armamentarium of all vitreoretinal surgeons. Visual and anatomic improvements seen after vitrectomy tend to be more long-lasting than those seen after intravitreal pharmacologic therapy. More definitive indications for vitrectomy over steroid or anti-VEGF therapy include CSDME associated with clinically and OCT-demonstrated posterior hyaloidal traction, CSDME refractory to laser and repeated intravitreal pharmacologic treatments, and CSDME in eyes with complications of pharmacologic therapy. Larger multicenter, controlled, prospective, randomized trials (e.g., SCORE and DRCR.net, NEI/NIH) are needed to adequately demonstrate the efficacy of both vitrectomy and pharmacologic therapy for all types of refractory CSDME and, importantly, to compare treatment regimens against one another and to evaluate the effectiveness of combination therapies.

The use of 25-gauge vitrectomy techniques to treat CSDME is quickly becoming the treatment approach of choice because of the ease with which the surgical goals can be accomplished and the relatively limited amount of ocular trauma, inflammation, and resultant patient morbidity that is seen.

Summary for the Clinician

- For all NPDR and PDR indications, the main surgical goals are to: a) clear media opacities, and b) remove or relieve anteroposterior and tangential vitreoretinal traction.
- With new stiff instrumentation, wide-field viewing systems, and new light sources, surgeons can approach essentially all PDR, other than combined rhegmatogenous/tractional retinal detachment, with 25-gauge vitrectomy.
- Eyes with refractory CSDME are ideal candidates for 25-gauge vitrectomy, as they generally do not have extensive peripheral vitreoretinal traction.
- Several mechanisms likely play a role in the beneficial effects of vitrectomy on CSDME. Separation of the posterior hyaloid relieves vitreomacular traction.
- Peeling of the ILM may remove its intrinsic pathologic effects on the macula and ensures complete removal of the posterior hyaloid from the macula.
- Higher vitreous levels of vasopermeable factors are seen in diffuse CSDME eyes. Removal of vitreous filled with these permeability factors may contribute to the reduction of CSDME.
- Vitrectomy has also been shown to lead to an approximately ten-fold increase in postoperative vitreous cavity oxygenation [59], which may in turn improve the oxygenation and perfusion of the retina and potentially aid in decreasing CSDME.
- Visual and anatomic improvements seen after vitrectomy tend to be more long-lasting than those seen after intravitreal pharmacologic therapy.
- The use of 25-gauge vitrectomy techniques to treat CSDME is quickly becoming the treatment approach of choice, because of the ease with which the surgical goals can be accomplished and the relatively limited amounts of ocular trauma, inflammation, and resultant patient morbidity that are seen.

10.5 25-Gauge Vitrectomy for Proliferative Diabetic Retinopathy

The most important determinant of the type and severity of proliferative diabetic complications is the relationship between the posterior hyaloid and the retina. It is fundamentally important for a surgeon to understand the variety of vitreoretinal adhesions in PDR to precisely plan a surgical repair. Surgical indications for PDR have evolved over 35 years towards earlier intervention as techniques and instrumentation improve, surgeons gain more experience, and procedures become safer with fewer complications. The ability to less traumatically perform potentially safer vitrectomy with 25-gauge instrumentation and techniques has driven some of this change.

10.5.1 Vitreous Hemorrhage

Nonclearing VH is the most common proliferative diabetic indication for 25-gauge sutureless vitrectomy. Though the Diabetic Retinopathy Vitrectomy Study (DRVS) suggested that acute intervention at 6 months is better than intervention at 1 year [18, 21], most surgeons currently do not wait nearly as long to perform vitrectomy given the increased safety and ease of surgery [18, 21, 60–64], particularly with 25-gauge vitrectomy. Most now wait 4–6 weeks from presentation to allow spontaneous clearing of the hemorrhage, and generally prefer to follow parameters such as the amount and pace of improvement, the need to apply laser in the face of anterior segment neovascularization, status of the other eye, and patient employment and lifestyle issues, among others. Fortunately, the ubiquitous use of office-based panretinal photocoagulation has reduced the incidence of nonclearing VH. When seen, 25-gauge vitrectomy may be used to clear the media, insure complete removal of the posterior hyaloid, relieve post-equatorial traction, and apply panretinal photocoagulation.

10.5.2 Loculated Premacular Vitreous Hemorrhage

Active VH into a premacular space created by a small, localized posterior vitreous detachment over the posterior pole can result in loculated dense hemorrhage tightly pressed against sensitive macular tissue. Vision is significantly reduced, and concern develops over retinal toxicity from the adjacent blood and the promotion of surface wrinkling and traction of premacular tissue under the blood. Epiretinal membranes, vitreomacular traction, and even macular traction retinal detachments may then occur [22, 23]. These roundish loculations of blood may clear spontaneously if breakthrough occurs into the central vitreous cavity or if the PVD continues, which thereby allows spread of the blood away from the macular surface as a more diffuse VH that generally clears. If this does not occur within 3 to 4 weeks, 25-gauge vitrectomy is recommended to evacuate this blood by removing the posterior hyaloid, identifying neovascular sources,

relieving all epiretinal surface traction, and applying PRP. Such cases are generally straightforward, as the posterior hyaloid is usually partially separated—particularly in the area of the premacular hemorrhage.

10.5.3 Ghost-Cell Glaucoma

Ghost-cell glaucoma may complicate cases of very severe VH if degenerated nonclearing red blood cells (ghost cells) reduce or block aqueous outflow through the trabecular meshwork; hemolytic glaucoma exists if the trabecular meshwork is blocked by degenerated red cell debris or macrophages with debris. 25-gauge vitrectomy is indicated if the intraocular pressure is uncontrollably elevated despite medical intervention [12–16, 65, 66]. Aphakic eyes offer easy access for 25-gauge instruments to the anterior chamber. In pseudophakic eyes, an opening can be made in the posterior capsule with a 25-gauge vitrector to allow access to the abnormal cellular accumulations. A zonular defect may allow a rare phakic patient to develop this condition. A 25-gauge cannula can be introduced obliquely at the limbus to allow direct access to the anterior chamber for the 25-gauge vitreous cutter, and even the infusion line, to enable a washout of the anterior chamber.

10.5.4 Tractional Retinal Detachment

Contraction of fibrovascular proliferation along the retinal surface can lead to tractional retinal detachment, potentially affecting the macula. The posterior hyaloid is generally attached to the retina, epiretinal fibrous tissue, and at times the vitreous base. Vitrectomy can relieve the traction between these structures. Extramacular tractional retinal detachments, particularly when nasally located, are infrequently approached surgically, as they do not often progress into visually significant regions [77–79]. However, some may induce retinal folds into the macula because they are broadly attached to the macula by a taut posterior hyaloid, and such visually threatening tractional conditions continue to become more common 25-gauge surgical indications as the safety of surgical intervention improves [11, 60, 67–76].

If progressive fibrous contraction occurs, the traction at epicenters or along vessels can create retinal breaks that lead to a combined traction/rhegmatogenous retinal detachment [75, 80, 82]. The detachment often has both concave and convex regions, as areas of immobile tractionally-detached retina may be adjacent to mobile bullous retina that has underlying subretinal fluid in the rhegmatogenous component.

Vitrectomy is required to repair a combined traction/rhegmatogenous retinal detachment as soon as possible, to minimize vision loss and limit progression of proliferative vitreoretinopathy [83–85]. It is rare that the combined detachment would be limited to the post-equatorial retina. If it is, though, it may be managed with 25-gauge vitrectomy if the anterior retina is attached. Unfortunately, most times the detachment extends anteriorly and is nearly always associated with an attached posterior hyaloid. Many feel this type of surgical repair is among the most difficult cases in vitreoretinal surgery, and generally best approached with 20-gauge vitrectomy techniques. It requires a full array of stiffer instruments and the ability to move the eye to near full excursion during surgical manipulation. With the advent of stiffer-shafted instrumentation and higher speed (2,500 cpm) and higher flow vitreous cutters that can act similar to intraocular scissors, some surgeons have become much more comfortable with 25-gauge vitrectomy, even in cases with extensive peripheral pathology. Pars plana lensectomy for dense nuclear sclerosis is typically performed with 20-gauge instrumentation when done during diabetic vitrectomy, since no 25-gauge phacofragmotome currently exists. Lens cortex and smaller pieces of nucleus are, however, removable with 25-gauge instrumentation, again particularly with newer high-flow vitreous cutters, though they are generally removed in this way when they are dislocated into the posterior segment following cataract surgery.

10.5.4.1 Vitrectomy Procedure

Standard three-port 25-gauge transconjunctival sutureless vitrectomy with current instrumentation allows for bimanual surgery when indicated. An advantage of a cannulated entry system is that nonstandard port positions can be used in cases where access to difficult posterior segment locations is needed, and the infusion and two instrument cannulas may be interchanged depending on the access requirements (Fig. 10.6). I prefer using a lighted infusion cannula powered by a high-intensity xenon light source that provides diffuse peripheral lighting. I may also use a hand-held light pipe to obtain tangential illumination of posterior pole structures. I prefer high-speed vitrectomy with either an electrically driven vitreous cutter, cutting at 1,500 cuts/minute and using variable aspiration from 0–550 mm Hg, or a second-generation pneumatic cutter which cuts at speeds up to 2,500 cuts/minute with variable aspiration, as the cutting and flow characteristics have been shown by some investigators to be potentially superior to that of first-generation pneumatically-driven vitreous cutters operating at higher cut rates [86, 87].

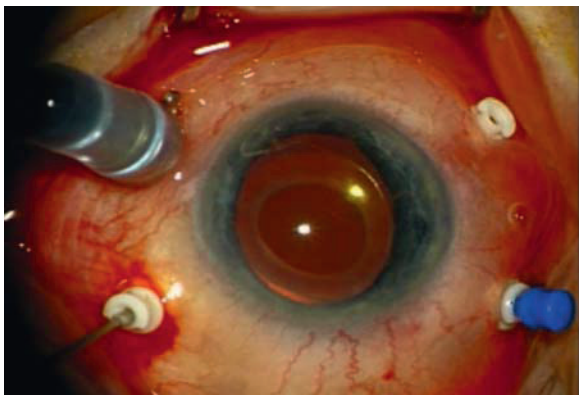


Fig. 10.6 Multiple cannulated 25-gauge ports allow for easy access to all peripheral locations. The use of a fourth illuminated infusion cannula enhances visualization and offers more access possibilities

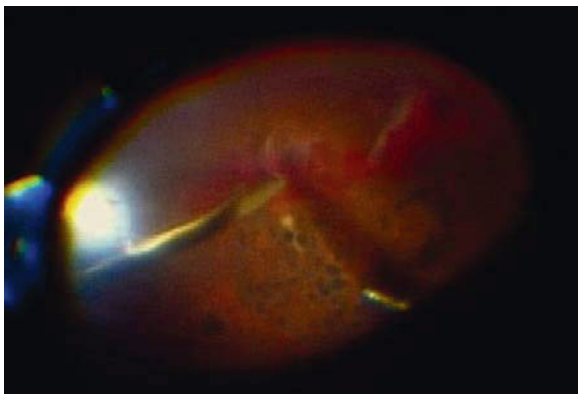


Fig. 10.7 Vitrectomy removal of the posterior vitreous base, posterior hyaloid, and hemorrhage with the aid of a lighted infusion cannula

The main surgical goals of diabetic vitrectomy are to clear the media and relieve traction. The pathologic relationships between the vitreous, specifically the posterior hyaloid, and the retina dictate the approach to vitrectomy in all diabetic eyes. Eyes with a complete preoperative PVD are less likely to need vitreous surgery. Without a hyaloidal attachment, vitreoretinal traction is generally not present, and a nonclearing VH is the typical surgical indication in such an eye. Even dense VH is successfully cleared with 25-gauge vitrectomy in most settings. Some investigators feel that the improved cutting and flow characteristics of an electrically-driven or second-generation pneumatically-driven 25-gauge vitreous cutter versus a first-generation pneumatically-driven 25-gauge vitreous cutter allow for more efficient clearing of the vitreous cavity in cases of thick VH [87]. An opening is created in the posterior hyaloid, and the cut edge is then followed peripherally to maximally and most efficiently remove vitreous. Current wide-field viewing and peripheral lighting systems allow the surgeon to visualize and remove an extensive amount of anterior vitreous, including the vitreous base in pseudophakic and aphakic eyes (Fig. 10.7). With scleral depression, the vitreous base may be trimmed in phakic eyes as well. Endolaser to focal areas of neovascular proliferation and PRP may be easily performed. A soft-tipped cannula, straight metal cannula, or even the small tip of the vitreous cutter can be used to remove layered pre-retinal hemorrhage.

If the posterior hyaloid is not completely detached from the retina, then the achievement of this separation becomes the first and potentially most important surgical goal. In most cases, the hyaloid is adherent to focal and broad areas of fibrovascular proliferation, though it may be elevated from the retinal surface elsewhere. Extensive membrane peeling techniques used to achieve separation of the posterior hyaloid are well described elsewhere [88]. The basic approaches fall into three categories: (1) segmentation—tractional attachments between the vitreous/posterior hyaloid and fibrovascular tissue/retina complexes are severed leaving isolated segments and no remaining vitreoretinal traction [89–91], (2) delamination—all attachments between the vitreous/posterior hyaloid and retina are severed and the fibrovascular tissue is entirely removed from the retinal surface [92], and (3) en bloc dissection—the vitreous body and all its adherent fibrovascular membranous tissue are removed together as a single unit [93–96]. Current peripheral lighting and new lighted 25-gauge handheld instruments allow any one of the three diabetic peeling techniques to be done with bimanual maneuvers. The high-speed 25-gauge vitreous cutter is much smaller than the 20-gauge vitreous cutter and can be used like a scissor, fitting into small spaces and cutting with little traction on the retina. It may be turned so its port is directed down into fibrovascular tissue to safely excise elevated areas of proliferation and traction (Figs. 10.8a, b). Forceps, scissors, picks, MVR blades, and tissue manipulators are used, as they are during 20-gauge vitrectomy. Some surgeons use intravitreally injected triamcinolone acetonide to stain the vitreous, particularly the posterior hyaloid, to make it more visible and easier to remove.

Once the posterior hyaloid has been identified, elevated, and entered, it can be carefully freed from the retina and all fibrovascular attachments. It may be necessary to use a sharp instrument like an MVR blade or lighted knife to enter the subhyaloid space if the posterior hyaloid is extremely adherent to the retina. Attachments from the anterior retina to posterior epicenters and the optic disc are severed, which then allows the surgeon to

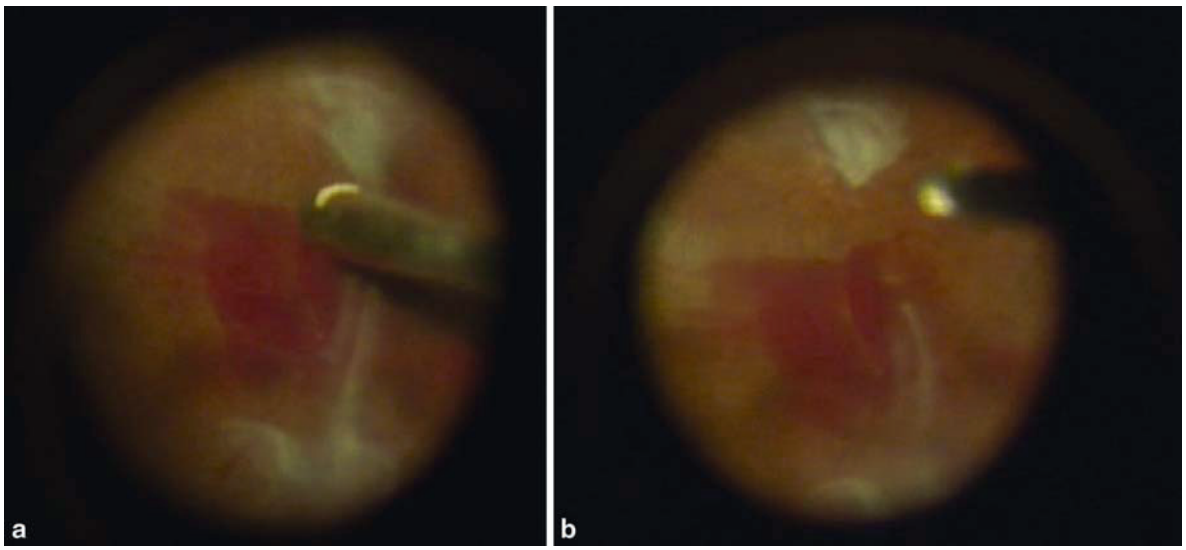


Fig. 10.8 (**a**) Small 25-gauge vitreous cutter tip just prior to cutting across tractional fibrovascular tissue. (**b**) Immediately after segmentation of tractional fibrovascular tissue with the 25-gauge cutter

manipulate posterior segment proliferation with various instruments without creating traction on the peripheral retina. This minimizes the risk of creating peripheral retinal tears and dialyses, and is a particularly important consideration in eyes in which the surgeon has a poor view of peripheral structures, as small iatrogenic breaks may be difficult to identify. There are 25-gauge horizontal scissors, lighted instruments, and others to aid in the dissection, which can now be done to the far periphery with good visualization. Some authors describe the use of hyaluronic acid to aid in the dissection [97–99], and this technique may be used during 25-gauge vitrectomy. Since the sclerotomies are cannulated, it is possible to move the infusion line from its usual inferotemporal location to a superior location and place the cutter or other instruments inferotemporally to enhance the approach to difficult-to-access areas.

Intraoperative hemorrhage is usually controllable with standard vitrectomy techniques. Intraocular pressure elevation, intraocular diathermy, and if severe, air, viscoelastics [98], liquid perfluorocarbon, or even thrombin [100,101] have been successfully used during 25-gauge diabetic vitrectomy.

As described earlier, vitreoschisis occurs commonly in diabetic eyes with proliferation, and must be identified so that the posterior hyaloid is completely removed from the retinal surface [49, 50, 102]. If the posterior split layer is left behind, traction will remain on fibrovascular sources and the surgical goals will not be realized.

If extensive anterior proliferation or tractional retinal detachment exists, particularly near the vitreous base, surgical manipulation of the pathologic tissue with 25-gauge instrumentation may be difficult because of the pliability of the instruments, although newer stiffer instruments continue to be developed. As it is imperative that all traction be removed, conversion of one or two 25-gauge ports to 20-gauge incision(s) is suggested by making a small cut in conjunctiva and enlarging the wound with a 20-gauge MVR blade (Figs. 10.9a–c). This simple step then allows the surgeon the flexibility to perform all vitreoretinal maneuvers needed to achieve the surgical goals, including lensectomy. If the phacofragmotome is used with a 25-gauge infusion line, the infusion pressure delivered by gas forced infusion or gravity must be elevated to near its maximum to maintain adequate infusion pressure to match the generated suction. If peripheral traction cannot be adequately relieved by vitreoretinal surgery, then an encircling scleral buckle may need to be placed. If this is disadvantageous because of significant pre-existing anterior segment ischemia, or if it is insufficient to relieve all traction, a relaxing retinotomy must be made.

Endolaser is applied to achieve thorough PRP after the media is cleared and all traction relieved. Wide-field viewing systems with peripheral lighting enable the surgeon to apply laser to the vitreous base. Extendable endolaser probes, used with or without additional scleral depression, aid in the application of peripheral laser, even to the ora serrata [103]; indirect laser may also be done to achieve treatment to the far periphery.

A depressed examination of the retinal periphery may be carefully performed at the completion of the vitrectomy to look for retinal tears or dialyses. The conjunctiva around the cannulas should be manipulated gently so it

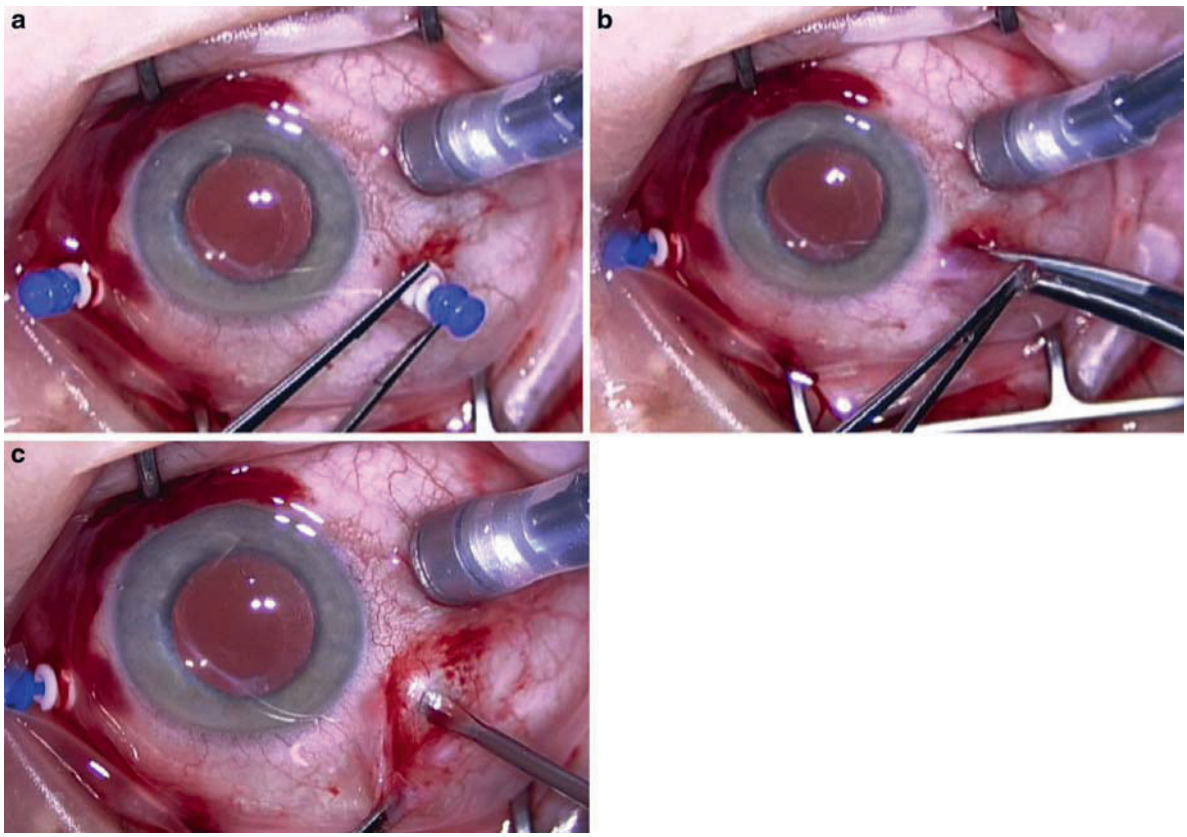


Fig. 10.9 (**a–c**) Removal of 25-gauge cannula, cut-down of conjunctiva to the sclera, and use of the MVR blade to convert one port to 20-gauge size

does not tear and so the conjunctival opening remains displaced from the scleral entry site as designed at the time of entry. However, the sclera can be adequately manipulated without dislodging the cannulas or damaging the self-sealing wounds. Retinal breaks must be freed from all traction, and then treated with laser retinopexy or cryotherapy. After the periphery is examined, an air–fluid exchange may be performed. Injecting SF6 or C3F8 gas through the infusion line and venting the air through an existing cannula allows for an easy air–gas exchange to achieve long-term tamponade. Alternatively, new silicone oil injection cannulas allow 1,000 cst silicone oil to be placed or removed during 25-gauge surgery without difficulty and with minimal increased surgical time.

Cases felt to require scleral buckling or pars plana lensectomy from the outset are best not approached with 25-gauge techniques, since the advantage of having sutureless incisions is lost. Similarly, cases with severe anterior fibrous proliferation or significant proliferative vitreoretinopathy associated with a combined tractional/rhegmatogenous retinal detachment are best approached with 20-gauge surgery from the beginning, as the instrument limitations and the inability to move the eye to its maximal excursion during peripheral dissection make 25-gauge vitrectomy insufficient to optimally treat these eyes.

At the completion of all vitrectomy steps, the cannulas are removed. Great care is taken to ensure that no significant wound leak exists. The anterior chamber should be left at normal depth. A pars plana injection of sterile air or a partial air–fluid exchange may be done to apply a short-lived tamponade to the sclerotomies if there is concern over a wound leak. A surgeon should have no hesitation to place a small suture to close a wound that is suspicious for a leak. Simply placing a single 7–0 vicryl suture will remove the fear of leaving a leaking sclerotomy, and make it so that concern over such a leak does not prevent a surgeon from using 25-gauge vitrectomy techniques.

Summary for the Clinician

- Nonclearing VH is the most common proliferative diabetic indication for 25-gauge sutureless vitrectomy.
- 25-gauge vitrectomy may be used to clear the media, insure complete removal of the posterior hyaloid, relieve post-equatorial traction, and apply panretinal photocoagulation.
- 25-gauge vitrectomy is recommended to eva-cuate this blood by removing the posterior hyaloid, identifying neovascular sources, relieving all epiretinal surface traction, and applying PRP.
- 25-gauge vitrectomy is indicated if the intraocular pressure is uncontrollably elevated despite medical intervention.
- In cases of tractional/rhegmatogenous RD, generally the best approach is with 20-gauge vitrectomy techniques. With the advent of stiffer-shafted instrumentation and higher speed (2,500 cpm) and higher flow vitreous cutters that can act similarly to intraocular scissors, some surgeons have become much more comfortable with 25-gauge vitrectomy

10.6 Complications

Post-diabetic vitrectomy complications commonly reported with 20-gauge vitrectomy (such as increased intraocular pressure, corneal epithelial defects, intraocular fibrin formation, and cataract formation/progression [88]) are also seen with 25-gauge vitrectomy, though theoretically some may occur less frequently because of the shorter duration of 25-gauge vitrectomy cases and the reduced amount of infusion fluid passed through the eye. More, and larger, series that report 25-gauge diabetic vitrectomy results are needed to verify this assertion. Anterior hyaloidal fibrous proliferation may occur in severely ischemic eyes, particularly in young phakic males with Type 1 diabetes. Fibrovascular tissue grows anteriorly from the peripheral retina onto the vitreous base and posterior lens capsule. Peripheral tractional retinal detachment results from this, and extensive vitrectomy, vitreous base dissection with pars plana lensectomy, and fill-in panretinal photocoagulation is required in these poor prognosis eyes [104]. The incidence of anterior hyaloidal fibrovascular proliferation is lower in eyes undergoing 25-gauge vitrectomy, as preoperative selection criteria likely prevent these eyes from being operated on with small-gauge instrumentation.

Summary for the Clinician

- Post-diabetic vitrectomy complications commonly reported with 20-gauge vitrectomy are also seen with 25-gauge vitrectomy.

10.7 Summary

The role of 25-gauge vitrectomy in the treatment of NPDR and PDR continues to expand. It is now the technique of choice for many surgeons for several diabetic indications as experience grows and instrumentation improves. Nonclearing VH and refractory CSDME are ideal candidates for 25-gauge sutureless vitrectomy. Glaucomatous eyes with functioning filtering blebs may be better approached with 25-gauge surgery to limit conjunctival manipulation. Proliferative pathology posterior to the equator, with or without tractional retinal detachment, has become significantly easier to approach, and may become another indication for which 25-gauge vitrectomy is the preferred technique as newer peripheral light sources and wide-field viewing systems become more ubiquitously available. Experienced 25-gauge surgeons are becoming comfortable approaching all but the most complex peripheral diabetic pathologies with 25-gauge vitrectomy, as they are armed with improved instrumentation and the realization that one, two, or all three ports may be easily converted from smaller cannulated 25-gauge incisions to standard 20-gauge incisions if necessary. Surgeons also more often realize that if they have concern over a leaking sclerotomy at the completion of a case, the wound may be simply closed with a single small absorbable suture. Reoperations following prior vitrectomy or scleral buckling are more often being done with 25-gauge techniques as surgeon experience has grown and it has been seen that the transconjunctival wounds in these eyes are, or can be made to be, self-sealing.

The majority of diabetic eyes that require vitrectomy may now be approached with 25-gauge surgical techniques. In the near future, further advancement of surgical instrumentation, pharmacologic adjuncts to surgery, and operative techniques will make 25-gauge vitrectomy more commonplace. Furthermore, the recent development and increasing popularity of 23-gauge vitrectomy techniques and instrumentation will continue to add to

the surgeon's armamentarium in the fight against diabetic retinopathy. Office-based pharmacologic therapy of diabetic macular edema and neovascularization will be increasingly investigated, and will likely become a more integral part of the management of diabetic retinopathy. This may result in fewer required vitrectomies in the future, and may make eyes that do need surgery more likely to be optimized for a good outcome. The advantages of 25-gauge vitrectomy—decreased scleral trauma, postoperative inflammation, and postoperative pain and discomfort, as well as faster patient recovery and a low incidence of postoperative complications—are contributing to the trend for earlier surgical intervention for a number of diabetic indications.

Current 25-gauge vitrectomy techniques equip surgeons to better care for patients. They will likely become more widely used as the surgical goals for diabetic vitrectomy evolve from visual and anatomic stabilization to the efficient, and minimally traumatic, delivery of timely visual improvement and long-term anatomic repair.

References

1. Machemer R, Buettner H, Norton EWD et al (1971) Vitrectomy: a pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 75:813–820
2. Breedveld P, Stasen HG, Meijer DW et al (2000) Observation in laparoscopic surgery: Overview of impeding effects and supporting aids. J Laparoendosc Adv Surg Tech A 10:231–241
3. Lundell L (2000) Anti-reflux surgery in the laparoscopic era. Baillieres Best Pract Res Clin Gastroenterol 14:793–810
4. Dunn Md, Clayman RV (2000) Laparoscopic management of renal cystic disease. World J Urol 18:272–277
5. Koh CH, Janik GM (1999) Laparoscopic microsurgery: current and future status. Curr Opin Obstet Gynecol 11:401–407
6. Fujii G, de Juan E Jr, Humayun MS et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1812
7. Fujii GY, de Juan E Jr, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:814–820
8. Yanyali A, Celik E, Horozoglu F, Oner S, Nohutcu AF (2006) 25-Gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16(1):141–147
9. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou TJ (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112(5):817–824
10. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139(5):831–836
11. Aaberg TM, Abrams GW (1987) Changing indications and techniques for vitrectomy in management of complications of diabetic retinopathy. Ophthalmology 94:775–779
12. Brucker AJ, Michels RG, Green WR (1978) Pars plana vitrectomy in the management of blood-induced glaucoma with vitreous hemorrhage. Ann Ophthalmol 10: 1427–1437
13. Campbell DG, Simmons RJ, Grant WM (1976) Ghost cells as a cause of glaucoma. Am J Ophthalmol 81:441–450
14. Campbell DG, Simmons RJ, Tolentino FI et al (1977) Glaucoma occurring after closed vitrectomy. Am J Ophthalmol 83:63–69
15. Weinberg RS, Peyman GA, Huamonte FU (1976) Elevation of intraocular pressure after pars plana vitrectomy. Graefes Arch Clin Exp Ophthalmol 200:157–161
16. Wilensky JT, Goldberg MF, Alward P (1977) Glaucoma after pars plana vitrectomy. Trans Am Acad Ophthalmol Otolaryngol 83:114–121
17. Diabetic Retinopathy Vitrectomy Study Research Group (1985) Early vitrectomy for severe vitreous hemorrhage in diabetic retinopathy: two-year course of visual acuity in severe proliferative diabetic retinopathy with conventional management. Diabetic Retinopathy Vitrectomy Study Report 1. Ophthalmology 92:492–502
18. Diabetic Retinopathy Vitrectomy Study Research Group (1985) Early vitrectomy for severe vitreous hemorrhage in diabetic retinopathy: two-year results of a randomized trial. Diabetic Retinopathy Vitrectomy Study Report 2. Arch Ophthalmol 103:1644–1652
19. Diabetic Retinopathy Vitrectomy Study Research Group (1988) Early vitrectomy for severe proliferative diabetic retinopathy in eyes with useful vision: results of a randomized trial. Diabetic Retinopathy Vitrectomy Study Report 3. Ophthalmology 95:1307–1320
20. Diabetic Retinopathy Vitrectomy Study Research Group (1988) Early vitrectomy for severe proliferative diabetic retinopathy in eyes with useful vision: clinical application of results of a randomized trial. Diabetic Retinopathy Vitrectomy Study Report 4. Ophthalmology 95:1321–1334
21. Diabetic Retinopathy Vitrectomy Study Research Group (1990) Early vitrectomy for severe vitreous hemorrhage in diabetic retinopathy: four year results of a randomized trial. Diabetic Retinopathy Vitrectomy Study Report 5. Arch Ophthalmol 108:958–964
22. O'Hanley GP, Cann CLB (1985) Diabetic dense premacular hemorrhage: a possible indication for prompt vitrectomy. Ophthalmology 92:507–511
23. Ramsay RC, Knobloch WH, Cantrill HL (1986) Timing of vitrectomy for active proliferative diabetic retinopathy. Ophthalmology 93:283–289
24. Lewis H, Abrams GW, Blumenkranz MS et al (1992) Vitrectomy for diabetic macular traction and edema associated with posterior hyaloidal traction. Ophthalmology 99:753–759
25. Kroll P, Wiegand W, Schmidt J (1999) Vitreopapillary traction in proliferative diabetic retinopathy. Br J Ophthalmol 83:261–264

26. McLeod D (1999) Diabetic tractional papillopathy: a new (and true) nosological entity? Br J Ophthalmol 83:257–258
27. Klein R, Klein BE, Moss SE, Davis MD, DeMets DL (1984) The Wisconsin epidemiologic study of diabetic retinopathy, IV: diabetic macular edema. Ophthalmology 91:1464–1474
28. Ferris FL, Patz A (1984) Macular edema: a complication of diabetic retinopathy. Surv Ophthalmol 28(suppl):452–461
29. Early Treatment Diabetic Retinopathy Study Report Number 1 (1985) Photocoagulation for diabetic macular edema. Arch Ophthalmol 103:1796–1806
30. Lee CM, Olk RJ (1981) Modified grid laser photocoagulation for diffuse diabetic macular edema: long-term visual results. Ophthalmology 98:1594–1602
31. Schepens CL, Avila MP, Jalkh AE, Trempe CL (1984) Role of the vitreous in cystoid macular edema. Surv Ophthalmol 28(suppl):499–504
32. Nasrallah FP, Jalkh AE, Van Coppenolle F et al (1988) The role of the vitreous in diabetic macular edema. Ophthalmology 95:1335–1339
33. Hikichi T, Fujio N, Akiba J, Azuma Y, Takahashi M, Yoshida A (1997) Association between the short-term natural history of diabetic macular edema and the vitreomacular relationship in type II diabetes mellitus. Ophthalmology 104:473–478
34. Kelly NE, Wendel RT (1991) Vitreous surgery for idiopathic macular holes: results of a pilot study. Arch Ophthalmol 109:654–659
35. Kaiser PK, Riemann CD, Sears JE, Lewis H (2001) Macular traction detachment and diabetic macular edema associated with posterior hyaloidal traction. Am J Ophthalmol 131:44–49
36. Van Effenterre G, Guyot-Argenton C, Guiberteau B, Hany I, Lacotte JL. [Macular edema caused by contraction of the posterior hyaloid in diabetic retinopathy: Surgical treatment of a series of 22 cases]. J Fr Ophthalmol 16:602–610
37. Harbour JW, Smiddy WE, Flynn HW Jr, Rubsamen PE (1996) Vitrectomy for diabetic macular edema associated with a thickened and taut posterior hyaloid membrane. Am J Ophthalmol 121:405–413
38. Pendergast SD, Hassan TS, Williams GA, Cox MS, Margherio RR, Ferrone PJ, Garretson BR, Trese MT (2000) Vitrectomy for diffuse diabetic macular edema associated with a taut premacular posterior hyaloid. Am J Ophthalmol 130:178–186
39. Gandorfer A, Messmer EM, Ulbig MW, Kampik A (2000) Resolution of diabetic macular edema after surgical removal of the posterior hyaloid and the inner limiting membrane. Retina 20:126–133
40. Tachi N, Ogino N (1996) Vitrectomy for diffuse macular edema in cases of diabetic retinopathy. Am J Ophthalmol 122:258–260
41. Kadonosono K, Itoh N, Ohno S (2000) Perifoveal microcirculation before and after vitrectomy for diabetic cystoid macular edema. Am J Ophthalmol 130:740–744
42. Ikeda T, Sato K, Katano T, Hayashi Y (1999) Vitrectomy for cystoid macular oedema with attached posterior hyaloid membrane in patients with diabetes. Br J Ophthalmol 83:12–14
43. Otani T, Kishi S (2001) Tomographic findings of foveal hard exudates in diabetic macular edema. Am J Ophthalmol 131:50–54
44. Ikeda T, Sato K, Katano T, Hayashi Y (1999) Attached posterior hyaloid membrane and the pathogenesis of honeycombed cystoid macular edema in patients with diabetes. Am J Ophthalmol 127:478–479
45. La Heij EC, Hendrikse F, Kessel AG, Derhaag PJ (2001) Vitrectomy results in diabetic macular oedema without evident vitreomacular traction. Graefes Arch Clin Exp Ophthalmol 239:264–270
46. Yamamoto T, Akabane N, Takeuchi S (2001) Vitrectomy for diabetic macular edema: the role of posterior vitreous detachment and epimacular membrane. Am J Ophthalmol 132:369–377
47. Otani T, Kishi S (2002) A controlled study of vitrectomy for diabetic macular edema. Am J Ophthalmol 134(2):214–219
48. Kishi S, Shimizu K (1993) Clinical manifestations of posterior precortical vitreous pocket in proliferative diabetic retinopathy. Ophthalmology 100:225–229
49. Faulborn J, Bowald S (1985) Microproliferations in proliferative diabetic retinopathy and their relationship to the vitreous: corresponding light and electron microscopic studies. Graefes Arch Clin Exp Ophthalmol 223: 130–138
50. Schwartz SD, Alexander R, Hiscott P, Gregor ZJ (1996) Recognition of vitreoschisis in proliferative diabetic retinopathy. A useful landmark in vitrectomy for diabetic traction retinal detachment. Ophthalmology 103:323–328
51. Jumper JM, Embabi SN, Toth CA, McCuen BW, Hatchell DL (2000) Electron immunocytochemical analysis of posterior hyaloid associated with diabetic macular edema. Retina 20:63–68
52. Gandorfer A, Rohleder M, Grosselfinger S, Haritoglou C, Ulbig M, Kampik A (2005) Epiretinal pathology of diffuse diabetic macular edema associated with vitreomacular traction. Am J Ophthalmol 139:638–652
53. Kimura T, Kiryu J, Nishiwaki H, Oh H, Suzuma K, Watanabe D, Kurimoto M, Takagi H (2005) Efficacy of surgical removal of the internal limiting membrane in diabetic cystoid macular edema. Retina 25(4):454–461
54. Kohno T, Sorgente N, Doodnight R, Ryan SJ (1987) Alterations in the distribution of fibronectin and laminin in the diabetic human eye. Invest Ophthalmol Vis Sci 28:515–521
55. Ljubimov AV, Burgeson RE, Butkowski RJ, Couchman JR, Zardi L, Ninomiya Y, Sado Y, Huang ZS, Nesburn AB, Kenney MC (1996) Basement membrane abnormalities in human eyes with diabetic retinopathy. J Histochem Cytochem 44:1469–1479
56. Matsunaga N, Ozeki H, Hirabayashi Y, Shimada S, Ogura Y (2005) Histopathologic evaluation of the internal limiting membrane surgically excised from eyes with diabetic maculopathy. Retina 25:311–316
57. Funatsu H, Yamashita H, Sakata K, Noma H, Mimura T, Suzuki M, Eguchi S, Hori S (2005) Vitreous levels of vascular endothelial growth factor and intercellular

adhesion molecule 1 are related to diabetic macular edema. Ophthalmology 112:806–816
58. Funatsu H, Yamashita H, Ikeda T, Mimura T, Eguchi S, Hori S (2003) Vitreous levels of interleukin-6 and vascular endothelial growth factor are related to diabetic macular edema. Ophthalmology 110:1690–1696
59. Holekamp NM, Shui YB, Beebe DC (2005) Vitrectomy surgery increases oxygen exposure to the lens: a possible mechanism for nuclear cataract formation. Am J Ophthalmol 139:302–310
60. Peyman GA, Huamonte FU, Goldberg MF et al (1978) Four hundred consecutive pars plana vitrectomies with the vitreophage. Arch Ophthalmol 96:45–50
61. Blankenship GW (1982) Preoperative prognostic factors in diabetic pars plana vitrectomy. Ophthalmology 89:1246–1249
62. Machemer R, Hickinbotham D (1985) The three-port microcannular system for closed vitrectomy. Am J Ophthalmol 100:590
63. Thompson JT, Auer CL, de Bustros S et al (1986) Prognostic indicators of success and failure in vitrectomy for diabetic retinopathy. Ophthalmology 93:290
64. Ho T, Smiddy WE, Flynn HW (1992) Vitrectomy in the management of diabetic eye disease. Surv Ophthalmol 37:190–202
65. Han DP, Lewis H, Lambrou FH et al (1989) Mechanisms of intraocular pressure elevation after pars plana vitrectomy. Ophthalmology 96:1357
66. Singh H, Grand MG (1981) Treatment of blood-induced glaucoma by trans pars plana vitrectomy. Retina 1:255–257
67. Aaberg TM (1979) Clinical results in vitrectomy for diabetic traction retinal detachment. Am J Ophthalmol 88:246–253
68. Aaberg TM (1981) Pars plana vitrectomy for diabetic traction retinal detachment. Ophthalmology 88:639–642
69. Hutton WL, Bernstein I, Fuller D (1980) Diabetic traction retinal detachment. Ophthalmology 87:1071
70. Michels RG (1978) Vitrectomy for complications of diabetic retinopathy. Arch Ophthalmol 96:237
71. Miller SA, Butler JB, Myers FL et al (1980) Pars plana vitrectomy: treatment for tractional macula detachment secondary to proliferative diabetic retinopathy. Arch Ophthalmol 98:659–664
72. Packer AJ (1987) Vitrectomy for progressive macular traction associated with proliferative diabetic retinopathy. Arch Ophthalmol 105:1679–1683
73. Ratner CM, Michels RG, Auer C et al (1983) Pars plana vitrectomy for complicated retinal detachments. Ophthalmology 90:1323
74. Rice TA, Michels CM, Rice EF (1983) Vitrectomy for diabetic traction retinal detachment involving the macula. Am J Ophthalmol 95:22–33
75. Tolentino FI, Freeman HM, Tolentino FL (1980) Closed vitrectomy in the management of diabetic traction retinal detachment. Ophthalmology 87:1078–1089
76. Thompson JT, de Bustros S, Michels RG et al (1987) Results and prognostic factors in vitrectomy for diabetic traction retinal detachment of the macula. Arch Ophthalmol 105:497–502
77. Charles S, Flinn CE (1981) The natural history of diabetic extramacular traction retinal detachment. Arch Ophthalmol 99:66–68
78. Cohen HB, McMeel JW, Franks EP (1979) Diabetic traction detachment. Arch Ophthalmol 97:1268
79. Spencer R, McMeel JW, Franks EP (1981) Visual outcome in moderate and severe proliferative diabetic retinopathy. Arch Ophthalmol 99:1551
80. Blankenship GW (1983) Posterior retinal holes secondary to diabetic retinopathy. Arch Ophthalmol 101:885
81. Gragoudas E, McMeel JW (1976) Treatment of rhegmatogenous retinal detachment secondary to proliferative diabetic retinopathy. Am J Ophthalmol 81:810–819
82. Morse LS, Chapman CB, Eliott D et al (1997) Subretinal hemorrhages in proliferative diabetic retinopathy. Retina 17:87–93
83. Thompson JT, de Bustros S, Michels RG et al (1983) Results and prognostic factors in vitrectomy for diabetic traction-rhegmatogenous retinal detachment. Arch Ophthalmol 105:503
84. Yeo JH, Glaser BM, Michels RG (1987) Silicone oil in the treatment of complicated retinal detachments. Ophthalmology 94:1109
85. Federman JL, Schubert HD (1988) Complications associated with the use of silicone oil in 150 eyes after retina-vitreous surgery. Ophthalmology 95:870
86. Ferrone PJ (2004) In vivo flow analysis of different 20 and 25 gauge vitrectomy systems. In: Annual Meeting of the American Society of Retina Specialists. New York, NY
87. Hassan TS (2006) A head-to-head clinical comparison of flow rates: Electrically-driven vs pneumatically-driven 25 gauge high-speed vitreous cutters. In: Annual Meeting of the American Society of Retina Specialists. Cannes, France
88. Eliott D, Lee MS, Abrams GW (2005) Proliferative diabetic retinopathy: principles and techniques of surgical treatment. In: Ryan SJ (ed) Retina, 4th edn. Mosby, St. Louis, pp 2413–2449
89. Machemer R (1975) Vitrectomy in diabetic retinopathy removal of preretinal proliferations. Trans Am Acad Ophthalmol Otolaryngol 79:394
90. Michels RG (1981) Vitrectomy for diabetic retinopathy: pathophysiology of extraretinal complications and principles of vitreous surgery. Retina 1:1
91. Meredith TA, Kaplan HJ, Aabert TM (1980) Pars plana vitrectomy techniques for relief of epiretinal traction by membrane segmentation. Am J Ophthalmol 89:408
92. Charles S (1987) Vitreous microsurgery, 3rd edn. Williams & Wilkins, Baltimore, MD
93. Abrams GW (1994) En bloc dissection techniques in vitrectomy for diabetic retinopathy. In: Lewis H, Ryan SJ (eds) Medical and surgical retina: advances, controversies, and management. Mosby, St. Louis, pp 304–320
94. Abrams GW, Williams GA (1987) "En bloc" excision of diabetic membranes. Am J Ophthalmol 103:302

95. Han DP, Murphy ML, Mieler WF (1984) A modified en bloc excision technique during vitrectomy for diabetic traction retinal detachment: results and complications. Ophthalmology 101:803–808
96. Williams DF, Williams GA, Hartz A et al (1989) Results of vitrectomy for diabetic traction retinal detachments using the en bloc excision technique. Ophthalmology 96:752–758
97. McLeod D, James CR (1988) Viscodelamination at the vitreoretinal juncture in severe diabetic eye disease. Br J Ophthalmol 72:413
98. Packer AJ, Folk JC, Weingeist TA et al (1985) Procoagulant effects of intraocular sodium hyaluronate. Am J Ophthalmol 100:479
99. Stenkula S, Ivert L (1984) Sodium hyaluronate (Healon) as an intravitreal aid in retinal and vitreous surgery. J Ocular Ther Surg 3:109
100. de Bustros S, Glaser BM, Johnson MA (1985) Thrombin infusion for the control of intraocular bleeding during vitreous surgery. Arch Ophthalmol 103:837
101. Thompson JT, Glaser BM, Michels RG et al (1986) The use of intravitreal thrombin to control hemorrhage during vitrectomy. Ophthalmology 93:279
102. Chu TG, Lopez PF, Cano MR et al (1996) Posterior vitreoschisis: an echographic finding in proliferative diabetic retinopathy. Ophthalmology 103:315–322
103. Friedman R (1988) Scleral depression to facilitate endophotocoagulation. Arch Ophthalmol 1988; 106:721
104. Lewis H, Abrams GW, Williams GA (1987) Anterior hyaloidal fibrovascular proliferation after diabetic vitrectomy. Am J Ophthalmol 104:607

Chapter 11

Small-Gauge Vitrectomy for Retinal Detachment

F. Patelli, P. Radice

Core Message

- With the advent of new surgical techniques, the approach of rhegmatogenous retinal detachment is changing
- Small-gauge vitrectomy could be the first choice for threating primary rhegmatogenous retinal detachment
- 23-gauge seems to be better than 25-gauge for complicated cases such as proliferative vitreoretinopathy

11.1 Historical Perspective

The management of retinal detachment (RD) dates from 1919 when Jules Gonin performed the first operation based on location of the break, drainage of subretinal fluid, and coagulation of the choroids and retina by thermocautery [1]. From this beginning, techniques for RD have changed and developed continuously, and the surgical success rate has improved enormously.

In 1938 Rosengren injected air into the vitreous to tamponade the retinal break after diathermy treatment and subretinal fluid drainage [2]; reattachment was successful in 76% of the cases. Scleral indentation ("buckling"), introduced by Custodis in 1949, is second in importance only to Gonin's contributions in the history of RD. He treated all breaks with surface diathermy, then closed them with an explant sewn to the sclera overlying the breaks [3]; 84% of his cases were cured. The next major advance in explant technique was made by Lincoff, who adapted cryotherapy for retinal surgery, and by Schepens [4–8]. The advent of closed vitrectomy, introduced by Robert Machemer in the early 1970s, changed the approach to RD [9].

There has also been rapid, extensive improvement in instrumentation, giving better results, or the same outcome with less invasive approaches [10, 11]. With the introduction of mini-invasive surgery, by Fujii and de Juan for the 25-gauge system [12, 13] and by Eckardt with the 23-gauge approach [14], vitrectomy became considerably less traumatic. This led many vitreoretinal surgeons to select vitrectomy as the first option for dealing with rhegmatogenous RD, rather than buckling. For detachments where vitrectomy is necessary, mini-invasive systems are gradually taking over from the traditional 20-gauge approach.

This chapter will assess the pros and cons of mini-invasive vitrectomy for RD compared with surgical buckling or encircling, and the 20-gauge technique.

11.2 Uncomplicated Primary Rhegmatogenous Retinal Detachment

11.2.1 Small-Gauge Vitrectomy vs Scleral Buckle

For uncomplicated primary rhegmatogenous RD, the preferred treatment until a few years ago was scleral buckling or encircling. If this failed, or relapse occurred, vitrectomy was the safest procedure, often the only one. Recent advances in vitrectomy technique have encouraged vitreoretinal surgeons to expand the role of primary pars plana vitrectomy in the management of uncomplicated RDs [15–17]. Primary vitrectomy especially has been considered as first-line surgical treatment in cases of pseudophakic and aphakic RD [18–23]. The rationale for such an approach includes the ability to remove vitreous opacities, and retinal pigment epithelial cells, while allowing controlled drainage of subretinal fluid. Other potential advantages of primary vitrectomy in these cases may be the ability to visualize small retinal breaks with or without simultaneous scleral depression and appropriate application of retinopexy.

A meta-analysis study about the management of pseudophakic RD emphasized a superior visual recovery after vitrectomy technique compared to conventional scleral buckling [24, 25]. With the advent of small-gauge surgery, the reduced surgical trauma has induced many surgeons to approach even phakic eyes with primary pars plana vitrectomy. The theoretical advantages of this technique, even if not proved yet, are less trauma to the eye wall, no muscles manipulation, none of the risks of draining subretinal fluid through the sclera, no effects on refraction, and better control of intraoperative ocular pressure.

A greater risk of cataract formation in phakic eyes is possible, even though not proved, while the risk of PVR is still controversial. Some authors suggest the strongest risk of PVR occurs when the vitrectomy is performed [26], while others hypothesize that removal of the vitreous traction bands and RPE cells may decrease the rate of postoperative PVR [20, 27]. One of the disadvantages of small-gauge vitrectomy is more costly materials.

11.2.2 Surgical Technique

11.2.2.1 Preoperatively

Anesthesia

Anesthesia for small-gauge vitrectomy follows the same rules as the 20-gauge approach. Peribulbar or retrobulbar local anesthesia is the method usually recommended. Topical anesthesia may be contemplated for vitrectomy only involving the vitreous, not requiring fine intraocular movements on the retina.

Complications: besides the general ones that must be borne in mind with any local ocular anesthesia, for small-gauge vitrectomy it is very important to prevent any eye movement. Since small-gauge surgical instruments (above all, 25-gauge) are not rigid, the surgeon cannot completely control eye movements.

Another aspect, though less important, is conjunctival swelling caused by the anesthetic injected around the eye. This is fairly frequent, and can be problematic with this technique. The swollen conjunctiva makes it difficult to assess precisely the entrance sites for the trocars, and the swelling can push a cannula out, but the main thing is that the surgeon cannot assess the sclerotomy properly at the end of the operation, and may not notice leakage that can cause troublesome postoperative hypotony.

Preparation of the Eye

The eye should be prepared following all the rules for disinfection and sterility of a normal vitrectomy. The only particular requirement for small-gauge vitrectomy is that the globe must be well exposed. If it is not, or if the lid speculum is not open wide enough, the cannulas may bend and escape during the operation because of contact with either the lid speculum or the eyelids.

11.2.2.2 Operatively

While the 23-gauge system is similar to 20-gauge in terms of intraocular flow rate and parameter setting, the 25-gauge vitrectomy system differs from the 20-gauge approach with regard to the intraocular flow rate during surgery. This is why complete vitrectomy takes longer than with the 20-gauge technique. It is very important to make sure the vitreous is not pushed out through the cannulas, so close attention to the infusion pressure is vital.

The parameters for 25-gauge vitrectomy are set differently from the 20-gauge operation. The infusion and aspiration flow rates are up to six times lower. The infusion pressure is kept fairly low when aspiration is not active, but must be raised during vitrectomy so as to keep a constant intraocular pressure (IOP). The recommended settings for the Accurus system (Alcon®) are: infusion pressure 20 mmHg in the non-aspiration phase, 45 mmHg when aspiration is on. The VGFI (Vented Gas Forced Infusion) system ensures excellent, immediate control of the pressure during this surgery.

With the aspiration/proportional cut system, the vacuum ranges from 100 at the beginning of the pedal to 600 at the end of the pedal, and cut ranges from 1,500 cpm (cuts per minute) at the beginning of the pedal to 600 cpm at the end of the pedal.

The cannula should be closed while the instruments are introduced. Once they are in, during central vitrectomy infusion pressure is raised to 45 mmHg with maximum vitrectome aspiration (vacuum 600).

The traditional three-way vitrectomy approach is an excellent approach. It follows the rules used in the 20-gauge technique, except for the parameters setting, as explained above.

I personally prefer a different technique. I employ a two-port vitrectomy technique, with one trocar for infusion and the other for instruments. The new photon source is employed for illumination, using the chandelier, or infusion plus lighting. The advantage of the two-way approach is that it leaves one hand completely free, so it can be used to indent or apply cryotherapy to breaks.

This technique is indicated only for primary rhegmatogenous RD, without proliferative vitreoretinopathy (PVR); vitreous debris or tobacco dust are inclusion criteria [27]. The infusion cannula is inserted 3.5 mm from the limbus infero-temporally or infero-nasally,

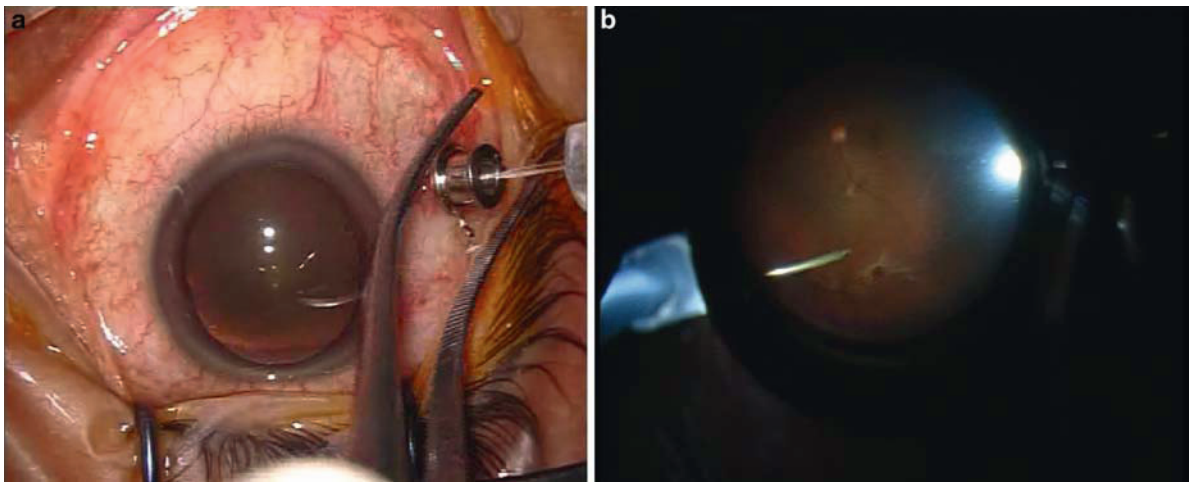


Fig. 11.1 (**a**) Intraoperative picture of a 25-gauge light + infusion trocar. (**b**) The 25-gauge light + infusion system illuminates the vitreous cavity well during surgery

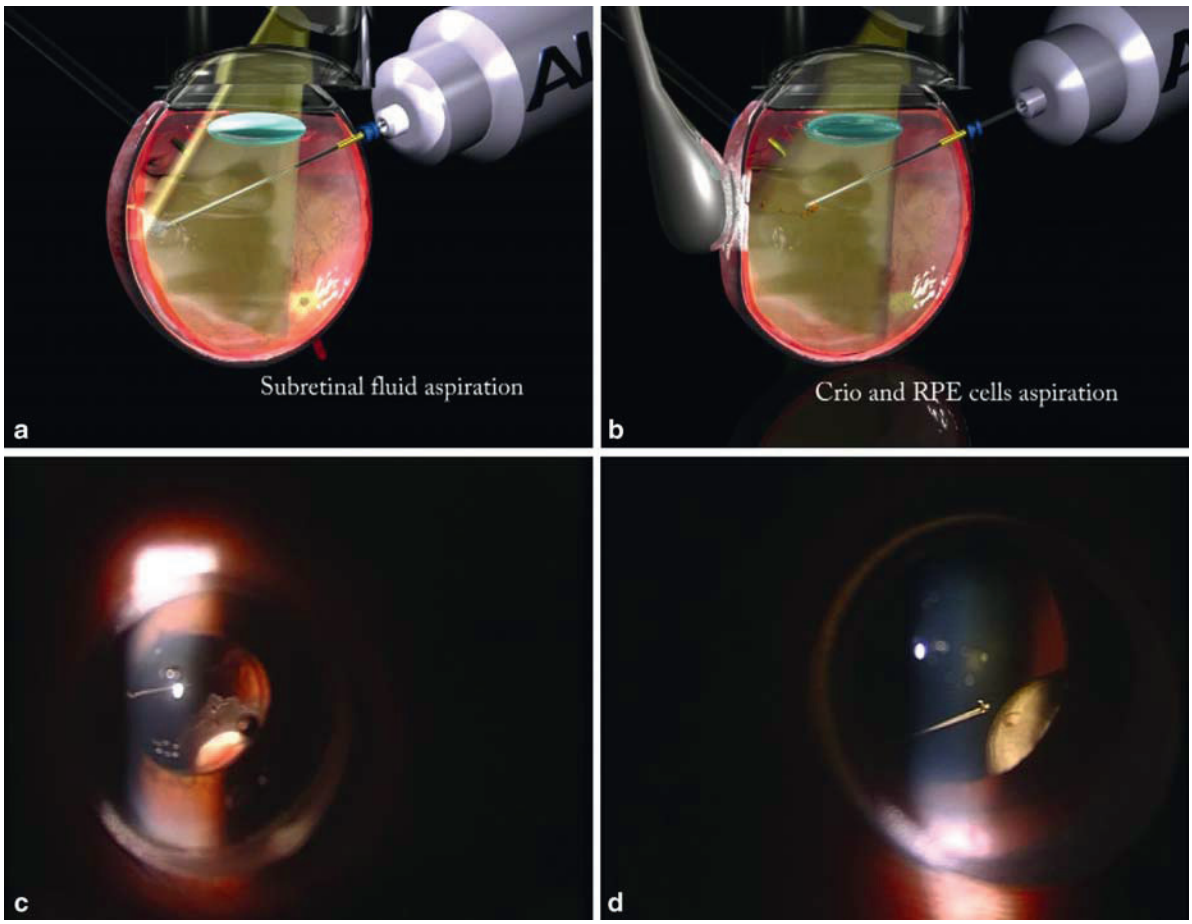


Fig. 11.2 (**a**) Drawing of an eye showing subretinal fluid aspiration through the retinal break using the vitrectome aspiration system. (**b**) Drawing of an eye representing transconjunctival cryotherapy over the retinal break. The RPE cells from the cryo-treatment are aspirated with the vitrectome during the procedure. (**c**, **d**) Intraoperative picture representing transconjunctival cryotherapy over the retinal break. The RPE cells from the cryo-treatment are aspirated with the vitrectome during the procedure. A 30° contact lens and a slit lamp are used as illuminating system

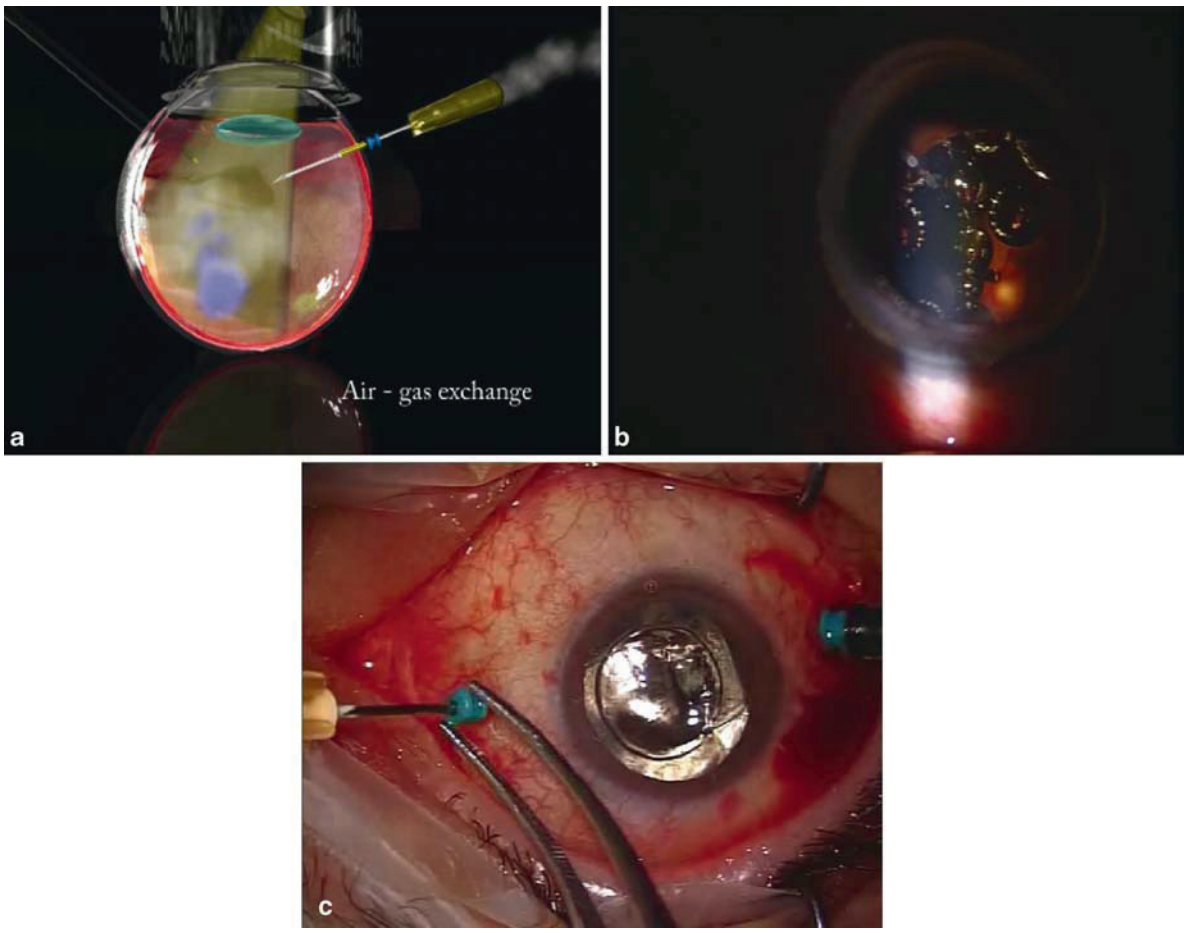


Fig. 11.3 (**a**) Drawing of an eye showing air–gas exchange. Gas (*blue*) is injected through the infusion line while air (*white*) is passively removed through the cannula using a 27-gauge needle. (**b**) Intraoperative picture showing air bubbles during the air–gas exchange. (**c**) Intraoperative picture of the air–gas exchange procedure explained in a above

opposite the retinal tear(s), and the trocar for vitrectomy is introduced in the supero-temporal or supero-nasal quadrant, also opposite the tear(s). To visualize the vitreous, the chandelier or infusion + light can be employed, with a photon light source (Fig. 11.1). The vitreous is completely removed, since a partial vitrectomy does not seem adequate for a good surgical result. Once the vitreal traction on the break(s) is relieved with vitrectome, transconjunctival cryotherapy is applied to the break(s) and subretinal fluid is aspirated with the cutter (Fig. 11.2). Endolaser retinopexy is an excellent alternative. At the end of the vitrectomy, fluid–air exchange is done using the cutter's suction system. The eye is then filled with 16% C_2F_6 gas through the infusion cannula, and the air is removed through the cannula using a 27-gauge needle (Fig. 11.3). The trocars are withdrawn, and subconjunctival steroid is injected at the end of the procedure. The patient is specially positioned for a few days.

Either the 25- or the 23-gauge system can be used for this approach. The vitreous can certainly be removed faster with the latter and silicone oil can be injected easily, if needed, whereas it is laborious and time-consuming with the 25-gauge system. Silicone is best injected under air, through the sclera.

11.2.2.3 End of Surgery

Make sure the ocular tone is satisfactory before removing the cannulas. Check the cannula infusion pressure to be sure. Clamp the infusion cannula before removing the surgical instruments. First remove the instruments cannulas, then—last—the infusion cannula. Withdraw the cannulas with forceps, pulling gently and tamponing the sclerotomy with a swab.

Do not press on the sclerotomy, and hold the swab in place for only a few seconds.

Before withdrawing the infusion cannula, check that there is no leakage from the sclerotomy and that the tone is normal.

Summary for the Clinician

- Advantages of small-gauge vitrectomy over scleral buckle:
  - Less trauma to the conjunctiva and sclera, no need for conjunctival peritomy
  - No manipulation of extraocular muscles, therefore less risk of postoperative strabismus
  - None of the risks of draining subretinal fluid through the sclera
  - No effects on refraction
  - Better control of intraoperative tone
  - Elimination of vitreous traction and opacity, with less risk of macular pucker.
- Disadvantages of small gauge vitrectomy compared to scleral buckle:
  - Greater risk of cataract
  - Greater risk of PVR (though not yet demonstrated)
  - More costly materials.

11.3 Complicated Rhegmatogenous Retinal Detachment

A rhegmatogenous RD requires vitrectomy when there are also vitreous bleeding or opacities, very posterior or multiple breaks on different planes, retinal breaks under the muscles giant tear, no visible tear, or PVR. The small-gauge system may offer some advantages over the usual 20-gauge technique in these cases.

11.3.1 Small-Gauge vs 20-Gauge Vitrectomy

The main advantage in using a small–gauge system instead of a 20-gauge system is less trauma to the conjunctiva and sclera, less exchange of intraocular fluids and better stabilization of the detached retina while the vitreous is being removed, partly because of the smaller vitrectome mouth.

With small-gauge vitrectomy for complicated RD, in my opinion there is a substantial difference between the 25- and 23-gauge approaches. The latter is very similar to the 20-gauge technique as regards fluid exchange and the stiffness of the instruments. The learning curve for progressing from 20-gauge to 23-gauge is very short in these cases. With the 23- and 20-gauge systems, the surgeon can make very similar intraocular movements, and silicone oil injection presents no particular problems, except that it takes only slightly longer.

With the 25-gauge system, however, instrumental flexibility and fluid use are very different from the 23-gauge approach. A skilled surgeon will have more difficulty dealing with complicated RD with the 25-gauge system, and the learning curve is much longer than with the 23-gauge technique. Vitreal replacement materials such as silicone oil are also harder to inject with a 25-gauge instrument.

The recommended technique in all cases is three-way vitrectomy, which can, if necessary, become bimanual, using the chandelier for illumination.

In my opinion the small-gauge technique offers the major advantage of being able to shift the infusion cannula easily, with no trauma to the sclera. This means that the surgical instruments for infero-temporal sclerotomy — the cutter or endolaser — can be used, facilitating the surgical approach to the superior quadrants of the retina.

Summary for the Clinician

- 23-gauge vitrectomy is better than 25-gauge for complicated RD.
- Advantages of 23-gauge over 20-gauge vitrectomy for complicated RD:
  - Less trauma to the conjunctiva and sclera
  - Less exchange of intraocular fluids and better stabilization of the detached retina while the vitreous is being removed, partly because of the smaller vitrectome mouth
  - The possibility of shifting the position of the instruments and the infusion cannula, for an easier approach to the superior sectors.
- Disadvantages of 23-gauge compared to 20-gauge vitrectomy for complicated RD:
  - Vitrectomy times are longer
  - It is difficult to inject high-viscosity silicone oil, if needed, because of the size of the cannula
  - It is impossible to use an angled instrument
  - More costly materials.

11.4 Conclusion

In primary rhegmatogenous RD, the small-gauge system offers several advantages over traditional techniques. This new approach is still under investigation, and the surgical indication has therefore still to be clearly defined, so obviously the results too.

In cases with complicated RD, when vitrectomy is indicated, the small-gauge approach presents various advantages over the traditional 20-gauge technique. This is particularly true for the 23-gauge system, as

the flexibility of the 25-gauge instruments somewhat complicates things.Since this small-gauge technique has only been introduced recently, many of the real points in its favor have still to be confirmed in the literature.

References

1. Gonin J (1921) Le traitement du decollement retinien. Ann Ocul 158:175–194
2. Rosengren (1938) Über die Behandlung der Netzhaut-Ablösung mittelst Diathermie und Luftinjektionen in den Glaskörper. Acta Ophthalmol (kbh) 16:3
3. Custodis E (1953) Bedeutet die Plombeaufnahung auf die Sklera einen Fortschritt im der operativen Behandlung der Netzhaut-Ablösung? Ber Dtsch Ophthalm Ges 58:102
4. Lincoff H, Coleman J, Kreissing F et al (1983) The perfluorocarbon gases in the treatment of retinal detachment. Ophthalmology 90:546–551
5. Chang S, Lincoff H, Coleman J et al (1985) Perfluorocarbon gases in vitreous surgery. Ophthalmology 92: 651–656
6. Lincoff H, Horowitz J, Kreissing I, Jakobiec F (1986) Morphological effects of gas compression on the cortical vitreous. Arch Ophthalmol 104:1212–1215
7. Lincoff HA, McLean JM, Nano H (1964) Cryosurgical treatment of RD. Trans Am Acad Ophthalmol Otolaryngol 68:412
8. Schepens CL, Okamma ID, Brockhurst RJ (1957) The scleral buckling procedures. Surgical techniques and management. Arch Ophthalmol 58:797
9. Machemer R, Buettner H, Norton EDW et al (1971) Vitrectomy. A pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 75:813
10. Charles S (1980) Vitrectomy for retinal detachment. Trans Ophthalmol Soc UK 100:542–549
11. Escoffery RF, Olk RJ, Grand MG, Boniuk I (1985) Vitrectomy without scleral buckling for primary rhegmatogenous retinal detachment. Am J Ophthalmol 99:275–281
12. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109(10):1814–1820
13. Fujii GY, de Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C, Ng E, Barnes A, Wu SL, Sommerville DN (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109(10):1807–1812; discussion 1813. Erratum in: Ophthalmology 2003 110(1):9
14. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25(2):208–211
15. Brazitikos PD, D'Amico DJ, Tsinopoulos IT, Stangos NT (1999) Primary vitrectomy with perfluoro-n-octane use in the treatment of pseudophakic retinal detachment with undetected retinal breaks. Retina 19(2):103–109
16. Campo RV, Sipperley JO, Sneed SR, Park DW, Dugel PU, Jacobsen J, Flindall RJ (1999) Pars plana vitrectomy without scleral buckle for pseudophakic retinal detachments. Ophthalmology 106(9):1811–1815; discussion 1816
17. Speicher MA, Fu AD, Martin JP, von Fricken MA (2000) Primary vitrectomy alone for repair of retinal detachments following cataract surgery. Retina 20(5):459–464
18. Brazitikos PD, Androudi S, Christen WG, Stangos NT (2005) Primary pars plana vitrectomy versus scleral buckle surgery for the treatment of pseudophakic retinal detachment: a randomized clinical trial. Retina 25(8):957–964
19. Heimann H, Bartz-Schmidt KU, Bornfeld N, Weiss C, Hilgers RD, Foerster MH; Scleral Buckling versus Primary Vitrectomy in Rhegmatogenous Retinal Detachment Study Group (2007) Scleral buckling versus primary vitrectomy in rhegmatogenous retinal detachment: a prospective randomized multicenter clinical study. Ophthalmology.114(12):2142–2154
20. Brazitikos PD (2000) The expanding role of primary pars plana vitrectomy in the treatment of rhegmatogenous noncomplicated retinal detachment. Semin Ophthalmol. 15(2):65–77. Review
21. Bartz-Schmidt KU, Kirchhof B, Heimann K (1996) Primary vitrectomy for pseudophakic retinal detachment. Br J Ophthalmol 80(4):346–349
22. Desai UR, Strassman IB (1997) Combined pars plana vitrectomy and scleral buckling for pseudophakic and aphakic retinal detachments in which a break is not seen preoperatively. Ophthalmic Surg Lasers 28(9):718–722
23. Devenyi RG, de Carvalho Nakamura H (1999) Combined scleral buckle and pars plana vitrectomy as a primary procedure for pseudophakic retinal detachments. Ophthalmic Surg Lasers 30(8):615–618
24. Ahmadieh H, Moradian S, Faghihi H, Parvaresh MM, Ghanbari H, Mehryar M, Heidari E, Behboudi H, Banaee T, Golestan B; Pseudophakic and Aphakic Retinal Detachment (PARD) Study Group (2005) Anatomic and visual outcomes of scleral buckling versus primary vitrectomy in pseudophakic and aphakic retinal detachment: six-month follow-up results of a single operation – report no. 1. Ophthalmology 112(8):1421–1429
25. Arya AV, Emerson JW, Engelbert M, Hagedorn CL, Adelman RA (2006) Surgical management of pseudophakic retinal detachments: a meta-analysis. Ophthalmology 113(10):1724–1733
26. Cowely M, Conway BP, Campochiaro PA et al (1989) Clinical risk factors for proliferative vitreoretinopaty. Arch Ophthalmol 107:1147–1151
27. Patelli F, Di Tizio FM, Zumbo G, Radice P, Fasolino G (2005) Two-port 25-gauge vitrectomy for primary rhegmatogenous retinal detachment: a new technique. Techniques in Ophthalmology 3(2):90–93

Chapter 12

Perfluorocarbon-Perfused 25-Gauge Vitrectomy

G. Garcia-Aguirre, H. Quiroz-Mercado

Core Message

- Perfluorocarbon liquids (PCL) have been used successfully in the management of several vitreoretinopathies with few complications.
- Perfluorocarbon-perfused vitrectomy. (PPV) allows a better visualization of the vitreous. It stabilizes the retina, allowing for the cut-suction probe to come very close to the retina, without the retinal movement. It nicely visualizes the posterior hyaloid. It is helpful during the dissection and peeling of membranes, because of retinal stabilization and clear visualization in spite of bleeding.
- Only few and rare complication can occur during this procedure.
- The 25-gauge system permits a small amount of PCL to be used.

12.1 Physical and Chemical Characteristics of Perfluorocarbon Liquids

Perfluorocarbon liquids (PCL) consist of a hydrocarbon molecule in which hydrogen atoms are replaced by fluorine atoms. They can exist in a solid, liquid, or gaseous state, and they have several characteristics that have made them suitable as tools in vitreoretinal surgery. We will focus on perfluoro-*n*-octane, which is the most available and most commonly used.

Perfluoro-*n*-octane (C_8F_{18}) is a saturated PCL, with highly stable carbon–fluorine bonds, which make this compound virtually inert. It has a high specific gravity (1.7), and very low kinetic viscosity (0.8 cst). Its refractive index (1.27) allows the forming of a visible interface with balanced saline solution. Its high vapor pressure (50 mmHg) minimizes the residual amount of PCL left in the vitreous cavity once fluid–air exchange has been performed [1]. One of the main advantages of perfluoro-*n*-octane and of PCL in general is that they are immiscible in water, and bodily fluids such as vitreous or blood (Fig. 12.1).

12.2 History

Perfluorocarbon liquids are used in several areas of medicine. Clark and Gollam used PCL for the first time, experimenting with liquid ventilation in rats [2]. Perfluorocarbon liquids have been used as hemoglobin substitutes in blood transfusion [3], to perfuse ischemic myocardium [4], and as an adjuvant to assisted ventilation ("liquid" ventilation) [5].

The first use of PCL in ophthalmology as a vitreous substitute was reported in 1982 by Haidt et al. [6], and in 1984, Clark patented the intraocular use of PCL, including vitreous replacement with perfluorocarbons, advocating their use as an intraoperative tool [7]. Also in 1984, Miyamoto et al. published the use of perfluoroether as a long-term vitreous substitute in rabbit eyes [8], which unfortunately induced retinal detachment and the formation of preretinal membranes, and was deemed unsuitable. Chang et al. tested perfluorotributylamine as a long-term vitreous substitute in rabbit eyes [9], and also found unwanted side-effects, but drew attention to its potential role as an intraoperative tool for the management of retinal detachment. It was not until 1988 that PCL were first used in human eyes, as an adjunct in the management of retinal detachment with proliferative vitreoretinopathy [10].

12.3 Uses of Perfluorocarbon Liquids in Vitreoretinal Surgery

Since their first use in human eyes, PCL have been used as adjuvants for the surgical treatment of several vitreoretinal conditions. They have been employed successfully in the management of rhegmatogenous retinal detachment

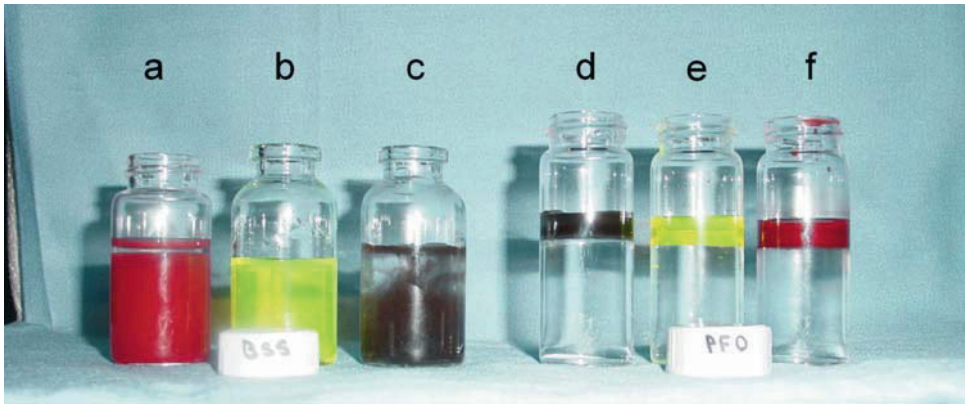


Fig. 12.1 Comparison of BSS and PCL vials containing the same amount of blood (**a, f**), fluorescein (**b, e**), and choroidal pigments (**c, d**). *BSS* – balanced saline solution; *PFO* – perfluoro-*n*-octane

(RRD) complicated with proliferative vitreoretinopathy [10–20], giant retinal tears [21–27], tractional retinal detachment (TRD) in proliferative diabetic retinopathy (PDR) [28–31], posteriorly dislocated crystalline lenses [32–36] or intraocular lenses [32, 34, 37], intraocular foreign bodies [38], and as short-term postoperative vitreous substitute [39–41].

12.4 Ocular Toxicity of Perfluorocarbon Liquids

Early experimental studies in rabbits where PCL were used as vitreous substitutes for varied periods of time found significant side-effects. Perfluoroethylene caused preretinal membrane formation, retinal disorganization and detachment after remaining in the vitreous cavity from 4 to 6 months [8]. Perfluorotributylamine caused cell deposition in the posterior lens and vitreous cortex after remaining 5 months in the vitreous cavity [9], and decrease in *b*-wave amplitude in the electroretinogram [42]. However, if PCL were removed from the vitreous cavity up to 2 days after instillation, no significant side effects were observed [43, 44]. In animal models which are more appropriate for studies of long-term tolerance, such as pigs [43, 45] or monkeys [46, 47], no significant morphological changes were observed in the retina.

Perfluorocarbon liquids have been used for quite some time in human eyes, with few complications. There have been several case reports in which retinal damage has been attributed to intravitreal [48] or subretinal [49] PCL. There is another report in which seven patients with PCL droplets in the anterior chamber were followed-up for more than 9 months, without signs of corneal toxicity or intraocular inflammation [50].

12.5 Perfluorocarbon-Perfused Vitrectomy

The term *perfluorocarbon-perfused vitrectomy* (PPV) refers to a procedure that is performed with a continuous infusion of PCL since the beginning of vitrectomy, instead of using balanced saline solution (BSS). Subsequent steps of the procedure, such as membrane peeling, dissection, endodiathermy, or endophotocoagulation, are performed with the vitreous cavity completely filled with PCL. Perfluorocarbon liquids are then completely removed when performing the fluid–air exchange.

The first procedures were performed in rabbits, in an experimental model of endophthalmitis [51]. Subsequent studies in rabbit and porcine eyes showed no significant toxicity, and the potential to take advantage of the physical–chemical properties of PCL during the whole procedure [52]. The first procedures performed on human eyes were reported in 2005 [53], consisting of 28 cases of rhegmatogenous retinal detachment or tractional retinal detachment secondary to proliferative retinopathy, with no repercussions on the endothelial cell count or the *b*-wave of the electroretinogram.

Summary for the Clinician

- Perfluoro-*n*-octane (C8F18) is virtually inert, it forms a visible interface with balanced salt solution, and it is immiscible in water and bodily fluids such as vitreous and blood.
- Perfluorocarbon liquids (PCL) have been used successfully in the management of several vitreoretinopathies with few complications.
- The term *perfluorocarbon-perfused vitrectomy* (PPV) refers to a procedure that is performed with a continuous infusion of PCL from the beginning of vitrectomy.

12.6 Perfluorocarbon-Perfused 25-Gauge Vitrectomy (PCP25GV): Technique

12.6.1 Preparation for Vitrectomy

Vitrectomy is performed with conventional vitrectomy machines, tubing, illumination and cut-suction probes, which are commercially available. The only additional materials needed are: (1) a PCL bottle for infusion, with tubing (we use a 100 cc bottle of perfluoro-*n*-octane, not commercially available), (2) an extra 3-way stopcock, and (3) a tripod to hang the PCL bottle approximately 80 cm above the level of the patient's eye.

In standard 25-gauge vitrectomy, the infusion cannula would be connected to the 3-way stopcock provided in the tubing kit (the "original" 3-way stopcock), which in order is connected to the air supply and the BSS supply. In PCP25GV, the cannula is connected to the extra 3-way stopcock, which at one end is connected to the PCL infusion and at the other is connected to the "original" 3-way stopcock (Fig. 12.2). The system is set to allow just PCL to go to the infusion cannula.

It is of paramount importance that the infusion cannula be adequately purged, which can be tricky in the first procedures. Perfluorocarbon liquids behave differently than BSS, so adequate purging of the infusion cannula is performed differently. Once the tubing is in place and the 3-way stopcocks are set for PCL infusion, the tip of the infusion cannula must be held pointing upward by the assisting surgeon, and lowered slowly. The high specific gravity of PCL will allow them to go downward, while air in the line is expelled upward. Eventually PCL will emerge from the tip of the cannula and the line will be devoid of air bubbles.

Sclerotomies are then performed in the same way as in conventional 25-gauge vitrectomy. The infusion cannula is placed, and core vitrectomy can then be performed.

12.6.2 Core Vitrectomy

Once the infusion is set, and the illumination and cut-suction probes are in place, core vitrectomy may begin. As soon as cut and suction are activated, PCL bubbles will enter the vitreous cavity. Since a considerable amount of vitreous is still present in the vitreous cavity, bubbles will not fuse with each other, but they will be separated by vitreous bands, which can be

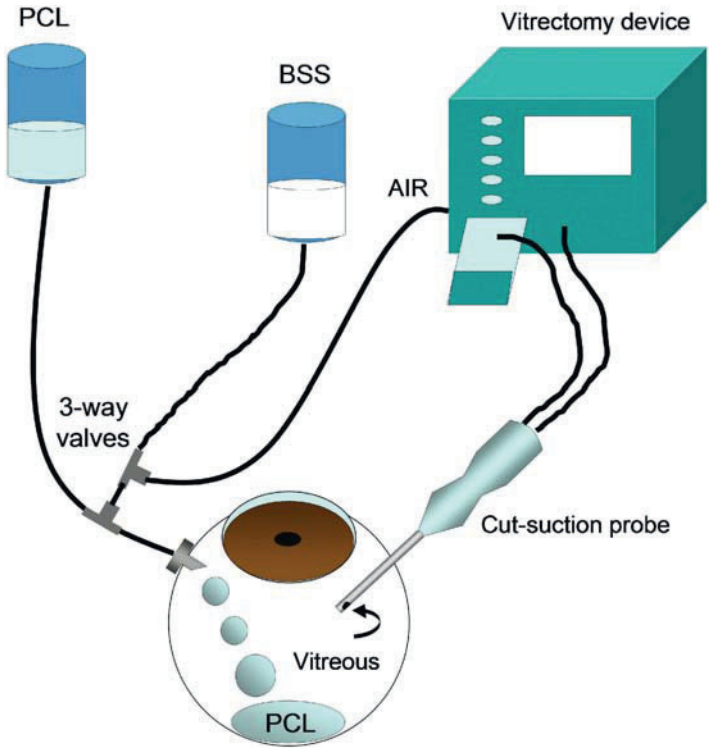


Fig. 12.2 Perfluorocarbon perfused vitrectomy – general scheme. The "original" 3-way valve provided with the commercially available vitrectomy kits (carrying the BSS and air infusions) is connected by an extra 3-way valve to the PCL infusion, and then into the eye via the infusion cannula. *BSS* – balanced saline solution; *PCL* – perfluorocarbon liquids

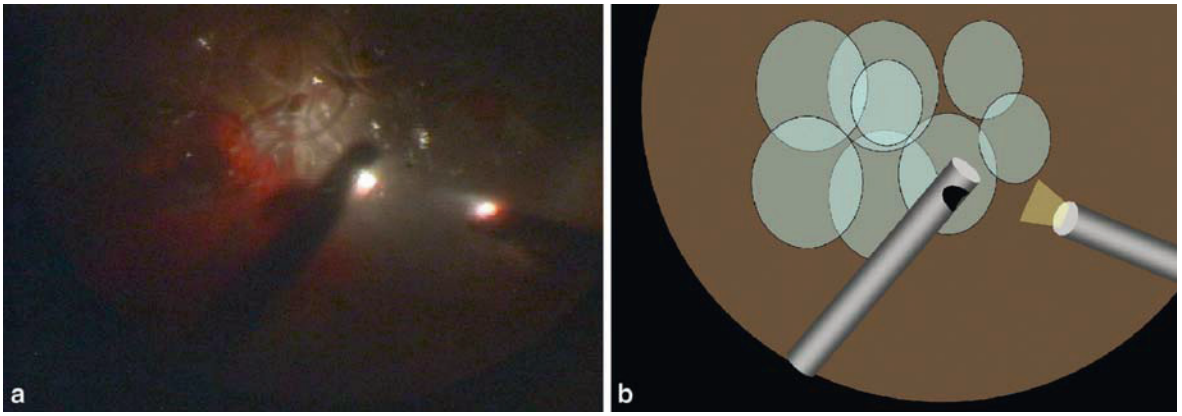


Fig. 12.3 **(a)** Screenshot of core vitrectomy being performed under continuous infusion of PCL. Notice that there are several bubbles, separated by vitreous bands. Bubbles will merge into a single bubble when vitreous bands are cut and aspirated. **(b)** Schematic diagram representing **(a)** above; *PCL* – perfluorocarbon liquids

easily identified (Fig. 12.3). As soon as the cut suction probe is placed between bubbles, vitreous bands will be cut and aspirated, and bubbles will merge, forming a larger bubble. This last step should be repeated until the vitreous cavity is filled by one large PCL bubble, an indication that core vitrectomy is complete. In cases of rhegmatogenous retinal detachment, the retina will start to reattach as soon as PCL start entering the vitreous cavity, expelling the subretinal fluid through the anterior retinal break. The retina will then be stabilized, allowing for the cut–suction probe to come very close to the retina, without the retinal movement or vibration that can be seen when performing procedures under BSS.

12.6.3 Posterior Hyaloid Separation

In cases in which posterior vitreous detachment (PVD) is already present, PCL will settle behind the posterior hyaloid and "push" the vitreous body anteriorly, so vitrectomy can be performed in the anterior vitreous cavity. In cases in which the posterior hyaloid is thickened, the best strategy is to separate the fibrotic and frequently distorted Weiss ring that can be identified in front or adjacent to the optic disc. This maneuver allows entrance of PCL behind the posterior hyaloid, dissecting it from the retina. The posterior hyaloid is visualized nicely and can then be removed with the cut-suction probe, and epicenters can be identified.

12.6.4 Membrane Peeling and Dissection

Perfluorocarbon liquids are helpful during the dissection and peeling of membranes because of retinal stabilization and clear visualization in spite of bleeding. PCL exert a downward pressure that stabilizes the retina, allowing the surgeon to perform more aggressive maneuvers in order to dissect fibrovascular membranes. This marked stabilization also allows the membranes to be segmented with the cut-suction probe instead of with scissors or a pick, which could compensate for the relative scarcity of 25-gauge instruments available.

It is not uncommon for fibrovascular membranes, especially in proliferative diabetic retinopathy, to bleed profusely when cut, which under BSS could signify a noteworthy loss of visualization and investment in surgical time trying to control the bleeding. Under PCL, bleeding is confined below the PCL bubble, the bleeding site can be easily identified, and diathermy can be safely applied without loss of visualization.

12.6.5 Additional Procedures

Since PCL are transparent, transmission of light is not hindered, and thus endophotocoagulation can be applied as safely as under BSS. Endodiathermy can also be applied, with the added benefit that PCL contain and compartmentalize blood. There has been some concern that procedures that apply energy under PCL could alter their chemical structure, creating compounds with the potential to damage the retina. It has been proven, however, that this is not the case [54].

12.6.6 Fluid–Air Exchange

After the retina has been reattached and there is no need for PCL, the PCL–air exchange can be performed. Both 3-way stopcocks must be set to allow air to come into the vitreous cavity, while PCL are being passively aspirated with a cannula. After PCL have been aspirated

and no apparent liquid remains in the vitreous cavity, time (approximately 5 min) must be allowed to pass, so that remaining PCL either pool in the posterior pole and can then be aspirated, or evaporate and exit the vitreous cavity through the sclerotomies. Tamponade is then selected according to the surgeon's preference.

12.6.7 Closing

At the end of the procedure, removal of the ports is done in the same manner as with conventional vitrectomy, making sure that fluid is not leaking from the vitreous cavity into the subconjunctival space.

Summary for the Clinician

- The procedure consists of a traditional vitrectomy. The only additional materials needed are: (1) a PCL bottle for infusion, with tubing, (2) an extra 3-way stopcock, and (3) a tripod to hang the PCL bottle approximately 80 cm above the level of the patient's eye.
- In PCP25GV, the cannula is connected to the extra 3-way valve, which at one end is connected to the PCL infusion and at the other is connected to the "original" 3-way stopcock.
- It is of paramount importance that the infusion cannula be adequately purged. The high specific gravity of PCL will allow them to go downward, while air in the line is expelled upward.
- When vitrectomy begins, PCL bubbles will enter the vitreous cavity. Bubbles will not fuse with each other, but they will be separated by vitreous bands, which can be easily identified. As soon as the cut–suction probe is placed between bubbles, vitreous bands will be cut and aspirated, and bubbles will merge, forming a larger bubble.
- The retina will be stabilized by the PCL, allowing for the cut–suction probe to come very close to the retina, without the retinal movement.
- The posterior hyaloid is visualized nicely, and can then be removed with the cut–suction probe.
- Perfluorocarbon liquids are helpful during the dissection and peeling of membranes because of retinal stabilization and clear visualization in spite of bleeding.
- After the retina has been reattached, the PCL–air exchange can be performed. Tamponade is then selected according to the surgeon's preference.

12.7 Advantages of Performing Perfluorocarbon-Perfused Vitrectomy with 25-Gauge Instruments

The use of PCL provides certain advantages that have been proven in previous studies [52, 53], and that could compensate for the difficulties encountered when performing 25-gauge vitrectomy in complicated cases. These advantages are derived from the specific physical–mechanical properties of PCL, which include immiscibility with bodily fluids and a high specific gravity.

Due to the immiscibility of vitreous in PCL, remaining vitreous bands are easily identified, and therefore removed, facilitating vitrectomy. During vitrectomy for severe PDR with TRD, hemorrhage at neovascularization sites is common, which in ordinary circumstances (under BSS) would preclude adequate visualization. Blood is also immiscible in PCL, accounting for an outstanding control of intraoperative bleeding, confining blood, and allowing a clear visualization throughout the procedure.

The high specific gravity of PCL results in downward pressure over the retina when injected continuously into the vitreous cavity, thus stabilizing the retina. In cases with RRD, subretinal fluid is expelled through anterior retinal breaks into the vitreous cavity, and rapid retinal reattachment can be achieved. Residual vitreous cortex can safely be aspirated with the cut-suction probe using high vacuum due to this stabilization effect, and this can be performed with the retina already attached, which avoids the retinal movements that are observed during vitrectomy with BSS. In cases of TRD due to severe PRD, PCL settles posteriorly in relation to proliferations and/or the posterior hyaloid, creating a "dissecting" effect, providing marked tissue stability, and allowing membrane dissection and relief of traction by the use of the cut–suction probe. After performing several surgeries, we have found that in cases in which the posterior hyaloid is thickened (such as TRD), the best strategy is to perform core vitrectomy until a single PCL bubble fills the vitreous cavity, and then separate the fibrotic and frequently distorted Weiss ring that can be identified in front or adjacent to the optic disc. This maneuver allows entrance of PCL behind the posterior hyaloid, which is visualized nicely and can be removed with the cut–suction probe. At the same time epicenters can be observed; these can be shaved and aspirated with vitrectomy, without the need of scissors for segmentation.

Perfluorocarbon-perfused vitrectomy takes advantage of one of the main characteristics of 25-gauge vitrectomy: the reduced internal lumen diameter of the instruments, which is normally considered a drawback. First, the amount of PCL needed using PCPV (an average of 87 ml

per procedure in a previous study [53]), considerably elevates surgical cost, when compared to the 5–7 ml used in conventional surgery. Using PCP25GV, the amount of PCL needed drops to an average of 24.38 ml [55]. Second, since perfluoro-*n*-octane has less kinematic viscosity than water (0.8 cst vs 1.004 cst), PCL can be aspirated easier than water.

12.8 Complications

Three complications have been identified when performing PCPV that are not normally encountered in conventional vitrectomy: profuse bleeding that covers the PCL bubble, PCL entering the subretinal space, and postoperative persistence of PCL in the vitreous cavity.

There are some cases in which bleeding is so substantial that blood "surrounds" the PCL bubble and precludes visualization. This problem can be solved by taking the cut–suction probe out of the eye and allowing blood to flush out through the sclerotomy, or changing PCL infusion to BSS, cleaning the top of the bubble, and then switching the infusion back to PCL.

In cases of RRD with severe PVR or TRD with massive proliferations, penetration of PCL into the subretinal space may be a risk, especially with iatrogenic retinotomies that are particularly large. We have found that this is rarely the case, since the surface tension of the PCL bubble usually avoids the leakage of PCL through the retinotomy. In the rare occurrence that PCL penetrate the subretinal space, a PCL–air exchange must be performed, and drainage or active aspiration (through the same retinotomy or through additional ones) must be performed.

There are some cases in which PCL remain in the vitreous cavity postoperatively, despite apparently adequate removal toward the end of the procedure. Remaining PCL can be detected clinically if present in a high amount, or by ophthalmic ultrasound, as has been previously described [56]. Patients harboring remaining intravitreal PCL postoperatively have to be closely monitored for signs of retinal toxicity, and an additional procedure must be performed in order to remove the remaining PCL.

12.9 Conclusion

The combination of 25-gauge vitrectomy with a continuous infusion of PCL considerably facilitates complex surgical maneuvers that would be difficult under conventional BSS infusion. Combining both procedures exploits the advantages that are offered by both, while minimizing their disadvantages, and should be considered when facing complex surgical challenges.

Summary for the Clinician

- Using perfluorocarbon infusion vitrectomy, remaining vitreous bands are easily identified, facilitating vitrectomy.
- PCL control intraoperative bleeding, confining blood and allowing clear visualization during vitrectomy. PCL stabilize the retina in case of retina detachment.
- When PCL enter behind the posteior hyaloid, this is nicely visualized and can be easily removed with the cut–suction probe.
- Using the 25-gauge system, the amount of PCL needed during the procedure is of 24.38 ml on average.
- The few complications which can arise during surgery are: (1) profuse bleeding that covers the PCL bubble, (2) PCL entering the subretinal space, and (3) postoperative persistence of PCL in vitreous chamber.

References

1. Chang S, Sparrow JR (1999) Vitreous substitutes. In: Guyer DR, Yannuzzi LA, Chang S, Shields JA, Green WR (eds) Retina-Vitreous-Macula. WB Saunders, Philadelphia, pp 1320–1321
2. Clark LC, Gollan F (1966) Survival of mammals breathing organic liquids equilibrated with oxygen at a atmospheric pressure. Science 152:1755–1756
3. Gould SA, Rosen AL, Sehgal LR et al (1986) Fluosol-DA as a red cell substitute in acute anemia. N Eng J Med 314:1653–1656
4. Spiess BD, Cochran RP (1996) Perfluorocarbon emulsion and cardiopulmonary bypass: a technique for the future. J Cardiothorac Vasc Anesth 10:8390
5. Shaffer TH, Wolfson MR, Clark LC (1992) State of the art review: liquid ventilation. Pediatr Pulmonol 14:102–119
6. Haidt SJ, Clark LC Jr, Grinsberg J (1982) Liquid perfluorocarbon replacement of the eye (abstract). Invest Ophthalmol Vis Sci 22(Suppl):233
7. Clark LC Jr (1984) Methods of treating disorders of an eye with liquid perfluorocarbons. US Patent [407] 4,490,351
8. Miyamoto K, Refojo MF, Tolentino FI, Fournier GA, Albert DM (1984) Perfluoroether liquid as a long-term vitreous substitute. An experimental study. Retina 4(4):264–268
9. Chang S, Zimmerman NJ, Iwamoto T, Ortiz R, Faris D (1987) Experimental vitreous replacement with perfluorotributylamine. Am J Ophthalmol 103(1):29–37
10. Chang S, Ozmert E, Zimmerman NJ (1988) Intraoperative perfluorocarbon liquids in the management of proliferative vitreoretinopathy. Am J Ophthalmol 106(6):668–674

11. Blinder KJ, Peyman GA, Paris CL, Dailey JP, Alturki W, Lui KR, Gremillion CM Jr, Clark LC Jr (1991) Vitreon, a new perfluorocarbon. Br J Ophthalmol 75(4):240–244
12. Comaratta MR, Chang S (1991) Perfluorocarbon liquids in the management of complicated retinal detachments. Curr Opin Ophthalmol 2(3):291–298
13. Han DP, Rychwalski PJ, Mieler WF, Abrams GW (1994) Management of complex retinal detachment with combined relaxing retinotomy and intravitreal perfluoro-*n*-octane injection. Am J Ophthalmol 118(1):24–32
14. Coll GE, Chang S, Sun J, Wieland MR, Berrocal MH (1995) Perfluorocarbon liquid in the management of retinal detachment with proliferative vitreoretinopathy. Ophthalmology 102(4):630–638
15. Crafoord S, Larsson J, Hansson LJ, Carlsson JO, Stenkula S (1995) The use of perfluorocarbon liquids in vitreoretinal surgery. Acta Ophthalmol Scand 73(5):442–445
16. Stolba U, Binder S, Velikay M, Datlinger P, Wedrich A (1995) Use of perfluorocarbon liquids in proliferative vitreoretinopathy: results and complications. Br J Ophthalmol 79(12):1106–1110
17. Banker AS, Freeman WR, Vander JF, Flores-Aguilar M, Munguia D (1996) Use of perflubron as a new temporary vitreous substitute and manipulation agent for vitreoretinal surgery. Wills Eye Hospital Perflubron Study Group. Retina 16(4):285–291
18. Soheilian M, Peyman GA, Wafapoor H, Navarro GC, Thompson H (1996–1997) Surgical management of traumatic retinal detachment with perfluorocarbon liquid. The Vitreon Study Group. Int Ophthalmol 20(5):241–249
19. Loewenstein A, Humayun MS, de Juan E Jr, Campochiaro PA, Haller JA (2000) Perfluoroperhydrophenanthrene versus perfluoro-*n*-octane in vitreoretinal surgery. Ophthalmology 107(6):1078–1082
20. Scott IU, Flynn HW Jr, Murray TG, Feuer WJ; Perfluoron Study Group (2003) Outcomes of surgery for retinal detachment associated with proliferative vitreoretinopathy using perfluoro-*n*-octane: a multicenter study. Am J Ophthalmol 136(3):454–463
21. Chang S, Lincoff H, Zimmerman NJ, Fuchs W (1989) Giant retinal tears. Surgical techniques and results using perfluorocarbon liquids. Arch Ophthalmol 107(5): 761–766
22. Glaser BM, Carter JB, Kuppermann BD, Michels RG (1991) Perfluoro-octane in the treatment of giant retinal tears with proliferative vitreoretinopathy. Ophthalmology 98(11):1613–1621
23. Mathis A, Pagot V, Gazagne C, Malecaze F (1992) Giant retinal tears. Surgical techniques and results using perfluorodecalin and silicone oil tamponade. Retina 12(3 Suppl):S7–S10
24. Kreiger AE, Lewis H (1992) Management of giant retinal tears without scleral buckling. Use of radical dissection of the vitreous base and perfluoro-octane and intraocular tamponade. Ophthalmology 99(4):491–497
25. Schulman JA, Peyman GA, Blinder KJ, Alturki WA, Desai UR, Nelson NC Jr (1993) Management of giant retinal tears with perfluoroperhydrophenanthrene (Vitreon). Jpn J Ophthalmol 37(1):70–77
26. Ie D, Glaser BM, Sjaarda RN, Thompson JT, Steinberg LE, Gordon LW (1994) The use of perfluoro-octane in the management of giant retinal tears without proliferative vitreoretinopathy. Retina 14(4):323–328
27. Scott IU, Murray TG, Flynn HW Jr, Feuer WJ, Schiffman JC; Perfluoron Study Group (2002) Outcomes and complications associated with giant retinal tear management using perfluoro-*n*-octane. Ophthalmology 109(10):1828–1833
28. Mathis A, Pagot V, David JL (1991) The use of perfluorodecalin in diabetic vitrectomy. Fortschr Ophthalmol 88(2):148–150
29. Wafapoor H, Kertes PJ, Navarro GC, Peyman GA, Meffert S, Ganiban GJ, Vierling S (1998–1999) The adjunctive use of perfluoroperhydrophenanthrene (Vitreon) in diabetic vitrectomy. Int Ophthalmol 22(2):89–96
30. Itoh R, Ikeda T, Sawa H, Kolzumi K, Yasuhara T, Yamamoto Y, Kusada E (1999) The use of perfluorocarbon liquids in diabetic vitrectomy. Ophthalmic Surg Lasers 30(8):672–675
31. Imamura Y, Minami M, Ueki M, Satoh B, Ikeda T (2003) Use of perfluorocarbon liquid during vitrectomy for severe proliferative diabetic retinopathy. Br J Ophthalmol 87(5):563–566
32. Liu KR, Peyman GA, Chen MS, Chang KB (1991) Use of high-density vitreous substitutes in the removal of posteriorly dislocated lenses or intraocular lenses. Ophthalmic Surg 22(9):503–507
33. Lewis H, Blumenkranz MS, Chang S (1992) Treatment of dislocated crystalline lens and retinal detachment with perfluorocarbon liquids. Retina 12(4):299–304
34. Greve MD, Peyman GA, Mehta NJ, Millsap CM (1993) Use of perfluoroperhydrophenanthrene in the management of posteriorly dislocated crystalline and intraocular lenses. Ophthalmic Surg 24(9):593–597
35. Yoshida K, Kiryu J, Kita M, Ogura Y (1998) Phacoemulsification of dislocated lens and suture fixation of intraocular lens using a perfluorocarbon liquid. Jpn J Ophthalmol 42(6):471–475
36. Verma L, Gogoi M, Tewari HK, Kumar A, Talwar D (2001) Comparative study of vitrectomy for dropped nucleus with and without the use of perfluorocarbon liquid. Clinical, electrophysiological and visual field outcomes. Acta Ophthalmol Scand 79(4):354–358
37. Lewis H, Sanchez G (1993) The use of perfluorocarbon liquids in the repositioning of posteriorly dislocated intraocular lenses. Ophthalmology 100(7):1055–1059
38. Sudhalkar HA, Johnson MW (1998) Perfluorocarbon liquid manipulation of high-density intraocular foreign bodies. Retina 18(5):460–465
39. Bottoni F, Sborgia M, Arpa P, De Casa N, Bertazzi E, Monticelli M, De Molfetta V (1993) Perfluorocarbon liquids as postoperative short-term vitreous substitutes in complicated retinal detachment. Graefes Arch Clin Exp Ophthalmol 231(11):619–628
40. Bottoni F, Bailo G, Arpa P, Prussiani A, Monticelli M, de Molfetta V (1994) Management of giant retinal tears using

perfluorodecalin as a postoperative short-term vitreoretinal tamponade: a long-term follow-up study. Ophthalmic Surg 25(6):365–373

41. Rofail M, Lee LR (2005) Perfluoro-*n*-octane as a postoperative vitreoretinal tamponade in the management of giant retinal tears. Retina 25(7):897–901
42. Terauchi H, Okinami S, Kozaki Z, Tanihara H, Nagata M, Segawa Y (1989) Experimental study on the effects of a replacement of the vitreous body with perfluorotributylamine on the rabbit eye. Nippon Ganka Gakkai Zasshi 93(3):294–301
43. Chang S, Sparrow JR, Iwampoto T et al (1991) Experimental studies of tolerance to intravitreal perfluoro-*n*-octane liquid. Retina 11:367
44. Eckhardt C, Nicolai U, Winter M, Knop E (1991) Experimental intraocular tolerance to perfluorooctante and perfluoropropylether. Retina 11:375
45. Flores-Aguilar M, Munguia D, Loeb E, Crapotta JA, Vuong C, Shakiba S, Bergeron-Lynn G, Wiley CA, Weers J, Freeman WR (1995) Intraocular tolerance of perfluorooctylbromide (perflubron). Retina 15(1):3–13
46. Peyman GA, Conway MD, Soike KF, Clark LC Jr (1991) Long-term vitreous replacement in primates with intravitreal Vitreon or Vitreon plus silicone. Ophthalmic Surg 22(11):657–664
47. Conway MD, Peyman GA, Karacorlu M, Bhatt N, Soike KF, Clark LC Jr, Hoffmann RE (1993) Perfluorooctylbromide (PFOB) as a vitreous substitute in non-human primates. Int Ophthalmol 17(5):259–264
48. Batman C, Cekic O (1998) Effects of the long-term use of perfluoroperhydrophenanthrene on the retina. Ophthalmic Surg Lasers 29(2):144–146
49. Lee GA, Finnegan SJ, Bourke RD (1998) Subretinal perfluorodecalin toxicity. Aust N Z J Ophthalmol 26(1):57–60
50. Weinberger D, Goldenberg-Cohen N, Axer-Siegel R, Gaton DD, Yassur Y (1998) Long-term follow-up of perfluorocarbon liquid in the anterior chamber. Retina 18(3):233–237
51. Suarez-Tatá L, Quiroz-Mercado H, Murillo S et al (2002) Inflammatory reaction after vitrectomy with perfluorocarbons vs saline solution in experimental endophthalmitis. Rev Soc Mex Ophthalmol 76:178–183
52. Quiroz-Mercado H, Suarez-Tata L, Magdalenic R, Murillo-Lopez S, Garcia-Aguirre G, Guerrero-Naranjo J, Rodriguez-Reyes AA (2004) Perfluorocarbon perfused vitrectomy: animal studies. Am J Ophthalmol 137(2):287–293
53. Quiroz-Mercado H, Guerrero-Naranjo J, Agurto-Rivera R, Leizaola-Fernandez C, Suarez-Tata L, Murillo-Lopez S, Reategui-Escalante G, Garcia-Aguirre G, Fromow-Guerra J (2005) Perfluorocarbon-perfused vitrectomy: a new method for vitrectomy—a safety and feasibility study. Graefes Arch Clin Exp Ophthalmol 243(6):551–562
54. Bourke RD, Simpson RN, Cooling RJ, Sparrow JR (1996) The stability of perfluoro-N-octane during vitreoretinal procedures. Arch Ophthalmol 114(5):537–544
55. Quiroz-Mercado H, Garcia-Aguirre G, Ustáriz-González O, Martín-Avià J, Martinez-Jardon S (2007) Perfluorocarbon-perfused vitrectomy using a transconjunctival 25-gauge system. Retina 27:926–931
56. Hasenfratz G, De La Torre M, Haigis W (1994) Evaluation of eyes harbouring perfluorocarbon liquid with standardized ophthalmic echography. Ger J Ophthalmol 3(1):19–21

Chapter 13

Primary 25-Gauge Vitrectomy with Topical Anesthesia for Persistent Vitreous Floaters

G. Garcia-Aguirre, V. Morales-Canton, H. Quiroz-Mercado

Core Message

- Vitreous floaters are entoptic phenomena, and account for a significant percentage of patient complaints.
- Pars plana vitrectomy is a good procedure for a complete resolution.
- The 25-gauge system provides advantages that can reduce some of the complications of 20-gauge vitrectomy.
- Patient selection is the most important part of this surgery.

13.1 Introduction

Vitreous floaters are entoptic phenomena which manifest as a moving shadow that often accompanies eye movement, and account for a significant percentage of patient complaints. Once developed, a floater may persist for life, and in some patients may cause a significant visual disturbance [1].

13.2 History

Several methods have been advocated for the treatment of persistent vitreous floaters, but the most useful have been Nd:YAG vitreolysis and pars plana vitrectomy. Neodinium:YAG vitreolysis was introduced starting in 1993 by Tsai et al. [2], who reported excellent results using this technique in a series of 15 patients. However, a subsequent report in 2002 by Delaney et al. [3] found symptomatic improvement in only 38% of 39 patients.

On the other hand, pars plana vitrectomy was initially reported in 2000 by Schiff et al. in a series of six eyes, measuring patient satisfaction with a standardized questionnaire, finding no postoperative complications, and high patient satisfaction with overall visual function in all cases [4]. Delaney described in 2002 a series of 15 patients who underwent pars plana vitrectomy for persistent vitreous floaters (some of who had previously been treated with Nd:YAG vitreolysis), reporting full resolution of symptoms in 93.3% of eyes, with only one patient developing a postoperative retinal detachment [3].

Another alternative that has been advocated in one case series is combined phacoemulsification with deep anterior vitrectomy ("floaterectomy") and posterior-chamber intraocular lens implantation, which Mossa et al. reported in 2002, finding complete symptomatic resolution in eight of ten cases [5]. Two eyes of one patient developed postoperative cystoid macular edema.

Summary for the Clinician

- In 2000, published data reported pars plana vitrectomy safe with no postoperative complications and high patient satisfaction.
- In 2002, published data reported full resolution of symptoms in 93.3% of eyes after vitrectomy for floaters.

13.3 Surgical Trends

Although a common symptom, there is a lack of published literature concerning persistent vitreous floaters. However, a PAT Survey of the American Society of Retina Specialists in 2000 showed that close to 50% of respondents would perform surgery for the treatment of persistent vitreous floaters in highly symptomatic patients.

13.4 Advantages of 25-Gauge Vitrectomy

The main reasons for not performing pars plana vitrectomy in a patient whose only complaint is persistent

vitreous floaters are intraoperative or postoperative complications, ranging from the less common but severe (such as retrobulbar hemorrhage from anesthesia, expulsive hemorrhage, cataract development, retinal detachment or postoperative endophthalmitis) to the more common but less severe (such as scarring of the conjunctiva or chronic red eye).

25-gauge vitrectomy provides advantages that can be exploited in order to reduce some of these complications, which in turn can favor the balance toward performing the procedure in a highly symptomatic patient. First, since there is no need to apply bipolar cautery or to suture the sclerotomy, topical anesthesia can be employed, and therefore the risks associated with retrobulbar or peribulbar anesthesia are eliminated. Also, several surgical steps are avoided compared to conventional pars plana vitrectomy, and surgical time is consequently reduced. Second, 25-gauge vitrectomy can be performed without the need to cut or suture the conjunctiva, resulting in almost no postoperative inflammation or scarring, improving patient satisfaction with the postoperative aesthetic result.

Summary for the Clinician

- The main reasons for not performing pars plana vitrectomy for persistent vitreous floaters are intraoperative or postoperative complications.
- 25-gauge vitrectomy provides advantages that can be exploited in order to reduce some of these complications.
- There is no need to apply bipolar cautery or to suture the sclerotomy, and topical anesthesia can be employed.
- There is no postoperative inflammation or scarring, improving patient satisfaction.

13.5 Patient Selection

Vitreous floaters are a common symptom, but not all patients are surgical candidates. We use the following criteria in order to select candidates that will obtain the most benefit from surgery.

(a) The patient's symptoms must be considerable and long-standing. The more the patient's quality of life is affected, the more he or she will benefit from the surgical intervention.
(b) The patient must have a preoperative posterior vitreous detachment (PVD). If the patient does not have this requisite, the occurrence of PVD after the procedure can cause symptom recurrence.
(c) Localization of the opacities. If the patient can specifically pin-point where the vitreous floaters are seen, and there is an anatomic correlation with the presence of a vitreous condensation or a fibroglial ring, there is a higher probability of postoperative symptom relief.

Summary for the Clinician

- The patient's symptoms must be considerable and long-standing.
- The patient must have a preoperative posterior vitreous detachment.
- Opacities must be localized before surgery.

13.6 Technique

Since vitrectomy for persistent vitreous floaters is performed in older patients and preoperative PVD is present, it is usually a quick procedure, and may be performed under topical anesthesia. We usually employ either propara-caine 0.5% or tetracaine 0.5%.

The surgical steps when performing vitrectomy for persistent vitreous floaters, such as port placement and removal, are the same as for conventional 25-gauge vitrectomy, and are discussed elsewhere in this book. Care has to be taken to perform a thorough vitrectomy, especially in the visual axis, and to induce a complete PVD. If there are no intraoperative complications, balanced saline solution is left filling the vitreous cavity at the end of the procedure.

13.6.1 Variation with 2-Port Vitrectomy

In some of our patients, the technique has been modified in order to use only two ports for the procedure; one of them for the infusion cannula and the other for the cut–suction probe. Illumination is provided by an indirect ophthalmoscope while the non-dominant hand holds a 20-diopter lens. We are aware that this technique is used by some retinal specialists from

several countries. This variation has the disadvantage of inverted surgical visualization, but provides advantages such as no need for an operating microscope, less damage to the pars plana, less surgical time and less patient discomfort.

Summary for the Clinician

- The surgical steps are the same as for conventional 25-gauge vitrectomy.
- Care has to be taken to perform a thorough vitrectomy, especially in the visual axis.
- Balanced saline solution is left filling the vitreous cavity at the end of the procedure.
- Only two ports are used for the procedure; one of them for the infusion cannula and the other for the cut–suction probe.
- Illumination is provided by an indirect ophthalmoscope, with the disadvantage of inverted surgical visualization, and the advantage of no need for an operating microscope

13.7 Complications

Complications from vitrectomy for persistent vitreous floaters are the same as every other vitrectomy procedure [6], and should be discussed thoroughly with the patient. The patient must be informed that this is an elective procedure, and that there is a small percentage of cases in which complications may occur, with potential permanent damage to visual function.

13.8 Conclusion

Primary 25-gauge vitrectomy for persistent vitreous floaters is a treatment option that can be offered to very symptomatic patients in whom the resulting visual disturbance interferes with daily activities. An adequate patient selection is essential in order to maximize the chances of a successful procedure.

References

1. Trick GL (2003) Chapter 20: Entoptic imagery and afterimages. In: Tasman W (ed) Duane's Foundations of Clinical Ophthalmology. Lippincot Williams & Wilkins, Philadelphia
2. Tsai WF, Chen YC, Su CY (1993) Treatment of vitreous floaters with neodymium YAG laser. Br J Ophthalmol 77: 485–488
3. Delaney YM, Oyinloye A, Benjamin L (2002) Nd:YAG vitreolysis and pars plana vitrectomy: surgical treatment for vitreous floaters. Eye 16:21–26
4. Schiff WM, Chang S, Mandava N, Barile GR (2000) Pars plana vitrectomy for persistent, visually significant vitreous opacities. Retina 20:591–596
5. Mossa F, Delaney YM, Rosen PH, Rahman R (2002) Floaterectomy: combined phacoemulsification and deep anterior vitrectomy. J Cataract Refract Surg 28:589–592
6. Abrams GW, Gentile RC (1999) Chapter 113: Vitrectomy. In: Guyer DR, Yannuzzi LA, Chang S, Shields JA, Green WR (eds). Retina-Vitreous-Macula. WB Saunders, Philadelphia

Chapter 14

25-Gauge Vitrectomy in Infectious Endophthalmitis

F.A. Rezende, M. Kickinger

Core Message

- Infectious endophthalmitis is characterized by intraocular replication of microorganisms associated with inflammatory reaction across a wide severity spectrum.
- Clinically, it is separated into exogenous or endogenous and acute or chronic endophthalmitis.
- Endophthalmitis is considered to be acute when the symptoms have started within 6 weeks of the initial event.
- Exogenous postoperative acute or chronic endophthalmitis are more common, due to the ever increasing number of intraocular procedures world-wide.
- Acute postoperative endophthalmitis usually presents with sudden loss of visual acuity, increased ocular pain, red eye, swollen lids, anterior chamber and vitreous reaction.
- Visual acuity after treatment may vary dramatically, with better outcomes commonly seen in eyes with culture-negative or coagulase-negative gram-positive organisms without corneal infiltrates.
- Chronic postoperative endophthalmitis may present several weeks to years after surgery. The delayed more subtle signs include granulomatous keratic precipitates, endocapsular hypopyon, and vitritis. The most common microorganisms involved are *Propionibacterium acnes* and coagulase-negative gram-positive *Staphylococcus*. Visual outcomes are generally better than acute cases, because these are lower virulence microorganisms.
- According to the Endophthalmitis Vitrectomy Study, if presenting visual acuity is light perception, immediate pars plana vitrectomy should be done in addition to intravitreal antibiotics. If presenting VA is hand motions or better, no statistically significant difference in outcomes have been found between vitrectomy and tap/biopsy.
- Regardless of presenting VA, media opacities clear faster with vitrectomy than with vitreous tap/biopsy.
- Techniques for surgical management of infectious endophthalmitis include 20-gauge pars plana core vitrectomy, 20-gauge total vitrectomy, scleral buckling, intravitreal silicone oil, and endoscopy.
- In 25-gauge transconjunctival vitrectomy, the conjunctiva is less manipulated, and this may decrease patient discomfort during surgery for an inflamed painful eye.
- Results comparable to those for other surgical options may be achieved with 25-gauge vitrectomy.
- Proper 25-gauge wound construction and care during surgery are important to maintain safe wound integrity.

14.1 Introduction

Infectious endophthalmitis is characterized by intraocular replication of microorganisms associated with inflammatory reaction across a wide severity spectrum, according to host immune responses and the load and virulence of infectious organisms. It may affect any intraocular structure, and in more extreme cases it may even spread to extraocular tissues as well.

Clinically, it is separated into exogenous or endogenous and acute or chronic endophthalmitis. Exogenous endophthalmitis occurs mainly after surgical or penetrating ocular trauma for open globe injury, and the endogenous type usually starts through the blood stream. According to the time of onset, most authors consider endophthalmitis to be acute when the symptoms have started within 6 weeks of the initial event [1]. Exogenous postoperative acute or chronic endophthalmitis are more common due to the ever increasing number of intraocular procedures world-wide, representing two-thirds of the cases, and for this reason this chapter will focus more on its surgical management.

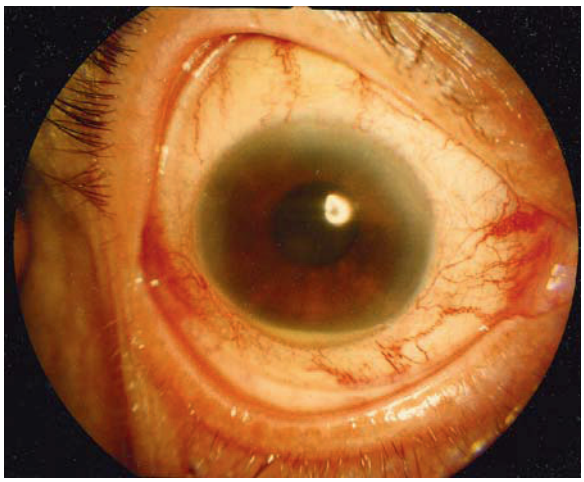


Fig. 14.1 Acute postop endophthalmitis 36 h after uncomplicated temporal clear corneal phacoemulsication without corneal involvement

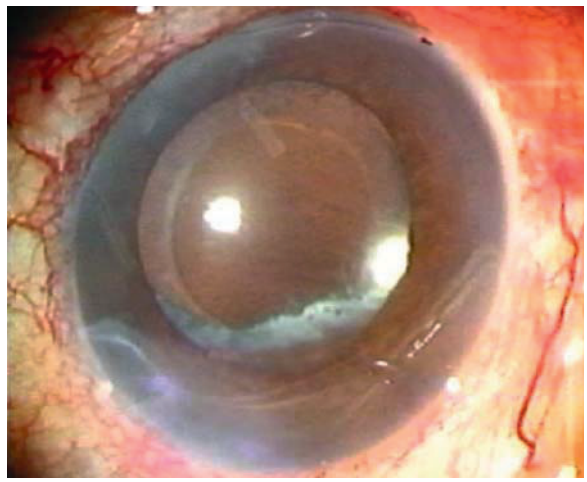


Fig. 14.3 Chronic postop endophthalmitis with endocapsular hypopyon (*arrow*)

Acute postoperative (postop) endophthalmitis usually presents with sudden loss of visual acuity (VA), increased ocular pain, red eye, swollen lids, anterior chamber reaction, hypopyon (Fig. 14.1), and fibrin formation, relative afferent pupillary defect, corneal edema and/or infiltrates (Fig. 14.2), vitreous opacities, periphlebitis, and retinitis with or without retinal necrosis. Retinal detachment and *phthisis bulbi* are the most feared complications of severe cases. Visual acuity after treatment may vary dramatically, with better outcomes commonly seen in eyes with culture-negative or coagulase-negative gram-positive (e.g., *Staphylococcus epidermidis*) bacterial cultures without corneal infiltrates. More severe cases are seen with gram-negative bacilli, *Staphylococcus aureus*, and *Streptococcus* [2].

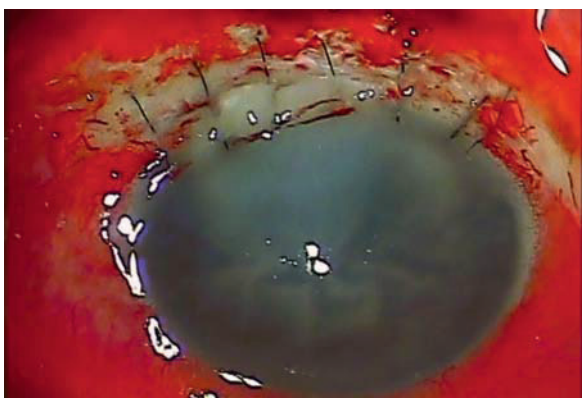


Fig. 14.2 Acute postop endophthalmitis 1 week after uncomplicated extra-capsular cataract surgery with severe corneal edema and melting at the limbus

Chronic postop endophthalmitis may present several weeks to years after surgery. The delayed more subtle signs include granulomatous keratic precipitates, endocapsular hypopyon (Fig. 14.3), and vitritis. It is commonly treated as a sterile postop inflammation with transient topical corticosteroid response. The most common microorganisms involved are *Propionibacterium acnes,* coagulase-negative gram-positive *Staphylococcus*, fungi (e.g., *Candida parapsilosis),* anaerobic *Streptococcus* species, *Nocardia asteroides*, *Actinomyces sp*., and *Corynebacterium sp*. Visual outcomes are generally better than for acute cases, because these are lower virulence microorganisms [3].

The goal of this chapter is to introduce the 25-gauge sutureless vitrectomy technique for the management of exogenous postop endophthalmitis, to address its safety and efficacy, and to compare its results with the other surgical techniques available. A brief review of acute and chronic post-cataract surgery and bleb-associated endophthalmitis will be provided.

14.2 Acute Post-Cataract Surgery Endophthalmitis

The ocular surface and adnexa are the main source of bacteria in postop endophthalmitis cases [4]. Some risk factors may increase the local bacterial flora, such as blepharitis, conjunctivitis, contact lens use, diabetes mellitus, immunosuppression, and keratoconjunctivitis sicca [5]. Other risk factors are related to surgical technique and complications. Capsular tear has been associated with an eight-fold higher incidence of postop endophthalmitis [6]. Although not well-established, there is mounting evidence of increased incidence of

endophthalmitis after sutureless temporal clear corneal when compared with superior scleral tunnel incisions for phacoemulsification [7, 8]. The intra-ocular lens (IOL) type and the way it is inserted in the eye has also been reported to influence postop infection rates [9, 10].

On the other hand, besides field sterilization, the most accepted pre-operative (pre-op) measurement to decrease the incidence of postop endophthalmitis is the use of topical povidone-iodine [11, 12]. But despite the dramatic decrease in wound size and surgical time of cataract surgeries in the past 20 years, the rate of postop endophthalmitis has increased in the last decade [13, 14].

14.2.1 Endophthalmitis Vitrectomy Study (EVS) Results [1, 2, 15]

14.2.1.1 Main EVS Recommendations

- All patients with acute postop endophthalmitis after cataract surgery or secondary IOL implantation should receive intra-vitreal antibiotics, including vancomycin 1 mg per 0.1 ml and amikacin 0.4 mg per 0.1 ml, regardless of presenting visual acuity.
- If presenting visual acuity is light perception (LP), immediate pars plana vitrectomy should be done in addition to intravitreal antibiotics.
- Intravenous ceftazidime and amikacin are not recommended as adjunctive therapy.

14.2.1.2 Cultures

- Anterior chamber. Aqueous humor samples were positive in 26.9% of eyes. In 4.2% of eyes aqueous was positive and undiluted vitreous sample was negative.
- Vitreous. Non-diluted sample: 58.9% positive cultures. Another 8.9% had positive culture from the vitrectomy cassette fluid alone.
- Vitreous tap/biopsy. Yielded 67.4% of positive cultures.
- Vitrectomy. Obtained 73.5% of positive cultures, without statistical significance between vitrectomy and vitreous tap/biopsy.
- Microorganisms. Among the 291 eyes with positive cultures, 68% showed coagulase-negative gram-positive organisms, 22% of other gram-positive organisms, like *Staphylococcus aureus* and streptococcus, and only 6% of gram-negative organisms.

14.2.1.3 Visual Acuity

- Of the 420 eyes included, 53% achieved 20/40 or better, and 74% reached 20/100 or better visual acuity at 9 months of follow-up. 11% ended with 20/800 or worse, and 5% with no light perception.
- Presenting VA of light perception: a three-fold higher percentage of eyes achieved 20/40 or better VA with vitrectomy (33%) when compared with vitreous tap/biopsy (11%), but if the presenting VA was hand motion or better, no statistically significant difference was found on final visual acuity;
- A higher percentage of eyes with no growth (55.3%) or coagulase-negative gram-positive organisms (61.5%) achieved 20/40 or better VA when compared with other gram-positive (28.6%) and gram-negative organisms (43.8%).

14.2.1.4 Comments

- Regardless of presenting VA, the media cleared faster with vitrectomy than with vitreous tap/biopsy.
- Presenting VA of light perception was present in only 26% of eyes.
- Macular complications such as epiretinal membrane, macular edema, pigmentary changes, and macular ischemia were the most common cause of impaired VA.
- Enucleation or *phthisis* rate: less than 1% had enucleation and 3% developed *phthisis*.
- Additional intervention was considered according to inflammatory and symptoms response within 36–60 h after the first procedure.
- Media opacity rate: 2% for vitrectomy and 15% for vitreous tap/biopsy. Independent risk factors for lower media clarity included light perception VA, corneal ulcer, and *rubeosis iridis*.
- Of the 855 patients with postop endophthalmitis after cataract surgery or secondary IOL implantation presenting within 6 weeks of surgery, 60% (510 patients) met inclusion criteria, but only 49% (420 patients) agreed to participate in the study.
- The inclusion criteria required sufficient corneal and anterior chamber clarity to visualize part of the iris and to allow vitrectomy.
- All patients were on Prednisone 30 mg PO bid for 5–10 days and received subconjunctival injection of dexamethasone 6 mg per 0.25 ml, but the value of intravitreal corticosteroids was not assessed.
- Subconjunctival antibiotics were administered in all patients (vancomycin – 25 mg per 0.5 ml and ceftazidime – 100 mg per 0.5 ml).
- Ceftazidime 2.25 mg per 0.1 ml is an option to replace amikacin for intravitreal injection, due to lower intraocular side effects [16].

Summary for the Clinician

Main EVS findings:

- If presenting VA is LP, immediate pars plana vitrectomy should be done in addition to intravitreal antibiotics (vancomycin and amykacin or ceftazidime);
- If presenting VA is hand motions or better, no statistically significant difference in outcomes were found between vitrectomy and tap/biopsy;
- Intravenous ceftazidime and amikacin are not recommended as adjunctive systemic therapy;
- Vitreous sample is more likely to yield positive cultures than anterior chamber sample;
- Coagulase-negative gram-positive organisms are more common, and associated with better prognosis;
- Regardless of presenting VA, the media cleared faster with vitrectomy than with vitreous tap/biopsy

14.3 Chronic Postoperative Endophthalmitis

Among the microorganisms mentioned above, *Propionibacterium acnes* is the most studied causative agent of chronic postop endophthalmitis. The endocapsular hypopyon corresponds to colonies of the organism situated between the posterior surface of the IOL and the posterior capsule (Fig. 14.3). This peculiar location may protect the organism from antimicrobial agents and host defense mechanisms, and could explain the high rate of recurrences with less invasive techniques [3].

Gathering two relatively large series of *P acnes* endophthalmitis treatment options, Deramo and Ting plotted the recurrence rates for different techniques [3, 17, 18]:

- Injection of intravitreal antibiotic: 93%
- Pars plana vitrectomy with intravitreal antibiotic: 50%
- Pars plana vitrectomy with partial capsulectomy, intravitreal antibiotic, and retention of the intraocular lens: 26%
- Pars plana vitrectomy with total capsulectomy, intravitreal antibiotic, and intra-ocular lens removal or exchange: 0%.

Based on these data, pars plana vitrectomy with total capsulectomy, intravitreal antibiotic, and intraocular lens removal or exchange seems to be the curative technique. Vancomycin is the intravitreal antibiotic of choice [3].

14.4 Bleb-Associated Endophthalmitis

The conjunctival flora has gram-positive and gram-negative microorganisms like *Staphylococcus epidermidis*, *Staphylococcus aureus*, Haemolytic streptococcus Group C, *Bacillus sp*., *Haemophilus influenzae*, and *Pseudomonas aeruginosa* capable of causing postop endophthalmitis [19]. The conjunctiva and sclera provide the main barriers against entry of infectious organisms into the eye. But through a leaky filtering bleb after trabeculectomy glaucoma surgery, the tear film containing the potential infecting flora has been documented to gain access into the anterior chamber [20].

Bleb-associated endophthalmitis is a severe complication characterized by the presence of blebitis with a mucopurulent infiltrate within the bleb associated with hypopyon and vitritis (Fig. 14.4) [21]. Risk factors include the use of antifibrotic agents, inferiorly located blebs, and leaky blebs [21, 22]. The incidence of bleb-associated endophthalmitis seems to be higher than for other intraocular surgeries, and it appears to be increasing [23, 24]. The mean time from glaucoma surgery to endophthalmitis is around 20 months, but it may develop from 3 days to 60 years [21, 24, 25]. In early bleb-associated endophthalmitis (within 1 month of surgery), the most common microorganisms include the coagulase-negative gram-positive *Staphylococcus* and *Propionibacterium acnes*. But late-onset bleb-associated endophthalmitis is usually caused by *Streptococcus sp*. and gram-negative bacteria such as *Haemophilus influenzae* [23]. Overall, *Streptococcus sp*. is the most common causative microorganism in bleb-associated endophthalmitis. A recent

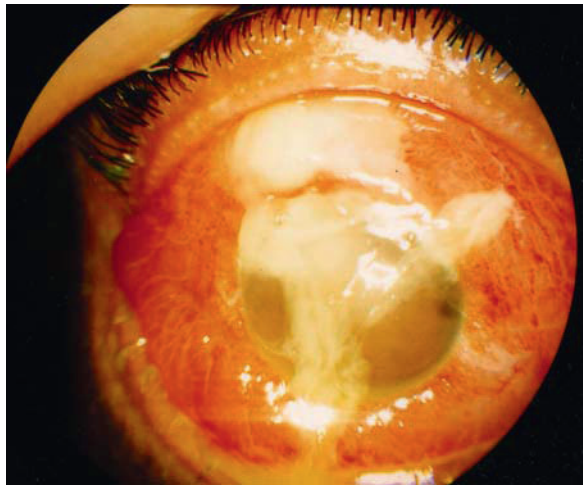


Fig. 14.4 Bleb-associated endophthalmitis 3 years after trabeculectomy with mitomycin. Culture was positive for *Streptococcus sp*.

report by Busbee et al. didn't find any difference in visual outcomes between early- versus late-onset bleb-associated endophthalmitis [24].

The EVS results didn't include patients undergoing filtering glaucoma surgery, and extrapolation of its data should be done carefully [1]. Although no randomized controlled clinical trial has been conducted to date, the surgical outcome for bleb-associated endophthalmitis seems to be better with prompt pars plana vitrectomy and intravitreal antibiotics than with vitreous tap and intravitreal antibiotics, regardless of time of onset and pre-op VA [23, 24]. Besides intravitreal, topical fortified antibiotics are used to treat the infected bleb (vancomycin 50 mg/ml^{-1} and gentamicin 15 mg/ml^{-1}) [25].

If a leaky bleb is present in association with blebitis and endophthalmitis, it is recommended that a bleb excision and conjunctival advancement are used in addition to pars plana vitrectomy and topical and intravitreal antibiotics.

Summary for the Clinician

- In chronic post-cataract surgery endophthalmitis, pars plana vitrectomy with total capsulectomy, intravitreal vancomycin, and intraocular lens removal or exchange is the procedure associated with the lowest recurrence rate.
- Bleb-associated endophthalmitis is characterized by the presence of blebitis with a mucopurulent infiltrate within the bleb, hypopyon, and vitritis.
- Risk factors include the use of antifibrotic agents, inferiorly located blebs, and leaky blebs.
- In early bleb-associated endophthalmitis (within 1 month of surgery), the most common microorganisms are coagulase-negative gram-positive *Staphylococcus* and *Propionibacterium acnes*. Late-onset bleb-associated endophthalmitis is usually caused by *Streptococcus sp*. (most common) and gram-negative bacteria.
- The EVS results didn't include patients undergoing filtering glaucoma surgery and extrapolation of its data should be done carefully. The surgical outcome for bleb-associated endophthalmitis seems to be better with prompt pars plana vitrectomy and intravitreal antibiotics.

14.5 Current Surgical Techniques

14.5.1 Vitreous Tap

- Topical 5% povidone-iodine 15–20 min before procedure.
- Subconjunctival anesthesia with 2% lidocaine without adrenaline.
- Transconjunctival pars plana vitreous tap 3.0–3.5 mm from the limbus with a 27-gauge needle on a tuberculin syringe. Collect between 0.1–0.3 ml of vitreous sample.
- Intravitreal injection of vancomycin 1 mg per 0.1 ml and ceftazidime 2.25 mg per 0.1 ml are done on separate tuberculin syringe through a 27- or 30-gauge needle.
- Intra-ocular pressure should be checked (preferably with a hand-held tonometer).

According to the EVS protocol, patients assigned to vitreous tap had a 0.1 ml sample from the anterior chamber with a 25–27-gauge needle on a tuberculin syringe. In 4.2% of eyes the anterior chamber sample was culture positive, and vitreous sample showed no growth [15]. The authors do not perform it routinely.

14.5.2 Vitreous Biopsy

The first sutureless transconjunctival pars plana vitrectomy system was introduced in 1995 (Josephberg – Vitreous Society, London). It was an integrated 23-gauge vitreous cutter and penetrating needle with tubing at the back of the vitrector's handle for manual aspiration connected to a syringe and an opening at the cutter shaft for irrigation [26]. Its use was popularized for vitreous biopsy in endophthalmitis, and a similar instrument wa s used on the EVS for the vitreous tap/biopsy group in eyes in which a needle aspiration tap could not obtain an adequate sample [1].

14.5.3 20-Gauge Pars Plana Core Vitrectomy

This procedure is usually performed under retro/peribulbar local anesthesia despite the inflamed eye, because the core vitrectomy is a fairly quick surgery. The opening and closing of the conjunctiva may be somewhat uncomfortable to the patient.

Anterior chamber fibrin may be removed through 2 19–20-gauge limbal incisions by anterior chamber washout or with an anterior chamber maintainer and the 20-gauge vitrector.

After conjunctival opening, corneal clarity may dictate how many pars plana sclerotomies will be done. If there is reasonable visibility, a standard 20-gauge 3-port vitrectomy can be performed. An alternative is a 2-port vitrectomy with the vitrector and an irrigating light pipe. If severe corneal opacity is present, a 2-port vitrectomy can be done only with an infusion line and the vitrector

placed in the mid vitreous without direct visualization ("blind vitrectomy").

The first undiluted vitreous sample (0.2–0.5 ml) is withdrawn manually with a syringe connected to the aspiration line of the vitrector (at a high cut rate) with the infusion closed. After the infusion is open, a core vitrectomy is performed, but no attempt is made to surgically separate the posterior hyaloid or to shave the vitreous base. The amount of vitreous debris removed is dictated by the visibility allowed by the anterior segment. Sclerotomies and conjunctiva are closed, and the undiluted and diluted (from the vitrectomy machine cassette) samples are sent for bacterioscopy, cultures, and antibiogram.

The results of this technique are represented by the EVS vitrectomy group (mentioned above). The percentage of positive cultures with this technique for acute postcataract surgery endophthalmitis is around 68% [27, 28].

Thirty-four percent of eyes on the EVS required additional surgery either for surgical complications or worsening of intraocular inflammation or infection [1]. The incidence of retinal detachment after 20-gauge vitrectomy for acute postop endophthalmitis ranges from 7.8% on the EVS to 14%, with a mean of 11.4% [27–29]. One study reported a 12.5% rate of giant retinal tear postop [28].

For eyes with pre-op VA of light perception, Kaynak et al. reported a visual outcome rate of 20/40 or better in 25% of eyes, and 33.3% remained with 20/200 or worse. *Phthisis bulbi* developed in 12.5% of eyes [28].

Disadvantages of this technique with core vitrectomy include persistent vitreous opacities after infection is resolved, increased need for additional procedures, and the fact that in most eyes with severe endophthalmitis it doesn't allow a clear intra-operative view of the retina [28].

14.5.4 20-Gauge Pars Plana Vitrectomy and Silicone Oil Tamponade

Silicone oil has been shown to have an antimicrobial activity against *S. aureus*, *S. epidermidis*, *P. aeruginosa*, *C. albicans* e *Aspergillus sp*., and endophthalmitis in silicone oil-filled eyes is rarely reported [30, 31]. Based on these facts, some authors have used silicone oil as an adjunct to vitrectomy to treat eyes with severe endophthalmitis without concomitant retinal detachment. They claim to have less additional procedures after vitrectomy with versus without silicone oil. Bali et al. found a better final visual acuity in eyes with silicone oil, but Kaynak et al. found no statistically significant difference in either visual acuity or in positive culture results when comparing to core vitrectomy alone [28,32]. This latter group performed a bigger procedure with total vitrectomy, including posterior hyaloid detachment and vitreous base shaving associated with encircling band and 360° peripheral endolaser.

Aras et al. have pointed out a few concerns with this technique [33]. Surgical posterior hyaloid detachment and vitreous shaving in eyes with endophthalmitis carries great risk for iatrogenic retinal tears and detachment, due to poor visualization and increased retinal fragility. Retinal detachment related with endophthalmitis is associated with poorer surgical outcomes [27, 34]. All eyes eventually may need an additional intervention for silicone oil removal, and eyes that stay with long-term silicone oil tamponade are at increased risk to develop optic atrophy. Silicone oil also causes compartmentalization in the eye that may trap inflammatory debris between the silicone oil and retina, leading to epiretinal membranes, and it may also interfere in the distribution and effect of intravitreal antibiotics [33]. Another potential concern is to place an encircling band on an infected eye, allowing increased risk of infection around the exoplant and even of panophthalmitis.

14.5.5 20-Gauge Pars Plana Vitrectomy and Endoscopy

Recently, a retrospective series of severe endophthalmitis cases managed with 20-gauge vitrectomy and endoscopy has been published. In this series, six cases of postop endophthalmitis after cataract surgery were included, all culture-positive. The advantages of using endoscopy in these cases include direct visualization of the retina during a more complete vitrectomy, even in the presence of corneal edema/infiltrates and anterior chamber fibrin. It also allows intra-operative detection and prompt treatment of retinal necrosis, tears, and detachment associated with endophthalmitis. Of six cases of post-cataract surgery endophthalmitis, in two (33%) a retinal tear was detected and treated intra-operatively; five (83%) had intra-retinal hemorrhage, and one (17%) had retinal necrosis.

Visual acuity of these six cases at 6 months follow-up ranged from 20/15 to no light perception; two cases developed *phthisis bulbi* and one eye was enucleated [35].

14.5.6 Adjunctive Therapies

14.5.6.1 Intravitreal Steroids

An important part of intraocular damage secondary to endophthalmitis is caused by the ocular inflammatory response to the infection. The use of oral and topical steroids is a generally accepted adjunct to vitrectomy and intravitreal antibiotics [1]. Subconjunctival steroids

can achieve therapeutic intraocular levels within the first hours after surgery and was also used in the EVS [1, 36]. But there are conflicting results concerning the adjunctive use of intravitreal steroids. A recent report showed that in eyes with experimentally induced bacterial endophthalmitis receiving early treatment with intravitreal antibiotics, triamcinolone acetonide 4 mg appeared to suppress the ocular inflammatory response without impairing the therapeutic effect [37].

A prospective randomised clinical study of exogenous bacterial endophthalmitis cases demonstrated that the concomitant use of intravitreal dexamethasone 400 µg per 0.1 ml with vitrectomy and intravitreal antibiotics is associated with faster recovery of ocular inflammation but no effect on visual outcome at 3 months follow-up [38]. These authors suggested the use of intravitreal steroids as an alternative only in patients with systemic diseases that may be affected by the use of oral steroids.

Another retrospective study of eyes with postop endophthalmitis after cataract surgery demonstrated that eyes undergoing either vitreous tap or vitrectomy and intravitreal antibiotics had a significantly reduced likelihood of obtaining a 3-line improvement in visual acuity if they had received intravitreal steroids [39].

14.5.6.2 Tissue Plasminogen Activator (tPa)

This has been used for various causes of post-vitrectomy fibrin formation, injected either intravitreal or in the anterior chamber, achieving complete fibrin resolution in about 80% of cases. Complications include increased IOP, hyphema, and corneal edema [40]. In endophthalmitis, postop fibrin recurrence is common after tPA injection.

14.5.6.3 Antibiotics

Although many vitreoretinal surgeons still follow the EVS original protocol of intravitreal antibiotics using vancomycin and amikacin, an increasing number of surgeons are switching from amikacin to safer alternatives for gram-negative microorganisms, such as ceftazidime (2.25 mg per 0.1 ml^{-1}) [1, 41]. But the concomitant use of vancomycin and ceftazidime has been shown to form precipitates that may interfere with antibiotic activity [42, 43]. More recently, ciprofloxacin (0.1 mg per 0.1 ml) has been presented as another alternative because of lower rates of precipitate formation when used with vancomycin [44, 45]. But ciprofloxacin resistance has risen in the Western World due to indiscriminate use, while the susceptibility of microorganisms to vancomycin and ceftazidime has remained mostly unchanged [46–48]. A recent report demonstrated therapeutic vitreous levels with oral fourth-generation fluoroquinolone moxifloxacin for a wide range of bacteria, and even though they may not seem to offer expanded coverage for ciprofloxacin-resistant coagulase-negative Staphylococcus isolates, further studies are needed to prove their efficacy in endophthalmitis [48, 49].

Despite reasonable anterior chamber penetration, vitreous levels are generally poor with subconjunctival antibiotics [50]. Smiddy et al. found that the nonuse of subconjunctival antibiotics did not adversely influence the outcomes of treatment for postop endophthalmitis after cataract and glaucoma filtering surgeries when the initial visual acuity was hand motions or better [51]. A recent report has shown the significant decrease in subconjunctival antibiotics use since the EVS [52].

Summary for the Clinician

- 20-gauge pars plana core vitrectomy is the technique used by the EVS vitrectomy group. The percentage of positive cultures with this technique for acute post-cataract surgery endophthalmitis is around 68%. Thirty-four percent of eyes on the EVS required additional surgery either for surgical complications or worsening of intraocular inflammation or infection.
- The mean incidence of retinal detachment after 20-gauge vitrectomy for acute postop endophthalmitis is around 11.5%.
- Silicone oil has been shown to have an antimicrobial activity. So some authors have used silicone oil as an adjunct to vitrectomy to treat eyes with severe endophthalmitis without concomitant retinal detachment.
- 20-gauge pars plana vitrectomy and endoscopy is an useful alternative for eyes with corneal edema and opacities.
- The benefits of intravitreal steroids are still not very clear. They may be useful in patients with systemic diseases that can be affected by oral corticosteroids.
- Vancomycin and amykacin or ceftazidime are still the main intravitreal antibiotics used in acute postop endophthalmitis. Newer-generation fluoquinolones may prove to be another antimicrobial option in the near future.
- Subconjunctival antibiotics usage has greatly decreased because of its questionable adjunctive role.

14.6 25-Gauge Transconjunctival Vitrectomy for Infectious Endophthalmitis

Previous chapters have discussed the basic surgical technique and fluidics of the 25-gauge transconjunctival vitrectomy system (TSV-25). Endophthalmitis is one of the most controversial indications of TSV-25, with very few cases reported in the literature [53–55]. This section will address the TSV-25 technique for severe infectious postop endophthalmitis (light perception vision), and compare our preliminary results of safety and efficacy with the data described above.

14.6.1 Surgical Technique

Although some advocate general anesthesia for longer cases because of the difficulty in obtaining local anesthesia in an inflamed, painful eye [36], the present technique is done under a combination of retro/peribulbar local anesthesia with sedation. The fact that the conjunctiva is less manipulated may decrease patient discomfort during surgery.

Preoperative disinfection is done with topical 5% povidone-iodine instilled 15–20 min before draping the patient (Fig. 14.5), and once again after putting the lid speculum. Periocular skin disinfection is carried out with 10% povidone-iodine. Both measures seem to reduce postoperative endophthalmitis [56], and are strongly recommended for a sutureless procedure on an infected eye.

14.6.1.1 Acute Postoperative Endophthalmitis

For eyes that had postop endophthalmitis after cataract surgery or secondary intra-ocular lens implant, the first step is to suture the corneal or limbal incision with 9–0 or 10–0 nylon (Fig. 14.6). If the previous surgery was a filtering glaucoma surgery, close any conjunctival dehiscence with 7–0 or 8–0 polygalactic acid (Vycril) suture and if needed do a conjunctival advancement.

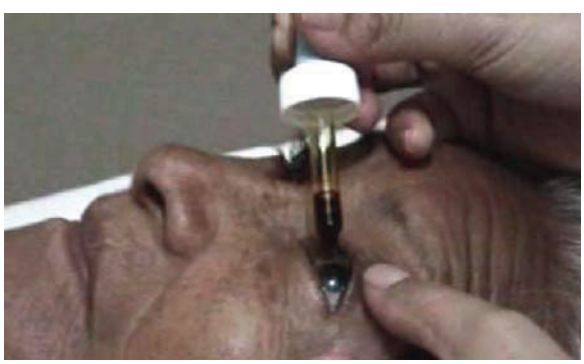


Fig. 14.5 Preop topical 5% povidone-iodine instilled 15–20 min before draping the patient

- After wound closure, carry out a limbal paracentesis infero-temporal to introduce the 25-gauge infusion line in the anterior chamber, with or without the 25-gauge cannula (Fig. 14.7). Turn on the fluid infusion (set at 44 mmHg).
- Perform a second limbal paracentesis with a 26-gauge needle (Fig. 14.8). The needle is used to dissect any hypopyon and fibrin plaques from the anterior chamber structures and to release anterior and posterior synechiae formations. Then the 25-gauge vitrector is introduced through this paracentesis and all the free floating debris is removed.
- Aspirate the removed diluted anterior chamber material by a syringe connected to the aspiration line of the vitrector (sample 1) (Fig. 14.9).
- Keeping the infusion open, remove the vitrector.
- Create an infero-temporal transconjunctival modified scleral tunnel (as detailed bellow) 3.0–3.5 mm posterior to the limbus (with or without the anterior chamber infusion still in place) (Fig. 14.10).
- Insert the 25-gauge vitrector through the cannula positioned at the pars plana, and activate aspiration (550–600 mmHg) and cut rate (1,200–1,500 cpm) (Fig. 14.10). When fluid is seen on the aspiration tubing, connect another syringe to get a vitreous sample (sample 2) (Fig. 14.9). Even though there is no infusion line in the vitreous cavity, some fluid goes around the zonules, making it a partially diluted sample (if the infusion line is kept turned on in the anterior chamber).
- Remove the vitrector and switch the infusion line from the anterior chamber to the pars plana cannula (Fig. 14.10c).
- Create a second transconjunctival modified scleral tunnel for the vitrector.
- If there is reasonable corneal and anterior chamber clarity, create a third sclerotomy for the 25-gauge fiber optic illumination. A xenon light is preferred because of the difficulties in visualization due to media opacities. A non-contact wide-angle viewing system is recommended to avoid corneal abrasions on an infected eye (although some authors remove the corneal epithelium to improve visualization).
- Carry out core vitrectomy to remove vitreous debris (Fig. 14.11). The amount of vitrectomy may be dictated by the quality of visualization. Attempts at posterior hyaloid detachment and vitreous base shaving are risky moves, and frequently lead to retinal breaks due to retinal fragility and lack of appropriate visualization.

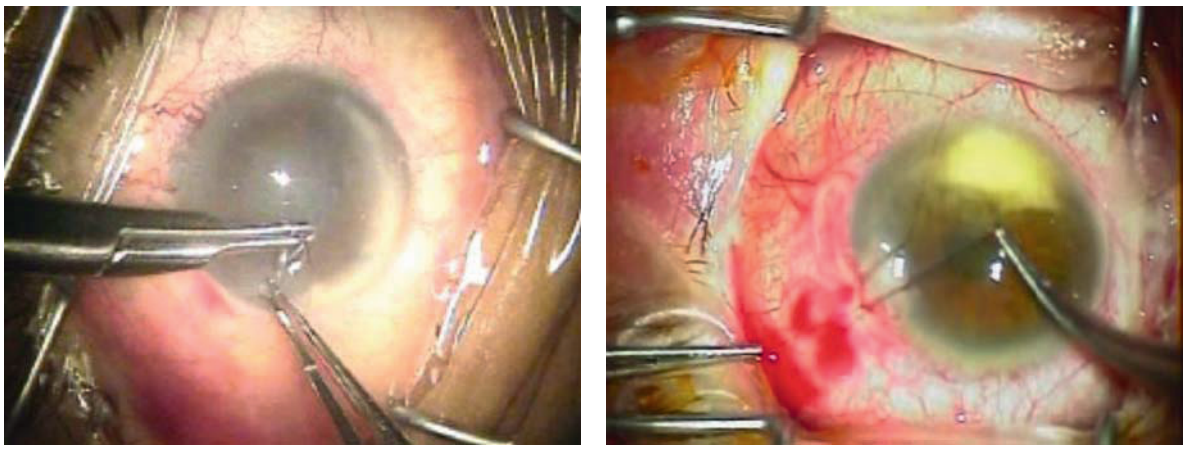


Fig. 14.6 Clear corneal wound closure with 10–0 nylon

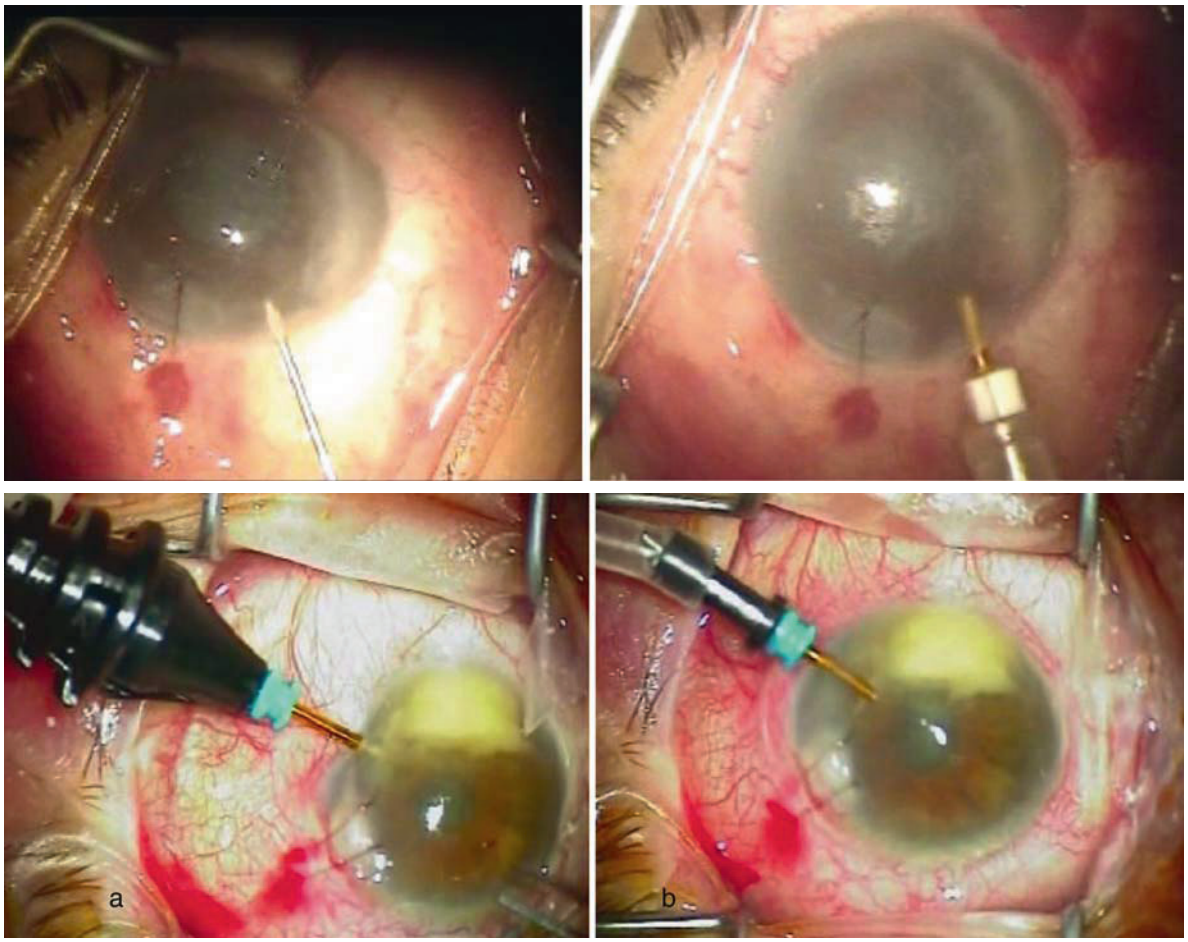


Fig. 14.7 (**a**) Infero-temporal limbal paracentesis with a 25-gauge trocar system for cannula insertion. (**b**) Anterior chamber 25-gauge infusion line

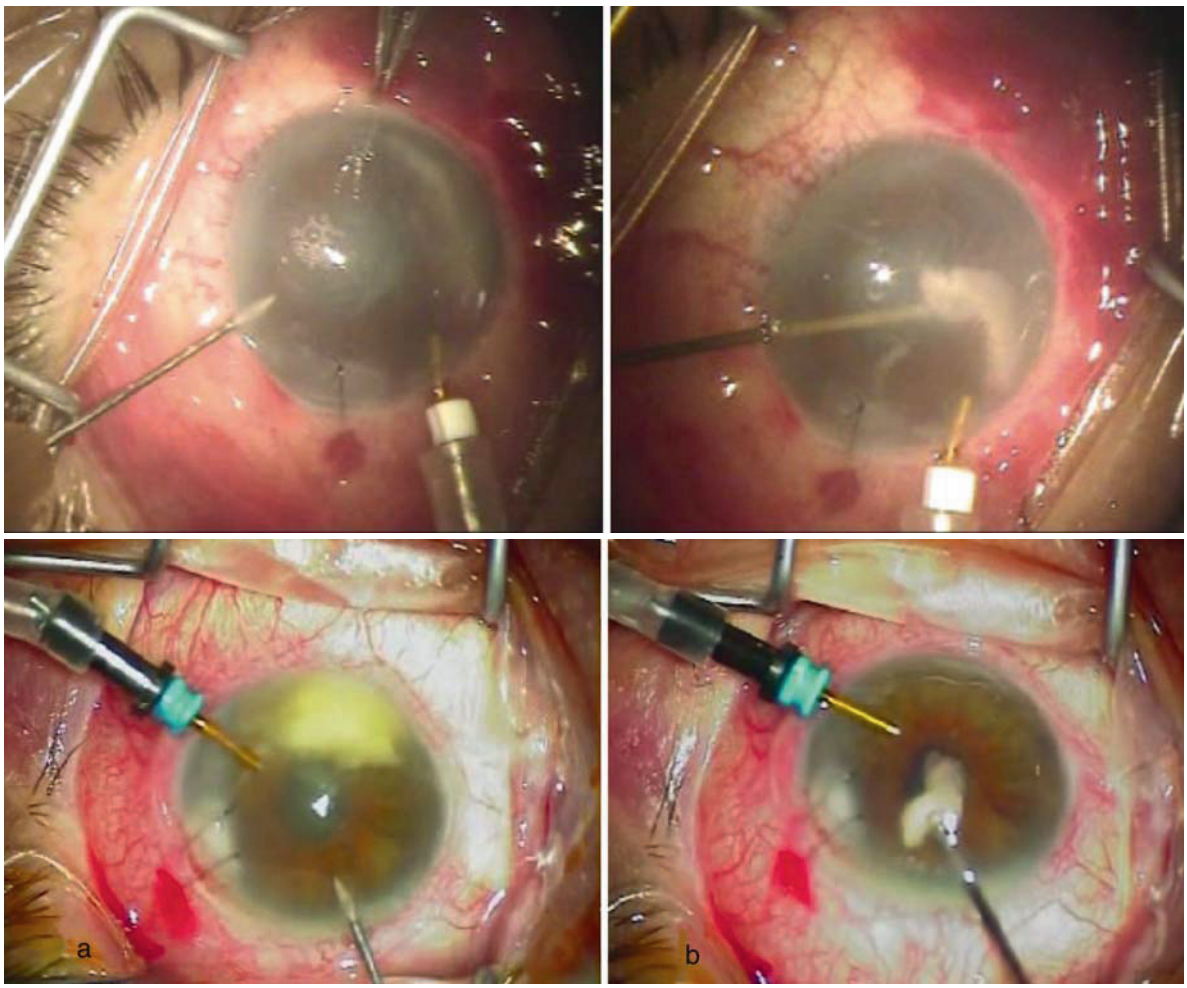


Fig. 14.8 (**a**) A second limbal paracentesis with a 26-gauge needle is done. (**b**) Removal of anterior chamber hypopyon and fibrin plaque with the 25-gauge vitrector

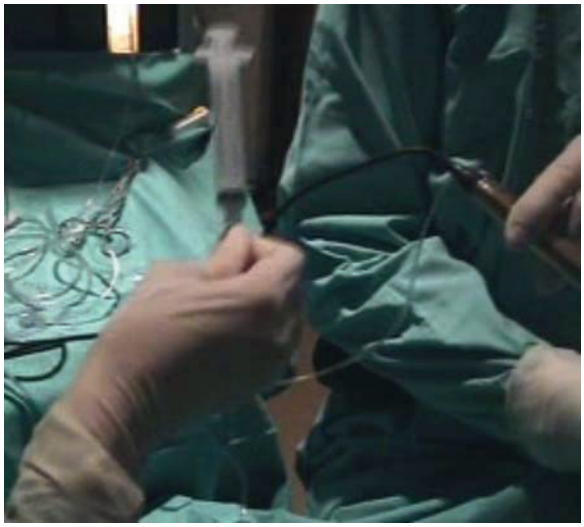


Fig. 14.9 A syringe is connected to the aspiration line for anterior chamber and vitreous sampling

- When vitrectomy is concluded, remove the vitrector from the eye and place a plug on the cannula. No fluid–air exchange is done.
- To avoid a syringe plunger effect when removing the instruments from the cannulas, increasing vitreous prolapse, it is advised to keep the light pipe inside the eye and remove the cannula first with a curved tying forceps without teeth, sliding it up the instrument shaft. Then, decrease the fluid infusion pressure to 20–29 mmHg and remove the light pipe, covering the sclerotomy site with a cotton-tip applicator (Fig. 14.12).
- Remove plug from the second sclerotomy, reintroduce the light pipe, remove the cannula first and then the light pipe.
- Remove the infusion line together with the last cannula, holding it with the curved tying forceps without teeth, leaving the eye with lower IOP.

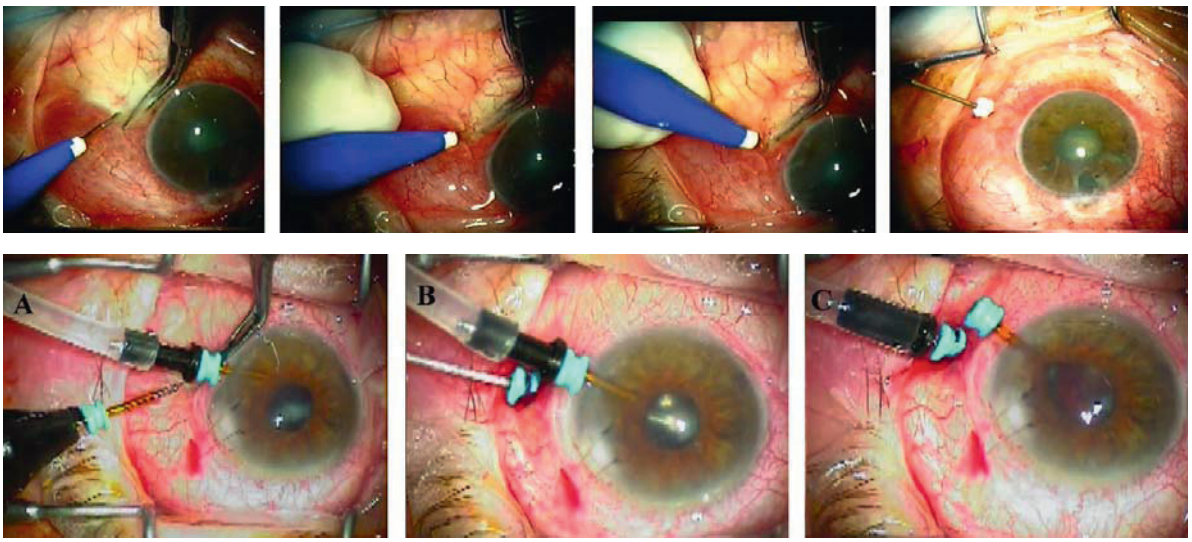


Fig. 14.10 (**a**) 25-gauge scleral tunnel (as detailed below). (**b**) Vitreous sampling with 25-gauge vitrector with anterior chamber infusion. (**c**) Infusion is switched posteriorly

- Transconjunctival 30-gauge needle pars plana injections of antibiotics (vancomycin 1 mg per 0.1 ml and ceftazidime 2.25 mg per 0.1 ml) will increase the IOP and resume the case (Fig. 14.13).
- Take care when removing the lid speculum, which may compress the eye and be responsible for immediate postop hypotony.
- Take a sample (sample 3) from the fluid deposited on the cassette (diluted sample). All three samples should be sent for Gram stain, cultures, and antibiogram. Report to microbiology any topical or systemic antibiotics being used.

Comments

Some cases are associated with intense corneal edema, and even corneal melting may be present. In this scenario, a 2-port 25-gauge core vitrectomy can be done without the port for illumination only to remove some vitreous debris for microbiological analysis and intravitreal antibiotic administration (Fig. 14.11a). Caution should be taken to avoid large conjunctival infiltration of anesthetics during retro/peribulbar block on this very congested conjunctiva, because it is more troublesome to create the scleral tunnel sclerotomies (sometimes not feasible) and also to place them at the appropriate distance from the limbus. In some eyes with severe hypotony, it is safer to place the infusion line in the first sclerotomy instead of the vitrector. In this instance, only a diluted sample will be collected. This maneuver may prevent more serious complications like hemorrhagic choroidal detachment.

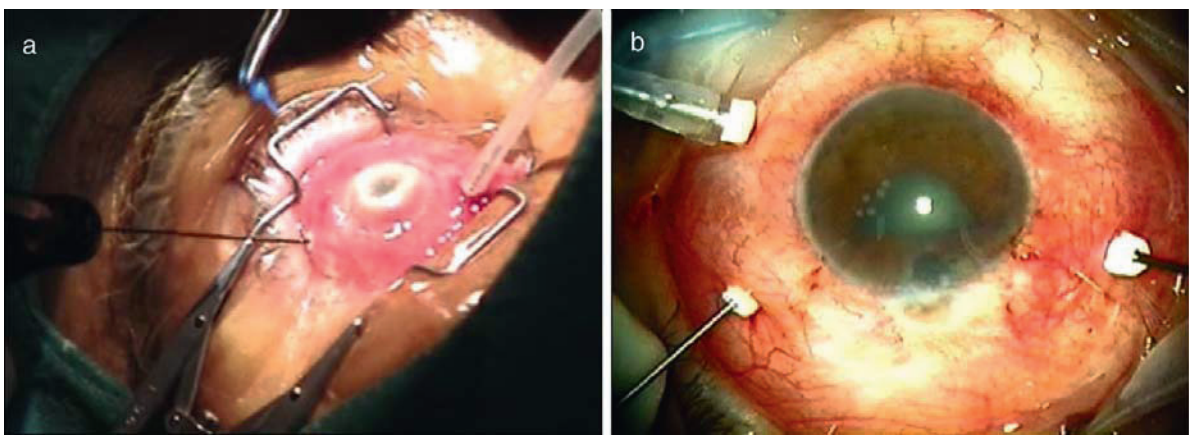


Fig. 14.11 Core vitrectomy in postop endophthalmitis. (**a**) 25-gauge two-port vitrectomy. (**b**) 25-gauge three-port vitrectomy

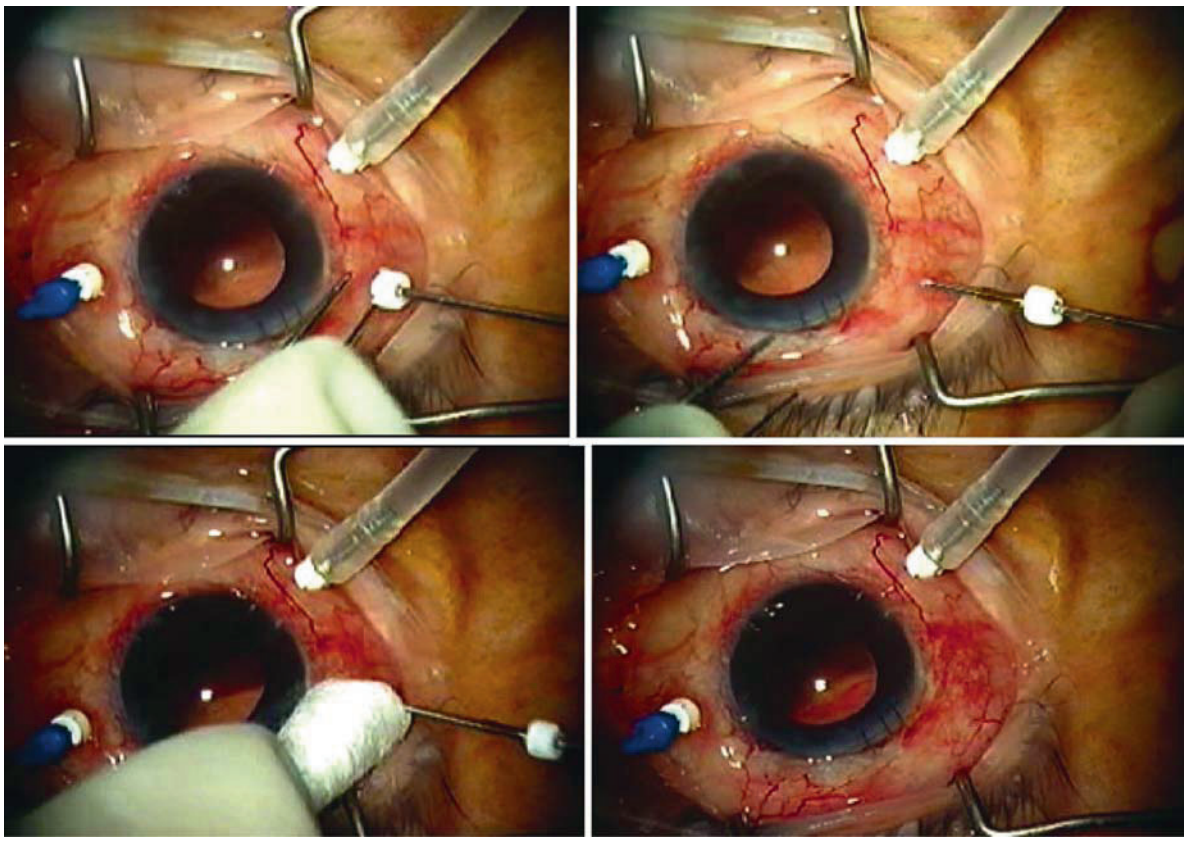


Fig. 14.12 Trocar removal. (**a**) Light pipe inside the cannula. (**b**) Removal of the cannula first with a curved tying forceps without teeth, sliding it up the light-pipe shaft. (**c**) Removal of the light pipe, covering the sclerotomy site with a cotton-tip applicator. (**d**) Sealed sclerotomy with less vitreous prolapse

14.6.1.2 Chronic Postoperative Endophthalmitis

The surgical approach of chronic postoperative endophthalmitis (post cataract surgery) that has the lowest recurrence rate is with pars plana vitrectomy, IOL removal, and total capsulectomy (as mentioned above) [3]. To this technique, we will introduce the 25-gauge vitrectomy, for eyes with foldable IOL:

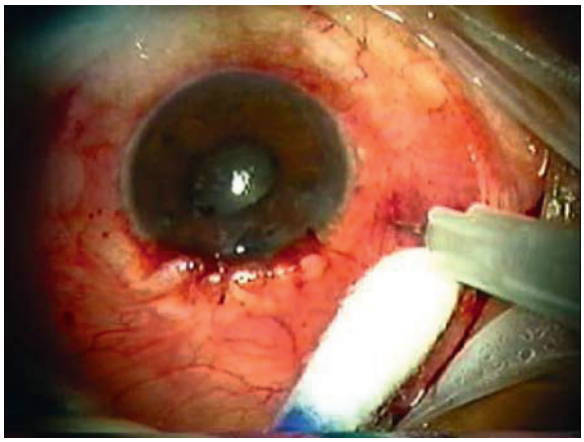


Fig. 14.13 Antibiotic injection with 30-gauge needle

- Create an infero-temporal transconjunctival scleral tunnel (as detailed below) 3.0–3.5 mm posterior to the limbus, and insert the 25-gauge infusion line. It may be turned on or off during the IOL removal.
- Create a 1.0 mm clear corneal side port at the 2 o'clock position, and inject viscoelastic to fill the anterior chamber (Fig. 14.14a).
- Create a 3.2 mm three plane superior clear corneal tunnel (Fig. 14.14b). In eyes with previous temporal clear corneal incision, the wound should be tested for leakage and, in doubt, be sutured.
- With two IOL hooks, rotate the lens out of the capsular bag (Fig. 14.14c).
- Cut the optic of the foldable IOL with an intraocular scissors about ¾ of its length, and remove in one piece (Fig. 14.14d–f).
- Suture the superior clear corneal wound.

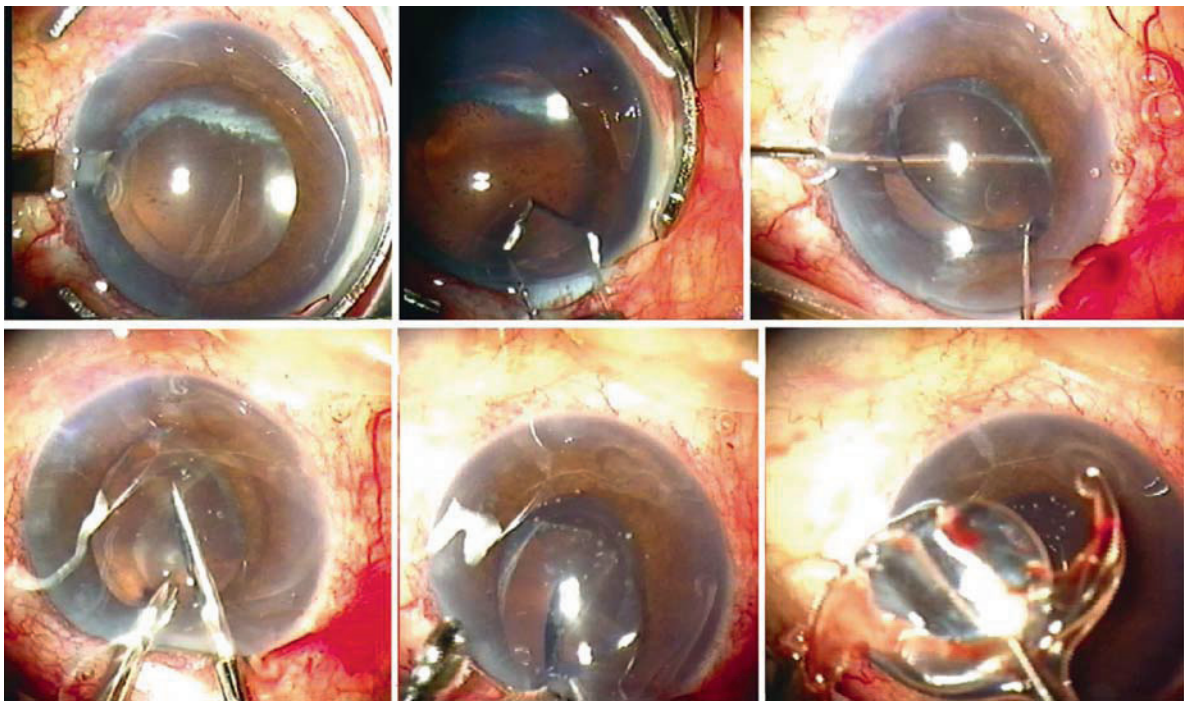


Fig. 14.14 Chronic postop endophthalmitis. **a** A 1.2 mm side port is created. **b** A 3.2 mm main incision is done after viscoelastic insertion through the side port. **c** Intraocular lens (IOL) is explanted from the capsular bag. **d** An intraocular forceps is used to grasp the IOL and an intraocular scissors is used to cut the IOL. **e** The one-piece IOL is removed without enlarging the clear corneal wound. **f** Intraocular lens removed. Note the cut through the IOL optic

- Place iris hooks to allow better visibility of the zonular apparatus (Fig. 14.15a);
- Create two other transconjunctival scleral tunnel sclerotomies for light pipe and vitrector. The light pipe cannula is closed with a plug.
- Insert an intra-ocular forceps through the clear corneal incision, between the sutures, to grasp the anterior capsule and stretch it to expose the zonules (Fig. 14.15a–b);
- Use the 25-gauge vitrector through a pars plana cannula to cut the zonules 360° (Fig. 14.15b). The entire capsular bag is then removed with the intra-ocular forceps and sent for Gram stain and direct inoculation onto bacterial and fungal media (Fig. 14.15c–d). At least two medias for anaerobes should be used (thioglycolate and CDC anaerobic blood agar) [57].
- Then perform core vitrectomy under non-contact wide-angle viewing system to avoid corneal abrasions on an infected eye. Usually the media clarity is good, and posterior hyaloid detachment and vitreous base shaving may be carried out safely. During capsular removal, the endocapsular hypopyon may spread into the vitreous cavity, forming multiple flocculated white deposits on the retinal surface. This material may be aspirated with a 25-gauge silicon soft tip connected to active suction. It will be accumulated in the cassette and should also be sent for microbiological analysis.
- After vitrectomy is concluded, follow the same steps mentioned above for cannula removal and intravitreal antibiotic injection (vancomycin 1.0 mg/0.1 ml).

Comments

In chronic postop endophthalmitis, the most likely microorganisms are gram-positive *Propionibacterium acnes* and *Staphylococcus epidermidis* [3]. Both are still sensitive to vancomycin, and it's the only antibiotic administered at the end of the case. The vancomycin may be administered through the limbus in aphakic eyes.

If the anterior segment surgeon is the one removing the IOL, the 25-gauge infusion line may be placed after the IOL removal. In this case, the first transconjunctival tunnel sclerotomy is harder to construct because the eye is usually softer.

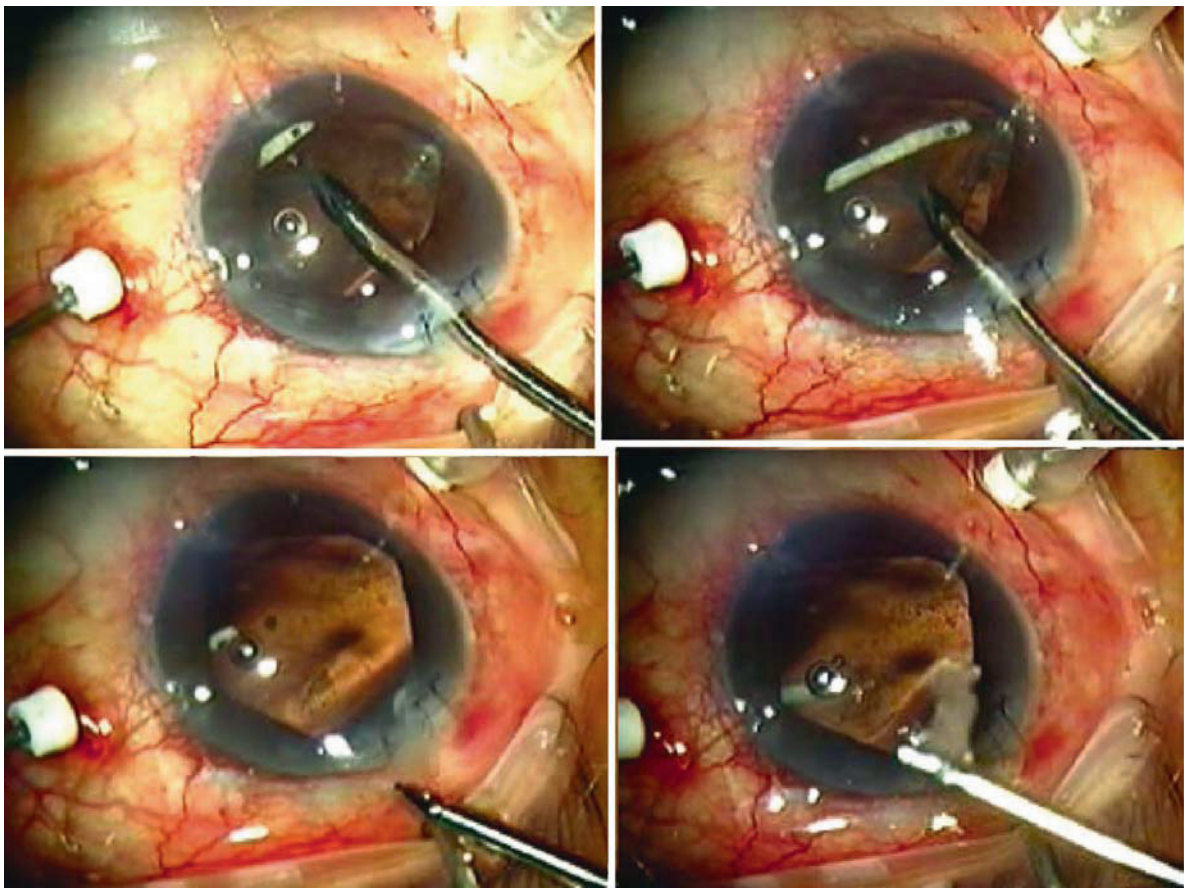


Fig. 14.15 Chronic postop endophthalmitis. (**a**) After placing the iris hooks, an intraocular forceps through the clear corneal incision grasps and stretches the anterior capsule to expose the zonules. (**b**) The 25-gauge vitrector then cuts the zonules 360°. (**c**) Capsular bag being removed. (**d**) Entire bag removed

14.6.1.3 Bleb-Associated Endophthalmitis

The only difference in the surgical technique between bleb-associated and acute post-cataract surgery endophthalmitis is the bleb management and the sclerotomy sites. The bleb should be managed either at the beginning or at the end of the case, depending on the presence or absence of leakage. In cases of associated blebitis, fortified topical vancomycin hydrochloride (50 mg/ml^{-1}) and gentamicin sulfate (15 mg/ml) should be added to intravitreal antibiotics [25]. Besides antibiotics, eyes with leaking blebs should have a conjunctival advancement [58]. The sclerotomies should be placed far from the bleb.

14.6.2 25-Gauge Surgical Results

We conducted a prospective consecutive noncomparative study of eyes with severe acute post-cataract surgery endophthalmitis between January 2004 and January 2005. All patients were diagnosed with endophthalmitis within the first 6 weeks after cataract surgery [1]. All eyes had 25-gauge transconjunctival pars plana vitrectomy and intravitreal antibiotic injections (as described above), and postop medications were Prednisone 1 mg/kg/day PO for 1–2 weeks and tapered thereafter, topical 1% prednisolone q 1 h, topical 1% atropine b.i.d., and topical gatifloxacin 6x/day. Eyes with corneal involvement also received Ciprofloxacin 500 mg PO b.i.d. for2 weeks. No subconjunctival steroids or antibiotics were given.

The collected data included age, gender, pre- and postop visual acuity (after 6 months of follow-up), preop, day 1, and day 30 postop IOP, culture and antibiogram results, and intra- and postop complications.

Eleven eyes of 11 patients were included (six females; 54.5%), with mean age of 67.5 years (57–78 years). All eyes had pre-op echographic findings of vitreous opacities with or without vitreous membranes but no retinal detachment [59]. All eyes had pre-op visual acuity

Summary for the Clinician

- Because of the difficulty in obtaining local anesthesia in an inflamed, painful eye, [36] the 25-gauge transconjunctival vitrectomy presents the benefits of less manipulation on the ocular surface.
- Special care with wound construction and cannula removal is critical in an infected eye using sutureless incisions.
- 25-gauge instruments are less traumatic for removal of anterior chamber hypopyon and fibrin.
- Care should be taken in keeping the eye pressurized during 25-gauge vitrectomy, because media opacity may prevent visibility of signs of intra-operative hypotony, like choroidal folds.
- For total capsulectomy in chronic postoperative endophthalmitis, 25-gauge vitrector port-based lower flow is less likely to damage the iris during 360° cut of the zonules.
- In bleb-associated endophthalmitis, 25-gauge trans-conjunctival sclerotomies should be placed away from the infected bleb

of light perception. At 6 months follow-up, visual acuity ranged from 20/25 to hand motion. (Table 14.1)

Pre-op IOP ranged from 0–5 mmHg in five patients, 6–10 mmHg in three patients, and from 11–15 mmHg in three patients. On day 1 postop, six eyes had IOP between 5–10 mmHg, and the remaining eyes had IOP above 10 mmHg. By day 30, four eyes remained with IOP between 5–10 mmHg, but none developed hypotony-related complications.

The mean interval between cataract surgery and endophthalmitis diagnosis was 7 days (2–12 days). Three eyes presented no growth on their cultures (27.3%) (Table 14.1). All microorganisms found were sensitive to either vancomycin or ceftazidime. One eye had extensive inferior retinal necrosis (patient 4) and developed intraoperative inferior retinal detachment. This eye required one sclerotomy to be enlarged for silicone oil injection, and had fluid–air exchange followed by laser photocoagulation around the necrotic retina. No serious postop complications were seen, like retinal tear or detachment and *phthisis bulbi*. Three eyes (patients 1, 2, and 10) had noninfectious persistent vitreous opacities (Fig. 14.16). The first two patients refused further intervention, and the third had a second 25-gauge vitrectomy with final visual acuity of 20/25 (Table 14.1). Infection control was judged by decrease in pain, better posterior segment visibility, and/or improvement of hypopyon in the first 3 days after TSV-25 [1].

Chronic post-cataract surgery endophthalmitis (≥6 weeks after cataract surgery) is a rarer condition. The following case illustrates the use of 25-gauge vitrectomy to treat this condition:

A 70-year-old female reported severe decrease in visual acuity in her right eye 2 months after uncomplicated temporal clear corneal phacoemulsification and foldable acrylic intra-ocular lens implant. Her uncorrected visual acuity was 20/25 1 week postop, and 2 months later her vision dropped to hand motion. Clinical findings suggested chronic endophthalmitis with endocapsular hypopyon behind the IOL and moderate anterior chamber inflammation (Fig. 14.17). She underwent 25-gauge vitrectomy, IOL removal, and total capsulectomy (as described above). Culture result of the capsular bag

Table 14.1 Pre- and postoperative findings

Patient	Gender	Preoperative visual acuity	Postoperative visual acuity	Culture result
1	Female	Light perception	20/400	*Staphyloccocus epidermidis*
2	Female	Light perception	20/80	No growth
3	Male	Light perception	Counting fingers	*Staphyloccocus epidermidis*
4	Female	Light perception	Hand motion	*Haemophilus sp.*
5	Female	Light perception	Counting fingers	*Streptoccocus sp.*
6	Male	Light perception	20/40	No growth
7	Female	Light perception	20/400	*Streptoccocus sp.*
8	Male	Light perception	Counting fingers	*Staphyloccocus epidermidis*
9	Male	Light perception	Hand motion	*Staphyloccocus epidermidis*
10	Female	Light perception	20/25	No growth
11	Male	Light perception	Hand motion	*Haemophilus sp.*

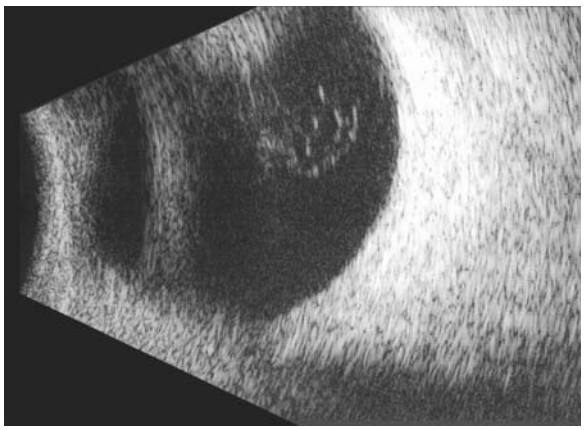


Fig. 14.16 Patient 2. Residual noninfectious vitreous opacities seen on B-scan ultrasonography

showed *Propionibacterium acnes*. One month postop (Fig. 14.17), she had visual improvement to 20/80.

14.7 Discussion

On the original published series and the subsequent larger sample, the pioneer group from the Doheny Eye Institute did not include any cases of acute or chronic postoperative endophthalmitis [60, 61]. More recently, a published abstract and a couple of published series have included successful management of a total of eight cases of endophthalmitis with 25-gauge vitrectomy [53–55].

To the best of our knowledge, this is the first series of postop endophthalmitis cases to detail the surgical technique, safety, and efficacy profile of 25-gauge sutureless vitrectomy. A few issues should be discussed, though, about the use of this system for the management of an infected eye.

14.7.1 Surgical Technique

The anterior segment management of the fibrin plaque seems a lot less traumatic with TSV-25 than when it's done with the standard 20-gauge vitrector, and more controlled than an anterior chamber washout. This is because the limbal incisions are made only with a 26-gauge needle, and the smaller port of the vitrector allows one to work closer to the iris without traumatizing it (avoiding inadvertent hyphema).

Scleral tunnel incisions are not always done, because in some eyes severe hypotony is present. To overcome scleral rigidity with a two-plane sclerotomy on a hypotonous inflamed eye is very difficult. One major advantage of the technique is the lack of conjunctival manipulation. In these eyes, the hyperemic conjunctiva bleeds easily, and increases considerably the surgical time in techniques that require conjunctival peritomy.

Charles has suggested that a partial fluid–air exchange reduces the rate of wound leaks with TSV-25 (ASRS Meeting, 2004) and further study has shown the benefits of air/gas to decrease postop hypotony [62]. But the use of intravitreal antibiotics in the presence of air may be a concern [27]. Modification of intravitreal antibiotic regimens may be indicated in eyes in which the vitreous cavity is partially filled with air or gas [63]. Whenever possible, the authors perform scleral tunnel sclerotomies

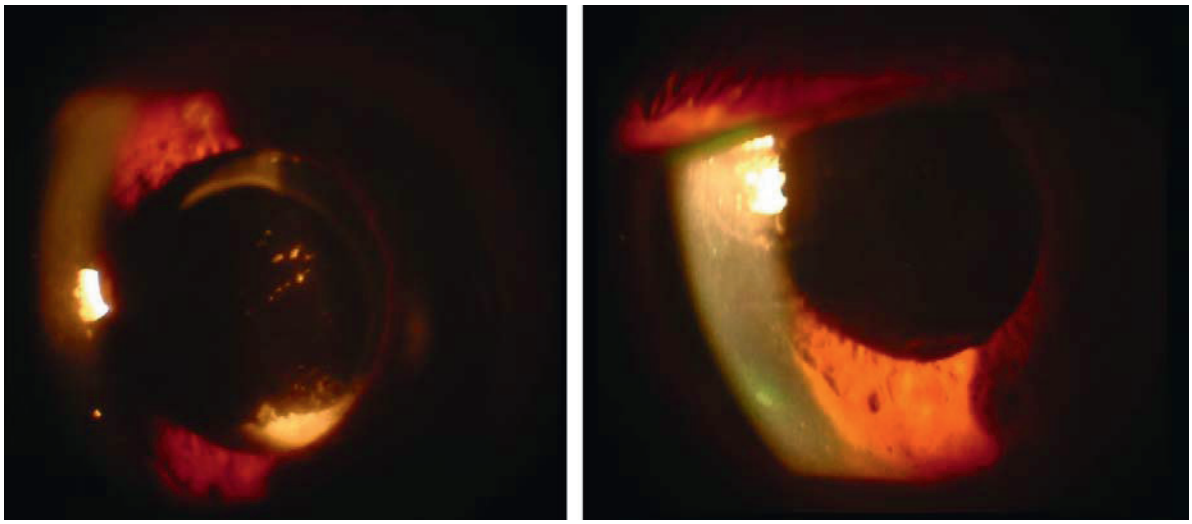


Fig. 14.17 Chronic postoperative *Propionibacterium acnes* endophthalmitis. Pre-operative biomicroscopy image of endocapsular hypopyon (*left*). One month postoperative, the eye was left aphakic and the patient regained useful vision (*right*)

rather than a partial fluid–air exchange, to avoid wound leaks in endophthalmitis cases.

14.7.2 Safety

Although all cases in this series had their infection controlled with only one 25-gauge vitrectomy and intravitreal antibiotics injection, this is a relatively small sample, and a few safety concerns should be kept in mind. It is bothersome to many surgeons to perform a sutureless procedure on an infected eye. The misalignment of conjunctival and scleral incisions, and the small size of the sclerotomies, may be sufficient to avoid ocular reinfection or even panophthalmitis. In eyes without severe hypotony, scleral tunnel sclerotomies may also increase incision safety [64].

A recent large retrospective series comparing 20- and 25-gauge results has raised concerns about a significant 12-fold higher incidence of endophthalmitis after 25-gauge vitrectomy (seven of 3103 cases — 0.23%) [65]. In their series, although conjunctival displacement was performed in most of the cases, the wounds were all non-beveled with straight entry. Even though postoperative hypotony was not documented in any of the endophthalmitis cases, they suggested that hypotony is a dynamic process and that intraocular pressure was not measured continuously in the early postoperative period [65].

Wound construction in an eye that is already infected is even more critical. Based on a recent prospective series by Rizzo et al. [66], which showed that scleral tunnels parallel to the orientation of the scleral fibers in the *pars plana* region seem to close faster and more completely by the first day postop, we introduced a slight modification to their wound construction to increase safety during the creation of the tunnel (Figs. 14.18, 14.19, 14.20).

Step-by-step wound construction:

- Slide the conjunctiva and Tenon's capsule to the side with a curved tying forceps without teeth to allow misalignment of the conjunctival from the scleral incision, using the same forceps to stabilize the eye (Figs. 14.19a,b and 14.20a,b).
- Instead of entering with the bevel perpendicular to the scleral fibers, turn the bevel 90° counterclockwise to enter parallel to the scleral fibers for the inferotemporal and superotemporal transconjunctival tunnels (Fig. 14.19b).
- Introduce the trocar angled at 20–30° approximately 2/3 of the scleral thickness (Figs. 14.19c and 14.20c).
- Then straighten up the trocar and enter the vitreous cavity perpendicular to the scleral wall, forming a two-plane sclerotomy (Figs. 14.19d and 14.20d).
- The orientation of the scleral fibers at the superonasal quadrant is somewhat different than for the superotemporal and inferotemporal quadrants. So to create a tunnel to enter parallel to the scleral fibers, the direction of the tunnel has to be adjusted accordingly (Fig. 14.18). We prefer to enter with the bevel down [67] in a posteroanterior direction (Fig. 14.20b, c), to avoid the potential trauma to the peripheral retina if one enters anteroposteriorly [66].

Another concern of this technique is that if you leave the eye hypotonous at the end of the case, it may also allow the influx of microorganisms through the sutureless sclerotomies. In our series we noted that in all cases, after removing the three cannulas at the end of the procedure, the two 0.1 ml intravitreal antibiotic injections were able to leave the eye with higher IOP. No clinically detectable antibiotics leakage was noted, and even if some spill did occur it wasn't enough to interfere with their antimicrobial action. As mentioned above, the authors recommend keeping the eye relatively soft when removing the infusion line, so that when antibiotics are injected they will only reestablish the intraocular volume without raising too much the IOP, thus avoiding antibiotics outflow.

To reduce the inflammatory damage associated with endophthalmitis, the great majority of vitreoretinal specialists use a combination of systemic, topical, and/or intravitreal corticosteroids [1, 36, 38]. The inhibitory effect of corticosteroids on wound healing is well-known, which can delay the sclerotomy scarring and contribute to sustained hypotony and possible reinfection [68]. The approach of doing only core vitrectomy (without vitreous base shaving) decreases the surgical time and avoids wound enlargement, decreasing the chances of leakage.

This series didn't include any diabetics or high myopes, but these patients may be at a higher risk of developing postop wound leaks because of the delay in wound healing and the thin sclera respectively. In these patients, sclerotomy suturing and perhaps stronger antibiotic prophylaxis, like intra-cameral cefuroxime [69], should be considered.

Proper pre-op disinfection with povidone-iodine is always recommended. The fourth-generation oral fluoroquinolones appear to achieve therapeutic levels in the vitreous cavity, and may be considered after TSV-25 for infectious endophthalmitis [49]. These measures may further decrease the possible risk of reinfection from conjunctivial microbial flora through sutureless transconjunctival incisions.

Another concern is the possible intraocular influx of antibiotics in higher concentration when injected in the subconjunctival space. Based on recent studies [51,52], and to avoid possible safety concerns, the authors do not encourage subconjunctival antibiotics at the end of TSV-25.

Even though the group that introduced the TSV-25 technique visualizes it as a potential office-based procedure [60], and the tap and intravitreal antibiotics for less severe endophthalmitis may be done in the office, at this point in time the authors do not recommend that TSV-25 for severe infectious endophthalmitis should be done in an office-based environment.

Although the EVS results showed no statistical benefits of vitrectomy over tap and intravitreal antibiotics for hand motion or better VA [2], there is a recent trend towards performing earlier and more complete vitrectomy without waiting for the vision to drop down to LP range [70]. Earlier vitrectomy in a less damaged eye may be another advantage for the 25-gauge technique.

Recently, 23-gauge transconjunctival vitrectomy has also broadened our surgical options in small-gauge transconjunctival vitrectomy. The two-step incision seems to be more stable and less traumatic than the first-generation one-step incision. But neither of the two studies to date reporting preliminary results with 23-gauge vitrectomy with two-step incisions included management of infectious endophthalmitis [71, 72]. Potential disadvantages of 23-gauge two-step incision for this disease include the difficulty of finding the sclerotomy to introduce the cannula after penetration of a congested conjunctiva, and leaving a larger sutureless incision at the end of the case. Lack of documented hypotony does not seem to guarantee a sealed wound, and does not seem to eliminate the threat of endophthalmitis [65].

14.7.3 Efficacy

All patients included in this series had postop visual improvement, and none developed no light perception, retinal tear, retinal detachment, or *phthisis bulbi* postop. It is important to note that all eyes in this study had preop visual acuity of light perception (Table 14.1).

Similarly to the results of the EVS [2], the eyes with culture showing no growth had the best visual outcomes (mean of 20/40). On the other hand, all eyes in our study with coagulase-negative gram-positive micrococci had visual acuity of 20/400 or worse at 6 months follow-up, while on the EVS 84% had visual acuity of 20/100 or better at 9 months [2]. This may be explained by the fact that three out of four patients in this subgroup had corneal melting at presentation (unlike the EVS results, where none had corneal infiltrates). In the EVS, 21% of eyes with light perception at presentation had final visual acuity of 20/400 or better. In the TSV-25 series, 45% achieved final VA of 20/400 or better. In the EVS, the main cause of lower final VA was macular complications while in the present series were corneal opacities (27%) and persistent vitreous opacities (27%).

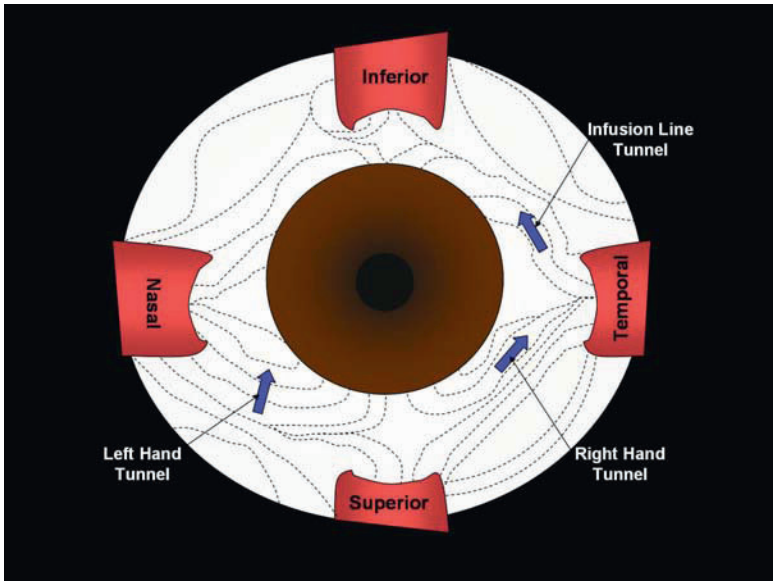


Fig. 14.18 Modified scleral tunnel orientation in relation to the scleral fibers (*right eye*). Note that the temporal tunnels are created in the same manner, being parallel to the limbus and the scleral fibers. On the other hand, scleral fibers superonasal are not parallel to the limbus so the tunnel orientation is created from posterior to anterior as a beveled incision

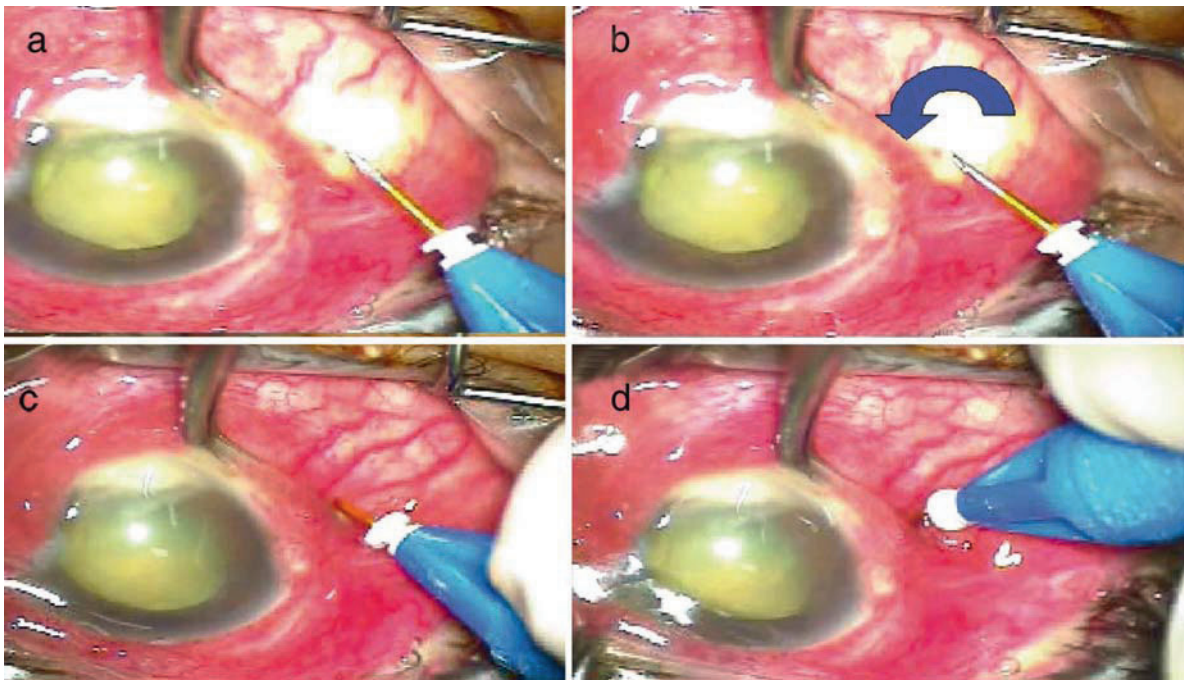


Fig. 14.19 25-gauge tranconjunctival inferotemporal modified scleral tunnel in infectious endopthalmitis (*right eye*). (**a**) Conjunctival sliding. Note the angle of trocar insertion. (**b**) Instead of entering with the bevel perpendicular to the scleral fibers (bevel down or up, as in **a**), turn the bevel 90° counterclockwise to enter parallel to the scleral fibers. (**c**) Introducing 2/3 of the trocar at a 20–30° angle. (**d**) Straightening the trocar to introduce the 1/3 left perpendicular to the scleral wall

The present results with TSV-25 for severe post-cataract surgery endophthalmitis compare favorably with a recent report using 20-gauge vitrectomy and endoscopy. While in our study all culture-proven patients achieved hand motion or better vision postop, their study had three patients with no light perception, two with *phthisis bulbi* [35].

Comparing 20-gauge core vitrectomy (like that used by the EVS vitrectomy group [1]) with 20-gauge total vitrectomy plus encircling equatorial band, 360° peripheral endolaser, and silicone oil injection, Kaynak et al. found that despite the fact that the group undergoing core vitrectomy only required additional procedures in 25% of cases, and for the total vitrectomy group none required further procedures, there was no statistically significant difference on final visual acuity of 20/40 or better (25% versus 28.5% respectively) [28]. In the TSV-25 series, 18% achieved 20/40 or better, and three patients needed further intervention for vitreous opacities (27%) at 6 months follow-up (two refused surgery).

Despite the small port of the 25-gauge vitrector, 73% culture-positive samples were obtained, compared to 73.5% with 20-gauge core vitrectomy during the EVS, 63% with total vitrectomy, and 100% with vitrectomy and endoscopy [15, 28, 35].

The rate of retinal detachment postoperatively may be related to the severity of the endophthalmitis, microorganism virulence, and complications from the surgical technique [27, 28]. In the EVS, 16% of eyes with initial VA of light perception developed postoperative retinal detachment, without statistical difference between tap/biopsy and vitrectomy. In a recent series, the rate of postoperative retinal detachment for eyes with LP vision dropped to 12.5% with core vitrectomy, and to 3.5% with total vitrectomy, buckle, laser, and silicone oil [28]. Our present series, with 25-gauge vitrectomy for eyes with LP vision, had no cases of postoperative retinal detachment. This may in part be explained by the increased safety of a small sclerotomy and the trocar usage, with potential decrease in the rate of sclerotomy-related retinal tears/detachment.

14.8 Conclusion

In summary, 25-gauge sutureless vitrectomy seems to be a safe and effective procedure, comparable to other available techniques, and should be considered as another alternative for surgical management of severe infectious endophthalmitis. Further studies with larger samples are needed to confirm our results.

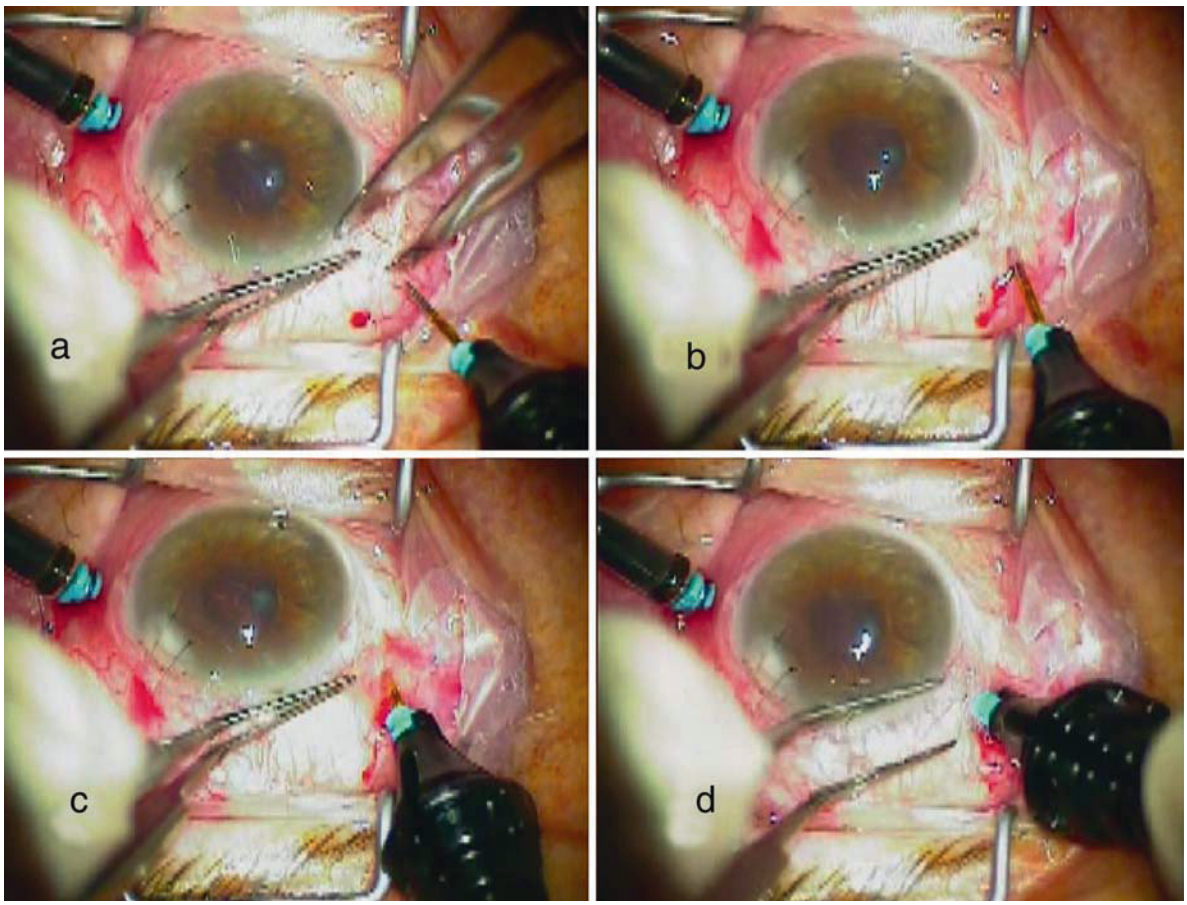


Fig. 14.20 25-gauge tranconjunctival superonasal modified scleral tunnel in infectious endophthalmitis (*left eye*). (**a)** Conjunctival sliding. Note that the trocar starts the tunnel a little posterior to the caliper mark. (**b)** Starting the scleral tunnel in a postero-anterior direction entering bevel down paralleled to the scleral fibers. (**c)** Introducing 2/3 of the trocar at a 20–30° angle. (**d)** Straightening the trocar to introduce the 1/3 left perpendicular to the scleral wall

References

1. Endophthalmitis Vitrectomy Study Group (1995) Results of the Endophthalmitis Vitrectomy Study. A randomized trial of immediate vitrectomy and intravenous antibiotics for the treatment of postoperative bacterial endophthalmitis. Arch Ophthalmol 113:1479–1496
2. Endophthalmitis Vitrectomy Study Group (1996) Microbiologic factors and visual outcome in the Endophthalmitis Vitrectomy Study. Am J Ophthalmol 122:830–846
3. Deramo VA, Ting TD (2001) Treatment of *Propionibacterium acnes* endophthalmitis. Curr Opin Ophthalmol 12:225–229
4. Speaker MG, Milch FA, Shah MK (1991) Role of external bacterial flora in the pathogenesis of acute postoperative endophthalmitis. Ophthalmology 98:639–649
5. Kresloff MS, Castellarin AA, Zarbin MA (1998) Endophthalmitis. Surv Ophthalmol 43:193–224
6. Wong TY, Chee SP (2004) The epidemiology of acute endophthalmitis after cataract surgery in an Asian population. Ophthalmology 111:699–705
7. Nagaki Y, Hayasaka S, Kadoi C, Matsumoto M, Yanagisawa S, Watanabe K et al (2003) Bacterial endophthalmitis after small-incision cataract surgery: effect of incision placement and intraocular lens type. J Cataract Refract Surg 29:20–26
8. Cooper BA, Holekamp NM, Bohigian G, Thompson PA (2003) Case-control study of endophthalmitis after cataract surgery comparing scleral tunnel and clear corneal wounds. Am J Ophthalmol 136:300–305
9. Wejde G, Samolov B, Seregard S, Koranyi G, Montan PG (2005) Risk factors for endophthalmitis following cataract surgery: a retrospective case–control study. J Hosp Infect 61:251–256
10. Miller JJ, Scott IU, Flynn HW Jr, Smiddy WE, Newton J, Miller D (2005) Acute-onset endophthalmitis after cataract surgery (2000–2004): incidence, clinical settings, and

visual acuity outcomes after treatment. Am J Ophthalmol 139:983–987
11. Olson RJ (2004) Reducing the risk of postoperative endophthalmitis. Surv Ophthalmol 49(Suppl 2):S55–S61
12. Ciulla TA, Starr MB, Masket S (2002) Bacterial endophthalmitis prophylaxis for cataract surgery: an evidence-based update. Ophthalmology 109:13–26
13. West ES, Behrens A, McDonnell PJ, Tielsch JM, Schein OD (2005) The Incidence of endophthalmitis after cataract surgery among the U.S. Medicare population increased between 1994 and 2001. Ophthalmology 112:1388–1394
14. Taban M, Behrens A, Newcomb RL, Nobe MY, Saedi G, Sweet PM et al (2005) Acute endophthalmitis following cataract surgery. A systematic review of the literature. Arch Ophthalmol 123:613–620
15. Barza M, Pavan PR, Doft BH, Wisniewski SR, Wilson LA, Han DP et al (1997) Evaluation of microbiological diagnostic techniques in postoperative endophthalmitis in Endophthalmitis Vitrectomy Study. Arch Ophthalmol 115:1142–1150
16. Almeida LNF, Canêdo MGRR, Almeida RNF, Sobrinho EFA, Nehemy MB (2005) Macular infarction after intravitreal injection of amikacin: case report. Arq Bras Oftalmol 68(6):837–840
17. Aldave AJ, Stein JD, Deramo VA, Shah GK, Fischer DH, Maguire JI (1996) Treatment strategies for postoperative Propionibacterium acnes endophthalmitis. Ophthalmology 106(12):2395–2401
18. Clark WL, Kaiser PK, Flynn HW Jr, Belfort A, Miller D, Meisler DM (1999) Treatment strategies and visual acuity outcomes in chronic postoperative Propionibacterium acnes endophthalmitis. Ophthalmology 106(9):1665–1670
19. Walker CB, Claoue CMP (1986) Incidence of conjunctival colonization by bacteria capable of causing postoperative endophthalmitis. J R Soc Med 79:520–521
20. Gollamudi SR, Hodapp EA, Cubillas A, Culbertson WM (1993) Photographically documented access of tear film to the anterior chamber through a leaky filtering bleb. Arch Ophthalmol 111:394–345
21. Soltau JB, Rothman RF, Budenz DL, Greenfield DS, Feuer WMS, Liebmann J et al (2000) Risk factors for glaucoma filtering bleb infections. Arch Ophthalmol 118:338–342
22. Greenfield DS, Suner IJ, Miller MP, Kangas TA, Palmberg PF, Flynn HW Jr (1996) Endophthalmitis after filtering surgery with mitomycin. Arch Ophthalmol 114(8):943–949
23. Mac I, Soltau JB (2003) Glaucoma-filtering bleb infections. Curr Opin Ophthalmol 14:91–94
24. Busbee BG, Recchia F M, Kaiser R, Nagra P, Rosenblatt B, Pearlman RB (2004) Bleb-associated endophthalmitis. Clinical characteristics and visual outcomes. Ophthalmology 111:1495–1503
25. Mandelbaum S, Forster RK, Gelender H, Culbertson W (1985) Late onset endophthalmitis associated with filtering blebs. Ophthalmology 92(7):964–972
26. Josephberg RG (2003) Sutureless vitrectomy surgery [Letter]. Ophthalmology 110(12):2427
27. Doft BM, Kelsey SF, Wisniewski SR (2000) Retinal detachment in the Endophthalmitis Vitrectomy Study; the Endophthalmitis Vitrectomy Study Group. Arch Ophthalmology 118:1661–1665
28. Kaynak S, Öner FH, Koçak N, Çingel G (2003) Surgical management of postoperative endophthalmitis: comparison of 2 techniques. J Cataract Refract Surg 29:966–969
29. Olson JC, Flynn HW, Forster RK, Culbertson WW (1983) Results in the treatment of postoperative endophthalmitis. Ophthalmology 90:692–699
30. Özdamar A, Aras C, Ozturk R, Akin E, Karacorlu M, Ercikan C (1999) In vitro antimicrobial activity of silicone oil against endophthalmitis-causing agents. Retina 19:122–126
31. Zimmer-Galler IE, Santos A, Haller JA, Campochiaro PA (1997) Management of endophthalmitis in a silicone oil filled eye. Retina 17:507–509
32. Bali E, Huyghe P, Caspers L, Libert J (2003) Vitrectomy and silicone oil in the treatment of acute endophthalmitis. Preliminary results. Bull Soc Belge Ophtalmol 288:9–14
33. Aras C, Yolar M, Sevim O (2004) Surgical management of postoperative endophthalmitis [Letter]. J Cataract Refract Surg 30:1612
34. Aras C, Ozdamar A, Karacorlu M, Ozkan S (2001) Silicone oil in the surgical treatment of endophtalmitis associated with retinal detachment. Intl Ophthalmol 24:147–156
35. De Smet MD, Carlborg EAE (2005) Managing severe endophthalmitis with the use of an endoscope. Retina 25:976–980
36. Meredith TA (2006) Vitrectomy for infectious endophthalmitis. In: Ryan SJ, Wilkinson CP (eds) Retina. Surgical Retina, 4th edn. Mosby, St Louis, pp 2255–2275
37. Bucher RS, Hall E, Reed DM, Richards JE, Johnson MW, Zacks DN (2005) Effect of intravitreal triamcinolone acetonide on susceptibility to experimental bacterial endophthalmitis and subsequent response to treatment. Arch Ophthalmol 123(5):649–653
38. Das T, Jalali S, Gothwal VK, Sharma S, Naduvilath TJ (1999) Intravitreal dexamethasone in exogenous bacterial endophthalmitis: results of a prospective randomised study. Br J Ophthalmol 83:1050–1055
39. Shah GK, Stein JD, Sharma S, Sivalingam A, Benson WE, Regillo CD et al (2000) Visual outcomes following the use of intravitreal steroids in the treatment of postoperative endophthalmitis. Ophthalmology 107:486–489
40. Kamei M, Estafanous M, Lewis H (2000) Tissue plasminogen activator in the treatment of vitreoretinal diseases. Semin Ophthalmol 15(1):44–50

41. Galloway G, Ramsay A, Jordan K, Vivian A (2002) Macular infarction after intravitreal amikacin: mounting evidence against amikacin [Letter]. Br J Ophthalmol 86:359–360
42. Kwok AK, Hui M, Pang CP, Chan RC, Cheung SW, Yip CM et al (2002) An in vitro study of ceftazidime and vancomycin concentrations in various fluid media: implications for use in treating endophthalmitis. Invest Ophthalmol Vis Sci 43:1182–1188
43. Lifshitz T, Lapid-Gortzak R, Finkelman Y, Klemperer I (2000) Vancomycin and ceftazidime incompatibility upon intravitreal injection [Letter]. Br J Ophthalmol 84:117
44. Hui M, Kwok AK, Pang CP, Cheung SW, Chan RC, Lam DS et al (2004) An in vitro study on the compatibility and precipitation of a combination of ciprofloxacin and vancomycin in human vitreous. Br J Ophthalmol 88:218–222
45. Vedantham V (2005) Ciprofloxacin in endophthalmitis: an alternative to ceftazidime and amikacin [Letter]. Br J Ophthalmol 89:249
46. Benz MS, Scott IU, Flynn HW Jr, Unonius N, Miller D (2004) Endophthalmitis isolates and antibiotic sensitivities: a 6-year review of culture-proven cases. Am J Ophthalmol 137:38–42
47. Recchia FM, Busbee BG, Pearlman RB, Carvalho-Recchia CA, Ho AC (2005) Changing trends in the microbiologic aspects of postcataract endophthalmitis. Arch Ophthalmol 123:341–346
48. Davis AS, Gentile RC, Shah M, Seedor JA, Ritterband DC, Will D (2004) Increasing resistance of endophthalmitis isolates to fluorquinolones– A sixteen year review. Invest Ophthalmol Vis Sci 45:E-Abstract 517
49. Hariprasad SM, Shah GK, Mieler WF, Feiner L, Blinder KJ, Holekamp NM et al (2006) Vitreous and aqueous penetration of orally administered moxifloxacin in humans. Arch Ophthalmol 124:178–182
50. Flynn HW, Pulido JS, Pflugfelder SC, Davis JL, Culbertson WW, Roussel TJ et al (1991) Endophthalmitis therapy: changing antiobiotic sensitivity patterns and current therapeutic recommendations. Arch Ophthalmol 109:175–176
51. Smiddy WE, Smiddy RJ, Ba'Arath B, Flynn, Jr. HW, Murray TG, Feuer WJ et al (2005) Subconjunctival antibiotics in the treatment of endophthalmitis managed without vitrectomy. Retina 25:751–758
52. Ng JQ, Morlet N, Pearman JW, Constable IJ, McAllister IL, Kennedy CJ et al for Team EPSWA (2005) Management and outcomes of postoperative endophthalmitis since the Endophthalmitis Vitrectomy Study. The Endophthalmitis Population Study of Western Australia (EPSWA)'s fifth report. Ophthalmology 112:1199–1206
53. Rudometkin NJ, Thomas EL, Hunter KA (2005) Case Selection, complications, and visual recovery during the initial sixty–two cases using 25–gauge vitrectomy. Invest Ophthalmol Vis Sci 46:E-Abstract 5460
54. Yanyali A, Celik E, Horozoglu F, Oner S, Nohutcu AF (2006) 25-Gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16(1):141–147
55. Rezende FA, Alcântara S, Regis LGT (2005) Transconjunctival vitrectomy: preliminary data using the TSV-25 Millennium System. Arq Bras Oftalmol 68(6):721–726
56. Wu PC, Li M, Chang SJ, Teng MC, Yow SG, Shin SJ et al (2006) Risk of endophthalmitis after cataract surgery using different protocols for povidone-iodine preoperative disinfection. J Ocul Pharmacol Ther 22(1):54–61
57. Carlson AN, Stewart WC, Tso PC (1998) Intraocular lens complications requiring removal or exchange [review]. Surv Ophthalmol 42:417–440
58. Burnstein AL, WuDunn D, Knotts SL, Catoira Y, Cantor LB (2002) Conjunctival advancement versus nonincisional treatment for late-onset glaucoma filtering bleb leaks. Ophthalmology 109(1):71–75
59. Dacey MP, Valencia M, Lee MB, Dugel PU, Ober RR, Green RL et al (1994) Echographic findings in infectious endophthalmitis. Arch Ophthalmol 112(10): 1325–1333
60. Fujii GY, de Juan E Jr., Humayun MS, Chang T, Pieramici DJ, Barnes A et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
61. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112(5):817–824
62. Shimada H, Nakashizuka H, Mori R, Mizutani Y, Hattori T(2006) 25-gauge scleral tunnel transconjunctival vitrectomy. Am J Ophthalmol 142:871–873
63. Mieler WF, Glazer LC, Bennett SR, Han DP (1992) Favourable outcome of traumatic endophthalmitis with associated retinal breaks or detachment. Can J Ophthalmol 27(7):348–352
64. Hagemann LF, Kostamaa HJ, Jehan FS, Marques LEA, Kurtz R, Kuppermann B (2005) How to create an immediate self sealing sclerotomy for cannula placement in 25 gauge vitrectomy using a tunnel incision. Invest Ophthalmol Vis Sci 46:E-Abstract 5463
65. Kunimoto DY, Kaiser RS, Wills (2007) Eye Retina Service. Incidence of endophthalmitis after 20- and 25-gauge vitrectomy. Ophthalmology 114:2133–2137
66. Rizzo S, Genovesi-Ebert F, Vento A, Miniaci S, Cresti F, Palla M (2007) Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicroscopic study. Graefes Arch Clin Exp Ophthalmol 245:1281–1288
67. López-Guajardo L, Pareja-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 141:1154–1156

68. Costa VP, Spaeth GL, Eiferman RA, Orengo-Nania S (1993) Wound healing modulation in glaucoma filtraton surgery. Ophthalmic Surg 24:152–170
69. Endophthalmitis Study Group, European Society of Cataract & Refractive Surgeons (2007) Prophylaxis of postoperative endophthalmitis following cataract surgery: results of the ESCRS multicenter study and identification of risk factors. J Cataract Refract Surg 33(6):978–988
70. Kuhn F, Gini G Vitrectomy for endophthalmitis. Ophthalmology (2006); 113(4):714.
71. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25(2):208–211
72. Fine HF, Iranmanesh R, Iturralde D, Spaide RF (2007) Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. Ophthalmology 114:1197–1200

Chapter 15

25-Gauge Transconjunctival Sutureless Vitrectomy for Vitreous and Retinal/Choroidal Biopsy

J.F. Arevalo, J.G. Sanchez, W.R. Freeman

Core Message

- Diagnostic vitreoretinal surgery should be considered when other noninvasive methods of diagnosis have failed to establish a pathoetiologic mechanism.
- The goals of ocular biopsy should be to acquire microbiological, cytologic, histologic, immunologic and genetic information, with minimum surgical trauma, for modifying and directing medical and surgical treatments.
- The development of a 25-gauge operating system introduces a new concept in vitreous, retinal and choroidal biopsy.
- Vitreous, retinal or choroidal biopsy are relatively safe procedures, and the results often change clinical management.
- 25-gauge procedures induce minimal ocular trauma, decrease the inflammatory response, and may allow faster overall patient recovery.

15.1 Introduction

The diagnosis of posterior segment inflammatory disease and tumoral lesions is based primarily on clinical examination. At presentation, however, some patients do not have the characteristic clinical features or classic appearance of a specific disease, and the cause of their disorder remains obscure. Recent progress in basic science, particularly in the fields of molecular biology and immunology, and advances in surgical instrumentation has greatly enhanced the diagnostic armamentarium. Diagnostic vitreoretinal surgery should be considered when other noninvasive methods of diagnosis have failed to establish a pathoetiologic mechanism.

One of the principles that guide the development of any given surgical procedure is the desire for less invasive approaches that will achieve the same or better outcomes. Therefore, the goals of ocular biopsy should be to acquire microbiological, cytologic, histologic, immunologic and genetic information, with minimum surgical trauma, for modifying and directing medical and surgical treatments. The 25-gauge transconjunctival sutureless vitrectomy (25-G TSV) (Fig. 15.1) is a new alternative procedure to the pars plana classical 20-gauge vitrectomy system, and the techniques to be described here allow the advantages of 25-G TSV to be combined with the advantages of the one-purpose 20-gauge sclerotomy in these particular cases.

The development of a 25-gauge operating system introduces a new concept in vitreous, retinal and choroidal biopsy, because the attractiveness of a smaller-gauge vitrectomy instrument system is based on the ability to minimize surgically induced trauma from conjunctival peritomy and sclerotomy sites, allow for self-sealing (sutureless) sclerotomies, improve operative efficiency, and hasten postoperative recovery [1–5]. In this chapter, we wish to report the feasibility and safety of using 25-G TSV for vitreous, retinal and choroidal biopsy.

15.2 Vitreous Biopsy

Advances in surgical vitrectomy and laboratory techniques have expanded the options for diagnosis of posterior segment uveitis of unknown cause and cancer. With the evolution of vitrectomy techniques, 25-G TSV may become the preferred method for biopsy because it is a relative simple and safe procedure. To perform diagnostic vitreous biopsy, a one-port vitreous biopsy can be performed either by needle aspiration or by mechanical vitrectomy. Huang et al. have demonstrated that the cytological detail is equivalent for specimens obtained either by needle aspiration or by mechanical vitrectomy [6]. However, obtaining an undiluted vitreous specimen by vitrectomy potentially reduces the risk of vitreoretinal traction and retinal detachment that is associated with

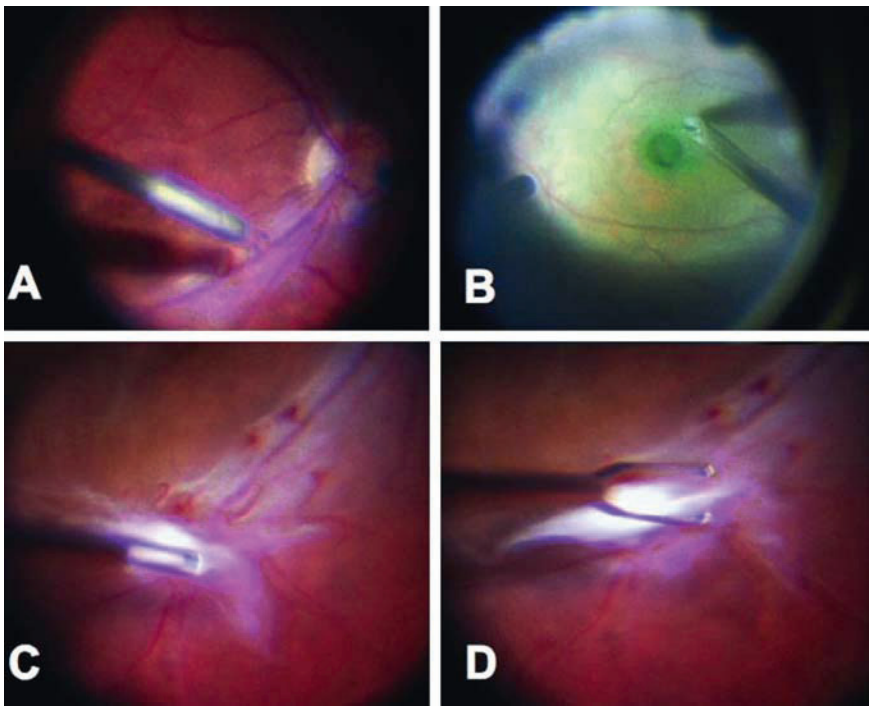


Fig. 15.1 25-gauge transconjunctival sutureless vitrectomy is gaining ground among vitreoretinal surgeons for many surgical vitreoretinal procedures including vitreomacular traction syndrome (**a**), macular hole (**b**), and proliferative diabetic retinopathy (**c** and **d**)

straight needle aspiration, because the vitreous cutter ensures that no vitreous still attached to the retina is aspirated. In addition, the 25-gauge system has been shown to result in a faster procedure and less postoperative discomfort than 20-gauge systems.

15.2.1 Indications for Diagnostic Vitrectomy

In general, the indications for diagnostic vitrectomy can be grouped into atypical diseases unresponsive to standard therapy, and conditions in which infection or cancer are suspected. Cytopathologic diagnosis has proved valuable in reported series or case reports of patients with endogenous and exogenous bacterial and fungal infections, nematode endophthalmitis, inflammatory pseudotumor of the iris and ciliary body, pars planitis, phacoanaphylaxis, intraocular lymphoma, leukemia, metastatic melanoma, metastatic carcinoma, medulloepithelioma of the ciliary body, epithelial ingrowth, proliferative vitreoretinopathy, and miscellaneous conditions with vitreous opacities (chronic inflammation in patients with suspected lymphoma, acute retinal necrosis, birdshot chorioretinopathy, toxoplasmosis, Whipple's disease, amyloidosis) [6–11].

15.2.2 Technique for Diagnostic Vitrectomy

Vitreous biopsy is limited by its dependency on the spillover of cells from the diseased tissue in question into the vitreous cavity to allow a diagnosis. A good evaluation of the clinical case is important before choosing the technique to use. If the patient does not need a therapeutic vitrectomy, the approach to be used may be a one-port mechanical vitrectomy; otherwise a three-port pars plana vitrectomy (PPV) approach may be preferred. We always prefer a three-port PPV because intraocular illumination during the procedure facilitates the attainment of a good and large enough sample, and prevents accidental damage to the retina or crystalline lens.

To perform a diagnostic vitrectomy, an undiluted vitreous sample is taken after preparation for a 25-G TSV as described by Fujii et al., with some technical modifications [1]. After appropriate anesthesia, the operative field is prepared for surgery. We have had excellent experience with peribulbar or sub-Tenon's lidocaine anesthesia for 25-gauge cases. Some reports have indicated that topical anesthesia might be adequate in simple cases. The microcannulas are inserted through the conjunctiva into the eye, 3.5–4 mm posterior to the limbus by means of a trocar. In order to reduce the chance of communication

between the ocular contents and the external environment, the conjunctiva is first grasped with the point of the trocar or a conjunctival forceps, and then moved into a position 3.5–4 mm from the limbus where penetration is to occur. In this way, the conjunctival and scleral openings are offset, and when the instrument is removed the openings return to their original position and there is a better seal of the sclerotomy site. Immediately after insertion through the eye wall, the microcannula can be held by the collar to provide stability when the trocar is withdrawn. After insertion of the first microcannula, the infusion cannula is directly inserted into the external opening of the microcannula. The infusion cannula should be closed (turned off) if an undiluted specimen is to be taken, or air may be used in the infusion to pressurize the eye and two other microcannulas are inserted in the superotemporal and superonasal quadrants once the eye is pressurized (Fig. 15.2). A 10-ml syringe is spliced via a three-way stopcock in to the aspiration line. The vitrectomy hand piece is placed in mid-vitreous cavity with the infusion turned off. Automated cutting and manual aspiration of the vitreous without concurrent infusion is then performed (Fig. 15.3). The infusion is turned on before the eye begins to collapse. Alternatively, air can be infused if a larger undiluted sample is to be taken, and for the purposes of cytology or non-quantitative specimen collection, diluted vitreous may be adequate and the balanced salt solution (BSS) infusion may be kept on. The vitrector is withdrawn from the eye, and the vitreous specimen is aspirated in to the syringe. At least 1 ml of undiluted vitreous is aspirated into the collection syringe and distributed for studies (Fig. 15.4). Finally, a three-port vitrectomy can then be completed (Fig. 15.5). To remove the infusion line, the collar at the base of the microcannula should be grasped without removing the infusion tube from the microcannula, and both the cannula and the infusion line should be removed simultaneously. After cannula withdrawal, a cotton tip should be used to misalign the conjunctival and scleral orifices.

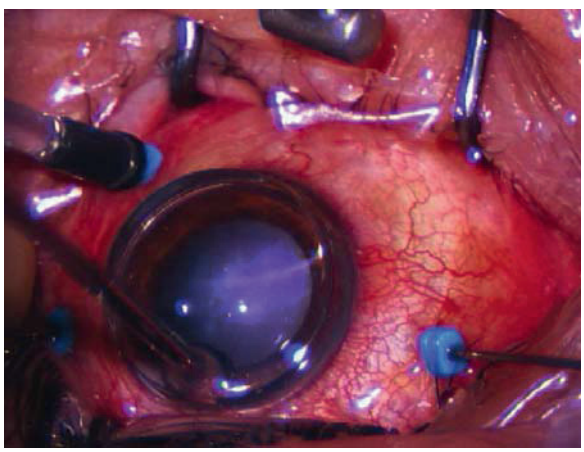


Fig. 15.2 After insertion of the first microcannula the infusion cannula is directly inserted into the external opening of the microcannula. The infusion cannula should be closed (turned- off) and two other microcannulas are inserted in the superotemporal and superonasal quadrants

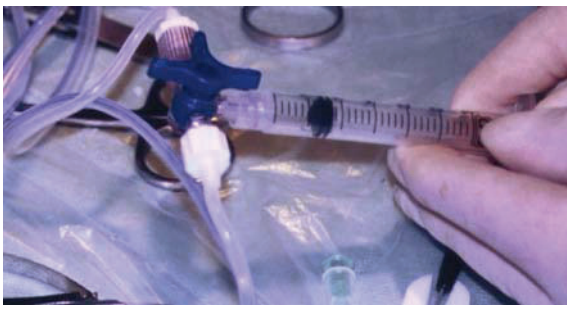


Fig. 15.3 A 10-ml syringe is spliced via a three-way stopcock in to the aspiration line. The vitrectomy hand piece is placed in mid-vitreous cavity with the infusion turned off. Automated cutting and manual aspiration of the vitreous without concurrent infusion is then performed. The vitrector is withdrawn from the eye, and the vitreous specimen is aspirated in to the syringe

Fig. 15.4 At least 1 ml of undiluted vitreous is aspirated into the collection syringe and distributed for studies

In the setting of a vitreous biopsy, a potential disadvantage of higher cutting rates is the greater mechanical disturbance of cellular elements within the specimen. Ratanapojnard et al. demonstrated that the clinical utility of all specimen types collected with high-speed cutting was preserved (using a 20-gauge vitrector); however, cutting rates of 1,500 cuts per minute (cuts/min) using a guillotine mechanism can mildly reduce fungal yield, and markedly diminish leukocyte viability [12]. Therefore, we suggest

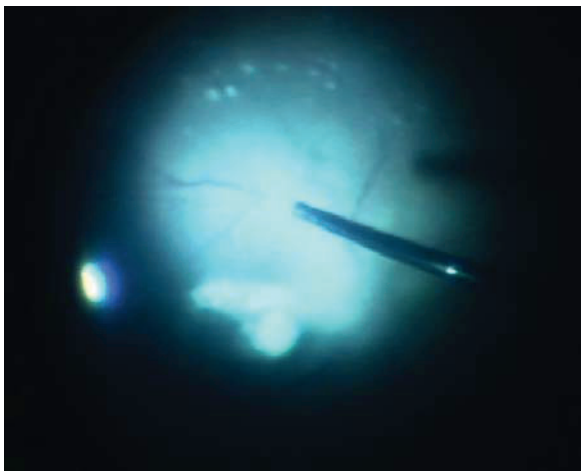


Fig. 15.5 After the undiluted sample is taken, the therapeutic three-port vitrectomy vitrectomy can then be completed if necessary

that cutting rates are selected on a case-by-case basis, by comparing merits of higher rates for the surgical goals with possible effects on sample collection. This study can probably be applied to 25-G TSV, because this system uses a guillotine mechanism too. We tend to use between 100 and 500 cuts per minute to minimize damage to cellular material.

15.2.3 Processing Vitreous Samples

Both the vitreous washings and undiluted vitreous aspirate should be immediately delivered for microbiologic, virologic, cytologic and immunologic analysis. The number of investigations that can be carried out on an individual specimen depends on the amount of harvested material. It is essential to coordinate the diagnostic vitrectomy with the microbiology laboratory, so that samples may be placed in appropriate culture media, and may be stained to detect the microorganisms (Table 15.1). Vitreous culture is a method that directly identifies replicating infection agents; bacterial, fungal and viral cultures may be obtained. To avoid false-negative results, it is essential to instruct the laboratory to hold cultures for at least 10–14 days. Viral cultures may be falsely negative because of the small quantity of organisms shed into the vitreous cavity. For suspected viral infection we suggest alternative approaches, such as the polymerase chain reaction (PCR).

Diagnostic vitrectomy has been useful to help establish the cause of viral infections of the posterior segment caused by herpes zoster, herpes simplex, and cytomegalovirus (CMV). Inmunofluorescent labeling of cells infected with virus particles has also been used to document intraocular infection [13]. Intraocular antibody testing can be of high utility for some diseases such as acute retinal necrosis syndrome [14] and ocular toxoplasmosis [15–17]. Levels of intraocular antibodies can be measured by techniques such as enzyme-linked inmmunosorbent assay (ELISA). The amount of the intraocular antibody reflects the host response, and therefore this is an indirect test for the presence of a microorganism. For antibody testing to be useful, it is essential that simultaneous serum samples are obtained [18].

Gram stain and other cytologic preparations are relatively insensitive. Culture is slow for viral diseases, has very low sensitivity for ocular toxoplasmosis, and has only 70% sensitivity for bacterial diseases such as postoperative endophthalmitis. Intraocular antibody testing has no utility for other diseases such as CMV retinitis [17, 19, 20]. The polymerase chain reaction (PCR) is a biochemical technique that allows for the detection of infinitesimal amounts of specific nucleic acids. Using this technique, the presence of pathogen DNA or RNA can be rapidly and very specifically detected. The technique thus fills a void in the current armamentarium of diagnostic tests. PCR and cDNA probes can be employed to detect DNA from many viruses such as herpes simplex virus, varicella zoster virus and CMV, as well as protozoal DNA, such as in *Toxoplasma gondii*.

Perhaps the most common indication for PCR diagnostics in posterior segment uveitis is differentiating between viral retinitis and ocular toxoplasmosis. PCR has sensitivities exceeding 90% for varicella zoster virus, herpes simplex virus, and CMV, with specificities in excess of 95% for these organisms [20–25]. Sensitivity for ocular toxoplasmosis is lower (60% from vitreous specimens) [26, 27], although this may be improved by combining PCR and intraocular antibody testing. A second useful aspect of PCR is the ability to subtype viral infections. Acute retinal necrosis syndrome may be caused by HSV type 1, HSV type 2, or varicella zoster virus.

Lohmann et al. used PCR to analyze 25 patients with late-onset endophthalmitis, and they showed that bacterial DNA (*Propionibacterium. acnes*, *Staphylococcus epidermis*, or *Actinomyces israelii*) was obtained from 92% of vitreous samples. By comparison, bacterial culture was positive in only 24% of these cases [28]. PCR can also be used for suspected fungal endophthalmitis. Anand et al. found that 32 of 43 cases (74%) were positive for fungal disease by PCR testing, compared to 24 of 43 cases (56%) by routine fungal culture [29]. In addition to the higher sensitivity, PCR testing allowed for quicker identification of the fungal organism, since cultures in this study took up to 14 days for a positive result.

Table 15.1 The number of investigations that can be carried out on an individual specimen depends on the amount of harvested material. It is essential to coordinate the diagnostic vitrectomy with the microbiology laboratory so that samples may be placed in appropriate culture media, and may be stained to detect the microorganisms

Diagnostic vitrectomy: sample analysis		
Microbiologic	Stains	Gram
		Periodic acid-Schiff
		Giemsa
		Methenamine silver (fungi)
	Cultures	Aerobic bacteria
		Anaerobic bacteria
		Fungal
		Viral (occasionally)
Citophatology	Morphology	
	Immunocytochemistry	
Antibody studies (simultaneous vitreous and serum)		
Polymerase chain reaction (PCR)		

Summary for the Clinician

- 25-G TSV may become the preferred method for vitreous biopsy, because it is a relative simple and safe procedure.
- 25-G TSV potentially reduces the risk of vitreoretinal traction and retinal detachment that is associated with straight needle aspiration.
- A standard 25-gauge three-port PPV is preferred, because intraocular illumination during the procedure facilitates the attainment of a good and large enough sample, and prevents accidental damage to the retina or crystalline lens.
- Select cutting rates on a case-by-case is suggested, based on a comparison of merits of higher rates for the surgical goals with possible effects on sample collection.
- It is essential to coordinate the diagnostic vitrectomy with the microbiology laboratory, so that samples may be placed in appropriate culture media and may be stained appropriately to detect the microorganisms.

15.3 Transvitreal Retinal Biopsy

In certain conditions, the inflammatory process is localized primarily in the sensory retina or the retinal pigment epithelium (RPE). The vitreous may harbor few or none of the responsible microorganisms; and idiopathic syndromes that have a poorly understood disease mechanism can primarily involve the retina, and only histologic examination of these areas can yield a diagnosis. In these patients, a diagnostic vitrectomy would yield very little information. Retina biopsy can be performed to better understand the disease process and to help establish a diagnosis.

15.3.1 Surgical Technique for Retinal Biopsy

We use the technique described by Fujii et al. for 25-G TSV before retinal biopsy is taken [1]. We always remove the cortical vitreous to gain access to the retina, to clear the media, and allow for gas tamponade. Before a retinal biopsy is performed, the location of the tissue to be sampled must be carefully considered. An appropriate site is chosen, to minimize both intraoperative and postoperative complications. Location is preferably in the superior and nasal retina, at the junction of infected and uninfected retina, as peripheral as possible, and in a relatively avascular area. The specimen should include the advancing edge of the affected area (such as in retinitis if that is the case) because this is where actively replicating, viable organisms are most likely to be found. Central areas of the lesion may contain only necrotic tissue. Cautery at the area of the biopsy site is occasionally needed if large vessels are present (25-gauge diathermy probe). In cases in which the retina is attached, a cannula is used to inject saline under the sensory retina to create a small bleb. An incision is then made in the retina using a 25-gauge flexible subretinal needle. Then, the tissue is excised with 25-gauge microvertical scissors, leaving a small area of anchoring attachment (Fig. 15.6). The biopsied retina is grasped securely with 25-gauge vertical forceps, so that as little as possible of the specimen is crushed and is removed from the eye (Fig. 15.6). Laser is not necessary at the biopsy edges involved by inflammation, but it is placed at the edges of normal retina (Fig. 15.7). An air–fluid exchange is performed, and occasionally a long-acting gas is injected.

15.3.2 Indications for Retinal Biopsy

A retinal biopsy may help explain and categorize inflammatory diseases; it may also influence therapeutic decisions. Ciulla et al. [30] reported a case of ocular lymphoma in which a diagnosis of large cell lymphoma was made by transvitreal subretinal aspiration biopsy, whereas two vitreous biopsies and a concurrent retinal biopsy were nondiagnostic. Pavan et al. [31] also reported a case in which subretinal aspiration of infiltrates revealed large atypical cells with positive staining for leukocyte-common antigen, confirming a diagnosis of high-grade

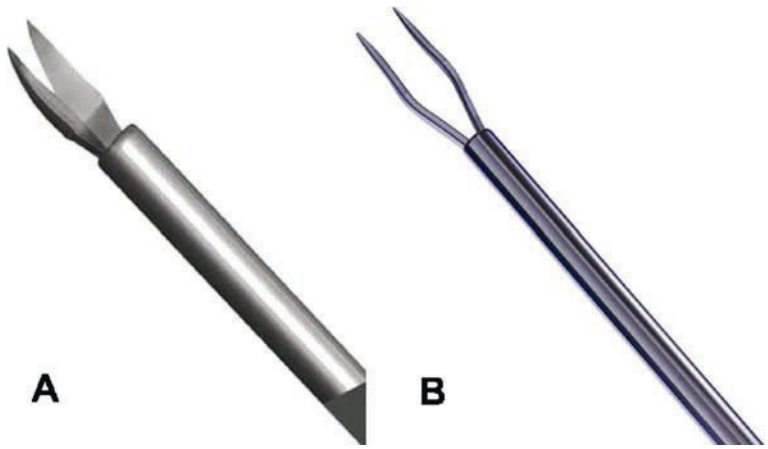


Fig. 15.6 25-gauge curve scissors, and 25-gauge end-gripping forceps (courtesy of and modified from Alcon Laboratories, Fort Worth, TX, USA)

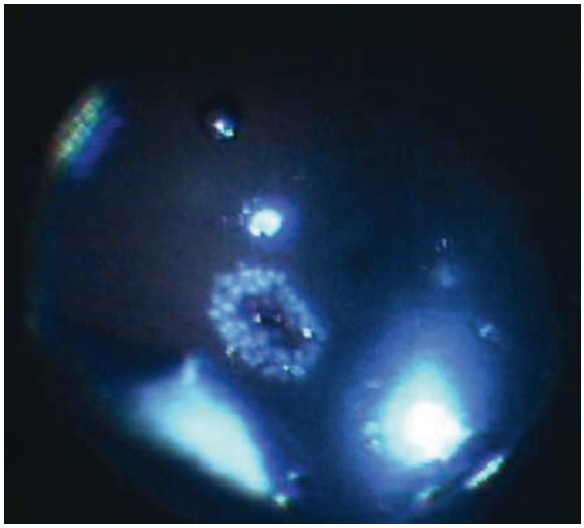


Fig. 15.7 Laser is not necessary at the biopsy edges involved by inflammation, but it is placed at the edges of normal retina

lymphoma. Coskuncan et al. [32] reported on a series of 397 patients who were followed up prospectively after bone marrow transplantation, 2% of whom developed infectious retinitis requiring intraocular biopsy. In these cases, retinal biopsy was crucial to diagnostic and therapeutic decision-making. Johnston et al. [33] performed a retrospective review of retinal and choroidal biopsies undertaken in cases of unclear uveitis of suspected infectious or malignant origin. In this series, 13 patients underwent either a retinal or choroidal biopsy. The pathologic diagnosis differed from the initial clinical diagnosis in five cases (38%), and helped to direct treatment in seven cases (54%). Retinal biopsies were invaluable in making the proper diagnosis in these cases.

15.3.3 Processing Retinal Samples

Removal of the sample from the eye can be difficult using a 25-gauge port, because it may be difficult to remove the retinal biopsy specimen through the relatively long length of trocar tubing protruding into the eye. For these reasons, it may be best to open the port corresponding to the forceps, and use a 20-gauge instrument to remove the specimen. After the tissue sample is removed from the eye, it is immediately placed in appropriate fixative. The retina specimen can be sectioned into three pieces under the operating microscope. If orientation is important, the sample may be placed on a piece of filter paper or other material, and the correct localization marked on the paper. This is an important point of discussion for the surgeon and the pathologist before the surgical procedure. One sample should be frozen in cryostat compound for immunopathology, the second piece fixed with 4% glutaraldehyde for light and electron microscopy study, and the third piece sent for culture and PCR. It should be recalled that glutaraldehyde would cross link proteins and usually make immunocytochemistry difficult.

Nevertheless, the routine methods for handling small biopsy specimens of other tissues are inadequate for preparing retinal specimens. The ability to recover small, friable pieces of retina in a manner that allows good histologic examination is essential if retinal biopsy specimens are to be used in the diagnosis and management of patients with infectious retinitis where the causative

agent is unclear. Schneiderman et al. [34] developed the agar–albumin sandwich technique for processing retinal biopsy specimens. It is an agar–albumin tissue mount for the sterile recovery and transport of small pieces of retina from the operative field to the laboratory (Fig. 15.8). The agar–albumin sandwich mount facilitates tissue processing without interfering with histologic sectioning or interpretation.

Summary for the Clinician

- Always remove the cortical vitreous to gain access to the retina, to clear the media, and allow for gas tamponade.
- Location of the tissue to be sampled is preferably in the superior and nasal retina, at the junction of infected and uninfected retina, as peripheral as possible, and in a relatively avascular area.
- Removal of the sample from the eye can be difficult using a 25-gauge port. It may be best to open the port corresponding to the forceps and use a 20-gauge instrument to remove the specimen.

15.4 Chorioretinal Biopsy

Chorioretinal biopsy allows harvesting of choroidal tissue and preservation of the anatomic relationship between the choroid and the retina, if the specimen is handled carefully. In a few ocular disease processes, the pathologic evidence is primarily located at the level of the choroid. In such cases, the cells recovered by vitrectomy may be nonspecifically inflammatory in nature and not representative of the actual disorder.

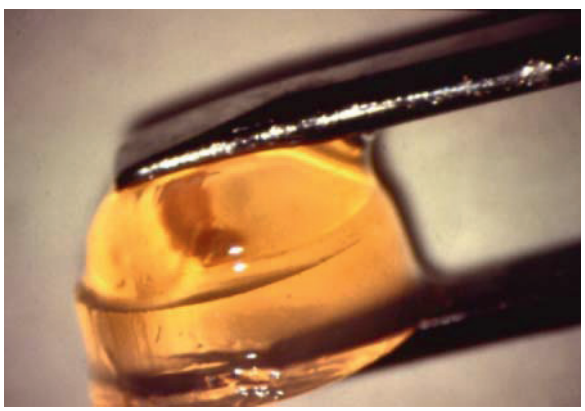


Fig. 15.8 An agar–albumin tissue mount for the sterile recovery and transport of small pieces of retina from the operative field to the laboratory

Prior to performance of a choroidal biopsy, the location of the biopsy should be carefully selected. A location in the upper half of the fundus should be picked to allow postoperative gas tamponade and repair of the chorioretinal defect. One drawback is the requirement that an active chorioretinal lesion be present in the far periphery. Technically, the most posterior site that can be used for biopsy is near the equator of the globe, because of the space required to manipulate the chorioretinal block adequately once it has been incised. The surgery is a major intervention. Since the tissue harvested uncommonly changes the clinical management, the procedure is very rarely indicated.

15.4.1 Surgical Technique for Chorioretinal Biopsy

In biopsies of the choroid and RPE, the retina tends to bulge into the biopsy site, with a risk of retinal tear or incarceration. Removing the cortical vitreous with standard 25-G TSV reduces this risk. Secondly, the laser indirect ophtalmoscope is used to perform a double or triple row of retinal photocoagulation surrounding the biopsy site. Afterwards, the eye is filled with air, and a partial thickness scleral flap is dissected over the marked area. The edges of the bed are treated with diathermy, and a needle knife is used to incise the sclera, choroid and retina. Vannas Scissors are then used to cut 2.5–3.5 mm square specimen (Fig. 15.9). Finally, the scleral flap is sutured closed with nylon sutures, and the eye is filled with a gas.

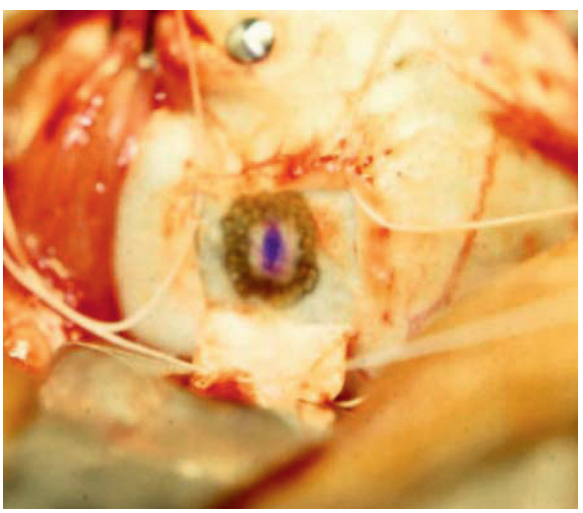


Fig. 15.9 The edges of the bed are treated with diathermy, and a needle knife is use to incise the sclera, choroid and retina. Vannas Scissors are then used to cut 2.5–3.5 mm^2 specimen

15.4.2 Indications for Chorioretinal Biopsy

Chorioretinal biopsy should be considered in patients who have an unidentified, medically unresponsive, bilateral, sight-threatening inflammatory process that involves the choroid or both the retina and the choroid. The information obtained should help establish whether the process is infectious, immunologic, malignant or degenerative [35, 36].

Martin et al. [36] have reported on chorioretinal biopsies on seven patients with progressive chorioretinal lesions of unknown etiology. On the basis of the biopsy findings, a diagnosis of multifocal choroiditis and subretinal fibrosis was rendered in three eyes, sarcoidosis in two eyes, and viral retinitis in two eyes. Therapy was changed in five patients. Final visual acuity was unchanged or improved in five eyes. They concluded that chorioretinal biopsy may provide useful information for determining the diagnosis and guiding the subsequent management of patients with progressive chorioretinal lesions of unknown etiology [36].

Rutzen et al. [37] reviewed the clinical and histopathologic features of 33 intraocular tissue biopsy specimens from 32 patients, and assessed the value of retinal and chorioretinal biopsies performed in patients with intraocular inflammation. Of the 24 endoretinal biopsy specimens, 19 were from patients with clinical signs suggestive of viral retinitis. Overall, electron microscopy, immunohistochemical staining, in situ DNA hybridization, or PCR suggested the diagnosis of viral retinitis in 10 of 19 biopsies (53%). The preoperative diagnosis was confirmed in seven of ten biopsies in cases of suspected CMV retinitis, in one of seven biopsies in cases of suspected acute retinal necrosis, and in two of two biopsies in cases of progressive outer retinal necrosis. The remaining five endoretinal biopsies disclosed Candida in one specimen, subretinal fibrosis in one, and chronic inflammation in three. Histologic examination of the nine chorioretinal or choroidal biopsies disclosed lymphoma in two specimens, a subretinal neovascular membrane in one, uveal melanocytic proliferation in one, toxoplasmic retinochoroiditis in one, viral retinitis in one, and long-standing inflammation in three. They concluded that in select cases of intraocular inflammation, intraocular tissue biopsies may provide clinically useful information [37].

When the clinical features of a tumor are such that two or more distinct pathologic lesions are both plausible diagnostic possibilities (amelanotic choroidal melanoma vs unilateral unifocal metastatic carcinoma to the choroid), an invasive specimen-producing approach with 25-G TSV may be useful. Ausburger [38] has mentioned three specific indications for biopsy of intraocular tumors. These specific indications include (1) major diagnostic uncertainty about the pathologic nature of the mass or lesion of interest, provided that the individual expressing the uncertainty is highly experienced in the field, (2) suspected metastatic carcinoma to the eye in a patient without a prior history of a non-ophthalmic cancer capable of metastasizing or any concurrent pathologically evaluable or antecedent pathologically confirmed metastases in other tissues or organs, and (3) request for biopsy by an informed patient who refuses recommended treatment in the absence of pathologic confirmation of the clinical diagnosis [38].

Choroidal biopsies in the management of indeterminate intraocular tumors have previously been performed by various techniques including transscleral approaches, fine-needle aspiration biopsies, and PPV techniques using a vitreous cutter. Notably, the earlier transcleral techniques had a relatively high incidence of extraocular tumor spread [39]. The fine-needle aspiration biopsy, being the least invasive of the available techniques, is favored in most cases but it is possibly less suitable for thin tumors, and the limited yield may not be sufficient for a conclusive cytopathologic diagnosis in these cases [40]. New techniques such 25-G TSV based on a PPV approach, followed by an incisional choroidal biopsy to optimize surgical control and facilitate adequate tissue sampling regardless of tumor thickness, may be of value and warrant further study.

15.4.3 Processing Choroidal Samples

The chorioretinal biopsy specimen is immediately divided into three parts in a sterile manner under a microscope. One section is submitted for light and

Summary for the Clinician

- Chorioretinal biopsy allows harvesting of choroidal tissue and preservation of the anatomic relationship between the choroid and the retina, if the specimen is handled carefully.
- Since the tissue harvested uncommonly changes the clinical management, the procedure is very rarely indicated.
- In biopsies of the choroid and RPE, the retina tends to bulge into the biopsy site with a risk of retinal tear or incarceration. Removing the cortical vitreous with standard 25-G TSV reduces this risk.

electron microscopy, one section for inmunopatology studies, and the third section for microbiology and tissue culture. The portion of the specimen for histologic examination is fixed in 4% paraformaldehyde, and half of this portion for electronmicroscopic studies is then post fixed in 2% glutaraldehyde and is embedded in glycol-methacrylate.

15.5 Complications of Intraocular Biopsy

The risks of intraocular biopsy are those of vitreoretinal surgery in general. These include increased intraocular pressure, cataract progression, peripheral retinal tears, retinal detachment, choroidal hemorrhage, vitreous hemorrhage, endophthalmitis, exacerbation of the underlying inflammatory disease, and proliferative vitreoretinopathy. The most hazardous of the biopsy procedures is the trans-scleral choroidal or retinochoroidal resection. Additionally, the risks of choroidal biopsy include intraoperative and postoperative hypotonic choroidal detachment, and vitreous hemorrhage [35, 36]. Martin et al. [36] reported the progression of lens opacity in all eyes and the development of phthisis in one eye that was extensively diseased preoperatively.

15.6 Summary

Vitreous, retinal and choroidal biopsy are of great value when the differential diagnosis includes chorioretinal disease of infectious or malignant origin and the diagnosis cannot be confirmed by less invasive techniques. It is a relatively safe procedure, and the results often change clinical management. Although vitreous, retinal and choroidal biopsy are unlikely to become a primary investigation, it should perhaps be considered at an earlier stage, because it might allow earlier initiation of specific therapy that might prevent severe visual loss.

Under optimal conditions, 25-gauge procedures induce minimal ocular trauma, decrease the inflammatory response, and may allow overall faster patient recovery. Further study, particularly a prospective, randomized trial examining the potential benefits of 25-G TVS instrumentation for vitreous and retinal/choroidal biopsy is warranted.

References

1. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
2. Yanyali A, Celik E, Horozoglu F, Oner S, Nohutcu AF (2006) 25-Gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16:141–147
3. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou TJ (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
4. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
5. Lam DS, Fan DS, Mohamed S, Yu CB, Zhang SB, Chen WQ (2005) 25-gauge transconjunctival sutureless vitrectomy system in the surgical management of children with posterior capsular opacification. Clin Exp Ophthalmol 33:495–498
6. Huang JS, Russack V, Flores-Aguilar M, Gharib M, Freeman WR (1993) Evaluation of cytologic specimens obtained during experimental vitreous biopsy. Retina 13:160–165
7. Green WR. (1984) Diagnostic cytopathology of ocular fluid specimens. Ophthalmology 91:726–749
8. Michels RG, Green WR, Engel HM et al (1984) Diagnostic vitrectomy. In: Jakobiec FA, Sigelman J (eds) Techniques in ocular surgery. WB Saunders, Philadelphia
9. Michels RG, Knox DL (1975) Reticulum cell sarcoma: diagnosis by pars plana vitrectomy. Arch Ophthalmol 93:1331–1335
10. Piro P, Pappas HR, Erozan YE et al (1982) Diagnostic vitrectomy in metastatic breast carcinoma in the vitreous. Retina 2:182–188
11. Davis JL, Miller DM, Ruiz P (2005) Diagnostic testing of vitrectomy specimens. Am J Ophthalmol 140:822–829
12. Ratanapojnard T, Roy CR, Gariano RF (2005) Effect of vitrector cutting rate on vitreous biopsy yield. Retina 25:795–797
13. Soushi S, Ozawa H, Matsuhashi M, Shimazaki J, Saga U, Kurata T (1988) Demonstration of varicella-zoster virus antigens in the vitreous aspirates of patients with acute retinal necrosis syndrome. Ophthalmology 95:1394–1398
14. de Boer JH, Luyendijk L, Rothova A, et al (1994) Detection of intraocular antibody production to herpesviruses in acute retinal necrosis syndrome. Am J Ophthalmol 117:201–210
15. Weiss MJ, Velazquez N, Hofeldt AJ (1990) Serologic tests in the diagnosis of presumed toxoplasmic retinochoroiditis. Am J Ophthalmol 109:407–411
16. Davis JL, Feuer W, Culbertson WW, Pflugfelder SC (1995) Interpretation of intraocular and serum antibody levels in necrotizing retinitis. Retina 15:233–240
17. Ronday MJH, Ongkosuwito JV, Rothova A, Kijlstra A (1999) Intraocular anti-Toxoplasma gondii antibody production in patients with ocular toxoplasmosis. Am J Ophthalmol 127:294–300
18. Pepose JS, Flowers B, Stewart JA, Grose C, Levy DS, Culbertson WW, Kreiger AE (1992) Herpesvirus antibody

levels in the etiologic diagnosis of the acute retinal necrosis syndrome. Am J Ophthalmol 113:248–256
19. Doornenbal P, Baarsma G, Quint W et al (1996) Diagnostic assays in cytomegalovirus retinitis: detection of herpesvirus by simultaneous application of the polymerase chain reaction and local antibody analysis on ocular fluid. Br J Ophthalmol 80:235–240
20. de Boer JH, Verhagen C, Bruinenberg M et al (1996) Serologic and polymerase chain reaction analysis of intraocular fluids in the diagnosis of infectious uveitis. Am J Ophthalmol 121:650–658
21. Short GA, Margolis TP, Kuppermann BD et al (1997) A polymerase chain reaction-based assay for diagnosing varicella-zoster virus retinitis in patients with acquired immunodeficiency syndrome. Am J Ophthalmol 123: 157–164
22. Abe T, Tsuchida K, Tamai M (1996) A comparative study of the polymerase chain reaction and local antibody production in acute retinal necrosis syndrome and cytomegalovirus retinitis. Graefes Arch Clin Exp Ophthalmol 234:419–424
23. Abe T, Sato M, Tamai M (1998) Correlation of varicella-zoster virus copies and final visual acuities of acute retinal necrosis syndrome. Graefes Arch Clin Exp Ophthalmol 236:747–752
24. Ganatra JB, Chandler D, Santos C et al (2000) Viral causes of acute retinal necrosis syndrome. Am J Ophthalmol 129:166–172
25. McCann J, Margolis T, Wong M et al (1995) A sensitive and specific polymerase chain reaction-based assay for the diagnosis of cytomegalovirus retinitis. Am J Ophthalmol 120:219–226
26. Montoya JG, Parmley S, Liesenfeld O et al. (1999) Use of the polymerase chain reaction for diagnosis of ocular toxoplasmosis. Ophthalmology 106:1554–1563
27. Jones CD, Okhravi N, Adamson P et al (2000) Comparison of PCR detection methods for B1, P30, and 18S rDNA genes of T. gondii in aqueous humor. Invest Ophthalmol Vis Sci 41:634–644
28. Lohmann CP, Linde HJ, Reischl U (2000) Improved detection of microorganisms by polymerase chain reaction in delayed endophthalmitis after cataract surgery. Ophthalmology 107:1047–1051
29. Anand A, Madhavan H, Neelam V et al (2001) Use of polymerase chain reaction in the diagnosis of fungal endophthalmitis. Ophthalmology 108:326–330
30. Ciulla TA, Pesavento RD, Yoo S (1997) Subretinal aspiration biopsy of ocular lymphoma. Am J Ophthalmol 123:420–422
31. Pavan PR, Oteiza EE, Margo CE (1995) Ocular lymphoma diagnosed by internal subretinal pigment epithelium biopsy. Arch Ophthalmol 113:1234
32. Coskuncan NM, Jabs DA, Dunn JP et al (1994) The eye in bone marrow transplantation. VI. Retinal complications. Arch Ophthalmol 112:372–379
33. Johnston RL, Tufail A, Lightman S et al (2004) Retinal and choroidal biopsies are helpful in unclear uveitis or suspected infectious or malignant origin. Ophthalmology 111:522–528
34. Schneiderman TE, Faber DW, Gross JG, Wiley CA, Freeman WR (1989) The agar–albumin sandwich technique for processing retinal biopsy specimens. Am J Ophthalmol 108:567–571
35. Freeman WR (1992) Application of vitreoretinal surgery to inflammatory and infectious disease of the posterior segment. Int Ophthalmol Clin 32:15–33
36. Martin DF, Chan CC, de Smet MD, Palestine AG, Davis JL, Whitcup SM, Burnier MN Jr, Nussenblatt RB (1993) The role of chorioretinal biopsy in the management of posterior uveitis. Ophthalmology 100:705–714
37. Rutzen AR, Ortega-Larrocea G, Dugel PU, Chong LP, Lopez PF, Smith RE, Rao NA (1995) Clinicopathologic study of retinal and choroidal biopsies in intraocular inflammation. Am J Ophthalmol 119:597–611
38. Augsburger JJ (2005) Diagnostic biopsy of selected intraocular tumors. Am J Ophthalmol 140:1094–1095
39. Sanders TE, Smith ME (1972) Biopsy of intraocular tumors: a reevaluation. Int Ophthalmol Clin 12:163–176
40. Shields JA, Shields CL, Ehya H, Eagle RC Jr, De Potter P (1993) Fine-needle aspiration biopsy of suspected intraocular tumors. The 1992 Urwick Lecture. Ophthalmology 100:1677–1684

Chapter 16

Uveal Biopsy with 25-Gauge Vitrector: Work in Progress

F. Altomare

Core Message

- Intraocular tumors are conventionally diagnosed with noninvasive techniques, namely, clinical characteristics, angiographic and ultrasonographic features.
- Rarely, intraocular masses require histopathology to increase diagnostic yield.
- Results from intraocular biopsy can lead to revision of the therapeutic plan.
- A variety of techniques exist to obtain intraocular tissue, most commonly fine-needle aspiration biopsy (FNAB).
- Vitrectomy-based biopsy techniques utilizing a 20-gauge aspiration cutter have been performed in an effort to increase the diagnostic yield compared to FNAB, but at the expense of increased complications.
- Intraocular biopsy based on a 25-gauge aspiration cutter is explored, with the intent of providing the safety benefits of FNAB and the potential benefit of increased diagnostic yield of vitrectomy.
- Biopsy with 25-gauge aspiration cutter can be performed for anterior segment and posterior segment indeterminate lesions.
- Albeit with limited follow-up and small number of cases, biopsy with the 25-gauge aspiration cutter did yield adequate amounts of specimen for histopathologic diagnosis, with no significant complications.

16.1 Introduction

Intraocular tumors are routinely diagnosed based on characteristic clinical, angiographic, and ultrasonographic features. Initial review of diagnostic accuracy employing noninvasive techniques was poor [1]. Ferry reported in 1964 that out of 529 enucleation specimens, 100 were clinically misdiagnosed as uveal melanoma. Since then, refinements in noninvasive diagnostic techniques have improved diagnostic accuracy [2–5]. More recently, the Collaborative Ocular Melanoma Study (COMS) reported that five out of 1,532 intraocular tumors were misdiagnosed as choroidal melanoma, representing an accuracy greater than 99.6% [6]. However, such high diagnostic accuracy required adherence to standardized protocols and exclusion criteria. Thus, in selected cases of intraocular tumors, COMS criteria will not be met, or the presentation will be atypical, and the correct diagnosis will be difficult to establish with noninvasive techniques. In such cases, histopathologic confirmation for diagnosis is sought.

Intraocular biopsy has been incorporated in the investigation of atypical tumors to reduce diagnostic uncertainty. The proportion of referred intraocular tumors requiring invasive techniques for diagnosis is approximately 2% in one large retrospective series [7]. When tissue diagnosis is obtained in this small group of atypical tumors, the final diagnosis may differ from the initial clinical diagnosis, and the planned management is revised accordingly. Several retrospective series reported a change in management following tissue biopsy in 16–48% of patients [7–9]. This alteration of therapeutic plan underlies the benefit of intraocular biopsy.

As techniques for uveal biopsy have evolved over the past 30 years, the indications for biopsy of intraocular tumors have been formulated [7, 10–12]. These indications include the following: (1) despite noninvasive measurements, diagnosis of the intraocular mass remains uncertain and treatment is recommended, (2) intraocular metastasis is suspected although systemic evaluation does not reveal a primary cancer nor other nonocular metastatic lesions as potential biopsy sites, and (3) the diagnosis is established by noninvasive measures, but the patient requests tissue diagnosis prior to commencing therapy. More recent developments in molecular biology

have introduced a new classification of uveal melanoma based on characteristic gene expression profiles [13]. This classification was highly predictive of metastatic death, with implications for modifying the therapeutic plan. Thus, prognostic accuracy is a possible fourth indication for biopsy of intraocular tumors [14, 15]. However, notable contraindications to intraocular biopsy include retinoblastoma, or potentially any condition that may cause significant morbidity to the patient [12].

A variety of invasive techniques exist to obtain histologic confirmation of suspicious uveal tumors. These methods include fine-needle aspiration biopsy (FNAB), vitrectomy, eyewall resection, or endoresection. The merits of these procedures are continually evaluated, in particular for the risk of intraocular or extraocular tumor spread following biopsy. FNAB of enucleated specimens have demonstrated tumor seeding along the needle path [16, 17]. Laboratory evidence in a non-ocular murine model demonstrated that regardless of the method of biopsy (FNAB, incisional and excisional biopsy), there was no increase in death related to tumor spread [18]. Clinically, since the initial experience of FNAB for intraocular tumors reported in 1979 [19], there has only been one documented case of tumor seeding and nodule formation arising at the scleral puncture site from transvitreal FNAB [20]. Similarly, there are few reports of intraocular tumor dissemination following biopsy via vitrectomy [15] or endoresection [21, 22]. It has been suggested that perhaps the risk of intraocular tumor dissemination and metastasis may not be dependent on the biopsy technique but more likely reflective of an aggressive tumor [14, 23].

This chapter will focus on vitrectomy, but in particular on the techniques using the 25-gauge aspiration cutter for biopsy of anterior segment tumors and posterior choroidal tumors. FNAB is the least invasive and most widely used procedure for intraocular biopsy, but it has limitations. These limits include insufficient aspirate material to arrive at a tissue diagnosis [7, 22], sampling error [24], or ocular complications, most often intraocular hemorrhage with transient visual loss [7]. Tumor thickness has been shown to influence the diagnostic yield of FNAB, [5, 25, 26], and modifications to FNAB technique have included increasing the needle bore size [7]. or multiple needle passes through the tumor [25] in order to increase the yield. Vitrectomy-type approaches were thus introduced in an effort to improve upon these limits [15, 27, 28].

There is a limited number of reports utilizing a 20-gauge aspiration cutter to manage anterior segment and posterior segment uveal lesions. Through a scleral tunnel or limbal incision, the 20-gauge vitreous cutter has been introduced to unroof iridoschisis [29] or obtain tissue from indeterminate iris tumors [15]. The biopsy techniques for choroidal tumors are more complex. All published series share the following steps: pars plana vitrectomy, retinotomy, sequestering of choroidal tissue, gas–fluid exchange, and closure of all entry points with sutures. However, the retinotomy may be small or 180° [30], and may be generated by the vitreous cutter or diamond knife [15, 27], with post-biopsy endophotocoagulation. The choroidal tissue can be obtained with the vitreous cutter on aspiration mode only [27], or with the cutting mechanism active [15], or the tissue can be incised with a diamond knife and extracted with forceps [28]. The type of gas used may be air or sulfur hexafluoride. Documented complications have included vitreous hemorrhage, retinal detachment, one case of intraocular tumor dissemination, and one case of insufficient tissue material (the specimen was lost during processing) [15].

The 25-gauge vitreous cutters offer the opportunity to combine the safety and benefits of the less invasive FNAB with the potential increased diagnostic yield of the vitreous cutter [31, 32]. The technique for anterior segment tumors and posterior segment tumors will be presented as follows.

16.2 Anterior Segment Biopsy: Technique

The Finger iridectomy technique [31] will be described, interjected with variances based on unpublished experience of the author. Most anterior segment lesions can be biopsied by this technique, whether the mass lies anterior to the iris, involves the iris, or (as in Fig. 16.1) is situated posterior to the iris. Based on tumor size and location, and path of best visualization of the lesion, the microvitreal blade is introduced through clear cornea opposite to or on the same side of the lesion. Careful attention is given to minimizing the risk of lens trauma. Miotic agents are used to constrict the pupil and stabilize the iris, although dilating agents are used for lesions posterior to the iris. Sodium hyaluronate 1% is introduced to stabilize the anterior chamber and elevate the iris from the lens. The additional benefit of viscoelastic is its resistance to the flow of blood should bleeding occur during tissue biopsy, thus helping to maintain visualization during the process. Alternatively, one can combine viscoelastic (sodium hyaluronate 2%), and the 25-gauge infusion line inserted through a second clear corneal incision (Fig. 16.2). The intraocular pressure can be elevated to reduce the risk of intraoperative bleeding as well as maintain an adequate anterior chamber, and the viscoelastic is able to coat and protect the intraocular structures. The 25-gauge vitreous cutter is passed through the clear corneal incision, and the lesion of interest is biopsied. Suction can be set at 300 mmHg with a cut rate of 600 cuts per minute, but these parameters are modified to maximize yield. The cutter

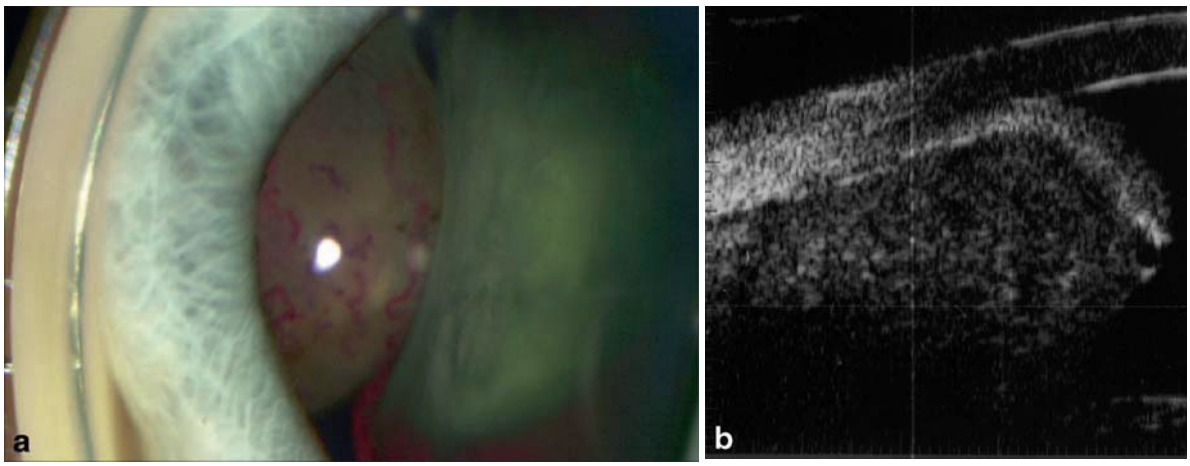


Fig. 16.1 Clinical photograph of a mass situated between iris and lens (**a**), with corresponding image on ultrasound biomicroscopy (**b**)

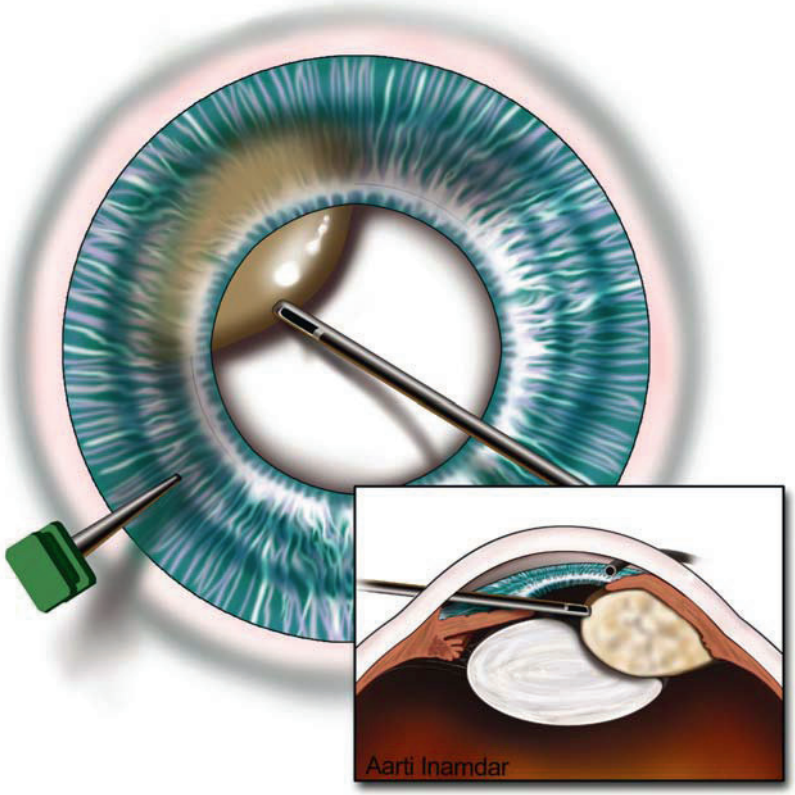


Fig. 16.2 Anterior segment biopsy: optional is the placement of the infusion trocar cannula; the 25-gauge aspiration cutter is introduced in opposite position of the intraocular mass seen in Fig. 16.1. *Inset*: cross-sectional view of the 25-gauge aspiration cutter's position relative to lens and tumor

is removed from the eye, and the aspirate is flushed and collected from the cutter for subsequent analysis. The cutter can be re-inserted into the anterior chamber for further tissue removal until an adequate incisional or excisional biopsy is achieved. The viscoelastic is removed and no sutures are required for closure of the corneal wound(s).

16.3 Posterior Segment Biopsy: Technique

The following description is based on the only published series to date [32] and personal experience from the author. The trocar cannulas are inserted transconjunctivally through the pars plana into the

vitreous cavity, and are positioned with reference to tumor size and location, media clarity, and any associated exudative retinal detachment. A limited vitrectomy is performed. The 25-gauge vitreous cutter is inserted through the retina into the tumor, and an aspirate is obtained. The retinotomy site is selected in an area where bleeding is anticipated to be minimal but also where a significant amount of tissue can be obtained. The infusion pressure is also elevated, to reduce bleeding intraoperatively. The vitreous cutter is removed and its content flushed. Under the microscope, tissue fragments can be visualized. The vitreous cutter can be reinserted into the eye for additional material. The collected specimen is fixed, centrifuged, placed in paraffin, followed by sectioning and staining, including immunohistochemistry stains.

A variation on the approach by the author is to introduce a 39-gauge cannula through the selected retinotomy site and infuse saline in the subretinal space separating the overlying retina from the tumor (Fig. 16.3). The cutter is subsequently passed through the retinotomy and the tumor tissue is obtained (Fig. 16.4). Separating the retina from the tumor at the biopsy site may be helpful if tumor at the selected biopsy site is not very thick and the desire is to minimize trauma to the retina during the biopsy (Fig. 16.5).

Once the biopsy is completed, an air–fluid exchange is performed, although Sen et al. no longer find it necessary. The trocar cannulas are removed as a cotton-tip applicator is rolled over the entry site and pressure applied to ensure no leakage transsclerally.

The 25-gauge vitreous cutter biopsy techniques provided pathological diagnosis in nine of ten cases by Finger et al. [31] and in 13 of 14 cases by Sen et al., although one ot these latter cases required a second attempt at 25-gauge biopsy [32]. Complications were limited to transient ocular hypertension in the anterior segment group, and limited clot at the biopsy site with no rhegmatogenous retinal detachment for the posterior segment group. Although follow-up is limited, there were no cases of intraocular tumor seeding in both groups.

In conclusion, most intraocular uveal tumors will not require invasive procedures for diagnosis and management. However, in a select group intraocular biopsy will be required. A variety of approaches are available to obtain tissue samples. The 25-gauge vitreous cutter is a new and simple approach that has potential benefits of a minimally invasive technique, and can provide adequate amount of tissue specimen for histopathology and if required, cytogenetics.

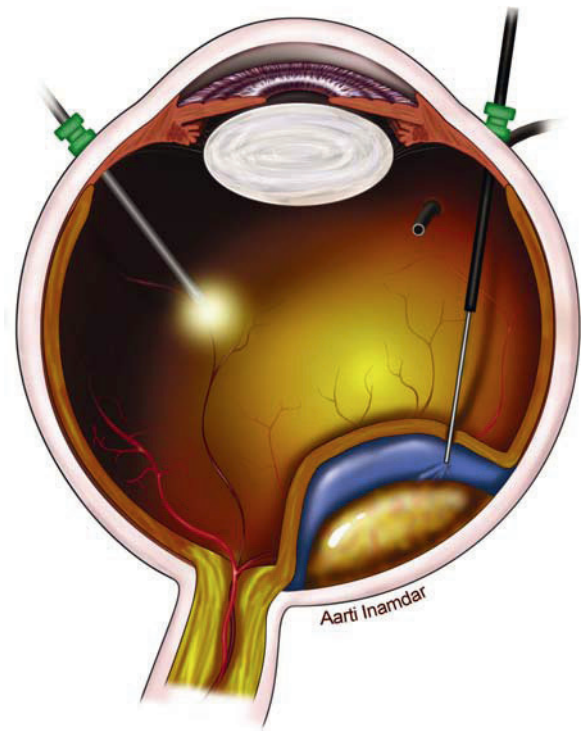


Fig. 16.3. The 39-gauge cannula is inserted through the retina, and saline is infused in the subretinal space separating the retina from the tumor

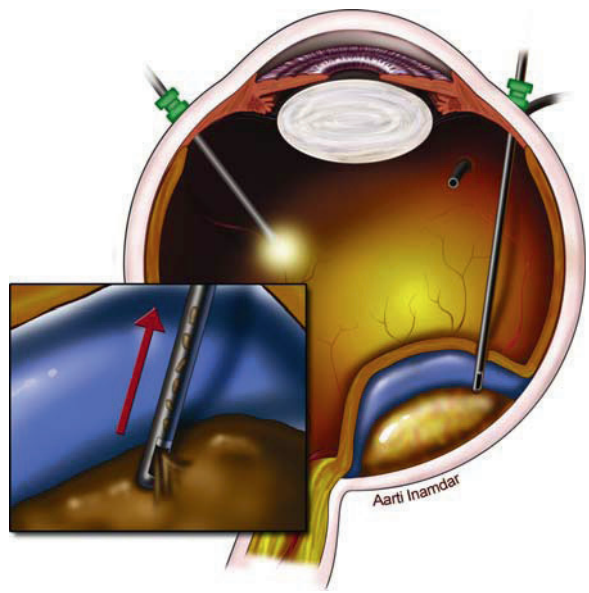


Fig. 16.4. The 25-gauge aspiration cutter is introduced through the 39-gauge retinotomy and a tumor biopsy is obtained. *Inset*: magnified view of the 25-gauge aspiration cutter engaging the choroidal tumor

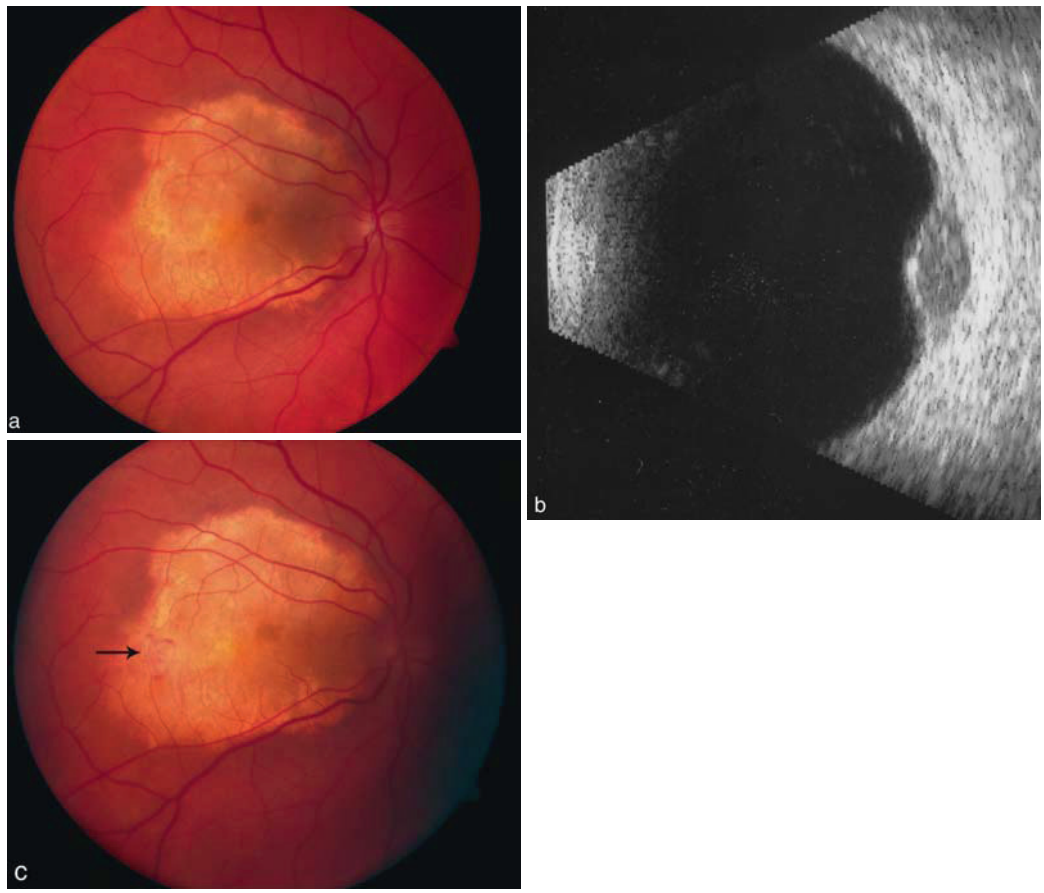


Fig. 16.5. (**a**) Preoperative fundus photograph of indeterminate choroidal lesion. **(b)** B-scan ultrasound of the lesion with a maximal height of 3.5 mm on A-scan. (**c**) One week post-biopsy, the retinotomy site (*arrow*) is closed with no overt subretinal fluid

Summary for the Clinician

- Noninvasive techniques are primarily used to diagnose intraocular tumors.
- Atypical presentation of intraocular tumors relies on biopsy to arrive at the correct diagnosis and appropriate therapy.
- Although fine-needle aspiration biopsy is the most common technique to acquire intraocular tissue, vitrectomy-based techniques have been developed in an attempt to increase diagnostic yield.
- Preliminary experience with the 25-gauge aspiration cutter technique simplified the procedure of vitrectomy-based biopsy, and provided adequate amounts of tissue for histopathology with no significant complications.

Acknowledgements

The author wishes to thank Ms. Aarti Inamdar for her invaluable assistance in designing the illustrations.

References

1. Ferry A (1964) Lesions mistaken for malignant melanoma of the posterior uvea. Arch Ophthalmol 72:463–469
2. Shields J, McDonald P (1974) Improvements in the diagnosis of posterior uveal melanomas. Arch Ophthalmol 91:259–264
3. Robertson D, Campbell R (1979) Errors in the diagnosis of malignant melanoma of the choroid. Am J Ophthalmol 87:269–275
4. Char D, Stone RD, Irvine AR, Crawford JB, Hilton GF, Lonn LI, Schwartz A (1989) Diagnostic modalities in choroidal melanoma. Am J Ophthalmol 89:223–230

5. Char DH, Miller T (1995) Accuracy of presumed uveal melanoma diagnosis before alternative therapy. Br J Ophthalmol 79:692–696
6. Collaborative Ocular Melanoma Study Group (1998) Histopathologic characteristics of uveal melanomas in eyes enucleated from the Collaborative Ocular Melanoma Study. COMS Report No. 6. Am J Ophthalmol 125:745–766
7. Shields JA, Shields CL, Ehya H, Eagle RC Jr, De Potter P (1993) Fine-needle aspiration biopsy of suspected intraocular tumors. The 1992 Urwick Lecture. Ophthalmology 100:1677–1684
8. Faulkner-Jones BE, Foster WJ, Harbour JW, Smith ME, Davila RM (2005) Fine needle aspiration biopsy with adjunct immunohistochemistry in intraocular tumor management. Acta Cytologica 49(3):297–308
9. Eide N, Syrdalen P, Walaas L, Hagmar B (1999) Fine-needle aspiration biopsy in selecting treatment for inconclusive intraocular disease. Acta Ophthalmol Scand 77:448–452
10. Augsburger JJ, Shields JA (1984) Fine-needle aspiration biopsy of solid intraocular tumors: indications, instrumentation and techniques. Ophthalmic Surg 15:34–40
11. Foulds WS (1992) The uses and limitations of intraocular biopsy. Eye 6:11–27
12. Augsburger JJ (2005) Diagnostic biopsy of selected intraocular tumors. Am J Ophthalmol 140:1094–1095
13. Onken MD, Worley LA, Ehlers JP, Harbour JW (2004) Gene expression profiling in uveal melanoma reveals two molecular classes and predicts metastatic death. Cancer Res 64:7205–7209
14. Damato B (2006) The role of eyewall resection in uveal melanoma management. Int Ophthalmol Clin 46:81–93
15. Bechrakis NE, Foerster MH, Bornfeld N (2002) Biopsy in indeterminate intraocular tumors. Ophthalmology 109:235–242
16. Karcioglu ZA, Gordon RA, Karcioglu GL (1985) Tumor seeding in ocular fine needle aspiration biopsy. Ophthalmology 92:1763–1767
17. Glasgow BJ, Brown HH, Zargoza AM, Foos RY (1988) Quantitation of tumor seeding from fine-needle aspiration of ocular melanomas. Am J Ophthalmol 105:538–546
18. Eriksson O, Hagmar B, Ryd W (1984) Effects of fine-needle aspiration and other biopsy procedures on tumor dissemination in mice. Cancer 54:73–78
19. Jakobiec FA, Coleman DJ, Chattock A (1979) Ultrasonically guided needle biopsy and cytologic diagnosis of solid intraocular tumors. Ophthalmology 86:1662–1681
20. Caminal JM, Sanz S, Carreras M, Catala I, Arruga J, Roca G (2006) Epibulbar seeding at the site of a transvitreal fine-needle aspiration biopsy. Arch Ophthalmol 124:587–589
21. Kertes PJ, Johnson JC, Peyman GA (1998) Internal resection of posterior uveal melanoma. Br J Ophthalmol 82:1147–1153
22. Hadden PW, Hiscott PS, Damato BE (2004) Histopathology of eyes enucleated after endoresection of choroidal melanoma. Ophthalmology 111:154–160
23. Damato B, Wong D, Green FD, Mackenzie JM (2001) Intrascleral recurrence of uveal melanoma after transretinal "endoresection". [Letter] Br J Ophthalmol 85:114–115
24. Folberg R, Augsburger JJ, Gamel JW, Shields JA, Lang WR (1985) Fine-needle aspirates of uveal melanomas and prognosis. Am J Ophthalmol 100:654–657
25. Augsburger JJ, Corrêa ZM, Schneider S, Yassin RS, Robinson-Smith T, Ehya H, Trichopoulos N (2002) Diagnostic transvitreal fine-needle aspiration biopsy of small melanocytic choroidal tumors in nevus versus melanoma category. Trans Am Ophthalmol Soc 100:225–234
26. Cohen VM, Dinakaran S, Parsons MA, Rennie IG (2001) Transvitreal fine-needle aspiration biopsy: the influence of intraocular lesion size on diagnostic biopsy result. Eye 15:143–147
27. Fastenberg DM, Finger PT, Chess Q, Koizumi JH, Packer S (1990) Vitrectomy retinotomy aspiration biopsy of choroidal tumors. Am J Ophthalmol 110:361–365
28. Kvanta A, Seregard S, Kopp ED, All-Ericsson C, Landau I, Berglin L (2005) Choroidal biopsies for intraocular tumors of indeterminate origin. Am J Ophthalmol 140:1002–1006
29. Ghanem VC, Ghanem EA, Ghanem RC (2003) Iridectomy of the anterior iris stroma using the vitreocutter during phacoemulsification in patients with iridoschisis. J Cataract Refract Surg 29:2057–2059
30. Coupland SE, Joussen A, Anastassiou G, Stein H (2005) Diagnosis of a primary uveal extranodal marginal zone B-cell lymphoma by chorioretinal biopsy: case report. Graefes Arch Clin Exp Ophthalmol 243:482–486
31. Finger PT, Latkany P, Kurli M, Iacob C (2005) The Finger iridectomy technique: small incision biopsy of anterior segment tumours. Br J Ophthalmol 89:946–949
32. Stein J, Groenewald C, Hiscott PS, Smith PA, Damato BE (2006) Transretinal choroidal tumor biopsy with a 25-gauge vitrector. Ophthalmology 113:1028–1031

Chapter 17

The Use of 25-Gauge Vitrectomy Systems in the Management of Trauma

J.L. Prenner

Core Message

- Traumatic injuries are a significant cause of visual loss.
- The 25-gauge system can successfully be used in selected cases, reducing surgical trauma.
- Cases that could be treated using 25-gauge techniques are: traumatic hyphema, traumatic injuries to the lens, traumatic vitreous hemorrhage, port-traumatic endophthalmitis, and traumatic macular hole.
- The use of the 25-gauge transconjunctival vitrectomy approach is a viable tool in the treatment of injured eyes. This approach in trauma will continue to be refined and expanded.

17.1 Introduction

Traumatic injuries are a significant cause of visual loss. In the United States, approximately 2 million eye injuries occur annually, resulting in an estimated $200 million per year of hospital charges [1, 2]. Worldwide, 2.3 million people have significant bilateral visual loss as a result of trauma, and an additional 19 million cases of traumatic monocular blindness (20/200 or less) also exist [3]. Causes of visual loss include primary mechanical damage to vital ocular structures and secondary complications, such as infectious endophthalmitis and retinal detachment due to proliferative vitreoretinopathy.

Technologic advances have facilitated the repair of traumatic eye injuries. Improved posterior segment visualization is possible as a result of wide-angle viewing systems and xenon-powered illumination (light pipe and chandeliers). High-speed vitreous cutters and improved instrumentation have expanded the role for vitreous surgery in the setting of ocular trauma over the last 2 decades, and success rates in the management of many eyes is improved with vitrectomy.

The 25-gauge sutureless, transconjunctival, small-incision approach has changed the face of vitreoretinal surgery in the past 5 years, and is a vital tool for many modern surgeons in the management of non-traumatic vitreoretinal diseases. This chapter will discuss the utilization of the 25-gauge system in the management of ocular trauma in detail. Interestingly, at the time when this chapter was written, no articles concerning the use of the 25-gauge approach in the setting of trauma existed in the peer-reviewed literature. The techniques described are based on personal experience and the experience of colleagues who have used the 25-gauge system in trauma cases.

The role of sutureless vitreoretinal surgery in the management of traumatic hyphema, cataract, lens malposition, vitreous hemorrhage, endophthalmitis and macular hole will be explored in detail.

17.2 Traumatic Hyphema

Blunt ocular trauma may commonly produce a hyphema. Fortunately, the vast majority of cases resolve spontaneously without surgical intervention, and have no visual consequence. However, significant complications can arise from hyphemas, including acute glaucoma, staining of the cornea with blood, and occlusion of the central retinal artery [4–7]. The incidence of complications is significantly higher in eyes that have a second episode of bleeding after the initial trauma, which typically occurs 2–3 days after the initial hyphema is recognized.

The decision to intervene surgically is guided by personal experience and guidance from the peer-reviewed literature [8–10]. Many authors suggest surgical intervention in cases where the intraocular pressure is persistently elevated despite maximal medical therapy (>60 mmHg for two days), where total hyphema (8-ball) is present for greater than 5 days with an elevated pressure (>25 mmHg), or if corneal blood staining is present. Special care is

taken in patients who have sickle cell disease, where the presence of an intraocular pressure of >24 mmHg for more than 1 day may prompt intervention. A host of techniques have been suggested to manage this problem surgically, including simple paracentesis, anterior chamber washout with a one-needle technique, washout with a two-needle technique, and evacuation associated with a trabeculectomy [11, 12].

The 25-gauge system can be utilized to elegantly manage a surgical hyphema. Positions for clear corneal, shelved incisions are chosen, at opposite horizontal meridians, typically just above the nasal meridian, and just below the temporal meridian. These incisions can be created with the 25-gauge trocar, a 23-gauge needle, or a microsurgical knife. The trocar system must be utilized carefully in phakic eyes, as the length of the sleeve may result in anterior capsule and lenticular touch during the washout. The corneal incisions are ideally created in a biplanar fashion, as these are most likely to be self-sealing. The biplanar incision should extend from the limbal edge of the clear cornea, through a depth approximately 50% of the cornea for 2–3 mm. The instrument utilized can then be angled into the anterior chamber, in the "dimple down" maneuver utilized in clear corneal cataract surgery. The internal opening of the corneal wound should be wider than the external opening, to allow for maximal excursion and manipulation of the instruments while still maintaining a self-sealing wound. The vast majority of these eyes will have elevated intraocular pressures, and therefore anterior chamber stabilization with a viscoelastic substance is typically not necessary. In cases where the eye is not firm, viscoelastic substance can be injected into the anterior chamber via a paracentesis incision to pressurize the eye. The pressurized infusion line is attached to a 23-gauge butterfly needle, which is then secured on a small hemostat clamp. This infusion device is then placed through the nasal corneal incision, and the vitreous cutter is then placed through the temporal incision. The infusion is then turned on, and should be infused at a high pressure of 60–80 mmHg. Because a significant portion of the cutting and aspirating will be of loose blood and infusate, intracameral pressures can become low quickly, as extrusion through the cutter can easily exceed the infusion if it is not set at a high pressure. This high pressure also expands the volume of the anterior chamber, decreasing the chance of damaging the corneal endothelium and crystalline lens with the instruments. In cases where the trocar system has been utilized to create the corneal wounds, the infusion and cutter can be placed through the trocars, obviating the need for the creation of the 23-gauge infusion device. The aspiration and cutting rates are set at those used typically for vitrectomy, as per the surgeon's preference. The vitrectomy handpiece is utilized to remove solid clot and allow for intracameral flow to wash out residual blood. Small amounts of blood will often remain in the angle, and these generally do not need to be removed. The instruments can be exchanged to allow for maximal access to the blood, but this also is not typically necessary if the internal opening of the temporal corneal wound is in fact larger than the external opening. After an adequate washout has been performed, the pressure is reduced to 10 mmHg, and the cutter is slowly activated to allow the anterior chamber pressure to gently equilibrate to match the infusion pressure. The cutter is then removed, and the clear corneal wound is inspected to ensure that it is self-sealing. If leaking, it can be closed with one 10–0 monofilament nylon suture, but this is typically unnecessary. The infusion line is then removed, and the corneal wound is examined to assure that it is self-sealing. The second wound can also be sutured, but this is typically not necessary if the wounds are truly biplanar.

Summary for the Clinician

- Blunt ocular trauma may commonly produce a hyphema.
- Many authors suggest surgical intervention in cases where the intraocular pressure is persistently elevated, where total hyphema is present for more than 5 days, or if corneal blood staining is present.
- The 25-gauge system can be utilized to elegantly manage a hyphema. Clear corneal incisions can be created with the 25-gauge trocar, a 23-gauge needle, or a microsurgical knife.
- The infusion is then turned on, and should be infused at a high pressure of 60–80 mmHg. The vitrectomy handpiece is utilized to remove solid clot and allow for intracameral flow to wash out residual blood.

17.3 Traumatic Injury to the Lens

Trauma can lead to dislocation or subluxation of the lens, with or without the formation of cataract. In some patients, the malpositioned lens is not problematic, and good visual acuity with spectacle correction is possible. In many patients, however, the trauma will result in significant lens opacity or refractive errors that are uncorrectable with spectacles. Several special issues should be considered when approaching the evaluation of a traumatic cataract. The presence of phakodenesis or iridodenesis on initial evaluation should alert the examining physician to suspect lens subluxation.

Vitreous in the anterior chamber indicates that zonular rupture is present. In the absence of cataractous change and related visual impairment, treatment is not indicated. A subluxated, cataractous lens can be removed by aspiration–irrigation or phacofragmentation through an anterior limbal or clear corneal incision. However, an anterior approach may lead to posterior dislocation of the lens or lens fragments, vitreous prolapse and incarceration, and vitreous aspiration with resultant vitreous base traction and retinal tear formation. In addition, visualization of the anterior vitreous by coaxial illumination is poor compared with fiberoptic halogen or xenon endoillumination. These challenges to performing anterior segment surgery make pars plana vitrectomy and lensectomy a potentially safer alternative. Patients will often have relatively soft lenses, due to the younger age of many trauma patients. In these cases, the 25-gauge system can be effectively utilized to remove the lens.

A standard three-port 25-gauge approach, described elsewhere in this text, is employed, with the trocars placed at 3 mm from the limbus in each of the three quadrants. A 25-gauge needle on a syringe filled with balanced salt solution (BSS) can be placed though the supero-temporal trocar into the substance of the lens. Gentle injection of BSS into the lens allows for hydrodissection of the lens nucleus from the cortex. It also provides a track into the lens substance through which the vitreous cutter can be placed. Bimanual techniques are employed that utilize the light pipe to permit fixation, and also allow for simultaneous removal of the lens by the vitreous suction-cutter. Lens removal is most easily achieved using the cutter on the highest suction and lowest possible cut rate. Many surgeons prefer to remove the entire capsule in eyes that have been traumatized, often by utilizing an endgrasping forceps to engage capsular tissue in the sulcus of the capsule. The capsule can then be removed through the trocar, or can be cut and aspirated with the vitrector.

If lens fragments dislocate posteriorly, they can be removed safely, with minimal vitreous traction, using the same incisions and instrumentation, to perform a complete vitrectomy. When working in the vitreous cavity, however, the cut rate should be returned to a high rate to take advantage of high-speed cutting and reduced vitreoretinal traction during the vitrectomy. With endoillumination and scleral depression, prolapsed and juxtalenticular vitreous is readily identified and excised with the vitrectomy probe. After complete vitrectomy is performed, residual lens fragments may exist that cannot be removed with the standard vitrectomy settings. After all vitreous has been removed from the targeted lens material, the cut rate can safely be reduced to allow for removal of residual tissue. At this point, the infusion rate should be elevated significantly, as the gel-free vitreous cavity provides little resistance to the aspirating effects of the vitrector, and posterior segment collapse may occur. When material is particularly firm, "force feeding" the vitrector can be accomplished by manipulating engaged lens material into the mouth of the vitrector with the light pipe bimanually.

Pars plana lensectomy is the preferred method for removing a completely dislocated lens. The procedure described above can be utilized with soft lenses. In such cases, a core vitrectomy is performed, followed by elevation of the hyaloid and anteriorization of the vitrectomy. Before engaging the lens with the low cut rate, high-suction technique, the lens should be completely separated from any vitreous attachment, and the infusion pressure should be increased significantly.

Summary for the Clinician

- Special issues to consider when approaching a traumatic cataract include phakodenesis or iridodenesis, subluxation, vitreous in anterior chamber, and zonular rupture.
- An anterior approach may lead to posterior dislocation of the lens or lens fragments, vitreous prolapse and incarceration, and vitreous aspiration with resultant vitreous base traction and retinal tear formation.
- Pars plana vitrectomy and lensectomy are a potentially safer alternative. Patients will often have relatively soft lenses, due to the younger age of many trauma patients. In these cases, the 25-gauge system can be effectively utilized to remove the lens.

17.4 Vitreous Hemorrhage

Traumatic vitreous hemorrhage may arise from tears in the iris, ciliary body, choroid, or retina. Hemorrhage from choroidal rupture accumulates beneath the neurosensory retina, and then may pass through the retina into the vitreous, without necessarily causing a retinal break.

A three-port 20-gauge vitrectomy technique is the standard approach for nonclearing vitreous hemorrhage. In cases where the blood is not particularly dense and no extremely peripheral pathology is suggested by preoperative ultrasonography, the 25-gauge, sutureless approach to the vitrectomy may be preferable. Many surgeons will utilize the 25-gauge approach in eyes with known hemorrhage and retinal detachments as well. Assuming

that the anterior chamber is fairly clear, a central core of opaque vitreous is initially removed, where the tips of the cutter and endoilluminator can be visualized and seen to be safely away from both the retina and lens. The vitrectomy is then carried posteriorly, and successive layers of hemorrhagic and fibrinous vitreous are removed until the anticipated plane of the posterior hyaloid is approached. Constant surveillance is maintained for a gray membrane containing radially oriented vessels (undiagnosed detached retina). A small opening is made in the detached posterior hyaloid, through which unclotted blood is aspirated by active suction from a soft-tipped cannula or vitreous cutter. Once the retina has been visualized, it is best to remove as much retrohyaloid blood as possible to prevent dispersion into the vitreous cavity with consequent loss of visualization.

If the posterior vitreous cortex is not detached, it can be separated from the retina by gentle suction with a soft-tipped cannula or vitreous cutter at the edge of the optic disc. In cases where the hyaloid is difficult to detach from the retina, such as in children, a small amount of triamcinolone acetonide can be introduced into the vitreous to aid with visualization. Visualization can actually worsen if an excessive amount of drug sticks to the vitreous, and therefore it is advantageous to dilute the drug by at least 50% with BSS before introduction into the eye. Instillation with the infusion off also helps to place the triamcinolone on the target tissue and prevent diffuse spread. The vitrector can then be placed in the eye with the infusion on, and any free triamcinolone can be removed. Residual triamcinolone will adhere to the hyaloid, highlighting the anatomy and facilitating the creation of a posterior vitreous separation.

After establishing the plane between the hyaloid and retina, the surgeon attempts to remove the entire cortical vitreous except for the firmly attached portion at the anterior vitreous base. Cortex that does not separate with gentle manipulation is isolated from surrounding vitreous to eliminate traction on the retina. It is important to remove the cortical vitreous from areas on and adjacent to retinal breaks. Failure to do so may result in subsequent tangential traction and retinal detachment. When possible, intraocular diathermy is applied to the posterior edge of the tear, and the flap of the tear is amputated with the vitrector. A scleral buckle should be considered if retinal breaks cannot be freed from surrounding vitreous cortex, and in some cases it may be considered when there is significant risk for the development of future anterior vitreous base contraction.

The placement of sclerotomies close to the 3 and 9 o'clock positions facilitates maximal removal of the hemorrhagic anterior vitreous skirt, which thereby improves visualization of the peripheral retina and pars plana. Aided by coaxial illumination and scleral depression, peripheral vitreous on the temporal side of the globe is trimmed with the cutter placed through the temporal port to reach both the superior and inferior quadrants, after which it is transferred to the nasal sclerotomy, and the process is repeated. The fiberoptic endoilluminator may damage the lens if used internally to illuminate the peripheral vitreous on the opposite side of the globe. However, the cone of light from the probe may be directed externally through the cornea to augment or replace the internal coaxial light source. Xenon-powered chandelier lights or lighted infusion cannulas are an excellent option in such situations, and can be utilized to provide diffuse, wide-field light to allow the surgeon to perform simultaneous vitrectomy and scleral depression without the aid of an assistant. Hemorrhagic retrolenticular vitreous can be stripped from the posterior lens capsule, with gentle aspiration into the cutting port followed by withdrawal of the probe and simultaneous activation of the cutting mode. This technique may be dangerous when used in young children because the retrolenticular vitreous is adherent to the lens, which is sufficiently pliable to be aspirated into the port, with consequent cataract formation. When the lens is clear, the process of removing peripheral and retrolenticular vitreous is less important than preserving lens integrity in most cases.

In cases where the flexibility of the instrumentation prevents vitrectomy in a particular location, the unsutured and moveable nature of the 25-gauge infusion should be taken advantage of. The infusion line is transferable, and can be exchanged to a different trocar location (i.e., supero-nasal) with the vitrector placed in the initial location (typically infero-temporal). This usually allows for extensive vitrectomy to be completed.

It is important to expose the peripheral retina and vitreous base, as most retinal breaks caused by ocular contusion are located in this area [13]. The use of wide-angle contact and non-contact viewing systems such as the BIOM (Binocular Indirect OphthalmoMicroscope, Insight Instruments) can greatly facilitate visualization of the peripheral fundus [14]. All retinal breaks should be treated. Endolaser is used for posterior breaks, whereas peripheral breaks are treated with either a curved endolaser probe, indirect laser assisted by scleral depression, or trans-scleral cryoretinopexy. Cryotherapy is preferred when residual opaque vitreous partially obscures the targeted break. Short acting gas or air should be considered in cases with retinal tears, to provide short-term tamponade while the retinopexy is maturing.

Summary for the Clinician

- Traumatic vitreous hemorrhage may arise from tears in the iris, ciliary body, choroid, or retina.
- A three-port 20-gauge vitrectomy technique is the standard approach for nonclearing vitreous hemorrhage. In cases where the blood is not particularly dense, the 25-gauge, sutureless approach to the vitrectomy may be preferable.
- After establishing the plane between the hyaloid and retina, the surgeon attempts to remove the entire cortical vitreous except for the firmly attached portion at the anterior vitreous base.
- When the lens is clear, the process of removing peripheral and retrolenticular vitreous is less important than preserving lens integrity in most cases.
- With the 25-gauge system the infusion line is transferable, and can be exchanged to a different trocar location. This usually allows for extensive vitrectomy to be completed.

17.5 Post-Traumatic Endophthalmitis

17.5.1 Epidemiology

Infection is a devastating complication of penetrating ocular trauma, and occurs in 1% to 10% of eyes following open globe injury [15]. Risk factors associated with the development of post-traumatic endophthalmitis include a dirty wound, retained intraocular foreign body, lens capsule breach, and delay in primary repair. The visual prognosis of post-traumatic endophthalmitis is less favorable than that of other postoperative infections, because of traumatic ocular damage and the virulent profile of the organisms typically involved [16, 17]. The diagnosis is frequently masked, and therefore delayed, by the inflammation of the injury itself. The relatively benign course of cases with *Staphylococcus epidermidis* endophthalmitis after surgery occurs less commonly in traumatized eyes infected with the same organism [18].

The prognosis is very poor when gram-negative organisms and *Bacillus* species are involved, which occurs in 10–20% of cases respectively [19]. *Bacillus* species cause a rapid onset of panophthalmitis associated with severe pain, proptosis, fever, and leukocytosis (Fig. 17.1). A characteristic ring corneal ulcer develops in 18–24 h [20]. The virulence of this species results from the production of potent exotoxins — an enterotoxin and a hemolysin [21]. Once produced, these exotoxins may cause destruction of tissue, even after antibiotics sterilize the eye, and bacteriolysis may result in their further release. Collagenase may enhance the diffusion of toxins and bacteria throughout the eye [22].

Gram-negative organisms are extremely virulent, because they produce destructive proteases and endotoxin [22]. Endotoxin is released after bacterial cell death and lysis. Removal of bacteria by vitrectomy may decrease endotoxin-mediated tissue destruction and further dilute exotoxins.

17.5.2 Treatment

In most cases of endophthalmitis, the 25-gauge sutureless vitrectomy system can be utilized. The decreased amount of globe manipulation and ease of entry and exit in an eye that will not receive an extensive vitrectomy make the 25-gauge system ideal. The standard vitrectomy setup is

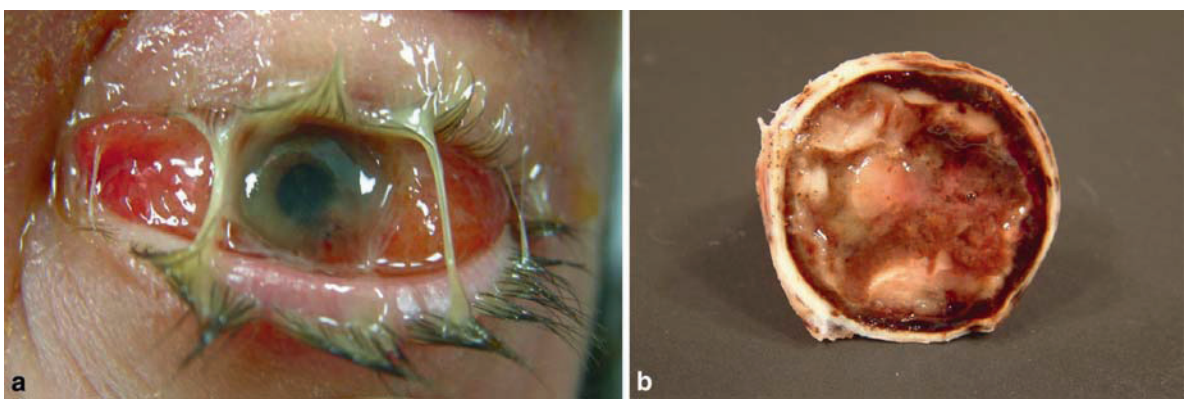


Fig. 17.1 Post-traumatic endophthalmitis caused by *Bacillus cereus*. (**a**) External photograph of *B. cereus* endophthalmitis that developed following perforating injury with retained intraocular foreign body. (**b**) Following enucleation, extensive suppurative inflammation is seen in the vitreous cavity

applied, but the infusion is not turned on. One tenth of a milliliter of aqueous is aspirated into a tuberculin syringe through a 27- or 30-gauge needle passed through the limbus, and is sent for staining, culture, and antibiotic sensitivity testing. Prior to turning on the posterior segment infusion, vitreous samples (0.3–6.5 ml) are obtained by manual aspiration while cutting with the vitrectomy probe safely placed in the anterior/middle of the vitreous cavity. If possible, vitreous sampling is deferred and infusion delayed until the suction-cutter and infusion cannula can be visualized. Aqueous and vitreous samples are immediately placed on slides for Gram and Giemsa stains, and plates of chocolate agar, blood agar, and Sabouraud's medium are inoculated. The possibility of anaerobic infection is investigated by inoculating thioglycolate broth.

A vitrectomy is performed on all eyes with obvious infectious vitritis. In some cases, infection of the vitreous is not apparent until opacities of the media, such as a cataractous lens and hemorrhage, are removed. A pars plana approach is delayed when the posterior segment of the eye cannot be visualized. In such cases, the vitrectomy probe and infusion system (as described in hyphema management above) are first introduced into the anterior chamber through corneal incisions. Opacities in the anterior segment are cleared to allow for visualization into the posterior segment. The extent of the vitrectomy is determined by the clarity of the cornea. A generous core vitrectomy is performed when visibility permits such an undertaking. No effort is made to separate the posterior vitreous cortex from the retina or remove the peripheral vitreous base, because infection-induced retinal necrosis increases the likelihood that retinal breaks would occur with only moderate vitreoretinal traction. In one series, all eyes that developed retinal breaks with endophthalmitis were lost. Presumably, iatrogenic breaks would lead to the same outcome. A more complete vitrectomy is safely performed in eyes with a preexisting posterior vitreous separation from the retina. When visibility is very limited, a small core of vitreous is removed from the central vitreous cavity, as long as detachment of the retina has been excluded by preoperative ultrasonography.

17.5.3 Intravitreal Antibiotics

Antibiotics are injected into the vitreous cavity after samples have been obtained for culture and the vitrectomy has been completed. Because of the recent emergence of gram-positive organisms resistant to penicillin and first-generation cephalosporins, particularly *Bacillus* species, we substitute vancomycin for the previously recommended combination of cefazolin and clindamycin. We also use ceftazidime in place of aminoglycosides to reduce the likelihood of retinal toxicity. Our current regimen of intravitreal antibiotics, therefore, consists of vancomycin 1 mg per 0.1 ml and ceftazidime 2.25 mg per 0.1 ml. On rare occasions, amikacin 250–400 µg per 0.1 ml, as recommended by the Endophthalmitis Vitrectomy Study Protocol for the treatment of postoperative endophthalmitis, is substituted for ceftazidime to achieve mechanistic synergy between a cell wall inhibitor and a protein synthesis inhibitor [22].

17.5.4 Postoperative Antibiotics

We use regular-strength broad-spectrum topical antibiotics (trimethoprim sulfate-polymyxin B, bacitracin-polymyxin B, ciprofloxacin, or gentamicin) four to six times daily when corneal infection is absent. Infectious corneal infiltrates are treated more aggressively with frequent "fortified" gentamicin and vancomycin. Topical steroids (prednisolone 1%) are used four times daily, or more frequently, depending on the amount of intraocular inflammation.

The fluoroquinolone antibiotic ciprofloxacin may be of prophylactic value because of its reported penetration of the eye with systemic administration [24–26]. Gatifloxacin has recently been shown to achieve high levels in the vitreous after oral administration [27]. We now typically utilize this oral fluoroquinolone in trauma patients, because of its ease of use, broad spectrum of antimicrobial activity, and significant ocular penetration. The orally administered fluoroquinolone gatifloxacin can achieve significant intravitreal concentrations, and may be of value as a supplement to intravitreal antibiotics in the treatment of post-traumatic endophthalmitis. Some surgeons continue to use intravenous vancomycin or cefazolin in combination with a third-generation cephalosporin effective for gram-negative organisms (ceftazidime) as well. The value of these systemic antibiotics is unclear, and may be questionable because of poor penetration through the blood–ocular barrier and the resultant low intravitreal concentration. Nevertheless, postoperative intravenous antibiotics will likely remain a component in the treatment of endophthalmitis secondary to trauma, as no clinical trial has approached this subject in a prospective fashion.

Summary for the Clinician

- Infection is a devastating complication of penetrating ocular trauma, and occurs in 1–10% of eyes following open globe injury.
- The diagnosis is frequently masked, and therefore delayed, by the inflammation of the injury itself.
- The decreased amount of globe manipulation and ease of entry and exit in an eye that will not receive an extensive vitrectomy make the 25-gauge system ideal.
- Prior to turning on the posterior segment infusion, vitreous samples (0.3–6.5 ml) are obtained by manual aspiration while cutting with the vitrectomy probe safely placed in the anterior/middle of the vitreous cavity.
- Antibiotics are injected into the vitreous cavity after samples have been obtained for culture and the vitrectomy has been completed. A preferred regimen of intravitreal antibiotics may consist of vancomycin 1 mg per 0.1 ml and ceftazidime 2.25 mg per 0.1 ml.
- After surgery, regular-strength broad-spectrum topical antibiotics are used (trimethoprim sulfate-polymyxin B, bacitracin-polymyxin B, ciprofloxacin, or gentamicin) four to six times daily when corneal infection is absent. Topical steroids are used frequently.
- The value of systemic antibiotics is unclear, and may be questionable because of poor penetration through the blood–ocular barrier and the resultant low intravitreal concentration.

17.6 Traumatic Macular Hole

First described by Herman Knapp in 1869, traumatic macular hole is a well-recognized complication of blunt ocular trauma [28]. It is thought to result from tangential traction to the posterior pole occurring with globe deformation from the blunt trauma [29]. Outward expansion of the equator is followed by flattening and subsequent posterior displacement of the posterior pole. The trampoline-like movement of the posterior pole creates tangential tractional forces on the retinal surface that lead to the formation of the macular hole. Spontaneous closure of the hole is not uncommon; therefore, a period of observation for several weeks following injury is appropriate prior to surgical repair [30]. Optical coherence tomography (OCT) is a useful diagnostic tool to follow the progress of traumatic macular holes and diagnose vitreomacular traction [31]. The presence of vitreomacular traction and/or the failure of the macular hole to close after a sufficient period of observation are indications for surgical repair.

The 25-gauge transconjunctival vitrectomy is ideal for the repair of a traumatic macular hole. A core vitrectomy, followed by removal of the posterior hyaloid is performed. The vitrectomy may then be carried anteriorly as per standard macular hole surgery technique. While the importance of routinely removing the internal limiting membrane (ILM) during the repair of idiopathic macular holes is controversial, it may be prudent to remove the ILM during the repair of traumatic macular holes [32]. We typically utilize 0.1–0.2 cc of 0.125% indocyanine green (ICG) dye to stain the ILM. We instill the dye tangentially across the macula with the infusion off, and allow it to sit on the surface of the retina for several seconds before removing the dye with aspiration. The ICG may highlight residual vitreous unintentionally left behind, but will generally stain the ILM. The ILM is then pinched down upon using an end-grasping forceps, and removed from the entire macula in a rhexis maneuver. Medium- to long-term gas tamponade, combined with facedown positioning, is performed in each case. In pediatric patients, 0.4 IU of intravitreally injected plasmin enzyme may facilitate the induction of a posterior vitreous detachment during surgery [33].

The prognosis for eyes with traumatic macular holes is excellent following surgical repair. In one series, 96% of macular holes were successfully closed following vitrectomy, and 64% of patients achieved a vision of 20/50 or better [29]. In a series of four pediatric traumatic macular holes repaired with the adjunctive use of intravitreally injected plasmin to aid in the creation of a complete posterior hyaloidal separation, macular hole closure was achieved in 100% of cases and visual acuity of 20/40 or better was seen in 75% of eyes [33].

Summary for the Clinician

- Spontaneous closure of traumatic macular hole is not uncommon; therefore, a period of observation for several weeks following injury is appropriate prior to surgical repair.
- The presence of vitreomacular traction and/or the failure of the macular hole to close after a sufficient period of observation are indications for surgical repair.
- The 25-gauge transconjunctival vitrectomy is ideal for the repair of a traumatic macular hole, and it could replace the standard 20-gauge technique.

17.7 Conclusions

Vitreoretinal surgical instrumentation and techniques continue to improve. Their evolution and refinement will allow retinal surgeons to increasingly obtain successful anatomic and visual outcomes in many injured eyes. The use of the 25-gauge transconjunctival vitrectomy approach is a viable tool in the treatment of injured eyes. The role of this approach in trauma will also continue to be refined and expanded as experience increases.

References

1. McGwin G Jr, Xie A, Owsley C (2005) Rate of eye injury in the United States. Arch Ophthalmol 123:970–976
2. Tielsch JM, Parver LM (1990) Determinants of hospital charges and length of stay for ocular trauma. Ophthalmology 97:231–237
3. Negrel AD, Thylefors B (1998) The global impact of eye injuries. Ophthalmic Epidemiol 5:143–169
4. Broadrick JD (1972) Corneal blooding staining after hyphema. Br J Ophthalmol 56:589–592
5. Campbell DG (1981) Ghost cell glaucoma following trauma. Ophthalmology 38:1151–1158
6. Fenton RH, Zimmerman LE (1963) Hemolytic glaucoma: an unusual cause of acute open-angle secondary glaucoma. Arch Ophthalmol 70:236–239
7. Radius RL, Finkelstein D (1976) Central retinal artery occlusion (reversible) in sickle trait with glaucoma. Br J Ophthalmol 60:428–430
8. Read J, Goldberg MF (1974) Comparison of medical treatment for traumatic hyphema. Trans Am Acad Ophthalmol Otolaryngol 78:799–806
9. Deutsch TA, Weinreb RN, Goldberg MF (1984) Indications for surgical management of hyphema in patients with sickle cell trait. Arch Ophthalmol 102:566–569
10. Read J (1975) Traumatic hyphema: surgical versus medical management. Ann Ophthalmol 7:659–670
11. Belcher CD, Brown SVL, Simmons RJ (1979) Anterior chamber washout for traumatic hyphema. Ophthalmology 16:475–479
12. Weiss JS, Parrish RK, Anderson DR (1983) Surgical therapy of traumatic hyphema. Ophthalmic Surg 14:343–345
13. Cox MS, Schepens CL, Freeman HM (1966) Retinal detachment due to ocular contusion. Arch Ophthalmol 76:678–685
14. Spitznas M (1987) A binocular indirect ophthalmomicroscope (BIOM) for non-contact wide-angle vitreous surgery. Graefes Arch Clin Exp Ophthalmol 225:13–15
15. Forster RK (1981) Endophthalmitis. In: Duane TD (ed) Clinical Ophthalmology, vol 4. Harper and Row, Philadelphia, p 1
16. Peyman GA, Carroll CP, Raichand M (1980) Prevention and management of traumatic endophthalmitis. Ophthalmology 87:320–324
17. Schemmer GB, Driebe WT (1987) Post traumatic Bacillus cereus endophthalmitis. Arch Ophthalmol 105:342–344
18. O'Day DM, Jones DB, Patrinely J et al (1982) Staphylococcus epidermidis endophthalmitis. Visual outcome following noninvasive therapy. Ophthalmology 89:354–360
19. Puliafito CA, Baker AS, Haaf J et al (1982) Infectious endophthalmitis. Review of 36 cases. Ophthalmology 89:921–929
20. O'Day DM, Ho PA, Andrews JS et al (1980) Mechanism of tissue destruction in ocular Bacillus cereus infections. The cornea in health and disease. In: Proceedings of the 6th International Congress of the European Society of Ophthalmology. Academic Press and the Royal Society of Medicine, London
21. Turnbull PC, Kramer JM (1983) Nongastrointestinal Bacillus cereus infections, an analysis of exotoxin production by strains isolated over a two-year period. J Clin Pathol 36:1091–1096
22. Jacobs DR, Cohen HB (1984) The inflammatory role of endotoxin rabbit gram-negative bacterial endophthalmitis. Invest Ophthalmol Vis Sci 25:1074–1079
23. Keren G, Alhalel A, Bartov E et al (1991) The intravitreal penetration of orally administered ciprofloxacin in humans. Invest Ophthalmol Vis Sci 32:2388–2392
24. Mounier M, Adenis JP, Denis F (1988) Intraocular penetration of ciprofloxacin after infusion and oral administration. Pathol Biol (Paris) 36(5 Pt 2):724–727
25. Skoutelis AT, Gartaganis SP, Chrysanthopoulos CJ et al (1988) Aqueous humor penetration of ciprofloxacin in the human eye. Arch Ophthalmol 106:404–405
26. Hariprasad, SM, Mieler W (2003) Vitreous and aqueous penetration of orally administered gatifloxacin in humans. Arch Ophthalmol 121:345–350
27. Knapp H (1869) Uber isolierte Zerreissungen der Aderhaut in Folge von Traumen auf dem Augapfel. Arch Augenheilkd 1:6–29
28. Johnson RN, McDonald HR, Lewis H et al (2001) Traumatic macular hole: observations, pathogenesis, and results of vitrectomy surgery. Ophthalmology 108:853–857
29. Yamashita T, Uemara A, Uchino E et al (2002) Spontaneous closure of traumatic macular hole. Am J Ophthalmol 133:230–235
30. Hee MR, Puliafito CA, Wong C et al (1995) Optical coherence tomography of macular holes. Ophthalmology 102:748–756
31. Hassan TS, Williams GA (2002) Counterpoint: to peel or not to peel: is that the question. Ophthalmology 109:11–12
32. Margherio AR, Margherio RR, Hartzer M et al (1998) Plasmin enzyme-assisted vitrectomy in traumatic pediatric macular holes. Ophthalmology 105:1617–1620

Chapter 18

Small-Gauge Approach in Pediatric Vitreoretinal Surgery

A. Capone Jr.

Core Message

- The small-incision approach to vitrectomy is not synonymous with pedriatic vitreoretinal surgery.
- Selection of appropriate pediatric eyes for a small-incision approach requires careful consideration.
- It is of primary importance to consider the importance of near-total vitreous removal, the ability to access the peripheral vitreous and vitreoretinal proliferation, and the importance of airtight/watertight wound closure.
- There are select pediatric vitreoretinal pathologies for which a small-incision vitrectomy approach is a viable consideration

18.1 Introduction

The last several years have witnessed significant advances in small-incision — or so-called "minimally invasive" — vitreous surgery.

A common misconception is that the small-incision approach to vitrectomy surgery is synonymous with pediatric vitreoretinal surgery. The logic goes something like this: the eyes are small, the instruments are small, and therefore the two should go together. Not necessarily so — although the minimally invasive vitrectomy approach to pediatric retinal disease has its proponents [1–4].

Within our high volume pediatric vitreoretinal surgical practice, we most often use a 20-gauge approach in pediatric vitreoretinal surgery, occasionally employing a 25-gauge approach and rarely using a 23-gauge approach. In what follows, I will elaborate as to the important considerations in small-gauge pediatric vitreoretinal surgery, and elaborate on the rationale for this approach. The practical determinants of selection of 20-gauge versus 23-gauge versus 25-gauge vitrectomy approach relate to: (1) the anatomy of pediatric vitreoretinal diseases requiring surgery, (2) the efficiency and extent of vitreous removal, (3) the facility of access to the retinal periphery, and (4) the need for watertight wound closure.

18.2 Anatomy

The first anatomic consideration relates to the trocar and sleeves used as part of the small-incision surgical approach. The main problem really is the length of the sleeve relative to the size of the eye. While this isn't an issue for post-equatorial pathology, the primary pediatric retinal disease requiring surgical attention is retinopathy of prematurity. This condition is characterized by anterior displacement of the retina. Proliferation extending from the preretinal ridge, typically arising in zone I or post-equatorial zone II, extends towards the ciliary body (Fig. 18.1).

When this transvitreal proliferation contracts, the retina is drawn anteriorly towards the ciliary body. When there is low-lying detachment of the retina, the use of trocars carries minimal risk (Fig. 18.2). However, with significant anterior retinal displacement and more advanced stage 4A detachments, and in virtually all stage 4B and 5 detachments, the use of trocars is not only impractical, but carries with it significant risk of creating an iatrogenic retinal break (Fig. 18.3).

Similarly, significant anterior retinal displacement may occur in congenital X-linked retinoschisis with large bullous peripheral schisis cavities (Fig. 18.4). Familial exudative vitreoretinopathy is a third surgical pediatric vitreoretinal condition, wherein the retina is commonly displaced towards the ciliary body. The anterior displacement of the retina can occur either as a consequence of traction from preretinal proliferation extending anteriorly towards the ciliary body and then contracting, drawing the retina anteriorly (Fig. 18.5), or alternatively as a consequence of extensive subretinal exudation, with high exudative retinal detachment occurring as a consequence (Fig. 18.6).

Lastly, eyes with persistent fetal vasculature are uniquely unsuited to 23- and 25-gauge surgery with use of trocars, for several reasons. The pars plana is commonly considerately foreshortened in eyes with PFVS, on occasion

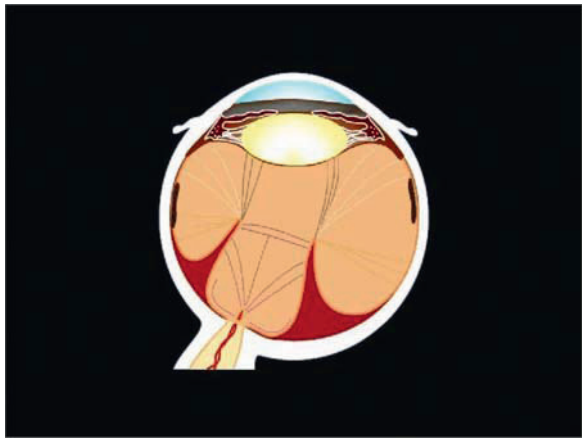


Fig. 18.1 Schematic of standard tractional vectors in stage 4A retinopathy of prematurity (ROP)-related traction retinal detachment

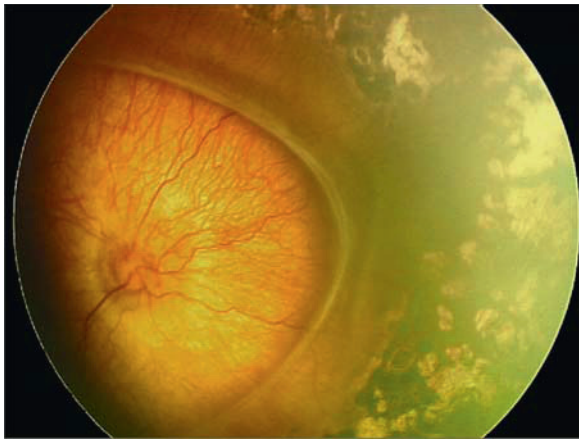


Fig. 18.2 Low-lying stage 4A ROP in zone 1

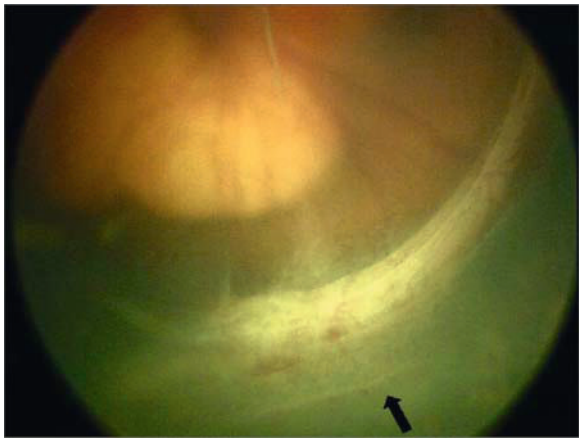


Fig. 18.3 Highly elevated stage 4 ROP-related traction retinal detachment

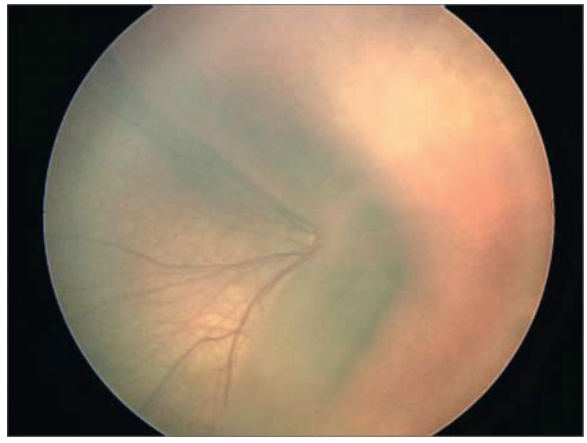


Fig. 18.4 Bullous congenital X-linked retinoschisis

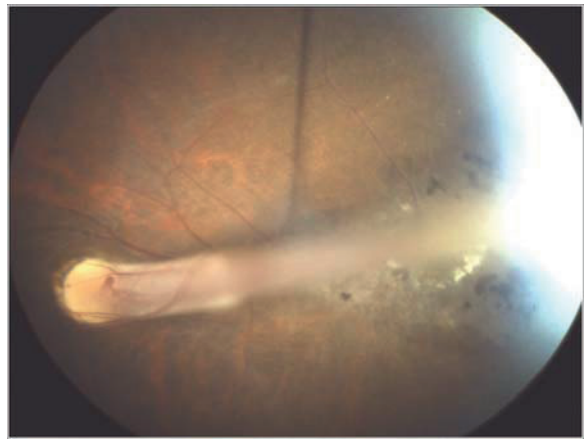


Fig.18.5 Predominantly tractional retinal detachment in familial exudative vitreoretinopathy (FEVR)

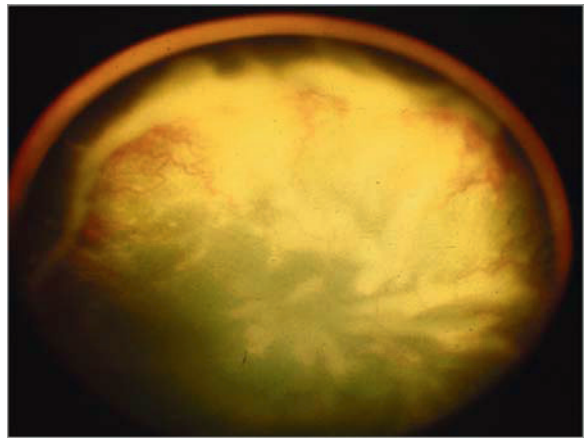


Fig.18.6 Predominantly exudative retinal detachment in FEVR

to the point where the ora serrata sits immediately behind the ciliary processes (corona ciliaris). Also, in eyes with PFVS the ocular abnormalities are not limited to cataract with a possible stalk. On occasion, there are multiple stalks extending from the posterior pole towards the anterior segment, and not all of the stalks extend to the optic nerve head. In such eyes, use of trocars again carries with it the risk of iatrogenic retinal break. When one considers that eyes with PFVS are often small as compared to the eyes of an age-matched child, the risk of iatrogenic damage to the retina is even greater.

18.3 Vitreous Removal

The surgical goal in pediatric retinal diseases is maximal removal of the vitreous. The rationale for this approach is that the vitreous serves as a proliferative scaffold for many pediatric proliferative vitreoretinopathies. This is especially true for retinopathy of prematurity.

As flow is proportional to the fourth power of the internal radius of the vitrector, this goal is still best achieved with a 20-gauge instrument. Current 23-gauge systems have fluidic properties which bestow them with similar rates of vitreous removal to the current 20-gauge systems. The need for near-total vitreous removal confers a relative disadvantage on the use of a 25-gauge system. The disadvantage is only relative, as total vitreous removal can also be achieved with a 25-gauge system, albeit requiring more time.

18.4 Peripheral Access

As noted in the sections above, the pre-equatorial retina and anterior vitreous are important locations relative to the repair of retinopathy of prematurity — ROP-related and FEVR-related tractional retinal detachments. This is again a disadvantage with electing to proceed with a 25-gauge approach. The current instrument flexion limitations for available 25-gauge instrumentation limit access to the far periphery in adults, as well as children. In consequence, peripheral pathology can neither be as well-visualized, nor as well-addressed, as with 23- or 20-gauge vitrectors.

18.5 Wound Closure

The wound size of 20-gauge vs 23-gauge vs 25-gauge vitrectomy systems is 0.9 mm vs approximately 0.7 mm vs approximately 0.5 mm respectively. As a consequence, tight wound closure when using these instruments as designed is greatest for a sutured 20-gauge incision, and considerably less tight with an unsutured 25-gauge or unsutured 23-gauge wound. Undeniably, tight wound closure is most effectively achieved with a sutured wound, which gives airtight and watertight closure and allows for pressurization of the globe. This last feature is important to minimize the likelihood of postoperative bleeding — particularly in children with vasoproliferative vitreoretinopathies such as ROP and FEVR. This consideration effectively eliminates the extensive use of 23-gauge instrumentation for pediatric vitrectomy, unless one is willing to suture these wounds.

Summary for the Clinician

- The main problem is the length of the sleeve relative to the size of the eye.
- When there is low-lying detachment of the retina, the use of trocars carries minimal risk.
- Significant anterior retinal displacement the use of trocars is not only impractical, but carries with it significant risk of creating an iatrogenic retinal break
- The surgical goal in pediatric retinal diseases is maximal removal of the vitreous.
- Current 23-gauge systems have fluidic properties which bestow them with similar rates of vitreous removal to the current 20-gauge systems
- The pre-equatorial retina and anterior vitreous are important locations relative to the repair of retinopathy of prematurity. This is a disadvantage with electing to proceed with a 25-gauge approach
- Tight wound closure is most effectively achieved with a sutured wound which gives airtight and watertight closure and allows for pressurization of the globe. This consideration effectively eliminates the extensive use of 23-gauge instrumentation for pediatric vitrectomy unless one is willing to suture these wounds.

18.6 Ideal "Minimally Invasive" Pediatric Vitrectomy Cases

From the considerations detailed above, it follows that the ideal posterior pole pathologies for a 23- or 25-gauge approach are those with primary posterior pole disease: zone 1 retinopathy of prematurity with low-lying detachment, posterior hyaloidal contraction with low-lying traction retinal detachment (Figs. 18.7 and 18.8), pediatric macular pucker (combined hamartoma, i.e., superficial inner retinal combined hamartoma), preretinal blood sequestered beneath the internal limiting membrane, traumatic pediatric macular hole, and eyes with

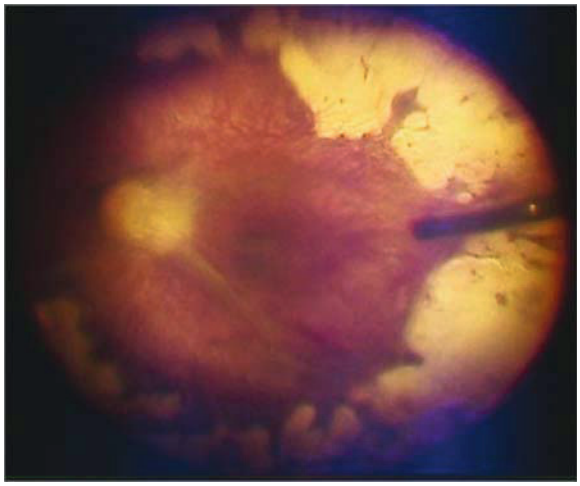


Fig.18.7 Intra-operative image of an eye with Zone 1 ROP and posterior hyaloidal contraction involving the macula

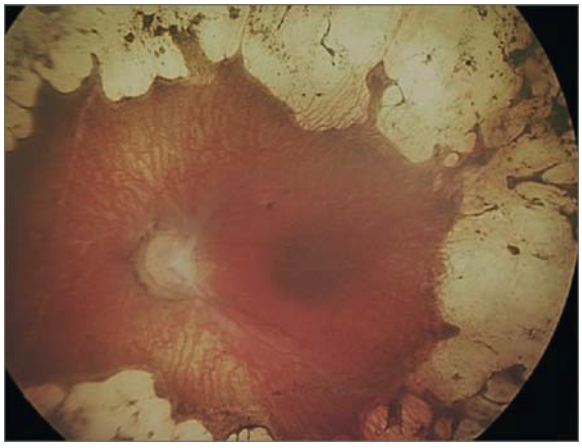


Fig.18.8 Post-operative image following relief of posterior hyaloidal contraction involving the macula in Zone 1 ROP

persistent fetal vasculature requiring transection of the stalk wherein the pars plana is well formed and the view to the posterior pole is quite clear.

18.7 Combined Approaches

A number of modifications may be incorporated to gain the advantages of a minimally invasive approach without compromising safety in children and infants. To improve the safety of 23- and 25-gauge vitrectomy in younger children, one may suture the sclerotomies and conjunctiva as described above. In addition, one may elect to use a 23-gauge vitrector with a 20-gauge illuminated irrigating light pick — as no analogous pick currently exists for 23-gauge vitreous surgery. This offers the surgeon the design advantages of current 23-gauge probes with the advantage of a two-port approach.

Summary for the Clinician

- The ideal posterior pole pathologies for a 23- or 25-gauge approach are those with primary posterior pole disease: zone 1 retinopathy of prematurity, posterior hyaloidal contraction, pediatric macular pucker, preretinal blood, traumatic pediatric macular hole, eyes with persistent fetal vasculature.
- To improve the safety of 23- and 25-gauge vitrectomy in younger children, one may suture the sclerotomies and conjunctiva.
- The use of a 23-gauge vitrector with a 20-gauge illuminated irrigating light pick offers the surgeon the design advantages of current 23-gauge probes with the advantage of a two-port approach.

18.8 Conclusions

To many it seems intuitively obvious that a small-incision (25-gauge or 23-gauge) vitrectomy approach would be appropriate — if not *most* appropriate — for pediatric vitreoretinal surgical conditions. In fact, selection of appropriate pediatric eyes for a small-incision approach requires careful consideration. The primary practical determinates relate to the vitreoretinal anatomy, the importance of near-total vitreous removal, the ability to access the peripheral vitreous and vitreoretinal proliferation, and the importance of airtight/watertight wound closure. With these considerations in mind, there are select pediatric vitreoretinal pathologies for which a small-incision vitrectomy approach is a viable consideration.

References

1. Fujii GY, de Juan E, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
2. Lam DS, Fan DS, Mohamed S et al (2005) 25-gauge transconjunctival sutureless vitrectomy system in the surgical management of children with posterior capsular opacification. Clin Exp Ophthalmol 33(5):495–498
3. Gonzales CR, Boshra J, Schwartz SD (2006) 25-gauge pars plicata vitrectomy for stage 4 and 5 retinopathy of prematurity. Retina 26(Suppl. 7):S42–S46
4. Cacciatori M, Arpa P (2006) Surgical technique for anterior segment surgery in pediatric patients using 25-gauge instruments. J Cataract Refract Surg 32:562–564

Chapter 19

Combined Phaco/25-Gauge Vitrectomy

F. Genovesi-Ebert, S. Rizzo, M. Palla

Core Message

- Cataract formation and progression are common after vitreoretinal surgery.
- Combo surgery facilitates vitrectomy and increases patient satisfaction, while delayed phacoemulsification may be difficult and risky.
- Place the trocar before starting the phaco.
- Currently MICS is the choice.
- Implant the IOL before the vitreoretinal procedures. Delay the implant after the end of PPV only if the posterior capsula has torn.
- At the end of the surgery, inject acetylcholine in the anterior chamber, remove the superotemporal and nasal plugs, lower the air infusion to 10-mm value and perform an air/gas exchange using a 30-gauge needle; then remove the infusion line.
- Considering the advantages of combo surgery, we suggest that combined phaco/25-gauge PPV should be routinely performed in presbiopic patients, even in absence of significant cataract.

19.1 Introduction

Cataract formation and progression of nuclear sclerotic lens changes are the most common complications after vitreoretinal surgery in phakic patients. The incidence of cataract reported after vitrectomy for ERMs varies from 12.5% to 80% [1–7]. Several mechanisms for the acceleration of nuclear sclerosis following vitrectomy have been postulated, including altered lens permeability after vitreous gel removal [1], light toxicity from the operating microscope, oxidative stress [8], inappropriate glucose concentration in the irrigating solution [9] and incorrect surgical technique.

Nuclear sclerotic progression is also the most common complication of vitrectomy for macular holes in phakic eyes [10–12]. In Thompson's series, 75% of eyes required cataract extraction within 2 years of macular hole surgery [13]. In Leonard's series, 75% of eyes followed for 1 year and 95% of eyes followed for 2 years developed progressive nuclear sclerotic cataract [14]. Accelerated cataract formation may be the result of an accidental mechanical injury to the lens or untoward physiological effects of intraocular irrigating solutions, or, mainly, the consequence of a prolonged exposure to gas during and/or following the procedure [15].

Therefore, on the one hand, progressive nuclear sclerosis of the lens is a very common complication after vitreoretinal surgery, and on the other hand, pre-existing opacities make retinal pathology repair difficult to achieve. Combining phacoemulsification and pars plana vitrectomy in patients with significant cataract and coexisting posterior segment involvement is thus becoming increasingly common, and has been reported as a first-line surgical management.

19.1.2 Rationale of Combo Surgery

Combined phaco and vitrectomy improves the operative view in patients with significant lens opacity, reduces the need for a second procedure and enhances postoperative visual rehabilitation at a reduced cost [16], increasing patient satisfaction.

In addition to a faster recovery, lens removal allows more complete vitrectomy and removal of the anterior vitreous without risking lens injury [17] when more extensive vitrectomy is required, such as in MH repair. Cataract removal also facilitates the scleral depression, which allows for better detection and treatment of small tears in the anterior retina, seeing as the incidence of retinal tears is relatively high in these eyes. Finally, the more complete vitrectomy allows for a better gas fill, providing longer tamponade and increasing the MH closure rate [17, 18].

In contrast, phacoemulsification in post-vitrectomized eyes presents a higher risk of complication because of the instability of Zinn's zonules, possible damage to the posterior capsule during the previous vitrectomy, and increased frequency of posterior capsular rupture without vitreous gel support, with possible dropped nucleous or lost nuclear fragments.

Delayed phacoemulsification may also be difficult due to a small pupil size, posterior synechiae or to abnormal fluctuations in anterior chamber depth, caused by zonular laxity and reduction of vitreous volume, including deepening and mydriasis followed by paradoxical shallowing and miosis, and swinging of the lens–iris diaphragm [19].

Choroidal complications such as suprachoroidal hemorrage may occur [20], especially in vitrectomized highly myopic eyes.

Moreover, in the postoperative period cystic macular edema may occur due to iris surgical trauma, and there is a risk of MH reopening [12].

Summary for the Clinician

- Cataract formation and progression are common after vitreoretinal surgery. Combo surgery facilitates vitrectomy and increases patient satisfaction. In contrast, delayed phacoemulsification may be difficult and risky.

19.2 Surgical Technique

19.2.1 Patient Preparation

Two days preoperatively, topical antibiotic (fluoroquinolone) eyedrop medication is started. One hour before surgery, cyclopentolate 1% and phelynephrine 10% are administered every 20 min. Five percent povidone iodine is instilled on the conjunctiva 10 minutes before beginning and at the end of the surgery.

Anesthesia. Surgery is performed using local anesthesia with a standard peribulbar block comprising a mixture of lidocaine hydrochloride 2% and bupivacaine hydrochloride 0.75% with hyaluronidase. Currently, however, we choose sub-tenon (see chapter) in macular surgery and in less time-consuming vitrectomy. General anesthesia is administered only to mentally retarded patients.

Surgical procedures. TSV-25 microcannulas system set-up, phacoemulsification (standard phaco, bimanual microincision phaco, coaxial microphaco), IOL implantation and vitreoretinal procedures, trocars removal.

19.2.2 1st Step: Trocar Positioning

Timing. Place the trocars before the incision for the phacoemulsification is created.

Based on our initial experience using the first-generation trocars, because of the needle-like design of the trocar and the stepped-up diameter at the transitional area from the trocar to the cannula, relatively high force is required for the insertion. Therefore, three microcannulas should be set up before making the corneal incision and following cataract procedures, because this step could raise the IOP to a high level, leading to possible dehiscence of the prior corneal wound and the collapse of the anterior chamber. The current second-generation trocars are sharper and easier to introduce, but we wish to point out that to puncture an eye immediately after phaco with relatively low IOP may in any case be difficult, and in addition, a previously positioned infusion line can permit a safer anterior vitrectomy if a rupture of the posterior capsula occurs.

Insertion technique. Three transconjunctival oblique incisions are performed using trocar microcannulas in the inferotemporal, superotemporal and superonasal quadrants, 3.5 mm from the limbus, with the entry site alignment microcannulas left in place (see chapter 3). As Charles recommends, place nasal sclerotomy at lowest point between bridge from nose and brow, temporal at lowest point of superior orbital rim, rotate head approximately 15° away from operated eye [21]. The orifice of the inferotemporal microcannula is connected to an infusion line, whereas the other two microcannulas are closed with plugs. Careful selection for the location of microcannulas is also mandatory, because the elevation of plugs and infusion line from the ocular surface may cause some difficulty in cataract procedure. The infusion line is kept shut in order to prevent posterior vitreous pressure during phacoemulsification and IOL implantation.

19.2.3 2nd Step: Phacoemulsification

Standard Phaco. Standard coaxial phacoemulsification involves fashioning a 2.75 mm corneal tunnel incision, injecting viscoelastic, creating a continuous curvilinear capsulorrhexis (CCC) with forceps, hydrodissecting the nucleus from the cortex, removing the nucleus using a chop or a divide-and-conquer technique, irrigating and aspirating residual cortex and finally, implanting a foldable acrylic posterior chamber IOL. The tunnel is sutured with nylon 10.0 in order to avoid anterior chamber collapse during the globe manipulation, especially in scleral indentation manoeuvres, because in the case of combo surgery we perform the incision in the superior sector,

even if it is more prone to leakage of the temporal. This is because, in our experience, suturing the tunnel is less time-consuming than moving the eye-piece of the microscope.

In standard phaco, we use the same dispersive viscoelastic during the first procedures: Viscoat (condroitinesolfatum 3% and sodium hyaluronate 4%), a low molecular weight and lower viscosity substance. Surgically, its most useful property is its resistance to aspiration, resulting in a good coating ability to protect the corneal endothelium. Indeed the three following factors — the dispersive nature of Viscoat, negative electrical charge and presence of hyaluronic acid binding to specific endothelial binding sites — improve the retention of Viscoat in the anterior chamber, allowing it to remain adjacent to the corneal endothelium during both phacoemulsification and irrigation/aspiration (I&A) phases [23]. Viscoat also has a good ability to part space, portioning the anterior chamber into two separate spaces, a viscoelastic-occupied space and a surgical zone, in which phaco or I&A can be continued without the two areas mixing. The main drawback of dispersive viscoelastics is that their relatively low viscosity and elasticity doesn't stabilize space as well as cohesive viscoelastic, especially during CCC performance. In our opinion, however, this makes no difference for an experienced surgeon.

On the contrary, the IOL insertion is performed after a highly viscous-cohesive high molecular weight viscoelastic like Healon GV (sodium hyaluronate 1.4%) is injected. The cohesive viscoelastic stabilizes the capsular bag, avoiding the risk that the haptic of the IOL catches on a fold in the posterior capsule (resulting in a torn capsule), and thanks to its cohesivity, is easily removed. Dispersive Viscoat is not suggested in this phase, as it doesn't provide good visualization and is more difficult to remove [24].

Up-dated Technique: Bimanual Micro Incision Cataract Surgery (MICS). Sutureless bimanual MICS involves performing two 1.5 mm corneal tunnel incisions at 10–2 o'clock (Fig. 19.1). In this technique, the surgeon certainly gains advantage from using two different viscosurgical devices according to the steps. After a highly viscous-cohesive high molecular weight viscoelastics like Healon GV is injected, a CCC is carried out with a needle. The highly viscous-cohesive viscoelastics ensures the maintenance of a deep anterior chamber after the creation of the tunnels because they are the best for creating space with their viscosity and preserving it through their elasticity. CCC is enhanced, because Healon GV pressurizes the anterior chamber so it is equal to the posterior pressure. The effect of flattening the anterior convexity of the lens is to reduce the vector force, compelling the flap to slip toward the equator. Therefore, considering the enhanced difficulty of operating through an ultra-small incision, a pressure-equalized environment facilitates the creation of a round CCC of the appropriate size. Subsequently, the nucleus is hydrodissected from the cortex. Then dispersive Viscoat is injected, and the nucleus is removed using on the one hand, irrigation (open-ended irrigating chopper or spatula) and on the other hand, a sleeveless phaco-microtip with a chop or divide-and-conquer technique (Fig. 19.2). Bimanual surgery with I&A through two different sources allows better fluidis, more freedom in surgical manoeuvre, less vacuum setting, and the separate irrigation line also can be used as a surgical tool. Residual cortex is irrigated and aspirated with the microcannulas, and a small-incision foldable acrylic posterior chamber IOL is implanted under Healon GV. The cohesive viscoelastic is easily removed through two small microcannulas, and a small incision foldable acrylic posterior chamber IOL is implanted under Healon GV.

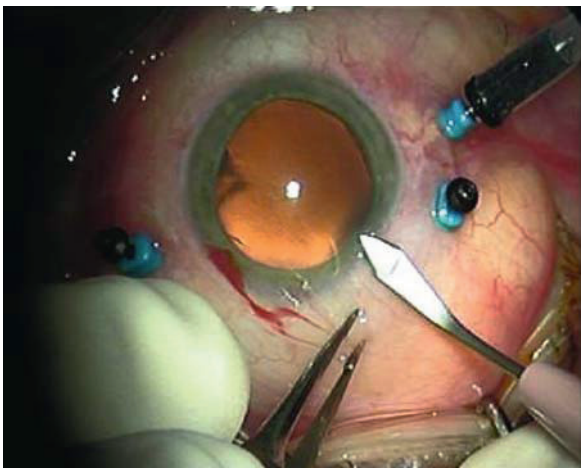


Fig. 19.1 Tunnel

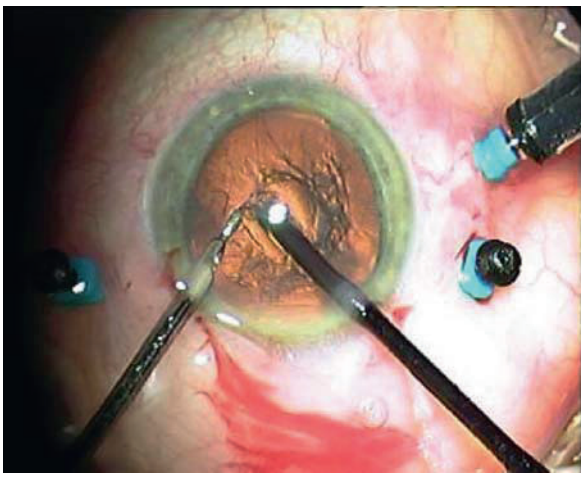


Fig. 19.2 Bimanual phaco

The cohesive viscoelastic is easily removed through two small microcannulas.

Updated Technique: Sutureless Coaxial Microincision Phaco. Recently, new microsleeves and nanosleeves have become available, allowing for a coaxial phacoemulsification through an ultra-small incision (1.8–2 mm). After cohesive Healon GV is injected, a CCC is carried out with a needle or microforceps. The nucleus is hydrodissected from the cortex. Then dispersive Viscoat is injected and the nucleus is removed using a nanosleeve phaco-microtip with a chop (Fig. 19.3) or divide-and-conquer technique.Residual cortex is irrigated and aspirated with the microaspirator, and a standard foldable acrylic posterior chamber IOL is implanted under Healon GV. Then viscoelastic is aspired both over and under the IOL (Fig. 19.4).

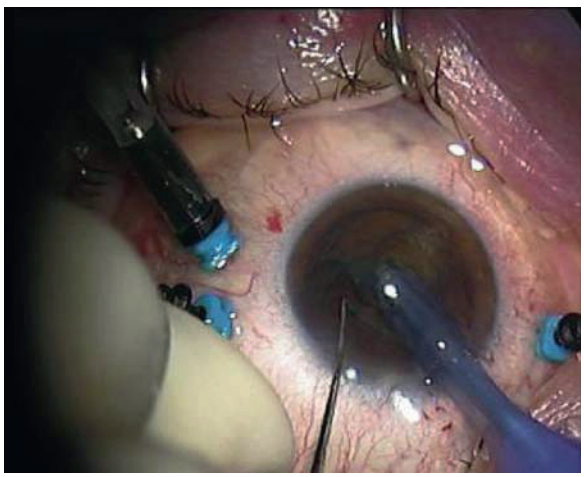


Fig. 19.3 MICS, chop technique

We decide to perform cataract surgery using one of the three techniques described above, depending on the eye condition, the crystalline lens we have to remove, and the type of IOL we have to insert. Obviously, as our goal is to perform a minimally invasive surgery, when possible we prefer the sutureless incisions. However, whatever technique we have chosen, once the IOL implantation has been completed, we always aspire the viscoelastic before the vitreoretinal surgery begins.

19.2.4 3rd Step: 25-Gauge Vitrectomy

The plugs are removed and the infusion line is turned on only when the tools enter the vitreous chamber so as to avoid vitreous wicks formation; then, using a plano disposable lens (Fig. 19.5), vitrectomy is started using a 1,500 cpm high-speed vitrectomy cutter. Vacuum setting is 500 mmHg, with infusion pressure nearly 60 mmHg when aspiration is applied. Infusion pressure is lowered to 20 mmHg when using microscissors or microforceps. The surgeon's third digit can be extended on tool shaft to offset tool-bending forces and resultant paradoxical movements. During surgery, rotate patient's head towards key pathology to facilitate peripheral access.

At the end of the surgery the infusion line is closed, and then the plugs are slowly and carefully removed. If more extensive vitrectomy is required to allow for a safer long-acting gas endotamponade, the removal is carried out under a wide-angle viewing system; the vitreous base shaving is performed using a scleral depressor under direct visualization. At the end of the surgery we inject acetylcholine

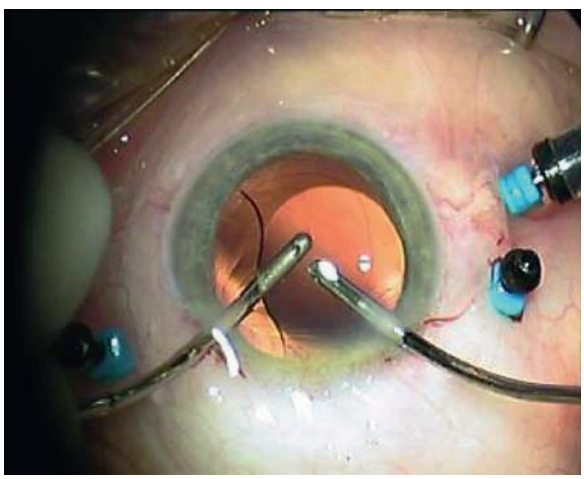


Fig. 19.4 Aspiring viscoelastic under the IOL

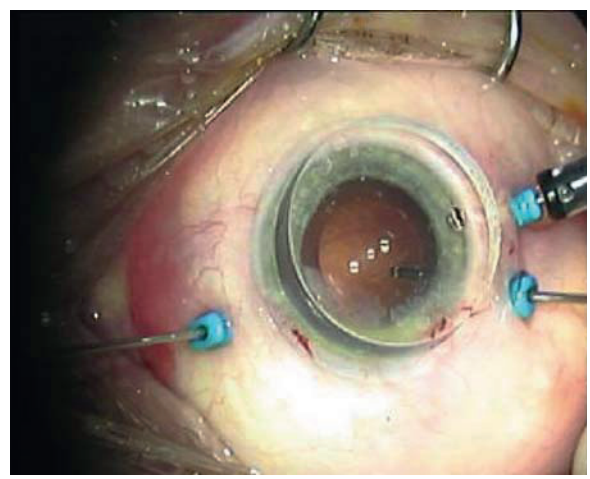


Fig. 19.5 Disposable flat vitreoretinal lens

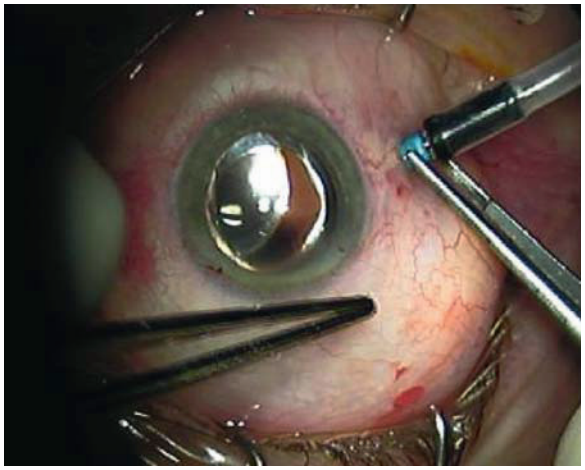


Fig. 19.6 Infusion line removal

in the anterior chamber, remove the superotemporal and nasal plugs, lower the air infusion to 10-mm value and perform an air/gas exchange using a 30-gauge needle. Lastly, we remove the infusion line (Fig. 19.6).

Postoperative Period. Topical antibiotic, steroid and weak mydratic agents are instilled. Patients are asked to keep prone positioning for 24 hours if BSS/air exchange is performed, or for 7 days if gas endotamponade is carried out to treat MH.

Summary for the Clinician

- Place the trocars before phacoemulsification, place the lens before vitrectomy. Currently we prefer the updated coaxial microincision phaco.

19.3 Dark Sides of COMBO Surgery

Machine defects. One of the problems dealing with the more diffuse vitrectomy machines is that we cannot keep the posterior infusion line on during the phaco. This could be very useful in highly myopic eyes where the sclera is extremely thin and tends to collapse, and also if the IOP is lowered during the insertion maneuver due to the escape of the colliquated vitreous through the microcannulas.

Surgeon training. The surgeon has to be trained in both anterior segment and vitreoretinal procedures, or alternatively, two different surgical teams have to be present at the same time.

Complications of the Technique

Intraoperative. The possibility of a sudden miosis or corneal striae and/or edema during the vitrectomy may hinder the visualization of the fundus; the edge of the lens may cause unwanted light reflex and optical changes. The tunnel may not be watertight, with subsequent anterior chamber collapse. Dislocation or pupillary capture of the IOL may also complicate vitrectomy [25]. *Postoperative*. Excessive anterior segment inflammation may occur, causing fibrin formation, synechiae between iris and IOL. Anterior dislocation of the IOL or pupillary capture may occur (especially with gas endotamponade) if the IOP raises or if the prone positioning is not kept in the first postoperative period.

19.4 Tips and Tricks

- Perform the size of capsulorrhexis slightly smaller than the diameter of the IOL optics, to avoid anterior dislocation of the IOL.
- Implant the IOL before the vitreoretinal procedures. This approach gains the advantage of stretching the capsular bag, and provides less chance of capsular rupture during vitrectomy.
- Always aspire the viscoelastic substance at the end of the phaco procedure, once the IOL implantation has been completed, to check if the tunnel incision is watertight and to permit better fundus visualization, especially if BSS/air exchanges are required.
- In contrast, delay the insertion of the IOL until after the end of vitreoretinal procedure, if the posterior capsula has torn. The pars plana vitrectomy is a closed system that effectively and precisely removes the vitreous from the capsular bag, avoiding the extension of the tear and allowing a safer implant.
- Use a wide-angle viewing system to minimize unwanted light reflex and optical changes due to the edge of the lens.

Summary for the Clinician

- Combo surgery has many advantages, including preventing the patients having to return for technically difficult cataract surgery, good visualization of the posterior pole and the periphery, and larger gas filling, reducing the need for buckling in retinal detachment repair.
- The inevitable development of cataract following vitrectomy has changed our practice. Considering the advantages of combo surgery, we now routinely perform combined phaco/25-g vitrectomy in presbiopic patients, even in absence of significant cataract [26, 27]. Presbiopic patients have in fact already lost their ability to accommodate, and therefore exchanging their crystalline lens for an IOL is of no detriment.

Summary for the Clinician

- In contrast, we would not perform combo surgery in diabetic patients with active retinopathy, ongoing uveitis or younger non-presbiopic patients.

The inevitable development of cataract following vitrectomy has changed our practice. Considering the advantages of combo surgery, we now routinely perform combined phaco/25-g vitrectomy in presbiopic patients, even in absence of significant cataract [26, 27]. Presbiopic patients have in fact already lost their ability to accommodate, and therefore exchanging their crystalline lens for an IOL is of no detriment.

In contrast, we would not perform combo surgery in diabetic patients with active retinopathy, ongoing uveitis or younger non-presbiopic patients.

References

1. Cherfan GM, Michels RG, De Bustros S, Enger C, Glaser BM (1991) Nuclear Sclerotic cataract after vitrectomy for idiopathic epiretinal membrane causing macular pucker. Am J Ophthalmol 111:434–438
2. De Bustros S, Thompson JT, Michels RG, Enger C, Rice TA, Glaser BM (1998) Nuclear sclerosis after vitrectomy for idiopathic epiretinal membrane. Am J Ophthalmol 105:160–164
3. Hsuan JD, Brown NA, Bron AJ, Patel CK, Rosen PH (2001) Posterior subcapsular and nuclear cataract after vitrectomy. J Cataract Refract Surg 27:437–444
4. Margherio RR, Cox MS Jr, Treses MT, Murphy PL, Johnson J, Minor LA (1985) Removal of epimacular membranes. Ophthalmology 92:1075–1083
5. Michels RG (1984) Vitrectomy for macular pucker. Ophthalmology 91:1384–1388
6. Ogura Y, Takanashi T, Ishigooka H, Ogino N (1991) Quantitative analysis of lens changes after vitrectomy by fluorophotometry. Am J Ophthalmol 111:179–83
7. Willis AW (1989) Surgical treatment of idiopathic macular epiretinal membrane. Ophthalmologie 3:29–30
8. Truscott RJ, Augustein RC (1997) Oxidative changes in human lens proteins during senile cataract formation. Biochim Biophys Acta 492:43–52
9. Haimann MH, Abrams GW (1984) Prevention of lens opacification during diabetic vitrectomy. Ophthalmology 91:116–21
10. Kotecha AV, Sinclair SH, De Bustros S (2000) Pars plana vitrectomy for macular holes combined with cataract extraction and lens implantation. Ophthalmic Surg Lasers 31:387–393
11. Brooks HL Jr. Macular hole surgery with and without internal limiting membrane peeling. Ophthalmology 108:1150–55
12. Paques M, Massin P, Santiago PY, Spielmann AC, Le Gargasson JF, Gaudric A (1997) Late reopening of successfully treated macula r holes. Br J Ophthalmol 81:658–662
13. Thompson JT, Glaser BM, Sjaarda RN, Murphy RP (1995). Progression of nuclear sclerosis and long-term visual results of vitrectomy with transforming growth factor beta-2 for macular holes. Am J Ophthalmol 119:48–54
14. Leonard RE, Smiddy WE, Flynn HN Jr, Fewer W (1997) Long-term visual outcomes in patients with successful macular hole surgery. Ophthalmology 104:1684–1752
15. D'Amico DJ (1994) Vitreoretinal surgery principles and application. In: Albert DM, Jacobiec FA (eds) Principle and Practice of Ophthalmology, vol. 2. WB Saunders, Philadelphia, pp 1133–1138
16. Teocharis I, Alexandridou A, Gili NJ, Tomic Z (2005) Combined phacoelmulsification and pars plana vitrectomy for macular hole treatment. Acta Ophthalmol Scand 83:172–175
17. Lahey JM, Francis RR, Fong DS, Kearney JJ, Tanaka S (2002) Combining phacoemulsification with vitrectomy for treatment of macular holes. Br J Ophthalmol 86: 876–878
18. Tompson JT, Smiddy WE, Glaser BM (1996) Retina 16:373–382
19. Cheung CM J. Hero M (2005) Stabilization of anterior chamber depth during phacoemulsification cataract surgery in vitrectomized eyes. Cataract Refract Surg 31:2055–2057
20. Wong KK, Saleh TA, Gray RH (2005) Suprachoroidal hemorrhage during cataract surgery in a vitrectomize eye. J Cataract Refract Surg 31:1242–1243
21. Charles ST (2005) 25-Gauge Vitrectomy techniques. AAO Subspecialty Day Retina, Chicago 14–15 October 2005, 169
22. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
23. Poyer JF, Chan KY, Arshinoff SA (1998) A new method to measure the retention of viscoelastics on a rabbit corneal endothelial cell line after irrigation ad aspiration. J Cataract Refract Surg 24:84–90
24. Arshinoff S (2002) Using viscoelastic to manage problems in cataract surgery. In: Fishkind WJ (eds) Complications in Phacoemulsification. Avoidance, Recognition and Management. Thieme, New York, pp 182–193
25. Chang CJ, Chang YH, Chiang SY, Lin LT (2005) Comparison of clear corneal phacoemulsification combined with 25-gauge transconjunctival sutureless vitrectomy and standard 20-gauge vitrectomy for patients with cataract and vitreoretinal diseases. Cataract Refract Surg 31:1198–1207
26. Ling R, Simcock P, McCoombes J, Shaw S (2003) Presbiopic Phacovitrectomy. Br J Ophthalmol 87:1333–1335
27. Kumudhan D, Simcock P (2005) Phaco-vitrectomy for macular holes. Acta Ophthalmol Scand 83:632

Chapter 20

Complications of 25-Gauge Vitrectomy

A. Gupta, S.D. Schwartz

Core Message

- 25-gauge vitrectomy has the same generic and potential risk as 20-gauge vitrectomy.
- In addition to generic vitrectomy risks, additional concerns have risen regarding potential hypotony, wound healing, and those associated with incomplete removal of vitreous gel with the 25-gauge system.
- Surgical experience may reduce potential complications of the 25-gauge vitrectomy system

20.1 Introduction

With technological advancements and increased experience, our understanding of the complications associated with pars plana vitrectomy has grown. Traditional pars plana vitrectomy has been associated with a myriad of complications, including creation of retinal tears and detachments [1], vitreous hemorrhage [2], incisional fibrovascular ingrowth [3–5], endophthalmitis [6], suprachoroidal hemorrhage [7–9], sympathetic ophthalmia [10], cataract progression [11, 12], corneal defects [13, 14], and glaucoma [15]. These same risks are associated with 25-gauge transconjunctival surgery. Due to the nature of this surgical technique, additional concerns have risen regarding potential hypotony, wound healing, and those associated with incomplete removal of vitreous gel.

20.2 Intraoperative Complications

While performing vitreous surgery with a 25-gauge transconjunctival system, concerns often arise regarding the insertion and use of small incision trocars. The original Entry Alignment System (EAS) for use with the Transconjunctival Sutureless Vitrectomy system (TSV-25) available from Bausch & Lomb Surgical (St. Louis, MO, USA) featured hollow-bore trocars that occasionally required excessive force for introduction of the cannulas. The globe could potentially be pushed deep into the orbit in patients with abundant periorbital tissue, causing distortion of the normal anatomy and potential injury to intraocular contents such as the crystalline lens. The potential risk of scleral tissue coring with the use of hollow trocars has not proven to be valid. The cannula insertion trocars used with the Accurus 25-gauge vitrectomy system from Alcon Surgical (Ft. Worth, TX, USA) were designed with solid, sharper trocars that allow for easier placement of the cannulas. The second-generation EAS has been redesigned to allow easier, smoother cannula placement compared to the predecessor (Fig. 20.1).

After the cannulas are inserted, they most often will stay in position throughout the surgery. Occasionally the cannulas may become displaced as the instruments are removed from the eye, resulting in chemosis or subconjunctival entrapment of air, depending on what is currently being infused (Fig. 20.2). Cannula replacement with the trocar makes it possible to continue with the surgery; however, the surgeon must take care to modify his surgical technique accordingly to avoid further conjunctival trauma.

The instruments used in conjunction with the 25-gauge vitrectomy systems are obviously finer than those used in 20-gauge surgery. During the initial learning period, it is not uncommon for the surgeon to attempt to torque the eye rather than rotating the instruments about the cannulas. This may result in unintentionally bending or breaking the instruments. The illuminating light pipes and laser probes are particularly fragile, and must be handled in a fashion unique to the 25-gauge vitrectomy systems. There have even been reports of breakage of the tip of the vitreous cutter during surgery [16].

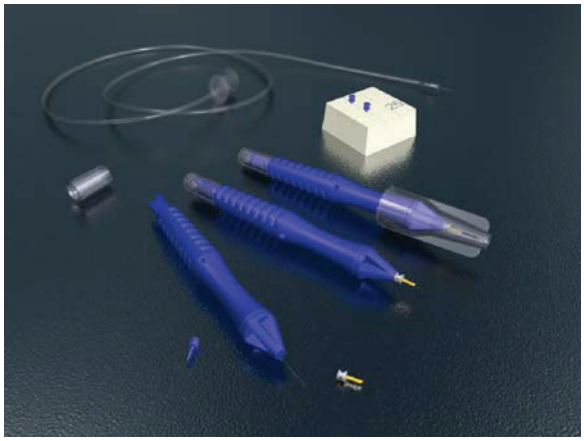


Fig. 20.1 Second-generation Entry Alignment System from Bausch and Lomb

A recent review of the authors' first-year experience with the 25-gauge transconjunctival vitrectomy system was performed to identify intraoperative surgical complications [17]. Two hundred and nine eyes of 200 consecutive patients undergoing pars plana vitrectomy with the TSV-25 between April 2002 and October 2003 were reviewed retrospectively. An intraoperative complication was defined as any adverse event that occurred or was discovered at the time of surgery. Conversion to 20-gauge pars plana vitrectomy or need for conjunctival or scleral sutures were considered adverse events. Of the 209 eyes studied, 15 eyes (7.2%) had intraoperative complications (Table 20.1). Retinal tears (n = 4), retinal holes (n = 2), retinal detachments (n = 1), and damage to the crystalline lens (n = 1) were experienced. Of the 15 complications,

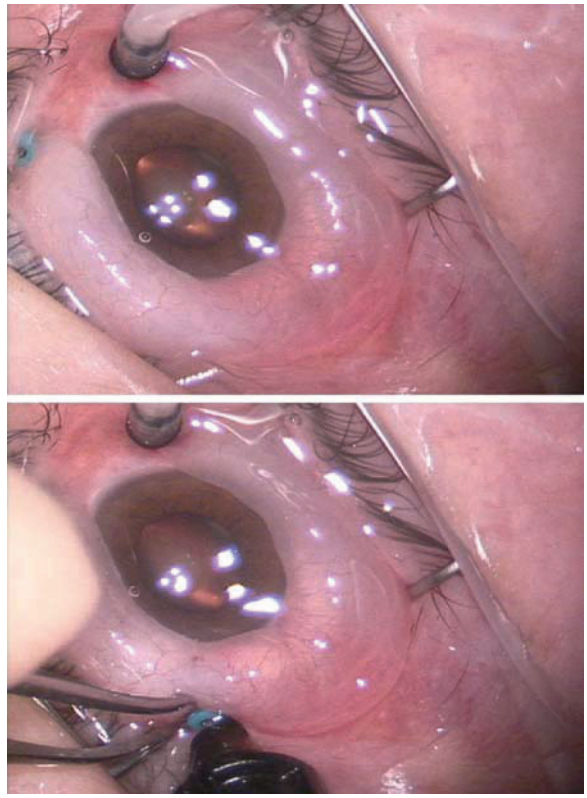


Fig. 20.2 Inadvertent intraoperative cannula removal results in rapid conjunctival chemosis (*top*). Cannula can be reinserted (*bottom*) and surgical procedure continued in most instances

seven were conversions to 20-gauge vitrectomy, most often performed because of required use of silicone oil or due to lack of appropriate instrumentation (Fig 20.3).

Table 20.1 Intraoperative complications with 25 gauge vitrectomy

Age	Pre-op diagnosis	Procedure	Complication
43	Vitreous hemorrhage/cataract	PPV/PPL/gas	Retinal tear
71	Macular hole	PPV/gas	Sclerotomy sutures
65	Vitreous hemorrhage	PPV/gas	Retinal tear
66	Retinal detachment	PPV/gas	Conjunctival sutures
27	Vitreous hemorrhage	PPV/PPL/gas	Retinal tear
61	Tractional retinal detachment	PPV/gas	Retinal hole
66	Macular pucker	PPV/air	Retinal tear
90	Vitreous hemorrhage	PPV/phaco/IOL	Conversion to 20-G
61	Macular hole	PPV/gas	Retinal hole
64	Macular hole	PPV	Conversion to 20-G
55	Fungal endophthalmitis	PPV/intravit drugs	Retinal detachment Conversion to 20-G
45	Tractional retinal detachment	PPV/retinectomy/oil	Conversion to 20-G
65	Vitreous hemorrhage Retinal detachment	PPV/PPL/oil	Conversion to 20-G
6	Vitreous hemorrhage	PPV/air	Conversion to 20-G
66	Vitreous hemorrhage	PPV/PPL	Conversion to 20-G

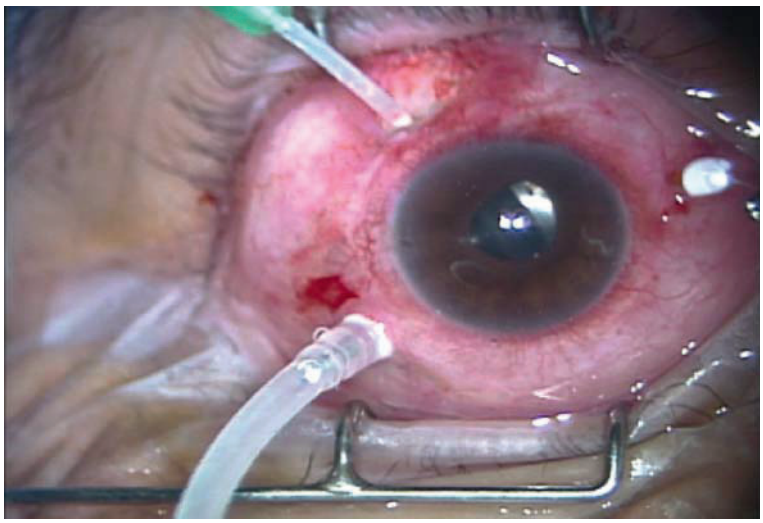


Fig. 20.3 Conversion of a single port for injection of silicone oil

With subsequent experience, other complications including giant retinal tears, suprachoroidal hemorrhages, and endophthalmitis have also been identified.

Summary for the Clinician

- With the technological advancements of instrumentation, solid and sharper trocars allow for easier placement of the cannulas.
- During the introduction of trocars, the globe could potentially be pushed deep into the orbit, causing distortion of the normal anatomy.
- A learning curve is needed for reducing intraoperative potential complication using the 25-gauge vitrectomy system

20.3 Postoperative Complications

After removal of the 25-gauge cannulas, the incisions are designed to be self-sealing. The open nature of the sclerotomies has led to concerns of hypotony, wound leakage, and vitreous incarceration. In addition, late complications of vitrectomy including retinal tears, retinal dialysis, and vitreous hemorrhage have also been associated with the creation of self-sealing sclerotomies [18].

A recent study by the authors of 209 consecutive surgeries using the 25-gauge vitrectomy system sought to identify any and all postoperative complications, with a mean follow-up of 12 months [19]. All postoperative adverse events were reported as complications for this study, but were not all necessarily due to 25-gauge surgery (Table 20.2). Forty four eyes (21%) of the 209 eyes studied had postoperative findings scored as complications; recurrent retinal detachment and vitreous hemorrhage were the most common complications in our series of patients.

20.3.1 Hypotony

In 2002, the initial experience with 25-gauge vitrectomy surgery was evaluated and presented by Steven Schwartz, MD, at the American Academy of Ophthalmology [20]. Of the initial 62 patients treated with the 25-gauge system, 10% had postoperative hypotony, defined as intraocular pressure lower than 5 mmHg. The surgical technique at the time involved directly inserting the trocars through the conjunctiva and scleral for cannula placement. Upon removal of the cannulas, the incisions in the conjunctiva were directly overlying the sclerotomies. By simply displacing the conjunctiva prior to trocar insertion (Fig. 20.4), creating conjunctival and scleral incisions in different locations, we saw a dramatic decrease in postoperative hypotony [21].

From April 2002 to March 2003, intraocular pressure was closely monitored on 151 eyes of patients undergoing 25-gauge vitrectomy. Intraocular pressure was measured on postoperative day zero (2–6 h after the conclusion of surgery) and day 1. After the change in surgical technique to offset the conjunctival and scleral incisions, two patients had an intraocular pressure less than five on day zero (Fig. 20.5), and only one patient had hypotony on postoperative day 1, which resolved by day 2.

20.3.2 Wound Healing

Sclerotomy wound healing is a concern with incisions that are purportedly self-sealing. In order to evaluate the timing of wound closure, integrity of overlying conjunctiva,

Table 20.2 Postoperative complications with 25 gauge vitrectomy

Complication	Incidence	Comment
Vitreous hemorrhage	4.3% (9/209)	9/9 patients with PDR or vascular occlusion pre-op
Retinal detachment	3.8% (8/209)	4/8 retinal detachment, 3/8 PDR with tractional retinal detachment, 1/8 FEVR with tractional retinal detachment pre-op
Macular pucker	2.4% (5/209)	5/5 with macular pucker pre-op
Neovascular glaucoma	2.4% (5/209)	4/5 with CRVO, 1/5 PDR pre-op
Recurrent or failed macular hole	2.4% (5/209)	29 total pre-op diagnosis of macular hole, 5/29 (17%) recurrence or failure
Persistent macular edema	1.9% (4/209)	4/4 macular pucker pre-op
Retinal detachment with proliferative vitreoretinopathy	1.0% (2/209)	2/2 retinal detachment pre-op
Central retinal vein occlusion	1.0% (2/209)	2/2 with hypertension, over 80 years old
Choroidal neovascular membrane	0.5% (1/209)	Pre-existing age related macular degeneration
Dislocated PCIOL	0.5% (1/209)	Trauma in post-op period

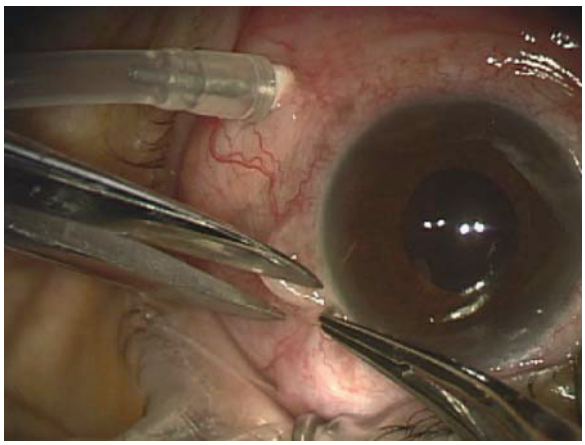


Fig. 20.4 Maximum displacement of conjunctiva with either forceps or cotton-tip applicator prior to insertion of the cannula with a trocar is essential to induce a misalignment between the conjunctival incision and the sclerotomy

and presence of vitreous incarceration, ultrasound biomicroscopy (UBM) was used to evaluate sclerotomies of patients undergoing vitrectomy with the TSV-25 system [22]. UBM scans were obtained on postoperative day 1, week 1, and month 1. Postoperative day 1 UBM evaluation of sclerotomies uniformly showed open sclerotomies with intact overlying conjunctiva (Fig. 20.6a). By postoperative week 1, all sclerotomies were closed, with variable amounts of vitreous gel incarcerated in all wounds (Fig. 20.6b). Postoperative month 1 UBM evaluation did not appreciably differ from postoperative week 1 scans (Fig. 20.6c).

20.3.3 Cataract

Cataract progression is a known complication of 20-gauge standard pars plana vitrectomy [11, 12]. Decreased ocular manipulation and surgical time with 25-gauge transconjunctival vitrectomy may theoretically lead to a decreased rate of cataract formation. In a series of consecutive phakic patients with no previous intraocular surgery undergoing 25-gauge vitrectomy, the severity of nuclear, cortical, and posterior subcapsular lens opacities was graded on slit-lamp examination during preoperative and follow-up examinations [23]. After a mean follow-up of over 1 year, 28% of eyes had cataract progression. Two-thirds of these eyes had gas tamponade.

Comparison of surgical techniques in this patient population is difficult due to the heterogeneous patient group; however, the rate of cataract progression following 25-gauge transconjunctival pars plana vitrectomy may be lower than 20-gauge standard pars plana vitrectomy. Decreased posterior segment manipulation, lower intraoperative infusion volumes, and case selection with 25-gauge transconjunctival vitrectomy may contribute to a lower rate of postoperative cataract progression.

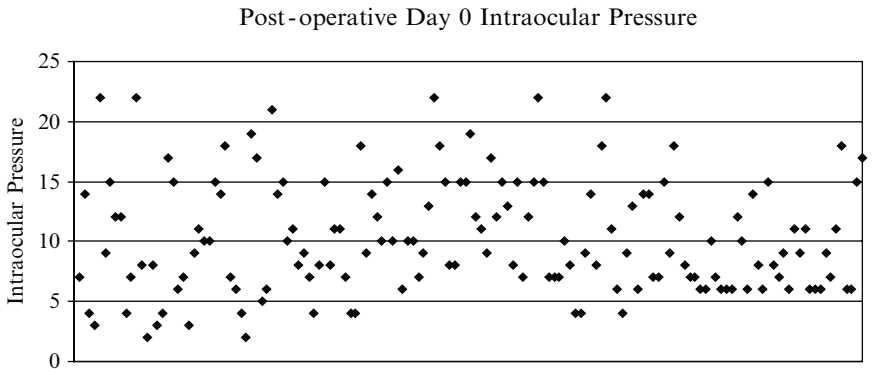


Fig. 20.5 Graph representing all intraocular pressures for patients 2–6 h after surgery. Of note; only two pressures measure below 5 mmHg after modification of surgical technique

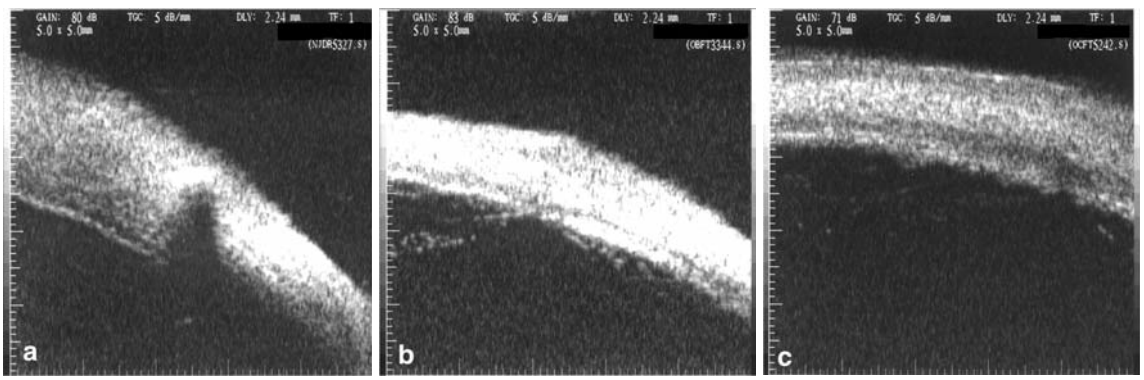


Fig. 20.6 Ultrasound biomicroscopy of sclerotomy at postoperative day 1 (**a**) shows an open scleral wound with intact overlying conjunctiva. At week 1 (**b**), the scleral wound has closed and there is vitreous adherence to the wound. At month 1 (**c**), the sclerotomy has closed with persistent vitreous adherence, and the overlying conjunctiva has attained a smooth contour

Summary for the Clinician

- After the change in surgical technique to offset the conjunctival and scleral incisions, three patients out of 151 had an intraocular pressure less than 5 mmHg.
- The rate of cataract progression following 25-gauge transconjunctival pars plana vitrectomy may be lower than 20-gauge standard pars plana vitrectomy.

20.4 Discussion

The 25-gauge vitrectomy systems represent a major leap forward in our ability to provide less invasive solutions to complicated ocular problems. The creation of self-sealing wounds has not been shown to be disadvantageous to the patient in the short or long term. 25-gauge transconjunctival vitrectomy complication rates are comparable to and may be lower than standard 20-gauge pars plana vitrectomy. Direct comparison to historical controls is limited for a number of reasons, including variable baseline characteristics and open entry criteria. Immediate recognition and appropriate treatment of any complication is important for optimal anatomic and functional outcomes.

References

1. Michels RG, Ryan SJ Jr (1975) Results and complications of 100 consecutive cases of pars plana vitrectomy. Am J Ophthalmol 80:24–29
2. Blankenship GW (1986) Management of vitreous cavity hemorrhage following pars plana vitrectomy for diabetic retinopathy. Ophthalmology 93:39–44

3. Kreiger AE (1993) Wound complications in pars plana vitrectomy. Retina 13:335–344
4. Krieger AE (1991) The pars plana incision: experimental studies, pathologic observations, and clinical experience. Trans Am Ophthalmol Soc 89:549–621
5. Kreiger AE, Sraatsma BR, Foos RY (1977) Incisional complications in pars plana vitrectomy. Mod Probl Ophthalmol 18:210–223
6. Blankenship GW (1977) Endophthalmitis after pars plana vitrectomy. Am J Ophthalmol 84:815–817
7. Ghoraba HH, Zayed AI (2001) Suprachoroidal hemorrhage as a complication of vitrectomy. Ophthalmic Surg Lasers 32:281–288
8. Tabandeh H, Sullivan PM, Smahliuk P, Flynn HW, Jr. and Schiffman J (1999) Suprachoroidal hemorrhage during pars plana vitrectomy. Risk factors and outcomes. Ophthalmology 106:236–242
9. Sharma T, Virdi DS, Parikh S, Gopal L, Badrinath SS, Mukesh BN (1997) A case-control study of suprachoroidal hemorrhage during pars plana vitrectomy. Ophthalmic Surg Lasers 28:640–644
10. Pollack AL, McDonald HR, Ai E et al (2001) Sympathetic ophthalmia associated with pars plana vitrectomy without antecedent penetrating trauma. Retina 21:146–154
11. Ghartey KN, Tolentino FI, Freeman HM, McMeel JW, Schepens CL, Aiello LM (1980) Closed vitreous surgery. XVII. Results and complications of pars plana vitrectomy. Arch Ophthalmol 98:1248–1252
12. Melberg NS, Thomas MA (1995) Nuclear sclerotic cataract after vitrectomy in patients younger than 50 years of age. Ophthalmology 102:1466–1471
13. Virata SR, Kylstra JA, Singh HT (1999) Corneal epithelial defects following vitrectomy surgery using handheld, sew-on, and noncontact viewing lenses. Retina 19:287–290
14. Perry HD, Foulks GN, Thoft RA, Tolentino FI (1978) Corneal complications after closed vitrectomy through the pars plana, Arch Ophthalmol 96:1401–1403
15. Wilensky JT, Goldberg MF, Alward P (1977) Glaucoma after pars plana vitrectomy. Trans Sect Ophthalmol Am Acad Ophthalmol Otolaryngol 83:114–121
16. Inoue M, Noda K, Ishida S, Nagai N, Imamura Y, Oguchi Y (2004) Intraoperative breakage of a 25-gauge vitreous cutter. Am J Ophthalmol 138:867–869
17. Chen C, Gupta A, Savar L et al (2005) 25-Gauge transconjunctival vitrectomy: intraoperative safety. Invest Ophthalmol Vis Sci (ARVO Abstracts) 46:5455
18. Chen JC (1996) Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 114:1273–1275
19. Mango C, Gupta A, Chen C et al (2005) 25-Gauge transconjunctival vitrectomy: postoperative complications, Invest Ophthalmol Vis Sci (ARVO Abstracts) 46:5459
20. Schwartz SD (2002) Advances in vitreoretinal surgery. American Academy of Ophthalmology, Orlando, FL
21. Gupta A, Gonzales C, Lee S et al (2003) Transient postoperative hypotony following transconjunctival 25-gauge vitrectomy, Association for Research in Vision and Ophthalmology (ARVO) Annual Meeting, Fort Lauderdale, FL
22. Gupta A, Gonzales C, Kreiger A, Schwartz S (2006) Ultrasound biomicroscopic evaluation of sclerotomies created by the 25-gauge transconjunctival vitrectomy system. Submitted to Retina for publication.
23. Gupta A, Chen C, Savar L et al (2005) 25-Gauge transconjunctival vitrectomy: cataract progression. Invest Ophthalmol Vis Sci (ARVO Abstracts) 46:5458

Chapter 21

A Comparison of 20- vs 25-Gauge Vitrectomy: Does Size Matter?

C.A. McCannel

Core Message

- Vitrectomy surgery's evolution to smaller-gauge instrumentation follows the general trend of surgical instrumentation in other surgical specialies becoming smaller and "less invasive".
- It is difficult to quantify how much less invasive 25-gauge vitrectomy surgery is than 20-gauge vitrectomy.
- Measures of invasiveness may include the amount of tissue disruption, patient discomfort, recovery time, and risk of complications.
- 25-gauge vitrectomy involves less tissue disruption, patient discomfort and recovery time.
- Vitrectomy surgery complications include endophthalmitis, rhegmatogenous complications (retinal tears and detachment), hypotony, cataract formation, and choroidal hemorrhage and effusion.
- Whether complications, especially such as endophthalmitis and retinal detachment, occur at a greater or lesser rate in 25-gauge vitrectomy remains controversial.
- Advantages such as increased patient satisfaction due to less pain, and faster vision recovery and reduced surgery time, must be weighed against increased risk of certain complications, and increased cost.
- Deficiencies of the instrumentation, especially with regard to lack of stiffness and inadequate light delivery, have been mostly overcome.
- Only the most complex vitrectomy cases may be inappropriate for 25-gauge surgery.
- At this time, there is limited clear-cut evidence that one gauge system is better than another.

21.1 Introduction

Perhaps the most common characterization of 25-gauge vitrectomy compared to 20-gauge vitrectomy is that 25-gauge vitrectomy is "less invasive." It turns out that the definition of "invasiveness" has not caught up with the way surgeons think about surgery, or different surgical techniques. In Webster, the definition of "invasive" states: "involving entry into the living body (as by incision or by insertion of an instrument)." This definition does not encompass any technical differentiation. If one were to define surgical invasiveness by the complications to which the patient is exposed, this definition also does not differentiate between risks of known complications, such as retinal detachment and endophthalmitis. The main difference between 20-gauge and 25-gauge vitrectomy is the amount of surgical tissue disruption. This in turn may influence the rate of visual recovery, and patient discomfort.

As in all surgical fields, ophthalmology has seen the evolution of "invasiveness" as demonstrated in cataract surgery, glaucoma filtering surgery and now, vitreoretinal surgery [1]. Each generation of surgical techniques has imparted a reduction of invasiveness in some fashion — less risk, less tissue disruption, less recovery time — toward better and safer patient outcomes.

Many of the topics discussed in this chapter are also covered in other chapters. This chapter will attempt to analyze and compare the relative advantages and disadvantages of 20-gauge vs 25-gauge vitrectomy surgery. Both the published literature and the author's experience will aid in providing a robust comparison.

21.2 Invasiveness

Although there is no agreed-upon measure of invasiveness, 25-gauge vitrectomy has been hailed by its proponents as "less invasive." However, there is no agreed-upon measure of invasiveness, other than it either is invasive or non-invasive. For purposes of discussion in this chapter, invasiveness is broken down into four

categories, 21 which may have some overlap. The categories are tissue disruption, patient comfort, recovery time, and risk of complications.

21.2.1 Tissue Disruption

A 20-gauge pars plana vitrectomy typically involves conjunctival peritomies with radialization; incisions are made to gain access to the sclera for sclerotomy sites (Fig. 21.1). Each of the three sclerotomy incisions is approximately 1 mm in length, for a total of approximately 3 mm of cut sclera. In contrast, during 25-gauge vitrectomy there are no conjunctival incisions, and the three sclerotomies are each only approximately 0.5 mm in length, for a total of 1.5 mm of cut sclera. Thus, during 20-gauge vitrectomy twice as much scleral tissue is cut to gain access to the eye. A 50% reduction in combined total scleral incision length involves clearly less tissue disruption, and should thus require less healing. Additionally, a lower level of scleral disruption makes available more unscarred scleral tissue for entry into the eye during reoperations.

21.2.2 Patient Discomfort

The clinical impression following 20-gauge vitrectomy is that patients often complain of foreign body or other sensations related to conjunctival sutures. In contrast, patients who have undergone 25-gauge vitrectomy experience little discomfort immediately after surgery. This has been documented by a prospective randomized study by Kellner and colleagues [2, 3] and by a study reported by Rizzo and colleagues [4]. A significant difference in reported discomfort score beginning on postoperative day 1 was observed in 25-gauge vitrectomy patients, who had lower discomfort scores.

21.2.3 Recovery Time

Rapid recovery of visual acuity is important to patients. There are several reports that indicate vision recovery [5] (Faia unpublished), as measured by visual acuity, is better sooner with 25-gauge vitrectomy than with 20-gauge vitrectomy. Our series demonstrated a significantly shorter duration of vision improvement to baseline among epimacular membrane and macular hole cases. This may be due to less induced astigmatism and less tear-film disturbance caused by irregular sutured conjunctiva. Lower rates of astigmatism after 25-gauge vitrectomy have been reported by Yanvali and colleagues compared to reports of 20-gauge vitrectomy associated astigmatism by Wirbelauer and colleagues [6, 7].

21.2.4 Risk of Complications

Complications of vitrectomy surgery principally include endophthalmitis, retinal detachment, retinal breaks, choroidal hemorrhage and intraocular pressure (IOP) problems.

21.2.4.1 Endophthalmitis

A study by Kunimoto and colleagues reported a 12-fold increased risk of endophthalmitis using 25-gauge vitrectomy instrumentation compared to 20-gauge surgery. In their study, the rate of endophthalmitis after 20-gauge surgery was 0.018%, compared to 25-gauge surgery which had a rate of 0.23% [8]. However, several smaller series comparing 20-gauge with 25-gauge vitrectomy have not shown this increased risk of endophthalmitis. The differences may be technique-dependent, or perhaps — as with sutureless clear cornea surgery — due to a true increased risk of endophthalmitis with the 25-gauge vitrectomy technique.

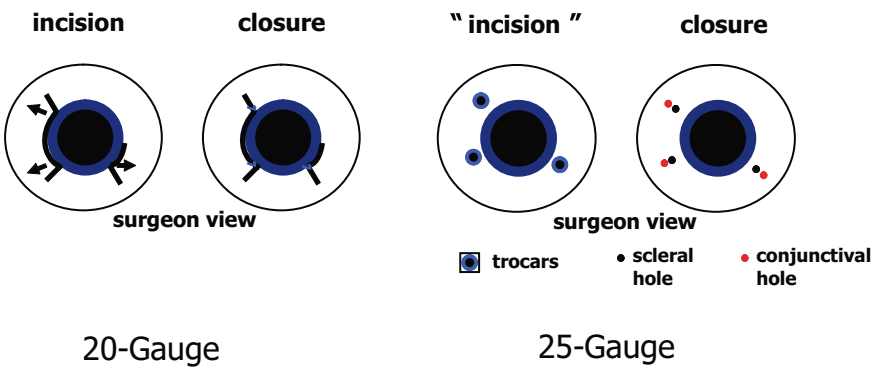


Fig. 21.1 The diagram illustrates the reduced conjunctival cutting and manipulation required when using the sutureless transconjunctival vitrectomy system. The conjunctival and scleral wounds are non-overlapping, due to anteriorization of the conjunctiva at the time of trocar insertion

21.2.4.2 Rhegmatogenous Complications: Retinal Tears and Detachment

Retinal detachment is perhaps the most common serious complication of vitrectomy surgery. Interestingly, recent series comparing the techniques reported discordant results. Valmaggia reported three of 64 cases of 20-gauge vitrectomy resulting in retinal detachment (4.6%), compared to none of 75 cases of 25-gauge vitrectomy, all for epimacular membranes [9]. Our recently summarized experience revealed no retinal detachments in either 68 cases of 20-gauge vitrectomy, or 71 cases of 25-gauge vitrectomy for varying indications (Faia, unpublished). In this same series, it was noted that retinal tears occurred in seven of the 68 20-gauge vitrectomy cases, compared to none of the 71 cases using the 25-gauge technique. Other unpublished reports have described far different findings, with a much higher rate of retinal detachment in 25-gauge cases (personal communication, Dave Williams, MD).

21.2.4.3 Intraocular Pressure

After 25-gauge vitrectomy, intraocular pressure may be low due to wound leakage. Several studies have evaluated postoperative intraocular pressure after 25-gauge vitrectomy. The reported outcome of hypotony (i.e., IOP less than 10 mmHg) is variable. It appears that 25-gauge vitrectomy is associated with a higher rate of hypotony than 20-gauge surgery. On the other hand, there appears to be a higher rate of elevated IOP (i.e., IOP greater than 20 mmHg), after 20-gauge surgery. None of the studies reported hypotony-related complications which compromised vision recovery. It can be concluded that the range of intraocular pressures is acceptable given the lack of serious complications [2, 10–12].

21.2.4.4 Choroidal Detachment

There may be an increased risk of serous and hemorrhagic choroidal detachment with low intraocular pressures, which may be more common following 25-gauge surgery. There are just three reports on intraocular pressure which also include choroidal detachments. These series report a total of 13 cases of choroidal effusions among 829 surgeries, or a rate of 1.6%. The real number may be lower, as most series did not report this complication. Although there are no reported cases of suprachoroidal hemorrhage, their theoretical risk exists [9, 13, 14]. These potentially vision-threatening complications must be considered during surgical decision making.

21.2.4.5 Cataract Formation

The reported rate of cataract formation after vitrectomy surgery varies greatly. Reported rates of cataract development after 20-gauge vitrectomy range from 12.5% to 80% [15–22] and, similarly after 25-gauge vitrectomy, from 2% to 79% [4, 10, 11, 23–25]. The large range in reported cataract progression for both gauges is impressive.

Reasons for these large ranges may include the non-standardized way in which lens changes have been evaluated, or surgical technique. After vitrectomy surgery, excellent vision is often not expected. It is possible that the contribution from lens changes are underestimated, leading to underestimation of cataract diagnosis.

A difference in surgery technique that would apply to both 20- and 25-gauge vitrectomy might be the amount of vitreous removed during surgery. It has been suggested that the increased oxygen tension in the eye after vitrectomy is responsible, at least in part, for the progression of nuclear sclerosis [26, 27]. This assertion is supported by a report of vitrectomy-less epimacular membrane peeling resulting in no nuclear sclerosis progression during follow-up [21]. It is likely that the amount of vitreous removed during surgery may have a greater effect on cataract progression than instrumentation size. If the amount of vitreous removal is similar in both techniques, there should be no differences in cataract progression. However, many surgeons are reporting shorter surgical times, and current 25-gauge instrumentation removes significantly less vitreous per unit time compared to 20-gauge surgery. Thus, the amount of vitreous left in the eye is probably greater for many 25-gauge surgeons, resulting in less protection of the lens by vitreous from the increased oxygen tension in the aqueous phase of the posterior chamber. This view is supported by our series, in which the amount of vitreous removal was similar between 20-gauge and 25-gauge vitrectomy cases, and where there was no significant difference in cataract progression or time between vitrectomy and cataract surgery between the 20-gauge and 25-gauge vitrectomy eyes (Fig. 21.2) (Faia unpublished).

Surgery time per se may be a contributing factor to cataract progression. After macular hole surgery using 20-gauge vitrectomy, Cheng and colleagues reported no effect of surgical duration on the rate of cataract progression [28]. Series showing that diabetic patients have lower cataract formation rates compared to non-diabetics after vitrectomy surgery also do not support the influence of case duration on cataract formation [26, 29]. The duration of diabetic surgery is likely no shorter than epimacular membrane surgery, yet cataract progression was lower in operated eyes of diabetics.

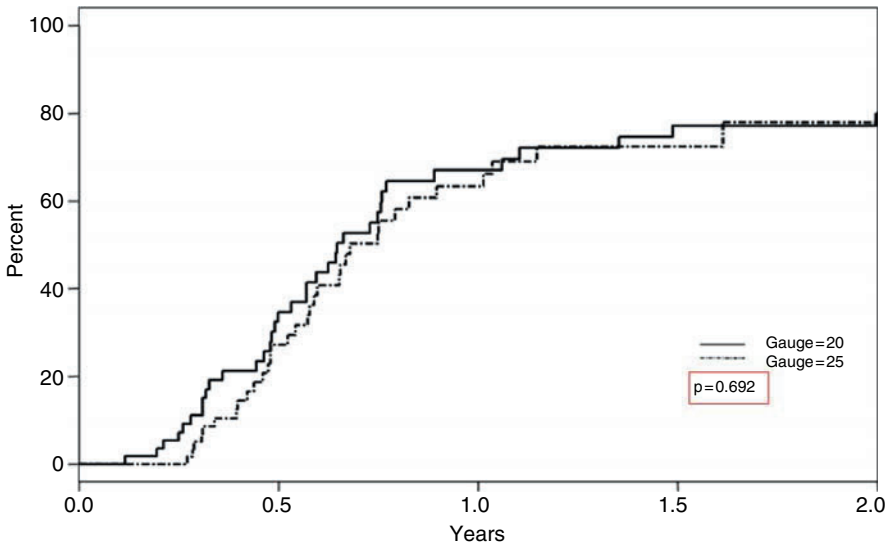


Fig. 21.2 The Kaplan–Meyer plot demonstrates the comparative cataract extraction rates in two cohorts of eyes having undergone 20- versus 25-gauge vitrectomy surgery. There is no difference in the rates. The cataract surgery was performed when the clinical judgment indicated that the lens changes had become the vision-limiting abnormality. (Faia unpublished data)

In summary, instrument gauge and cataract progression are likely independent.

21.3 Operative Time

Pars plana vitrectomy includes opening, vitrectomy, membrane peeling or delamination, and closing. Although a 25-gauge vitrectomy approach may require less time with opening and closing, the smaller gauge has a significantly lower flow rate, which may result in increased vitrectomy time for removal of an equal volume of vitreous. However, the introduction by MID labs of the AVE 25-gauge cutter has resulted in a system with flow rates which outperform even current-generation vitrectomy cutters [30] (Fig. 21.3) shows a comparison of water flow rate vs cut rate of several vitrectomy probes. Water flow is not entirely representative of the performance when vitreous is aspirated, but demonstrates the relative flow limitations based on port size, internal lumen, and duty cycle.

The issue of operating time is highly surgeon-dependent; some believe that the significant time saved by the reduced opening and closing time makes 25-gauge vitrectomy more efficient. On the other hand, others assert that efficiency is decreased because the vitrectomy portion actually increases operating time. The latter opinion may be held by surgeons who prefer a thorough vitrectomy for all cases. New higher flow rate technologies may continue to improve surgical time efficiencies by reducing vitrectomy time.

21.4 Instrumentation

There have been some significant and valid criticisms regarding 25-gauge vitrectomy instrumentation. The first generation of instruments was significantly more flexible than 20-gauge instrumentation. However, recent advances in instrument design and metal selection have resulted in more rigid instruments more similar to 20-gauge instrumentation.

The finer tips of the vitrectomy probe facilitate certain surgical techniques. Surgeries for complex complications of proliferate diabetic retinopathy are not usually thought to be optimal 25-gauge cases. However, the fineness of the instrumentation can actually facilitate efficiency and good results. The 25-gauge vitrectomy instrument, unlike its 20-gauge counterpart, is well-suited for removing proliferate membranes, including "shaving" them off the retinal surface. This is due to smaller port size, good flow control and more distal location of the guillotine port on the vitrectomy probe. When delamination is sill required, the fineness of the instrument tips makes cutting of "pegs" (bridging vessels between the retinal vessels and epiretinal proliferation) easier and safer. The scissor blades are so short that cutting a peg and penetrating the retina inadvertently is difficult.

With regard to illumination, standard light sources deliver less light to the interior of the eye with 25-gauge fiberoptics. However, with the advent of more powerful light sources, this disadvantage has been negated. Recently enhanced light sources deliver as much or more

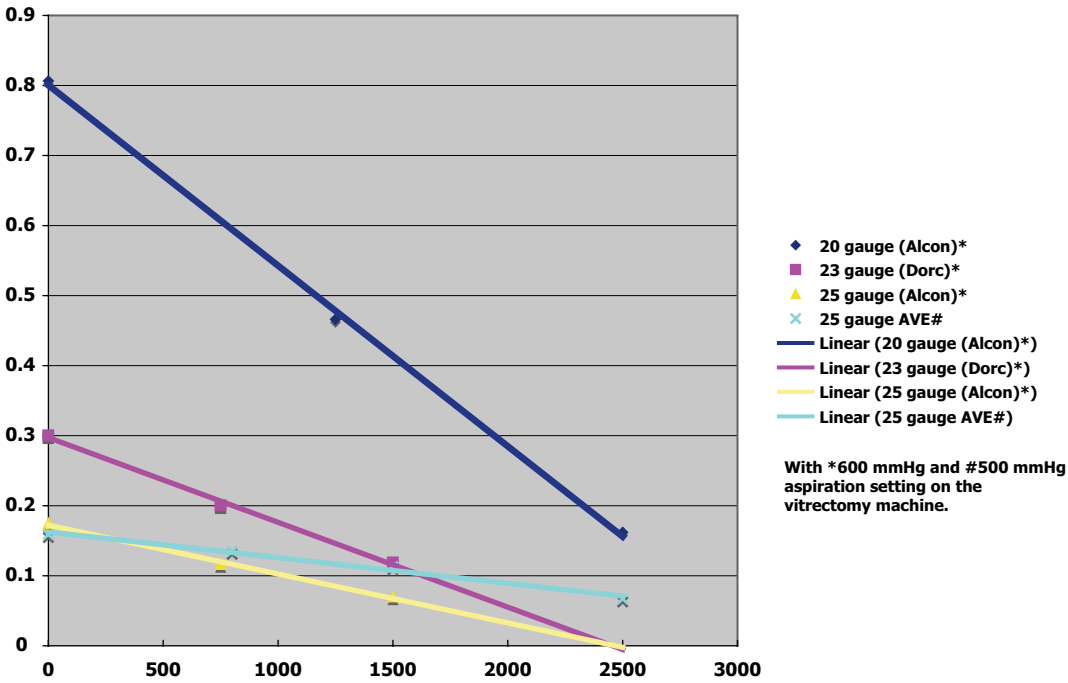


Fig. 21.3 The graph demonstrates the comparative water aspiration rates of various vitrectomy probes. The Alcon and DORC vitrectomy probes were evaluated with a machine aspiration vacuum setting of 600 mmHg (McCannel unpublished data), and the AVE vitrectomy probe was evaluated with a machine aspiration vacuum setting of 600 mmHg [30]. It should be noted that the AVE probe at a lower aspiration setting outperforms the Alcon 25 gauge, and equals the DORC 23 gauge probe's water aspiration

light to the interior of the eye through 25-gauge fiberoptics than pre 25-gauge era illumination systems delivered with 20-gauge fiberoptics.

Although there is currently no 25-gauge fragmatome, vitrectomy for retained lens material following complicated cataract surgery may often be performed with a 25-gauge vitrectomy probe. However, the removal of dense late nuclear lens material may not be suitable for 25-gauge surgery.

Technical innovation on the part of instrument manufacturers continues to improve 25-gauge instrumentation.

21.5 Success Rates

Surgical success of vitrectomy depends on the primary goal of surgery, where visual acuity may be a secondary endpoint. With respect to macular hole surgery, there is little literature comparing hole closure rates in 20-gauge vs 25-gauge surgery. Rizzo reported a closure rate of 93% utilizing 25-gauge vitrectomy instrumentation, which is similar to the best reports on macular hole closure using 20-gauge instrumentation [3]. In retinal reattachment surgery, there are conflicting reports on success rate, with little published information. Horozoglu and colleagues report a success in 14 of 15 cases (93%) of primary 25-gauge vitrectomy for rhegmatogenous retinal detachment [31]. Drawing conclusions from such a small series is premature, especially since there are success rates as low as 75% reported at meetings. Rates of successful repair in primary retinal detachments with primary 20-gauge vitrectomy without scleral buckle range from 70% [32] to 88% [33] and 93% [34]. In a recent review of the cases at the Mayo Clinic, the single surgery success rate was greater than 90% for both 20-gauge (n = 83) and 25-gauge (n = 26) primary vitrectomy surgery for rhegmatogenous retinal detachment. It is important to note that these series generally include differences in surgical approach and case selection bias. Furthermore, the lens status, whether the eye is phakic or pseudophakic, may have an important influence on vitrectomy surgery success rates, as has been recently shown in a prospective randomized study of 20-gauge vitrectomy surgery and scleral buckling [35]. Nevertheless, it appears that it may be possible to achieve similar success rates independent of instrument gauge.

21.6 Cost

In general, the current cost in dollars of 25-gauge instrumentation is greater than with 20-gauge. However, the potential advantages, such as increased patient comfort during the postoperative period, shorter visual acuity recovery time, perceived "cutting edgeness" of the technology, possible time savings, all must be balanced against the additional cost. The price differential may diminish as the technology is no longer considered premium.

21.7 Conclusion

There are certainly advantages, disadvantages and uncertainties regarding 25-gauge vitrectomy surgery. According to the 2007 Preferences and Trends Survey of the American Society of Retina Specialists, approximately 72% of surgeons have indicated that they use 25-gauge surgery for at least some surgeries and 34% for more than half of their vitrectomy surgeries. The controversy surrounding risk of infection is reminiscent of the early days of clear cornea cataract surgery. However, the outcome of that discussion, and similar criticisms, such as increased risk of retinal detachment, is unclear at this time. Longer follow-up and increased experience with 25-gauge vitrectomy will determine whether or not this technology represents a true advantage over 20-gauge technology. In the mean time, there is limited clear-cut evidence that one gauge system is better than another.

Summary for the Clinician

- Compared to 20-gauge vitrectomy surgery, complication rates of 25-vitrectomy surgery vary by complication, and varying rates among publications may represent the typical variation seen when new techniques are adopted
  1. Endophthalmitis may occur at a significantly higher rate after 25-gauge surgery according to some, but not other studies.
  2. Retinal detachment rates have been reported to be higher, lower and equal to those found after 20-gauge vitrectomy surgery.
  3. Choroidal detachments, either hemorrhagic or effusive, are very rarely reported as a complication after 25-gauge vitrectomy.
  4. Hypotony is more common after 25-gauge surgery, but significantly elevated IOP is virtually absent, while for 20-gauge vitrectomy the opposite is true.
  5. Cataract progression rates appear to vary by series. The actual rate of cataract progression may be more dependent on the amount of vitreous removed than on the gauge of the instruments.

Acknowledgement

This work was supported in part by an unrestricted grant by Research to Prevent Blindness, New York, NY, USA and the Mayo Foundation.

The author has no proprietary interest in the topics discussed in the manuscript.

References

1. Buchmann P, Dincler S (2006) [Progress of the laparoscopic colorectal surgery with special consideration regarding cancer treatment]. Schweiz Rundsch Med Prax 95:663–669
2. Kellner L, Wimpissinger B, Stolba U, Brannath W, Binder S (2007) 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. Br J Ophthalmol 91:945–948
3. Rizzo S, Belting C, Cresti F, Genovesi-Ebert F (2007) Sutureless 25-gauge vitrectomy for idiopathic macular hole repair. Graefes Arch Clin Exp Ophthalmol 245:1437–1440
4. Rizzo S, Genovesi-Ebert F, Murri S et al (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol 244:472–479
5. Shinoda H, Shinoda K, Satofuka S et al (2008) Visual recovery after vitrectomy for macular hole using 25-gauge instruments. Acta Ophthalmol Scand 86:151–155
6. Wirbelauer C, Hoerauf H, Roider J, Laqua H (1998) Corneal shape changes after pars plana vitrectomy. Graefes Arch Clin Exp Ophthalmol 236:822–828
7. Yanyali A, Celik E, Horozoglu F, Nohutcu AF (2005) Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. Am J Ophthalmol 140:939–941
8. Kunimoto DY, Kaiser RS (2007) Incidence of endophthalmitis after 20- and 25-Gauge vitrectomy. Ophthalmology 114:2133–2137
9. Valmaggia C (2007) Pars plana vitrectomy with 25-gauge instruments in the treatment of idiopathic epiretinal membranes. Klin Monatsbl Augenheilkd 224:292–296
10. Patelli F, Radice P, Zumbo G, Frisone G, Fasolino G (2007) 25-gauge macular surgery: results and complications. Retina 27:750–754
11. Gupta OP, Weichel ED, Regillo CD et al (2007) Postoperative complications associated with 25-gauge pars plana vitrectomy. Ophthalmic Surg Laser Imag 38:270–275

12. Yanyali A, Celik E, Horozoglu F, Oner S and Nohutcu AF (2006) 25-Gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16:141–147
13. Lommatzsch A, Heimes B, Trieschmann M, Spital G, Pauleikhoff D (2008) [Long-term results after pars plana vitrectomy with 25 gauge technique.]. Ophthalmologe 105:445–451
14. Lakhanpal RR, Humayun MS, de Juan E Jr et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112:817–824
15. Cherfan GM, Michels RG, de Bustros S, Enger C, Glaser BM (1991) Nuclear sclerotic cataract after vitrectomy for idiopathic epiretinal membranes causing macular pucker. Am J Ophthalmol 111:434–438
16. Hsuan JD, Brown NA, Bron AJ, Patel CK, Rosen PH (2001) Posterior subcapsular ad nuclear cataract after vitrectomy. J Cataract Refract Surg 27:437–444
17. Margherio RR, Cox MS Jr, Trese MT, Murphy PL, Johnson J, Minor LA (1985) Removal of epimacular membranes. Ophthalmology 92:1075–1083
18. Michels RG (1984) Vitrectomy for macular pucker. Ophthalmology 91:1384–1388
19. Ogura Y, Takanashi T, Ishigooka H, Ogino N (1991) Quantitative analysis of lens changes after vitrectomy by fluorophotometry. Am J Ophthalmol 111:179–183
20. Panozzo G, Parolini B (2004) Cataracts associated with posterior segment surgery. Ophthalmol Clin N Am 17:557–568
21. Sawa M, Ohji M, Kusaka S et al (2005) Nonvitrectomizing vitreous surgery for epiretinal membrane long-term follow-up. Ophthalmology 112:1402–1408
22. Willis AW (1989) [Surgical treatment of idiopathic macular epiretinal membrane]. Ophtalmologie 3:29–30
23. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139:831–836
24. Faia LJ, McCannel CA, Pulido JS, Hatfield RM, Hatfield ME, McNulty VE (2007) Outcomes following 25-gauge vitrectomies. Eye 20 April 2007 [Epub ahead of print]
25. Amato JE, Akduman L (2007) Incidence of complications in 25-gauge transconjunctival sutureless vitrectomy based on the surgical indications. Ophthalm Surg Laser Imag 38:100–102
26. Holekamp NM, Shui YB, Beebe D (2006) Lower intraocular oxygen tension in diabetic patients: possible contribution to decreased incidence of nuclear sclerotic cataract. Am J Ophthalmol 141:1027–1032
27. Holekamp NM, Shui YB, Beebe DC (2005) Vitrectomy surgery increases oxygen exposure to the lens: a possible mechanism for nuclear cataract formation. Am J Ophthalmol 139:302–310
28. Cheng L, Azen SP, El-Bradey MH et al (2001) Duration of vitrectomy and postoperative cataract in the vitrectomy for macular hole study. Am J Ophthalmol 132:881–887
29. Smiddy WE, Feuer W (2004) Incidence of cataract extraction after diabetic vitrectomy. Retina 24:574–581
30. Fang SY, Deboer CM, Humayun MS (2008) Performance analysis of new-generation vitreous cutters. Graefes Arch Clin Exp Ophthalmol 246:61–67
31. Horozoglu F, Yanyali A, Celik E, Aytug B, Nohutcu AF (2007) Primary 25-gauge transconjunctival sutureless vitrectomy in pseudophakic retinal detachment. Indian J Ophthalmol 55:337–340
32. Heimann H, Zou X, Jandeck C et al (2006) Primary vitrectomy for rhegmatogenous retinal detachment: an analysis of 512 cases. Graefes Arch Clin Exp Ophthalmol 244:69–78
33. Campo RV, Sipperley JO, Sneed SR et al (1999) Pars plana vitrectomy without scleral buckle for pseudophakic retinal detachments. Ophthalmology 106:1811–1815; discussion 1816
34. Weichel ED, Martidis A, Fineman MS et al (2006) Pars plana vitrectomy versus combined pars plana vitrectomy-scleral buckle for primary repair of pseudophakic retinal detachment. Ophthalmology 113:2033–2040
35. Heimann H, Bartz-Schmidt KU, Bornfeld N, Weiss C, Hilgers RD, Foerster MH (2007) Scleral buckling versus primary vitrectomy in rhegmatogenous retinal detachment: a prospective randomized multicenter clinical study. Ophthalmology 114:2142–2154

Chapter 22

20-Gauge Sutureless Vitrectomy Trocar System

C. Claes, A. Lafeta

Core Message

- Sutureless surgery is available in 25- and 23-gauge.
- Many restrictions are present with those systems.
- 20-gauge sutureless sitrectomy offers the advantages of 20-gauge conventional vitrectomy in a sutureless setting.
- There is a steep learning curve to get acquainted with the trocars.
- It is possible to perform a fast and well-controlled sutureless vitrectomy with the 20-gauge trocar system, with good access to the periphery during vitreous base shaving.
- Almost every pathology can be treated with the use of this system.

22.1 Introduction

Over the past decade, the 20-gauge three-port pars plana vitreoretinal surgery started to trace a path towards sutureless surgery. Starting with Chen [1] and his 20-gauge self-sealing tunnels and all the complications related to them [2–7], and continuing with the smaller-gauge surgeries like the 25-gauge described by Fujii et al. [8, 9] and the 23-gauge described by Eckardt [10], we ended up with many questions on sizes, types of incisions and fluidics parameters.

At this moment, much has already been told about 25- and 23-gauge surgeries, but we can still make some comments. The use of trocars for sutureless vitrectomy was first described by Fujii et al. [8, 9]. A scleral perpendicular 25-gauge incision was used, and they suggested that the holes would be closed because they were small and the conjunctiva would also cover it, serving as a protection. But, is it safe to leave vitreous closing the wound? It might increase the risk of incarceration and secondary retinal detachment, but if this peripheral vitreous were removed, leakage would happen. In our concept, no leakage should be present after peripheral vitrectomy. Thorough peripheral vitrectomy is almost impossible with the flexible and fragile 25-gauge instruments [11] and also less controllable with its low infusion and aspiration volumes [8].

An alternative method with less, but still flexible instruments was described by Eckardt [10] using a 23-gauge system. He used a 30°–40° tunnel incision made with a stiletto, and inserted the cannulas using a blunt inserter. The fluidics are still different from the 20-gauge we have always been used to, and it still requires a whole new set of instruments what would increase surgical costs and still limit indications.

In 2007 we introduced a new 20-gauge transconjunctival trocar system (DORC, Zuidland, Holland) [12] that allows the use of the conventional 20-gauge vitrectomy in sutureless surgeries. It is analogous to the 23-gauge system; a tangential tunnel is made with a bend stiletto and the trocars are introduced with a blunt inserter in a two-step technique.

22.2 Instrumentation and Technique

The first-generation trocars were designed 3 years ago, but the intense leakage of infusion fluids through those gaping 20-gauge ports caused severe conditions of hypotony at various moments during the surgery. To solve this problem, different types of disposable valves (Fig. 22.1) were developed. The valves keep the eye sealed after retraction of the instruments, and allow the surgeon to have complete control of the intraocular pressure. In addition, they reduce the consumption of infusion fluids. They fit the distal trocar tip and are easily removable (Figs. 22.2 and 22.3). A set (Fig. 22.4) includes: (1) one infusion inserter that

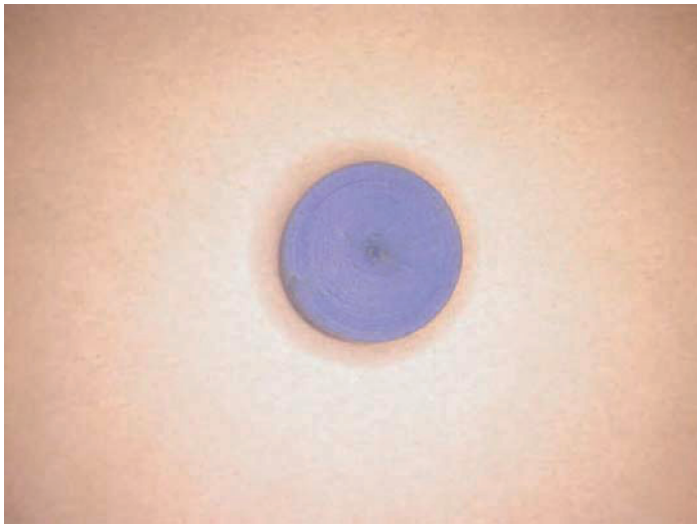


Fig. 22.1 Valve

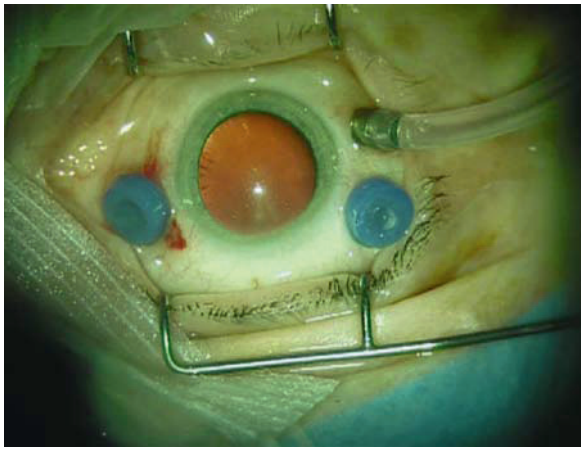


Fig. 22.2 Trocars in place with valves

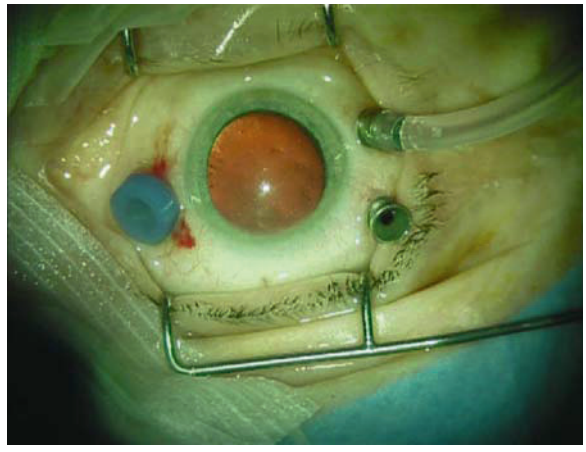


Fig. 22.3 Trocars in place without one valve

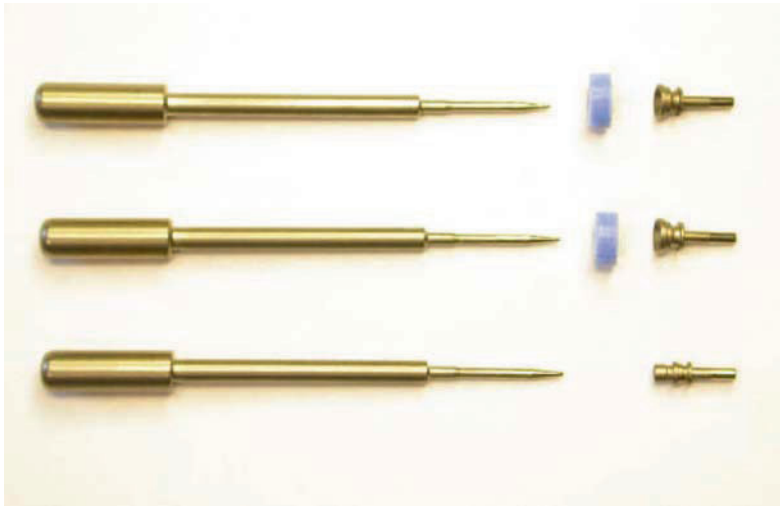


Fig. 22.4 A complete set

measures 11.5 mm, (2) one infusion trocar measuring 8.5 mm with a 4.0 mm intra-ocular extension, and (3) two blunt trocar-inserters, measuring 10.0 mm, to place the 6.5 mm trocars, also with a 4.0 mm intra-ocular extension. The external diameter for the infusion and trocars is of 1.0 mm and the internal one is of 0.9 mm. The trocars protect the entry sites from erosion, and plugs are not needed when using this system.

A second generation of trocars has recently become available, and the basic difference is the tip of the infusion line that fits in any one of the trocars.

The procedure is initiated using a 20-gauge bend stiletto (45° angle; 0.9 mm; Blumenthal; BD Visitec) that is inserted at a 10° angle through the conjunctiva, without displacement (Fig. 22.5), to create a 3.5 mm scleral tunnel (Fig. 22.6). Incisions are made radially at 3 mm from the limbus and tunnels are made limbus-parallel (Figs. 22.5 and 22.6). The infusion trocar is placed first into the inferotemporal tunnel (Fig. 22.7) and then trocars are placed at the superior quadrants (Fig. 22.8). With the second generation of trocars the infusion is easily exchanged with the superior ports, and also very efficiently exchanged for a silicone oil infusion.

Because it is less traumatic, a two-step procedure is preferred, creating first the tunnels with the stiletto and placing the trocars after. This creates better sclerotomies with slit configurations, as you can see in this intraoperative picture where the trocar was removed (Fig. 22.9), and is considered decisive for good wound closure.

At the end, the eye is pressurized at 20 mmHg and the infusion is closed before removing the two trocars from the superior quadrants. Then, the infusion is reopened, increasing the eye pressure for a few seconds with simultaneous cotton-tip massage at the entry ports in order to close the tunnels (Fig. 22.10). The massaging is continued until the absence of leakage. Since a complete vitrectomy with careful shaving of the vitreous base is our routine in all patients, after the removal

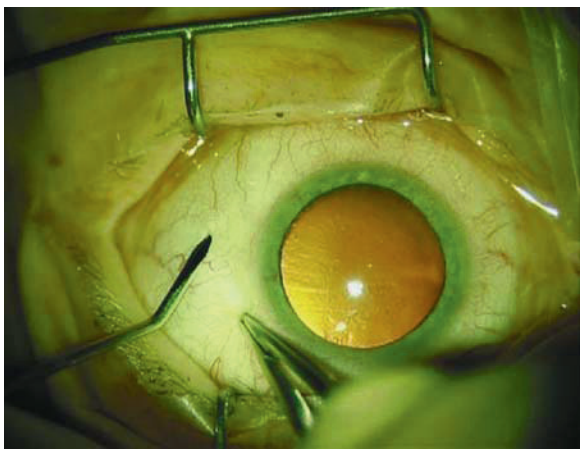


Fig. 22.5 Incision made with 20-gauge stiletto at a 10° angle through the conjunctiva

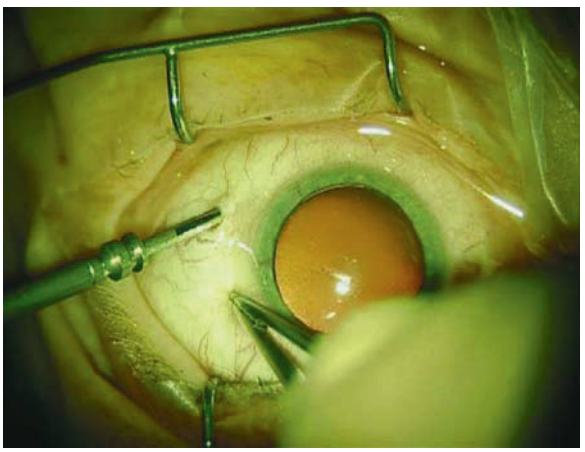


Fig. 22.7 Placement of the infusion trocar

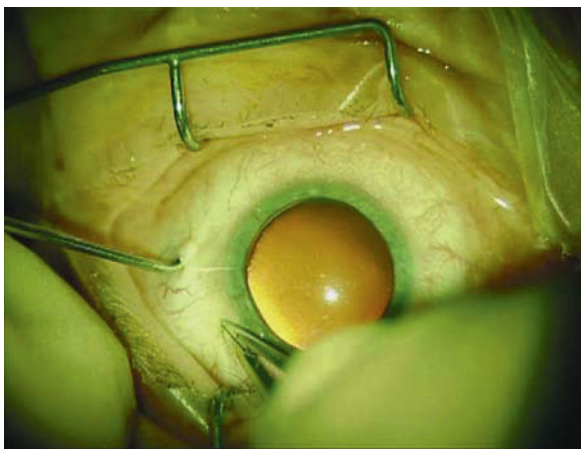


Fig. 22.6 Scleral tunnel made with stiletto

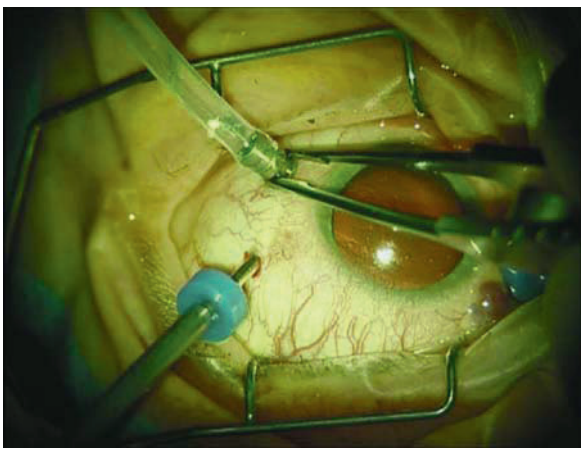


Fig. 22.8 Placement of the valved trocar

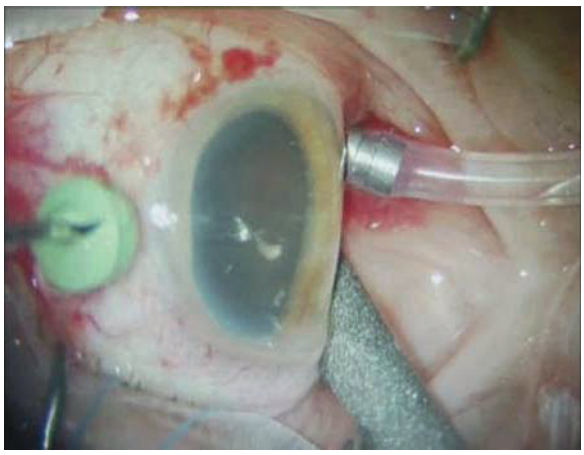


Fig. 22.9 Inside vision from incision

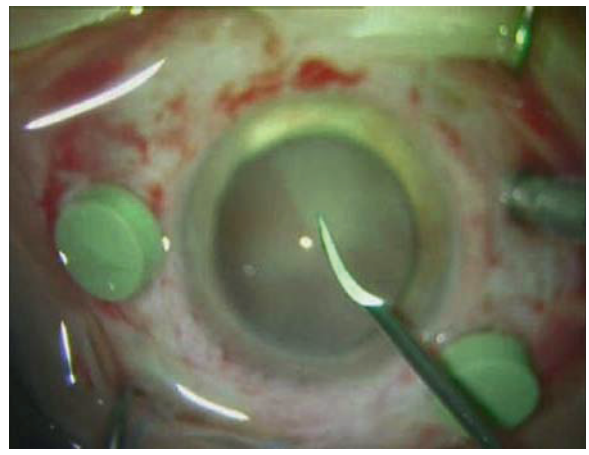


Fig. 22.11 Illuminated spatula

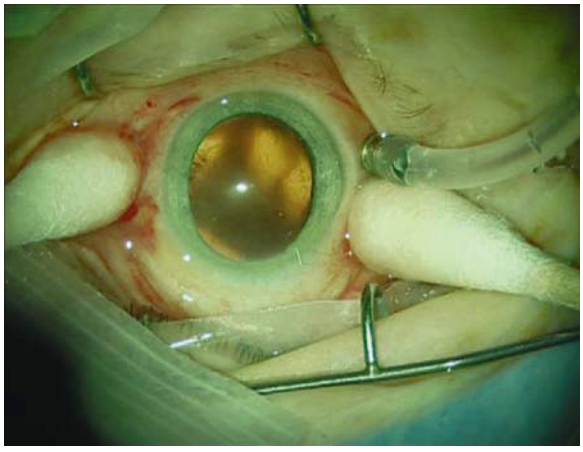


Fig. 22.10 Massage at entry ports

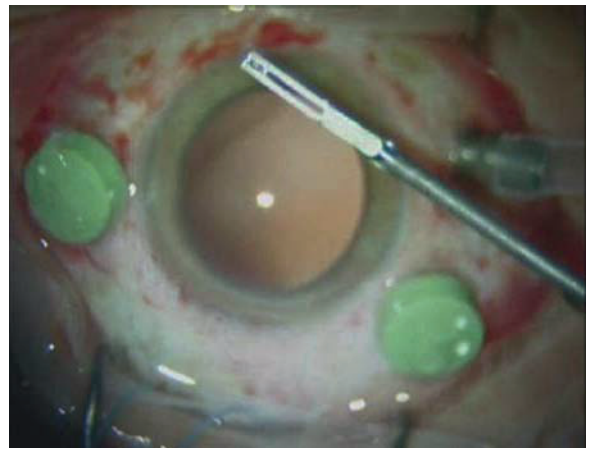


Fig. 22.12 Illuminated fork

of the first two trocars the closure of the tunnels is obtained by the apposition of their walls when the infusion pressure is raised. So, using 10° incisions, we create longer tunnels, which close easier. The last one, the infusion trocar, is removed with closed infusion and simultaneously massage at its entry port. In the case of hypotony, after the trocars removal, air is injected through the pars plana using a 3 cc syringe with a 30-gauge needle. Additional diathermy can be applied to close conjunctival buttonholes.

The surgery is performed using the regular straight or adapted curved 20-gauge instruments. Many curved instruments can easily pass through the trocars. The illuminated spatula (Fig. 22.11) is our preferred instrument to dissect membranes in difficult PVR and diabetic cases. The illuminated fork (Fig. 22.12) is very useful in preventing retinal breaks when dissecting membranes from a detached retina. As the 20-gauge lumen is big enough, by inserting a 27-gauge optic fibber through the infusion tubing and placing another one transsclerally, bimanual surgery can be performed under excellent illumination conditions. Indentation can be executed without difficulty and the periphery is easily accessible. Also, the 20-gauge system is, until now, the only one that has a specially coated phacofragmentation probe to be used with the trocars (Fig. 22.13).

22.3 Discussion: Advantages/Disadvantages

The 20-gauge system presents advantages over the 25/23 gauges, without their inconveniences. It shortens the procedure for being transconjunctival and sutureless. It also provides faster healing and less postoperative inflammation compared to other existing trocar systems.

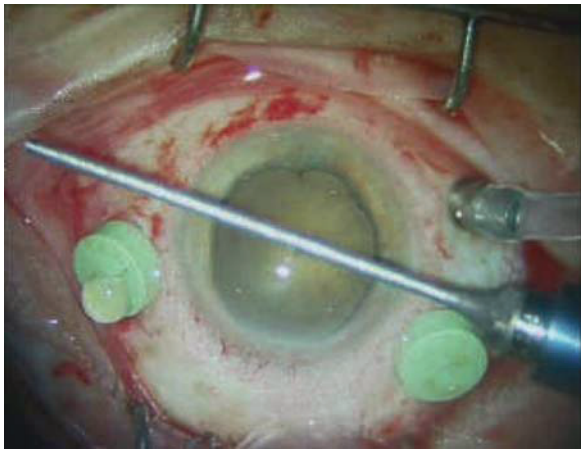


Fig. 22.13 Coated Phacofragmentor probe

The 20-gauge trocars allow the use of high-speed cutters with high infusion/aspiration volumes, easy posterior vitreous detachment creation, faster vitreous removal with easier clearance of organized vitreous, and reduced iatrogenic traction. The higher infusion volume reduces hypotony periods, giving more control to the surgeon. It is also very easy and faster to work with silicone oil compared to the smaller-gauge systems, even with 5,000 centistoke silicone oil.

The learning curve is short, since the instruments used are basically the same as in 20-gauge conventional vitrectomy; probes, scissors, forceps and many others. At first, the surgeon can experience a reduced liberty in moving the instruments inside the eye, but after doing a few procedures this minor discomfort disappears and is replaced by a very comfortable and secure feeling.

Starting with straightforward cases, after experiencing the absence of major complications, the system can now be used in almost all vitreoretinal surgeries. It provides easy access to the entire periphery with nonflexible instrumentation. Also the coated facofragmentation probe allows aspiration of the hardest cataracts from the posterior pole. The 20-gauge trocar system can be used with air, gas, BSS and silicone oil tamponade.

As the closure of the tunnels is done by the apposition of their walls, as in cataract surgery, longer tunnels are easier to close. For this perfect closure of the tunnels, it is also important that they have a linear configuration made by a stiletto and not a round opening in the sclera.

Superior postoperative patient comfort and less eye inflammation are provided by the sutureless technique. Small conjunctival hemorrhage caused by the grasping forceps used to hold the eye during the insertion of the trocars does not cause any discomfort to the patients.

We consider conjunctival displacing not to be really necessary during the trocar introduction. When using silicone oil tamponade, any difficulty in removing it from subconjunctival space can be countered with this technique at the time of trocar removal.

The possible disadvantages have already been solved with the development of new curved instruments, retractile probes for directional laser and the valves to prevent leakage. The technique has no absolute restrictions, but should be avoided in patients with thin sclera and multiple reoperations.

In the long-term follow-up, of the first 50 patients operated with the technique presented at the American Academy of Ophthalmology Meeting in 2007, we reported the absence of major complications. No intraoperative complications, endophthalmitis, choroidal detachments or retinal detachments were noted. No sutures were needed. We saw one eye with temporary hypotony, 14 with temporary ocular hypertension, two new cases of ocular hypertension and eight eyes with cataract development in a 6- to 12-month follow-up period.

22.4 Conclusion

Summarizing; in this era of sutureless surgeries, this 20-gauge trocar system with valves is a safe, comfortable and less expensive alternative to conventional 25- and 23-gauge vitrectomy. And now having experience with over 1,000 cases, we are really convinced about its safety and feasibility for almost all vitreoretinal surgeries.

Furthermore, it offers a complete set of instrumentation as does conventional 20-gauge vitrectomy, allowing the surgeon to deal with all kinds of pathologies, even dropped nucleus and macular translocation.

Summary for the Clinician

- The 20-gauge trocar system for sutureless vitrectomy is a new and easy way to perform vitrectomies.
- Care has to be taken to select patients with good scleral tissue in the pars plana area.
- It is important to leave normal tension at the end of the procedure.
- Patient comfort and healing process has improved a lot compared to sutured technique.
- Thanks to adapted instruments and valved trocars, sutureless surgery can be done in almost every vitreoretinal pathology.

References

1. Chen JC (1996) Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 114:1273–1275
2. Milibak T, Suveges I (1998) Complications of sutureless pars plana vitrectomy through self-sealing sclerotomies [letter]. Arch Ophthmol 116:119
3. Kwok AK, Tham CC, Lam, DS, et al (1999) Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 127:731–733
4. Schmidt J, Nietgen GW, Briedan S (1999) Selbstverchliessende, nahtlose Sklerotomie zur Pars-plana-Vitrektomie. Klin Monatsbl Augenheilkd 215:247–251
5. Jackson T (2000) Modified sutureless scleroromies in pars plana vitrectomy [letter]. Am J Ophthalmol 129:116–117
6. Assi AC, Scott RAH, Charteris DG (2000) Reversed self-sealing pars plana sclerotomies. Retina 20:689–692
7. Rahman R, Rosen PH, Riddell C, Towler H (2000) Self-sealing sclerotomies for sutureless pars plana vitrectomy. Ophthalmic Surg Lasers 31:462–466
8. Fujii GY, de Juan E Jr, Humayun MS et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109:1807–1812
9. Fujii GY, de Juan E Jr, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109:1814–1820
10. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25:208–211
11. Inoue M, Noda K, Ishida S, Nagai N et al (2004) Intraoperative breakage of a 25-gauge vitreous cutter. Am J Ophthalmol 138(5): 867–869
12. Lafetá AP, Claes C (2007) Twenty-gauge transconjunctival sutureless vitrectomy trocar system. Retina 27:1136–1141

Chapter 23

20-Gauge Non-Cannulated Sutureless Vitrectomy

D.R. Chow, D. Polya

Core Message

- Advantages of sutureless non-cannulated 20-gauge vitrectomy vs 23- and 25-gauge vitrectomy:
  - Stiffest instruments with best access to retinal periphery (20-gauge: 130 g to displace 0.12. 23-gauge: 35 g to displace 0.12. 25-gauge: 14 g to displace 0.12). Thus, 20-gauge is 4× stiffer than 23-gauge and 10× stiffer than 25-gauge
  - Brightest ancillary light sources (chandeliers, lighted instruments)
  - Capable of widest range of FLOW rates
  - No instrumentation limitations (there is no 23- or 25-gauge fragmetome)
  - Most economical
- Disadvantages of sutureless non-cannulated 20-gauge vitrectomy vs 23- and 25-gauge vitrectomy:
  - Instrument exchanges can be difficult
  - Non-displacement of conjunctiva over wounds

23.1 Introduction

As an early and enthusiastic proponent of 25-gauge vitrectomy, it is amazing to me that a short 3 years later I am writing a chapter on 20-gauge sutureless vitrectomy for this textbook! But, as I found out on my move to a new hospital and city a few years ago, one issue which has become too frequent a problem for many of us as surgeons is that our hospitals are no longer willing to buy each and every new technology which is released for our operating rooms. Having done about 90% of all my cases using 25-gauge technologies before moving, I was faced with having to revert to 20-gauge vitrectomy due to the lack of 25-gauge instrumentation at the new hospital. The transition back to 20-gauge technology was made more palatable by the obvious advantages in instrument stiffness and access to the retinal periphery with 20-gauge instruments and my adaptation of a sutureless 20-gauge technique. The notion of 20-gauge sutureless vitrectomy is not a new one, with multiple previous authors having reported on this over the last decade (Chen, Theelen, Yeshurun, Sebag, Claes, Gotzaridis). In fact, as a resident I was exposed to one of the early surgeons who attempted a 20-gauge sutureless technique, Dr John Chen, who used a crescent blade to create a scleral tunnel after doing a conjunctival peritomy. During my transition back to 20-gauge vitrectomy, I also witnessed another variation on a 20-gauge sutureless technique by Dr Mikael Sebag, who presented a variation of a technique described by Dr Theelen, which involved the creation of an "X incision" to aid in sclerotomy closure. Based on these experiences, I converted to a 20-gauge sutureless technique which I have now had the chance to perfect and enhance over 300+ cases.

23.2 My Early Experience

Beginning in March of 2006, I attempted 20-gauge sutureless vitrectomy in an initial 35 cases. In these initial cases, I created angled sclerotomies using the standard 20 g MVR blade that comes in the pack, and entered transconjunctivally at an angle of about 20–40° (Fig. 23.1). At the end of the procedure, an air–fluid exchange was performed in most cases. This was followed by massaging the superior lip of the wound back into place (using an inferior to superior massaging movement) over a 10–20 s interval. If at this point the wound was found to be still leaking, an "X incision" was created. This involved taking the MVR blade again and creating a counter-angled incision back through the plane of the initial sclerotomy (Fig. 23.2). If the wound was found to be still leaking following the "X incision", a 7–0 vicryl suture was used to secure the wound. Using this approach, I made the following initial observations:

1. *Wound Closure*: 40% of all sclerotomies spontaneously closed, 47% required an "X incision" for closure, and

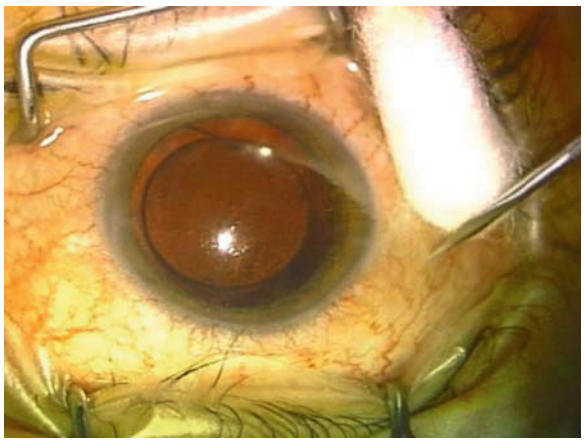


Fig. 23.1 Early experience: 20 g MVR blade creates a sclerotomy at an angle of 20–40°

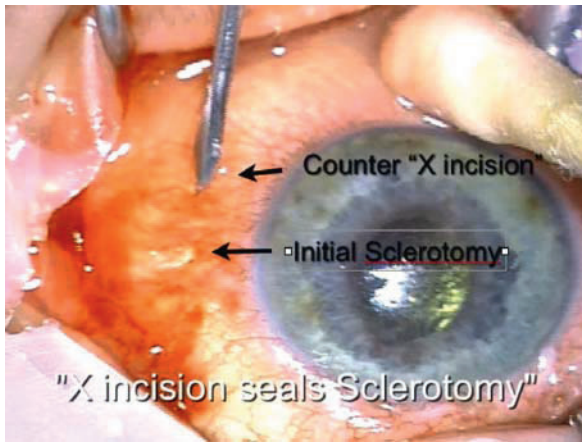


Fig. 23.2 "X incision": 20 g MVR blade is taken back across original sclerotomy to create an internal wedge

14% required a suture. It was noted that the inferior sclerotomy was most likely to spontaneously seal (83%), which was almost certainly the result of no wound manipulation since this sclerotomy was the infusion cannula site in all cases.

2. *Range of Applicability*: the technique was applicable to all pathologies with no limitations. The advantages of using 20-gauge technologies was immediately evident in the stiffness of the instrumentation allowing access to the periphery, the lack of limitations in products available, and the grasping power of the forceps for macular surgery. It was noted for more complex pathologies such as PVR Retinal Detachment and Tractional Diabetic retinal detachment, during which multiple instrument exchanges occurred with the use of ancillary instrumentation, that the need for sutures was higher than for cases with pure macular pathology (Fig. 23.3). This confirmed what we would expect, that the amount of wound manipulation during the procedure would ultimately play a role in the ability to maintain the wound as self-sealing.
3. *Complications*: intraoperatively, it was noted that 4% of the cases were complicated by the infusion line either displacing and falling out of the eye or moving in to the suprachoroidal space. These frustrating complications led us to replace the standard 4 mm infusion cannula that comes in the vitrectomy pack with a 5 or 6 mm self-retaining infusion cannula. After converting to the longer infusion cannula that does not move, these complications stopped occurring (Fig. 23.4). Postoperatively, the rate of hypotony (<5 mm Hg) was found to be 2%, with a rate of retinal detachment of 2%.
4. *Concerns*: the most difficult part of the technique was found to be the instrument exchanges, which required finding the conjunctival opening and then sliding the instrument through the angled wound into the eye. This was particularly tricky when the conjunctiva ballooned up with fluid or blood (a problem which became less frequent as the incision angle was flattened). In some cases, the conjunctival incision was enlarged to allow visualization of the sclerotomy for the instrument exchanges. Over time, one of the tricks we learnt to make the instrument exchanges easier was to use the edge of the light pipe to catch the lip of the superior wound and then slide the instrument along the plane of the incision. The other concern we noted was the lack of displacement of the conjunctiva over the wounds, which created a concern about potential endophthalmitis.

Summary for the Clinician

- The inferior sclerotomy is most likely to spontaneously seal (83%), which is almost certainly the result of no wound manipulation since this sclerotomy is the infusion cannula site.
- The advantage of using 20-gauge technologies is immediately evident in the stiffness of the instrumentation.
- The amount of wound manipulation during the procedure would ultimately play a role in the ability to maintain the wound as self-sealing.
- Postoperatively, the rate of hypotony (<5 mm Hg) was found to be 2%, with a rate of retinal detachment of 2%.
- The most difficult part of the technique is the instrument exchanges, which require finding the conjunctival opening and then sliding the instrument through the angled wound into the eye.

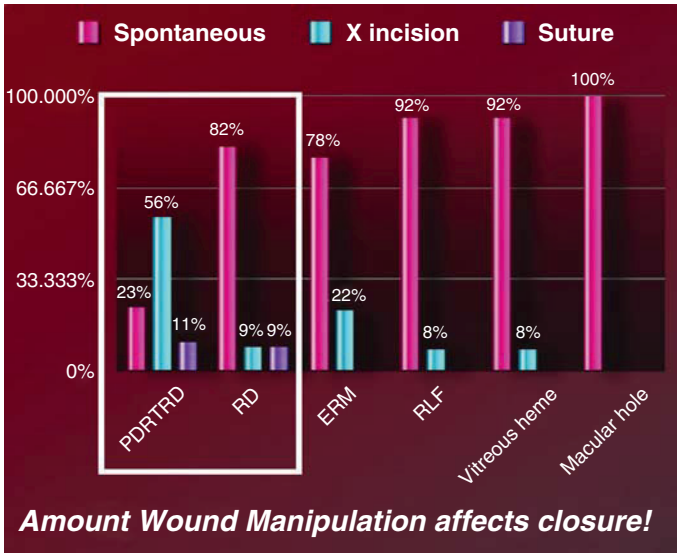


Fig. 23.3 Closure rate of sclerotomies as a function of disease pathology

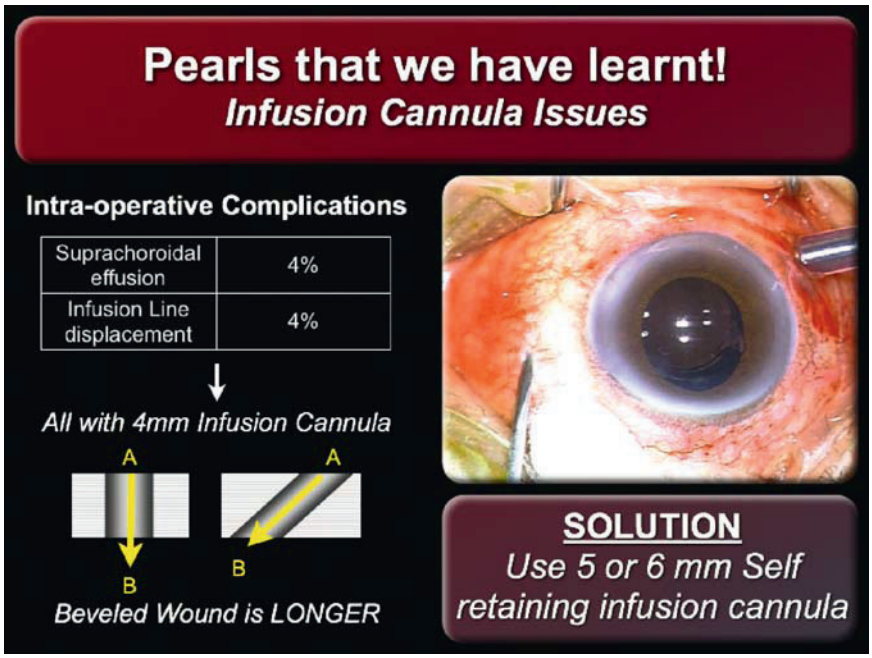


Fig. 23.4 Early intraoperative complications were related to usage of 4 mm infusion cannula. Use of a 5–6 mm self-retaining infusion cannula eliminates complications

23.3 Evolution into "Longer and Flatter Wounds"

Following these initial 35 cases, we gained increasing confidence in the technique and started to make some alterations in our wound construction. The most notable alteration we made was to progressively flatten the angle of entry on the sclerotomies, to the point where at the beginning of creating the sclerotomy the blade was virtually flat on the sclera (angle of incidence 5–10°) (Fig. 23.5). By flattening the angle of entry we also noted that our wounds became longer. We also converted to a 6 mm self-retaining infusion cannula, and took care on instrument exchanges not to macerate the edges of the

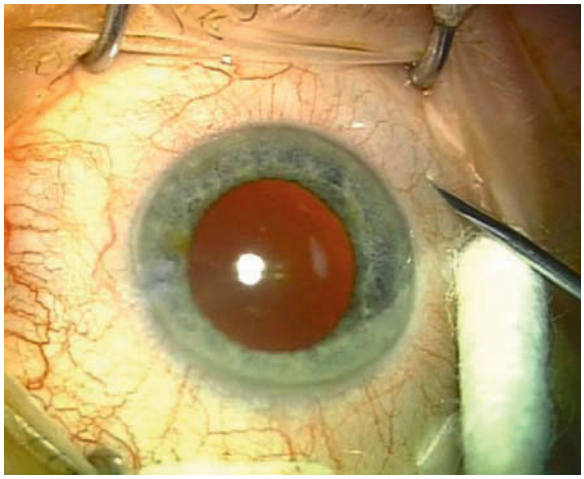


Fig. 23.5 Later experience: 20 g MVR blade creates a longer sclerotomy at an angle of 0–10°

sclerotomy. With these modifications over the next 51 cases, we noted that 81% of all sclerotomies spontaneously sealed, that the need for "X incisions" dropped to 16% from 47%, and that the need for sutures dropped to 4% from 14%. The intraoperative complications related to the infusion cannula disappeared.

23.4 Our Most Recent Experience

Since the initial 86 cases we reported, we have continued to use this 20-gauge sutureless technique, and recently looked at our data, which show a total of 294 cases performed between March of 2006 and October of 2007. The median follow-up in this group of patients was 8 months. The indications for surgery in this group were; retinal detachment 29%, epiretinal membrane 25%, macular hole 11%, vitreous hemorrhage 10%, retained lens fragments 8%, diabetic tractional retinal detachment 6%, misc 9%. 91% of the cases involved the use of ancillary instrumentation (66% endolaser, 49% forceps). The following observations were made:

1. *Wound Closure*: 81% of all sclerotomies were found to spontaneously seal at the end of surgery. These data replicated our experience for the initial 86 cases, and confirmed that the use of a longer flatter wound was indeed able to create a self-sealing wound about 80% of the time. The use of "X incisions" dropped to 7%, mainly because of our increasing ability to create self-sealing wounds with better wound construction and maintenance. The need for sutures actually increased to 11% (Fig. 23.6). As we analyzed this, we found that this was largely due to allowing the 1st year fellows to perform this technique at the beginning of their training. This confirmed to us that there is indeed a learning curve to creating the incisions, but that it is a technique that can be adopted by novice retina surgeons and still be able to be *sutureless* ~90% of the time!
2. *Complications*: the rate of intraoperative complications fell to less than 0.3%. Postoperatively, the rate of hypotony (<5 mmHg) was found to be 2.2%, the rate of retinal detachment 5.4%, and the rate of endophthalmitis 0%. Overall, we are quite comfortable with these complication rates, and feel they are comparable to what we experienced with 25-gauge vitrectomy techniques. The only complication which became more prevalent over time was the rate of retinal detachment, which increased to 5%. On analyzing these data, we found that this reflected an increasing use of the technique in PVR retinal detachments, not just primary recent retinal detachments. We found that our rate of anatomic reattachment (single operation success rate) in all the retinal detachments was 90%, a success rate we were comfortable with to here

23.5 Tips for Performing 20-Gauge Non-Cannulated Sutureless Vitrectomy

23.5.1 Entry

1. A cotton-tip swab is typically used to stabilize the eye — we prefer this to minimize the risk of conjunctival trauma. We sometimes alter the location: we stabilize the eye with the cotton tip to gain maximum stabilization of the eye during this step. A scleral stabilizer can also be used for this purpose, and there are numerous different stabilizers which have been developed, most of which incorporate a scleral marker as well. I have developed a Chow Marker for 20/23-gauge sutureless vitrectomy which features cleats on the bottom of the footplate and an X design with marker to facilitate entry on either side of the eye (Fig. 23.7).
2. The standard 20 g MVR blade in the pack is used to create the inferotemporal sclerotomy first. For all the sclerotomies, the initial entry angle is kept at virtually 0–5°. The blade is almost flat on the conjunctiva/sclera, it is lifted minimally to create the initial entry wound and then driven transconjunctivally and intrasclerally until the widest part of the MVR blade has already entered the sclera before the blade is elevated to enter the vitreous cavity. The wounds are made in a standard orientation, perpendicular and 3–4 mm posterior

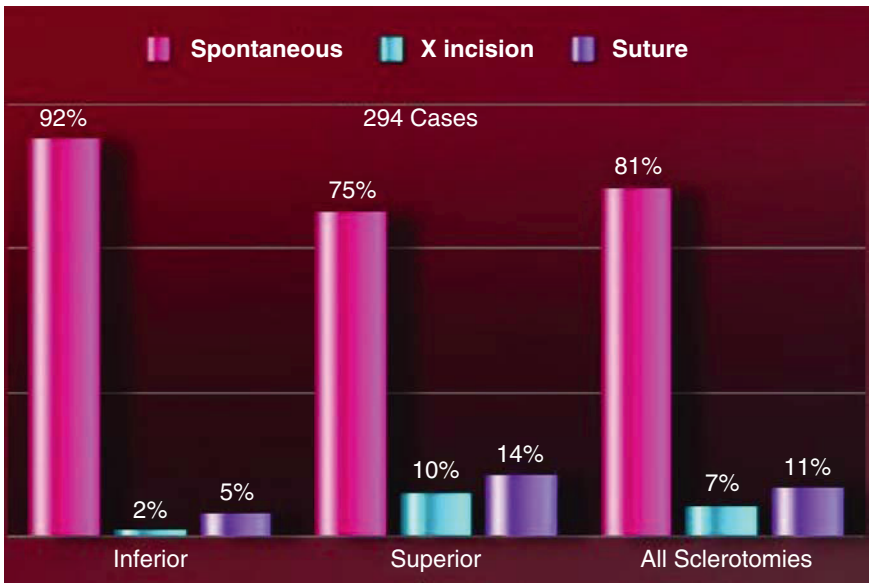


Fig. 23.6 Closure rate of sclerotomies in 294 cases

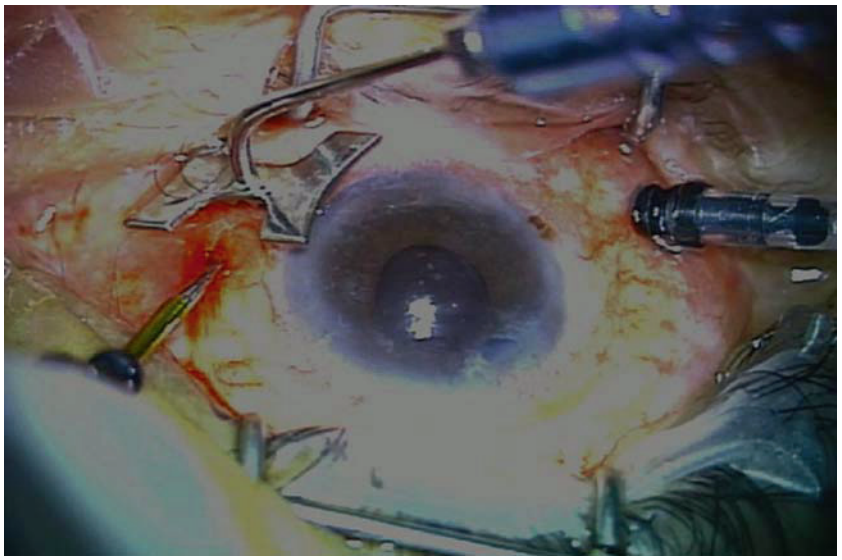


Fig. 23.7 Chow "X" scleral marker (Synergetics) for 20-gauge (or 23-gauge) sutureless vitrectomy

to the limbus. Once the blade is removed, a 5 or 6 mm infusion cannula, ideally self-retaining, is inserted into the sclerotomy and taped into place once the tip is seen internally free of the pars plana/choroid. The two superior sclerotomies are then created in the same manner. Care should be taken to enter transconjunctivally, avoiding conjunctival vessels. Subconjunctival hemorrhages, besides being an aesthetic compromise, are more importantly an obstacle to instrument exchanges.

23.5.2 Instrument Exchanges

3. During the procedure, instrument exchanges can be tricky particularly during the learning curve. It is important to identify the conjunctival opening first then the edges of the sclerotomy. After passing through the conjunctival opening, the light pipe is often used to catch the edge of the superior lip of the sclerotomy and gain access to the sclerotomy. The light pipe is then

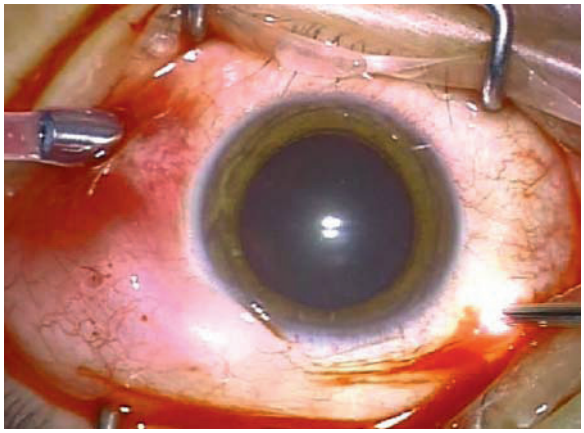


Fig. 23.8 Conjunctival ballooning can make instrument exchanges difficult

redirected to match the orientation of the sclerotomy and passed into the eye. The instrument exchanges often get easier as the case progresses, due to stretching of the lips of the sclerotomy. Care should be taken to avoid excessive manipulation of the wounds, and to try to enter along the orientation of the sclerotomies. These steps will increase the chances of maintaining a self-sealing wound. A step which can be added if necessary is the use of dye to stain the conjunctiva in the area of the entry. This highlights the conjunctival opening. If a subconjunctival hemorrhage is encountered or more frequently if the conjunctiva starts to balloon up obscuring the view of the sclerotomy, then a conjunctival cutdown can be performed to allow visualization of the sclerotomy (Fig. 23.8). Either a full conjunctival peritomy can be created, or the conjunctival opening can just be enlarged in a radial direction. The later is often preferable, since it will often not require closure at the end of the procedure.

23.5.3 Closure

4. At the end of the procedure an air–fluid exchange is usually performed. The reasons for this are two-fold. First, the surface tension of the air–tissue interface at the wound may aid in the closure of the wound and minimize hypotony, something Steve Charles has long been an advocate of, but which we were unable to demonstrate in a previous 25-gauge series. Second, and more importantly to us, it aids us in determining at the end of surgery whether the sclerotomy is indeed self-sealing. By dripping BSS on the wound at the end of surgery, we are able to tell if the wound is leaking by the presence or absence of air bubbling out of the wound. On exiting the eye for the last time, we often increase the air pressure up to 60 for 10–20 s to push the wound edges together, while simultaneously massaging the superior lip of the sclerotomy back into place. An inferior to superior massaging movement is used to push the superior lip of the sclerotomy back into place. My assistant will drip BSS on to the eye during this period to test the integrity of the wounds. If the wounds appear to be still leaking after 10–20 s, continue the massaging process, as most of these wounds will often become self-sealing with a little more time. Patience is often necessary! If after an extended period of time the wound is not closed to our satisfaction, then an X incision will often be attempted in the manner previously described. Finally, if this is

Summary for the Clinician

- For a better wound construction
  - Flatten the angle of entry on the sclerotomies to the point where at the beginning of creating the sclerotomy the blade is virtually flat on the sclera (angle of incidence 5–10°). The wound becomes longer.
  - Convert to a 6 mm self-retaining infusion cannula.
- There is a learning curve to creating the incisions, but it is a technique that novice retina surgeons can adopt and still be able to be sutureless ~90% of the time.
- Entry step: a cotton-tip swab is typically used to stabilize the eye.
- Entry step: the standard 20 g MVR blade in the pack is used to create the inferotemporal sclerotomy first. The blade is driven transconjunctivally and intrasclerally until the widest part of the MVR blade has already entered the sclera before the blade is elevated to enter the vitreous cavity.
- Subconjunctival hemorrhages are an obstacle to instrument exchanges.
- Instrument exchanges: it is important to identify the conjunctival opening first, then the edges of the sclerotomy.
- Closure step: at the end of the procedure, an air–fluid exchange is usually performed for two reasons
  - The surface tension of the air–tissue interface at the wound may aid in the closure of the wound and minimize hypotony.
  - It aids in determining at the end of surgery whether the sclerotomy is indeed self-sealing, by dripping BSS on the wound.

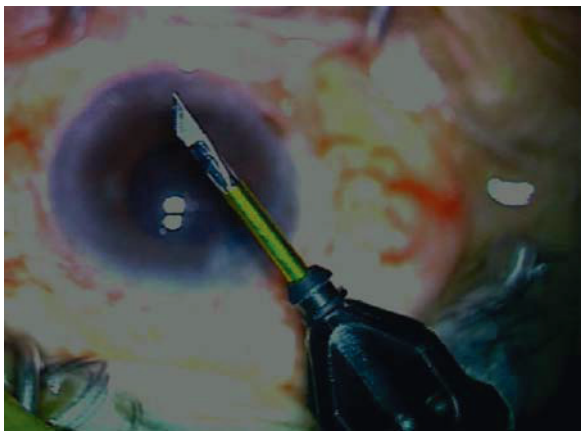


Fig. 23.9 20-gauge valved trocar/cannula system (synergetics)

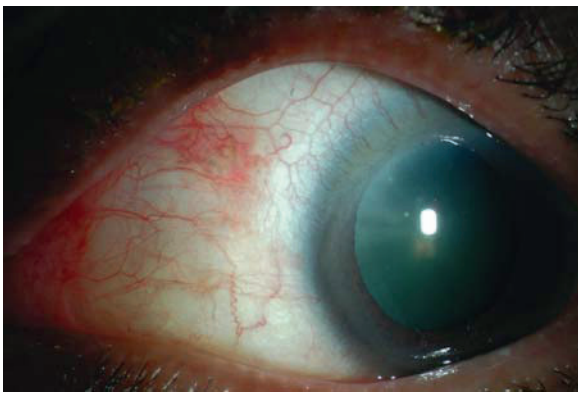


Fig. 23.10 Day 1 postop 20-gauge non-cannulated sutureless vitrectomy

unsuccessful then a 7–0 vicryl suture will be used to secure the wound. We have not been routine advocates of subconjunctival antibiotics, but see the rationale for this, particularly with a non-displaced conjunctival opening to separate the conjunctiva away from the sclerotomy. We do advocate routinely removing any vitreous prolapsed into the sclerotomy.

23.6 20-Gauge vs 23-Gauge vs 25-Gauge Vitrectomy: Which One?

Based on our experiences, we are quite comfortable in stating that 20-gauge vitrectomy can be performed in a sutureless manner using a non-cannulated technique. In comparison to the 23- and 25-gauge cannulated techniques, we think 20-gauge vitrectomy offers surgeons the stiffest instruments and easiest access to the retinal periphery, the widest range of instrumentation with a fragmetome, the brightest lights, best fluidics and forceps with strongest grasping abilities. In addition, 20-gauge vitrectomy is the most economical, with the instrumentation already stocked in your OR and vitrectomy packs that cost about 25% less per procedure than 23-gauge or 25-gauge packs.

23.7 Sutureless 20-Gauge Vitrectomy: Cannulated or Non-Cannulated?

Two of the main concerns with the technique that I have described are the difficulty with instrument exchanges and the lack of conjunctival displacement, which might increase the risk of endophthalmitis. The obvious solution to both of these is of course to develop a 20-gauge vitrectomy cannula system. Carl Claes, in conjunction with DORC, has released just such a system which is valved, and we have been working with Carl Awh and Synergetics on another variation of such a system (Fig. 23.9). Having used the 20-gauge cannula system from Synergetics, which features a new blade design, it is indeed much easier to do instrument exchanges, and conjunctival displacement is again possible, both of which are nice advantages of a cannulated system. There are some concerns, however, with a cannulated system which are not encountered with a non-cannulated system. First, if the cannulas are not valved, then the flow of fluid through the cannula on instrument exchanges is significant, with a continuous gush of fluid pouring out of the eye. This can be limited if you use cannula plugs, but this adds an extra step to the surgery. Valved cannulas would certainly seem to be the way to go, but the catch here is developing a valve which allows easy entry and removal of our full range of instrumentation while still functioning as a valve. Second, the 20-gauge cannulas and trocar by necessity need to create a wound that is larger than our typical 20 g MVR blade, to accommodate the cannula and our standard instrumentation. As such, the wound is bigger. Third, cannulas by their nature, limit the usage of any curved instrumentation — so if you like horizontal scissors you will have to let them go. This is not necessary with our non-cannulated technique. In my opinion there are clearly advantages of each scenario — probably the greatest advantage in my opinion of a cannulated system is that the cannula itself protects the wound from manipulation on instrument exchanges, which may allow for better wound integrity and a self-sealing wound.

In conclusion, we think that 20-gauge vitrectomy can be performed in a sutureless manner without a trocar/cannula system, and that the technique offers many advantages to vitreoretinal surgeons while still allowing for an aesthetic outcome similar to 23-gauge and 25-gauge vitrectomy (Fig. 23.10). Before relegating 20-gauge vitrectomy to the history books we challenge you to give the technique a try, and pay attention to the advantages offered by the larger instrumentation.

Chapter 24

Small-Gauge Vitrectomy: Which Calliper Should We Choose and When?

S. Rizzo, F. Genovesi-Ebert, F. Patelli

Core Message

- Both 25- and 23-gauge sutureless vitrectomy techniques decrease surgical trauma and improve patients' postoperative comfort.
- The disadvantages of the 25-gauge system, however, include pliable instruments and slower gel removal time.
- The 23-gauge system provides faster speed of vitrectomy and the instruments have stiffer shafts, but it requires a larger incision.
- Therefore 25-gauge is suitable in macular surgery and for less complex cases, while 23-gauge allows the performance of complex retinal detachment. Patients suffering from more severe pathologies with poor visual recovery are still managed with 20-gauge technology.

24.1 Small-Gauge Vitrectomy: Current Opinions

Both small-gauge vitrectomy systems are safe and effective, and help to reduce operating time by eliminating suturing. In addition they provide numerous potential advantages over traditional 20-gauge vitrectomy, including faster wound healing, diminished conjunctival scarring, reduced postoperative astigmatic changes, faster visual recovery and quicker patient rehabilitation [1]. We compared sutureless vitrectomy in the treatment of idiopathic epiretinal membranes (ERM) with a standard 20-gauge vitrectomy system [2]. Postoperative patient discomfort and intraocular inflammation were significantly reduced in the 25-gauge group. Moreover, in the 25-gauge group the improvement in vision was more rapid.

A literature research conducted on a cluster of different medical databases and focused on the safety and efficiency of 20-, 23- and 25-gauge vitrectomy systems [3] showed that there was no significant difference in postoperative complications following 25-gauge and 20-gauge vitrectomy.

25-gauge instruments, however, show greater flexibility. For this reason a certain learning curve is required and the range of application is limited.

Moreover the flow rate is greater dealing with 20- and 23-gauge compared to 25-gauge, thus making the 25-gauge surgery time longer.

Due to its greater stiffness and larger diameter, the 23-gauge system — while still allowing a transconjunctival access — may overcome the disadvantages of the 25-gauge system.

However, 23-gauge vitrectomy systems do have important limitation that they share with 25-gauge.

Currently there is no fragmatome smaller than 20-gauge, and removal of larger nuclear pieces needs one 20-gauge sclerotomy.

24.2 25-Gauge Selective Indications

We currently use 25-gauge for the treatment of all macular pathologies, including epiretinal membranes and macular holes, where it has been demonstrated to be safe and efficient [2, 4].

25-gauge is suitable for vitreous opacity, mild vitreous hemorrhage and proliferative diabetic retinopathy, and we also use it for dealing with cataract surgery complications.

Advances in 25-gauge pars plana vitrectomy (PPV) instrumentation have enabled expanding indications for 25-G PPV: moreover 25-G PPV with SO tamponade has been demonstrated safe and efficient [5]. Although it has also been suggested for the surgical management of complex vitreoretinal disease, in these cases we usually prefer 23-G PPV.

However, the use of silicone oil may lead to leakage of the sclerotomies, and thus may sometimes necessitate additional suturing.

However, if unplanned silicone oil tamponade is required, we use the Charles' technique: enlarging one sclerotomy to 20-gauge, instilling oil and then placing an additional suture.

24.3 23-Gauge Selective Indications

The 23-gauge vitrectomy may overcome 25-gauge disadvantages. Thanks to its more efficient vitrectomy cutter and powerful fiberlight, the 23-gauge system allows a wider range of application and may be used instead of conventional 20-G PPV in most cases.

Currently we use 23-gauge in macular hole (that is borderline indications overlapping with 25-gauge) but mainly we choose 23-gauge for the treatment of complicated retinal detachment requiring standard or heavy silicone oil endotamponade, and for complications of severe diabetic retinopathy. Silicone oil tamponade has been demonstrated in fact to be a feasible option in conjunction with 23-gauge transconjunctival sutureless vitrectomy in the treatment of complex retinal detachment [6].

Finally, using topical anaesthesia, vitrectomy procedures were performed more easily with 23-gauge than with 25-gauge instruments [7], as the 23-gauge tools are stiffer and can control better undesired eye movements allowing the necessary eye pivoting.

24.3 Conclusions

At present any disease can be managed with any calliper. The characteristics for each gauge size in V-R surgery are summarized in Table 24.1 [8]. But the main concerns are the velocity of the surgery, the efficiency of the vitrectomy cutter and the true advantages. So in our opinion we should have all the three calliper options available. The only drawback could be that in a small hospital the use of all the three options may lead to economic complications as well to difficult management of the supply room, of the operatory room and of the surgery list. Indeed, today there is still a role for standard 20-G PPV. Less invasive small-gauge callipers offer in fact a great advantage in patients with a good visual prognosis, as recovery and visual rehabilitation are faster. On the other hand, in eyes with extreme pathologies such as advanced PVR and severe trauma, the poor visual prognosis make the effort fruitless because the quicker recovery is pointless; therefore, it is better to choose the more efficient 20-gauge vitrectomy in these circumstances.

Table 24.1 Characteristics for each gauge size

	20-gauge	23-gauge	25-gauge
Size	0.9 mm	0.7 mm	0.5 mm
Need for suture	Yes	No literature data	No
Angled instruments	Yes	No literature data	No
Instr. Stiffness (grams per 4 mm)	130 g	35 g	14 g
Intraocular maneuvers	Easy	Easy	Not easy
Flow rate	High	High	Low
Oil injection	Easy, all oil viscosities	Slow, all oil viscosities	Very slow, only 1,000 cS
Vitrectomy time	Fast	Fast	Slow
Post-op inflammation	Yes	Poor	Poor
Post-op astigmatism	Yes	No	No
Risk of post-op hypotony	No	No literature data	Low
Risk of endophthalmitis	Very low	No literature data	No literature data
Use of fragmetome	Yes	No	No
Change of cannula position	Cumbersome	Easy	Easy
Vitreous incarceration	No	Possible	Possible
Endo-illumination	Good	Good	Good with chandelier
Oil removal	Fast	Slow	Very slow
Use of endolaser	Yes	Yes	Yes
Vitrector cutting rate	Up to 2,500 cpm	Up to 2,500 cpm	Up to 1,500 cpm

Summary for the Clinician

- Today we can treat any pathology with any calliper, but using all three options may be a costly and difficult to manage process.
- 25-gauge is indicated for the treatment of all macular pathologies, vitreous opacity, mild vitreous hemorrhage, proliferative diabetic retinopathy and cataract surgery complications.
- We choose 23-gauge for the treatment of complicated retinal detachment requiring standard or heavy silicone oil endotamponade, and for complications of severe diabetic retinopathy.
- 20-gauge is still better for the treatment of eyes with poor visual prognosis, such as advanced PVR and severe trauma.

References

1. Kellner L, Wimpissinger B, Stolba U et al (2007) 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. Br J Ophthalmol 91(7):945–948. Epub 3 Jan 2007
2. Rizzo S, Genovesi-Ebert F, Murri S et al (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol 244(4):472–479. Epub 19 Jan 2006 PMID: 16421743
3. Augustin AJ, Offermann I (2007) Scope and limititions of innovative vitrectomy systems. Klin Monatsbl Augenheilkd 224(9):707–715
4. Rizzo S, Belting C, Cresti F, Genovesi-Ebert F (2007) Sutureless 25-gauge vitrectomy for idiopathic macular hole repair. Graefes Arch Clin Exp Ophthalmol 245(10):1437–1440. Epub 15 March 2007
5. Riemann CD, Miller DM, Foster RE, Petersen MR (2007) Outcomes of transconjunctival sutureless 25-gauge vitrectomy with silicone oil infusion. Retina 27(3):296–303
6. Oliveira RB, Reis PA (2007) Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. Retina 27(8):1054–1058
7. Theocharis IP, Alexandridou A, Tomic Z (2007) A two-year prospective study comparing lidocaine 2% jelly versus peribulbar anaesthesia for 25 G and 23 G sutureless vitrectomy. Graefes Arch Clin Exp phthalmol 245(9):1253–1258. Epub 7 March 2007
8. Patelli F (2007) Preferences for gauge selection in vitreoretinal surgery, ASRS Meeting Palm Springs, poster

Chapter 25

Current Clinical Data and Future (for Small-Gauge Vitreoretinal Surgery)

S. Binder, B. Wimpissinger, L. Kellner

25.1 Introduction

During the last decade, pars plana vitrectomy has been passing through significant changes. Self-sealing sclerotomies with smaller-gauge instruments were first described by Chen et al. [1] in 1996, and the 25-gauge sutureless transconjunctival system for pars pana vitrectomy has been in use since 2002. In 2005, Eckardt [2] introduced the 23-gauge system, which although representing a more challenging technique than 25-gauge has rapidly been used by numerous surgeons. The value of these new technologies is now discussed worldwide, mainly to clarify whether advantages do outweigh disadvantages, and if the gain for the patient is constant and important. As knowledge can only be obtained and conclusion be drawn by looking at scientific data, in this article we summarize the current clinical data of both 25- and 23-gauge literature, and organize them according to the questions and topics mainly debated.

A search of literature was performed from the first publication in 1990 until January 2008.

25.2 25-Gauge Vitrectomy

Sixty one original articles dealing with 25-gauge instrumentation for pars plana vitrectomy were found in PubMed. It includes only two randomised trials [3, 4], 24 prospective studies [5–29], and 24 retrospective studies [30–53]. Furthermore, five case reports [54–58], four reviews [59–62], two device reports [63, 64] and five letters to the editor [65–96] deal with this topic.

25.2.1 Time for Surgery

In 2002, Fujii et al. [14] introduced the 25-gauge transconjunctival sutureless vitrectomy system. This in vitro experimental and comparative interventional study investigated infusion and aspiration rates and surgical time of 25-gauge and 20-gauge vitrectomy. The authors concluded that 25-gauge vitrectomy may effectively reduce the time needed for surgery in selected cases. In accordance with those findings, four other studies [7, 14, 17, 18] recorded a significantly shorter surgical time when comparing the new technology to conventional 20-gauge vitrectomy. Moreover, reviews of literature featuring the development of 25-gauge transconjunctival sutureless vitrectomy [60] in particular, and the development and status quo of the whole spectrum of pars plana vitrectomy [62], summarize the surgical procedure to be faster than using conventional 20-gauge vitrectomy. In contrast, Kellner et al. [3] presented a prospective, randomized clinical trial indicating equal duration of surgery. The shorter time needed for wound opening and closure in the 25-gauge group was equalized by the longer vitrectomy duration when the same amount of vitreous was removed. Hubschman [13] assessed and compared the efficacy of 20- and 25-gauge instrumentation and two different cutting modes (pneumatic and high-speed), and found the 25-gauge probe to be less efficient than the 20-gauge probe.

25.2.2 Surgical Trauma, Perioperative Comfort and Pain

The second report of Fujii et al. [37] described the initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery, and found the 25-gauge system capable of minimizing surgically induced trauma, as well as decreasing the convalescence period and the postoperative inflammatory response. In our trial [3], we were able to confirm a significantly improved patient comfort during the 1st postoperative week in the 25-gauge vitrectomy group. Other prospective [7, 18] and retrospective studies [32, 36] and the reviews of literature mentioned above [60, 61] also show accordance regarding decreased postoperative inflammation and better patient comfort after 25-gauge vitrectomy.

25.2.3 Sclerotomies

By the use of ultrasound biomicroscopy of the sclerotomy sites in one patient, Keshavamurthy et al. [54] found the

healing of a 25-gauge sclerotomy to be quite rapid, with inability to detect the site of sclerotomy 2 weeks after surgery. This stands in contrast to experiences regarding conventional 20-gauge sclerotomies, which are reported requiring up to 6–8 weeks for healing [29].

25.2.4 Instruments and Efficiency

Hubschman [13] assessed and compared the efficacy of 20- and 25-gauge instrumentation, and two different cutting modes (pneumatic and high-speed) and found the 25-gauge probe to be technically less efficient than the 20-gauge probe. Chen [60] found the 25-gauge system overall safe and efficacious, but also stated that proper case selection is imperative, due to the smaller scale of instruments gaining their highest efficiency in absence of tight membranes or the necessity of extensive manipulation. This is partially caused by the instruments' decreased fluidics. In our trial [3] we reported technical difficulties with the 25-gauge system in 37% of cases, and (similarly to Yoon et al. [11]) stated that these factors imposed limitations, especially in cases of complicated vitreoretinal pathologies. Both study groups [3, 11] reported the necessity of an intraoperative switch from the 25-gauge to the 20-gauge system for reasons of patient safety in 16% [3] and 10% [11] respectively. With regard to technical difficulties, Byeon et al. [42] described the insertion of the microcannulas as leading to deformity, instability and infusion disconnection, resulting in damage of the crystalline lens. Inoue et al. [56] reported about breakage of a 25-gauge vitreous cutter during surgery. In highly myopic eyes with an axial length of more than 31 mm, Singh et al. [21] found the 25-gauge soft-tip needle unable to remove fluid completely during fluid–air exchange, as well as other 25-gauge instruments being too short in size to reach the posterior pole of the globe.

25.2.5 Need for Sutures

Postoperative transient hypotony due to leaking sclerotomies has been a concern of surgeons since the development of sutureless transconjuctival surgery. In a large retrospective study including 625 eyes, Lommatzsch et al. [52] found a mean intraocular pressure of 8 mmHg on the 1st postoperative day, and 2.7% of patients suffering a choroidal detachment making suturing of the sclerotomies necessary on the 1st postoperative day. Oshima et al. [31] sutured their sclerotomies in 8% and Lakhanpal et al. [34] placed sutures in 7.1% of their cases. Interestingly, Lakhanpal et al. included 14.3% of eyes undergoing 25-gauge surgical procedures without performing vitreous removal. Gupta et al. [39] had to place sutures in 7.1% of their cases. Amato and Akduman [40] postulated suturing of every leaking sclerotomy to be necessary, especially in previously completely vitrectomized eyes, due to the lack of the plugging effect of the peripheral vitreous. In our trial [3] as well as in Kapran's report [26], no sutures were needed at the end of surgery.

25.2.6 Intraocular Pressure

Since hypotony might lead to a higher incidence of postoperative infections, its occurrence and possible persistence over an elongated period has been an important issue in sutureless vitrectomy. Several studies [3, 7, 11, 16, 20, 23, 31–33, 35, 37, 39, 40, 42, 49, 50, 52] reported one or more cases of postoperative hypotony. Our study [3], Romero et al. [7] and Bahar et al. [17] found the average intraocular pressure lower in the 25-gauge group than in the 20-gauge groups. Oshima et al. [31] found postoperative hypotony in 13% during the 1st week in the group of eyes having undergone 25-gauge surgery, Yanyali et al. [32] reported about 16.9% of eyes showing intraocular pressure below 10 mmHg during the 1st postoperative week. However, he described no effect upon the visual acuity outcome. Fujii et al. [37] observed intraocular pressures of down to 6 mmHg on the first postoperative day. Gupta et al. [39] noted all hypotonies except one occuring in fluid-filled eye,s and concluded that fluid-filled eyes are more likely to develop postoperative hypotony than gas-filled eyes. Amato and Akduman [40] reported choroidal detachment in 5% of the eyes, and related this finding to postoperative hypotony. In a study performed by Byeon et al. [42], a 16% incidence of hypotony after surgery was observed, whereas 12% of eyes had an elevated intraocular pressure on the 1st postoperative day. Valmaggia [16] found transient hypotony lower than 5 mmHg in 12% of patients after 25-gauge surgery, and Lam et al. [20] measured an intraocular pressure of 3–5 mmHg on the 1st postoperative day in 40% of their cases.

In an attempt to overcome this problem, Inoue et al. [23, 50] were able to lower the incidence of postoperative hypotony from 18% to 2% by using a new insertion MVR blade. In contrast, other authors (Horozoglu et al. [15] and Lakhanpal et al. [48]) did not report postoperative hypotony in their case series. It is of interest that Horozoglu et al. [15] used an intraocular gas tamponade in all eyes being operated on for treatment of pseudophakic retinal detachment, and that Lakhanpal et al. [48] did not remove vitreous at all when performing limited arteriovenous-crossing manipulation (LAM) for the treatment of branch vein occlusion.

There are also reports regarding a postoperatively elevated intraocular pressure: Yanyali et al. [32] reported about a 7% incidence of postoperative hypertony needing topical antiglaucomatous medication, and Byeon et al. [42] found elevated intraocular pressure after surgery in 12% of their patients.

And the topic of pressure rise during insertion of cannulas deserves notice, too. In an interesting experiment, Dalma-Weiszhaus et al. [24] performed a study in pig eyes and human cadaver eyes to determine eye pressure changes during the trocar insertion. They measured a mean intraocular pressure of 57.5 mmHg in pig eyes and 63.7 mmHg in human cadaver eyes.

25.2.7 Choroidal Detachment

Shallow choroidal detachment on the 1st postoperative day was observed by Lakhanpal et al. [34] in 3.8% of eyes but in all cases was resolved 1 week after surgery. Valmaggia [16] linked the 4.7% choroidal detachments observed to eyes having suffered severe postoperative hypotony, and also Lommatzsch et al. [52] connected their 2.7% incidence of postoperative choroidal detachments to low postoperative intraocular pressure (see above).

25.2.8 Vitreous Hemorrhage

With regard to vitreous hemorrhage, indications for surgery present as an important basic factor. Diabetic secondary vitreous hemorrhages, as well as hemorrhages occurring after silicone oil removal, should be discussed separately.

Yanyali et al. [32] described a recurrence of vitreous hemorrhage in 3% of cases having undergone 25-gauge surgery. The indications for surgical intervention were diabetic vitreous hemorrhage (29 eyes), diabetic macular edema (14 eyes), macular epiretinal membrane (13 eyes), endophthalmitis (five eyes), vitreous opacities secondary to Behcet's disease (four eyes), vitreous hemorrhage secondary to branch retinal vein occlusion (four eyes), and vitreous hemorrhage secondary to age-related macular degeneration (two eyes). In a study featuring silicone oil removal (1,000 centistokes density) using a 25-gauge system, Kapran and Acar [26] saw transient vitreous hemorrhage in 7.6%. Quiroz-Mercado et al. [27] treated complicated retinal detachment cases, either of rhegmatogenous or of diabetic origin, by using perfluorcarbone liquid perfused vitrectomy. They saw mild recurrent vitreous hemorrhage in 15.4% of their patients. In a prospective randomized study, Kellner et al. [3] saw no vitreous hemorrhage in patients having undergone 25-gauge surgery, whereas vitreous hemorrhage occurred in 6.7% after 20 gauge surgery.

An additional indication demanding separate discussion is small-incision surgery in infants. Performing a study using 25-gauge vitrectomy in infants presenting with stage 4 or 5 retinopathy of prematurity, Gonzales et al. [47] reported a recurrence rate of vitreous hemorrhage of 13.3%. He furthermore described the results of surgery as being comparable to those when the 20-gauge technique was used. In this study, the conjunctiva was dissected and the sclerotomies were sutured at the end of the surgery, so here 25-gauge systems were used only because of their smaller size.

25.2.9 Endophthalmitis

In the first 2 years after invention, endophthalmitis was not reported in the context of 25-gauge surgery. Due to the smaller incision size, reduced operating times, lack of foreign-body suture material and reduced conjunctival manipulation, it was suggested that 25-gauge surgery reduced the risk of this dreaded complication. Only recently, reports about this serious and potentially devastating complication do accumulate. In 2005, Taylor and Aylward [65] presented the first case report of endophthalmitis following 25-gauge vitrectomy. They suggested that the unsutured sclerotomy wounds might provide a conduit for bacterial ingress, and that the approximately six times lower flow-rates of the 25-gauge system [66] could allow bacteria an increased opportunity to gain foothold perioperatively. Furthermore, Stewart [67] reflected whether scleral depression for examination of the periphery near the site of a 25-gauge cannula could cause enlargement or at least distortion of the normal wound architecture of the sclerotomy. Similarly, scleral depression could tear the conjunctiva by pulling it posteriorly while it remains anchored at the cannula, leading to an increased risk of subclinical wound leak. In reply, Shah et al. [68] suggested displacing the conjunctiva superiorly while introducing the 25-gauge trocar and cannula to overcome the potential complication of postoperative hypotony and resultant potential increase in bacterial influx. In a large computerized multicenter database search performed by Scott et al. [49] upon the files of patients operated in the years 2005 and 2006, the authors found a significantly higher incidence of post pars plana vitrectomy endophthalmitis after 25-gauge surgery (11 cases per 1,307 patients, i.e., 0.84%) vs after 20-gauge surgery (two cases per 6,375 patients, i.e., 0.03%). Median time between pars plana vitrectomy and endophthalmitis presentation was 3 days (range 1–15 days). All patients received intraocular antibiotics,

including Vancomycine®. Most of the cases were culture-positive and presented coagulase-negative staphylococci. Visual outcomes were variable. Kunimoto and Kaiser [51] presented similar findings: endophthalmitis occurred in one of 5,498 eyes after 20-gauge vitrectomy (0.018%) vs in seven of 3,103 eyes (0.23%) in 25-gauge surgery. The results of visual outcome were comparably poor for both the 20- and 25-gauge groups. 25-gauge had a statistically significant 12-fold higher incidence of endophthalmitis compared with 20-gauge vitrectomy. Because of the retrospective nature of this large study, one has to be prudent about this high difference. However, in an editorial by Martidis and Chang [69] these figures were discussed, quoting that prospective randomized studies including far larger numbers of subjects were performed to achieve evidence-based rates of postoperative endophthalmitis after using sutureless techniques in cataract surgery. This, and the neglect of other factors like the use of triamcinolone in 38% of endophthalmitis cases, possibly causing sterile inflammation, are obvious limitations in the study performed by Kunimoto and Kaiser [51]. Clearly, a prospective, randomized study with comparable indications for surgery will be necessary for clarification.

25.2.10 Retinal Detachment and Retinal Breaks

Retinal detachment seems to be a minor problem in 25-gauge surgery, and in fact using a trocar system might be an advantage because the number of entry site related retinal detachments should decrease. In 20-gauge studies, an incidence of retinal detachments between 1.8% and 14% is described [66–73]. Oshima et al. [31] reported 0.7% of retinal detachments after a series of 150 eyes undergoing combined 25-gauge vitreous and cataract surgery. Shimada et al. [33] found a rate of 1.2% in a series of 169 eyes, and got all retinas attached by a second intervention. Unfortunately, no comparative data with 20-gauge vitrectomies are given in these two large series. In a randomised prospective clinical trial including 60 patients, we [3] observed no retinal detachment in the 25-gauge vitrectomy group compared to two in the 20-gauge group. Ibarra et al. [35] reported 2.2% of retinal detachment in a series of 45 eyes, and stated that no relation could be found between the complication and the sutureless nature of the technique. Fujii et al. [37], when first describing their initial experiences of the new technique, reported a retinal detachment rate of 2.9% in a series of 35 eyes suffering from various pathologies. Gupta et al. [39] observed a 1.4% incidence of retinal detachment in their cases, and Amato and Akduman [40] 2%. Byeon et al. [42] retrospectively reviewed 50 consecutive cases, and found a 6% postoperative retinal detachment rate; in the same study they also reported several cases with severe problems inserting the trocars, deformation of the trocars and the eye globe, lens injury and switch to 20-gauge vitrectomy. In a series of 75 eyes, Okuda et al. [43] found 5.3% of cases where retinal peripheral breaks had occurred without causing a retinal detachment. They seemed to be free of vitreous traction, and therefore were successfully managed by laser-photocoagulation. Scartozzi et al. [41] performed a single-institution review of 347 consecutive eyes having undergone pars plana 20- or 25-gauge vitrectomy for macular hole and macular pucker repair, and found a slightly lower trend for peripheral sclerotomy related retinal breaks in the 25-gauge vitrectomy group (3.1% vs 6.4% in the 20-gauge group). Lommatzsch et al. [52] found 1.1% of retinal detachment in a series of 625 eyes. Shinoda et al. [53] reported three jammed 25-gauge cutting instruments in the trocar channels during removal of vitreous hemorrhages [of 112 (7%)], and two of three eyes developed giant retinal breaks near the sclerotomy. In a retrospective series of 35 patients having undergone 25-gauge silicone oil removal (1,000 centistoke density), Riemann et al. [45] found 8.6% of recurrent retinal detachment in a series of obviously more complex cases. Kapran and Acar [26] observed a 15.4% incidence of retinal detachment after 1,000 centistoke silicone oil removal, but efforts to construct a relation to small-incision instrumentation might be unfair in silicone cases.

25.2.11 Vitreous Incarceration

Amato and Akduman [40] stated that previously vitrectomized eyes have a higher incidence of hypotony, due to the lack of plugging effect of the peripheral vitreous. This was supported by a finding by López-Guajardo et al. [5] performing an ultrasound biomicroscopy (UBM) of the sclerotomies and their healing process: they found vitreous incarceration in 72% of the cases, regardless of the incisions having been made directly or oblique. Conjunctival fluid blebs had a significantly higher rate of incidence if the incisions had been made directly (64%) vs oblique (25%).

25.2.12 Macular Edema

Gupta et al. [39] reported exacerbation of cystoid macular edema after 25-gauge vitrectomy in 7.1% in non-diabetic patients suffering from epiretinal membrane, macular hole and vitreous hemorrhage. Valmaggia [16] reported postoperative macular edema accompanied by severe postoperative hypotony in 1.6% of patients.

25.2.13 Corneal Topography

In a prospective interventional case series, Yanyali et al. [12] evaluated the topographic changes of the corneas of 32 patients having undergone pars plana vitrectomy with the 25-gauge system, and found no significant changes in the corneal surface or astigmatic changes during the early postoperative period. Okamoto et al. [25] compared 25- and 20-gauge vitrectomized patients (32 vs 25 eyes) by corneal topography during the 1st postoperative month by the dioptric data of the central 3 mm zone of the cornea. They found no changes in the 25 gauge group vs a significantly increased regular astigmatism, asymmetry and higher order irregularity in the 20-gauge group during the first two postoperative weeks. All parameters returned to preoperative levels after 1 month.

25.2.14 Visual Acuity

Thirteen different studies observed a significant improvement of visual acuity after 25-gauge transconjunctival sutureless vitrectomy [11, 20, 31, 32, 34–39, 44, 46, 48], but only Rizzo et al. [18] confirmed this in a comparative study. Furthermore, Rizzo et al. [50] reported that the improvement in vision was more rapid in the 25-gauge group than in the 20-gauge group and this is in accordance with the results of Valmaggia [16].

25.3 23-Gauge Vitrectomy

A PubMed search of literature performed in January 2008 gave the total of 12 original articles dealing with the 23-gauge system for pars plana vitrectomy. This number includes two prospective, non-randomized trials [74, 75], eight retrospective studies [2, 76–82], one review [83] and one technical description [84]. One prospective, randomized study [85] performed by our department is currently in press.

Peyman [84] was the first to develop a miniaturized vitrectomy system at the 23-gauge size in 1990, using it for vitreous and retinal biopsies and in pediatric vitreous surgery. At that time, all sclerotomies were sutured and differing from today's surgery, vitrectomy was not miniaturized with the main goal of being sutureless.

For many vitreoretinal surgeons, 25-gauge instrumentation appeared as too flexible and fragile, especially when dealing with more complex cases. The lights were too dim, although over time also the material for 25-gauge has been made stiffer and less breakable and the lights have been improved. Postoperative hypotony was an issue, and at least in part related to the vertical nature of the sclerotomy incisions of this technique.

25.3.1 Surgical Technique

In 2005, Eckardt [2] introduced a 23-gauge (0.72 mm) incision technique obtaining scleral tunnels parallel to the corneo-scleral limbus by making 30° *oblique incisions*. He used a specially designed pressure plate for fixation of the conjunctiva and a stiletto blade for preparing the channel for the insertion of the microcannulas. In 35% of the eyes, small microbleeding at the incision occurred. All intraocular instruments usually available in 25-gauge surgery were used, too. The advantage described by almost all authors was the *higher stability* of the 23-gauge instruments, being comparable to that of the 20-gauge system. This started to allow broader indications of where the system could be used. Moreover, postoperative comfort of patients was significantly higher after 23-gauge vitrectomy than after 20-gauge surgery [81]. Overall time for surgery was almost equal in both groups when almost complete vitrectomy was performed [81]. In a review regarding the use of miniaturized 23-and 25-gauge vitrectors in the treatment of diabetic retinopathy and maculopathy, Mason [83] described the advantages of less trauma, less postoperative discomfort and quicker healing after small incision vitrectomies. Koch et al. [78] gave us an interesting 'inside-out view' through the sclerotomies using high-resolution endoscopy. They observed that the major amount of vitreous incarceration occurs during the implantation of cannulas. Incarcerated vitreous causes significant anterior–posterior vitreous traction. Intraocular cleaning of the port with the suction cutter releases the anterior–posterior traction without increasing the postoperative rate and degree of hypotony. Side effects like bleeding of the wound are likely to occur due to any sort of manipulation to the outside of the sclerotomy (i.e., cotton tips) other than the essential replacement of the conjunctiva.

25.3.2 Need for Sutures

In 23-gauge vitrectomy, the sclerotomies are placed performing tight self-sealing tunnel incisions. The system is meant and intended to be sutureless. In fact, no sutures were used in any of the cases presented by Eckardt [2], but in contrast other authors reported the necessity to close sclerotomies and conjunctiva: Fine et al. [80] had to place sutures in one of 77 eyes (1.3%), Kim et al. [82] found intraoperative sutures necessary in three cases (7.5%), and 14% of the incisions needed suturing in the study by Wimpissinger et al. [85].

25.3.3 Intraocular Pressure

In the study performed by Eckardt [2], no hypotony occurred, showing the self-sealing property of the technique. Other authors [80, 82], however, described single cases of postoperative hypotonies. Fine et al. [80] experienced two cases with 5 and 4 mmHg intraocular pressure, respectively, on the 1st postoperative day; the same values were measured in one patient after 2 and 5 h respectively in the study by Kim et al. [82]. Wimpissinger et al. [85] reported that during the first 2 postoperative days the eye pressure dropped below 10 mmHg (lowest: 3 mmHg in one patient) in 26.7% of patients with the 23-gauge system, but the average eye pressure change over the whole group did not differ significantly between 23- and 20-gauge surgery. In contrast, Tan et al. [76] and Hubschman et al. [79] did not find any hypotonies in their cases.

Temporary elevation of intraocular pressure was found in one eye in a study by Hilton et al. [81]: the eye pressure was above 20 mmHg (maximum 36 mmHg) in 23% of patients during the first 2 days following 23-gauge vitrectomy [85].

25.3.4 Complications

Performing a multicenter series of office-based vitrectomies, Hilton et al. [81] found complications in 6% of the eyes, including intraocular hemorrhages, choroidal detachment, retinal detachment and new retinal breaks, most of them resolving spontaneously. Wimpissinger et al. [85] saw choroidal hemorrhages in three cases; two of them resorbed without further intervention. One eye needed re-vitrectomy and silicone oil tamponade, and ended up with ambulatory vision.

25.3.5 Endophthalmitis

No cases of endophthalmitis at all were described in any of these studies.

25.3.6 Retinal Tears and Retinal Detachment

Eckardt [2] presents similar retinal findings after surgery to those after 20-gauge vitrectomy, and does not mention any breaks or detachment in his series. In the study by Fine et al. [80], two patients (13%) suffered from recurrent retinal detachment after repair of rhegmatogenous retinal detachment. Both recurrences were remote from the original surgery, 6 and 13 weeks postoperatively, long after absorption of the gas tamponade. Origin was a small peripheral retinal tear at 12 o' clock, 2 o' clock hours away from either sclerotomy in one case. The second patient had evidence of proliferative vitreoretinopathy. Hilton et al. [81] noted new retinal breaks and retinal detachment at 2% in their office-based series.

25.3.7 Use of Silicone Oil

This topic was addressed by only one study. Oliveira and Reis [75] presented silicone oil at 1,000 cs to be a feasible option to treat complex cases, in combination with 23-gauge pars plana vitrectomy.

25.4 Topical Anaesthesia

In a 2-year prospective study, Theocharis et al. [74] compared lidocaine 2% jelly vs peribulbar anaesthesia for 25- and 23-gauge vitrectomy. No statistically significant difference in the level of pain was detected. Topical anaesthesia vitrectomy procedures were more easily performed with 23-gauge than with 25-gauge instruments. The painful steps of the surgery were endolaser, scleral indentation and peribulbar injection. The topical anaesthesia could be combined with peroral preoperative antipain drugs. Lack of akinesia does not hinder successful surgery.

25.5 The Future

- Although the primary enthusiasm towards small-incision vitrectomies has calmed down and reports about complications are increasing, small-incision sutureless vitrectomy will stay because it offers a higher comfort to our patients, a better control of the instruments and a higher precision in our work close to retinal tissue.
- More prospective studies will give us harder data on complication rates, and we will learn to avoid them. Comparable to clear corneal incision in cataract surgery, which has always been reported to have a higher incidence of endophthalmitis, intracameral antibiotics are now used to minimize this complication, but the technique is maintained.
- Unfortunately, early reports about time gain might have led many surgeons to careless vitrectomies, and there is always a price to pay for this. The reason for higher infection rates might have been related to too little fluid dynamics, incarceration of more vitreous than usually present in sutured vitrectomies, too much residual vitreous, and primarily too little attention to postoperative hypotony.
- Variant entry sizes and instruments will be used for different vitrectomy indications, and we will also improve our 20-gauge technique because more attention is being given to careful suturing of the conjunctiva with thinner sutures which absorb more rapidly.

- 27- and 30-gauge instrumentation is on the horizon, and their use might be more frequent in additional four-port vitrectomies, pediatric surgery and anterior segment surgery.
- New self-sealing trocar systems will be designed to avoid both vitreous incarceration and loss of pressure.
- Perhaps minimal vitrectomizing vitrectomy, which was already introduced by Yasuo Tano several years ago to remove preretinal membranes without the disadvantage of rapid cataract development, will become useful, especially to remove posterior hyaloid early in the course of diseases like exudative AMD and diabetes.
- Finally, two important factors have not been studied so far in small-incision vitrectomy. One is its influence on cataract development, and the second is the incidence of entry-site retinal detachments, but here longer observation times are needed.
- After 30 years of 20-gauge vitrectomy, new smaller instrumentations have been developed. We will have to adapt to new techniques but this development will continue.

References

1. Chen JC (1996) Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 114(10):1273–1275
2. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. Retina 25(2):208–211
3. Kellner L, Wimpissinger B, Stolba U, Brannath W, Binder S (2007) 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. Br J Ophthalmol 91(7):945–948
4. Kadonosono K, Yamakawa T, Uchio E, Yanagi Y, Tamaki Y, Araie M (2006) Comparison of visual function after epiretinal membrane removal by 20-gauge and 25-gauge vitrectomy. Am J Ophthalmol 142(3):513–515
5. López-Guajardo L, Vleming-Pinilla E, Pareja-Esteban J, Teus-Guezala MA (2007) Ultrasound biomicroscopy study of direct and oblique 25-gauge vitrectomy sclerotomies. Am J Ophthalmol 143(5):881–883
6. Tang S, Lai P, Lai M, Zou Y, Li J, Li S (2007) Topical anesthesia in transconjunctival sutureless 25-gauge vitrectomy for macular-based disorders. Ophthalmologica 221(1):65–68
7. Romero P, Salvat M, Almena M, Baget M, Méndez I (2006) Experience with 25-gauge transconjunctival vitrectomy compared to a 20-gauge system. Analysis of 132 cases. J Fr Ophtalmol 29(9):1025–1032
8. Raju B, Raju NS, Raju AS (2006) 25-gauge vitrectomy under topical anesthesia: a pilot study. Indian J Ophthalmol 54(3):185–188
9. Hwang JU, Yoon YH, Kim DS, Kim JG (2006) Combined phacoemulsification, foldable intraocular lens implantation, and 25-gauge transconjunctival sutureless vitrectomy. J Cataract Refract Surg 32(5):727–731
10. López-Guajardo L, Pareja-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 141(6):1154–1156
11. Yoon YH, Kim DS, Kim JG, Hwang JU (2006) Sutureless vitreoretinal surgery using a new 25-gauge transconjunctival system. Ophthalmic Surg Lasers Imaging 37(1):12–19
12. Yanyali A, Celik E, Horozoglu F, Nohutcu AF (2005) Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. Am J Ophthalmol 140(5):939–941
13. Hubschman JP (2005) Comparison of different vitrectomy systems. J Fr Ophtalmol 28(6):606–609
14. Fujii GY, de Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C, Ng E, Barnes A, Wu SL, Sommerville DN (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 109(10):1807–1812; discussion 1813
15. Horozoglu F, Yanyali A, Celik E, Aytug B, Nohutcu AF (2007) Primary 25-gauge transconjunctival sutureless vitrectomy in pseudophakic retinal detachment. Indian J Ophthalmol 55(5):337–340
16. Valmaggia C (2007) Pars plana vitrectomy with 25-gauge instruments in the treatment of idiopathic epiretinal membranes. Klin Monatsbl Augenheilkd 224(4):292–296
17. Bahar I, Axer-Siegel R, Weinberger D (2006) Pars plana vitrectomy: comparison of three techniques for the treatment of diabetic vitreous hemorrhage. Ophthalmic Surg Lasers Imaging 37(5):364–369
18. Rizzo S, Genovesi-Ebert F, Murri S, Belting C, Vento A, Cresti F, Manca ML (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol 244(4):472–479
19. Chalam KV, Gupta SK, Agarwal S, Shah VA (2005) Sutureless limited vitrectomy for positive vitreous pressure in cataract surgery. Ophthalmic Surg Lasers Imaging 36(6):518–522
20. Lam DS, Fan DS, Mohamed S, Yu CB, Zhang SB, Chen WQ (2005) 25-gauge transconjunctival sutureless vitrectomy system in the surgical management of children with posterior capsular opacification. Clin Experiment Ophthalmol 33(5):495–498
21. Singh A, Fawzi AA, Stewart JM (2007) Limitation of 25-gauge vitrectomy instrumentation in highly myopic eyes. Ophthalmic Surg Lasers Imaging 38(5):437–438
22. Hubschman JP, Gonzales CR, Bourla DH, Gupta A, Schwartz SD (2007) Combined 25- and 23-gauge surgery: a new sutureless vitrectomy technique. Ophthalmic Surg Lasers Imaging 38(4):345–348

23. Inoue M, Shinoda K, Shinoda H, Suzuki K, Kawamura R, Ishida S (2007) 25-gauge cannula system with microvitreoretinal blade trocar. Am J Ophthalmol 144(2):302–304
24. Dalma-Weiszhausz J, Gordon-Angelozzi M, Ustariz-Gonzalez O, Suarez-Licona AM (2008) Intraocular pressure rise during 25-gauge vitrectomy trocar placement. Graefes Arch Clin Exp Ophthalmol 246(2):187–189
25. Okamoto F, Okamoto C, Sakata N, Hiratsuka K, Yamane N, Hiraoka T, Kaji Y, Oshika T (2007) Changes in corneal topography after 25-gauge transconjunctival sutureless vitrectomy versus after 20-gauge standard vitrectomy. Ophthalmology 114(12):2138–2141
26. Kapran Z, Acar N (2007) Removal of silicone oil with 25-gauge transconjunctival sutureless vitrectomy system. Retina 27(8):1059–1064
27. Quiroz-Mercado H, Garcia-Aguirre G, Ustáriz-González O, Martín-Avià J, Martinez-Jardon S (2007) Perfluorocarbon-perfused vitrectomy using a transconjunctival 25-gauge system. Retina 27(7):926–931
28. Fang SY, Deboer CM, Humayun MS (2008) Performance analysis of new-generation vitreous cutters. Graefes Arch Clin Exp Ophthalmol 246(1):61–67
29. Bhende M, Agraharam SG, Gopal L, Sumasri K, Sukumar B, George J, Sharma T, Shanmugam MP, Bhende PS, Shetty NS, Agrawal RN, Deshpande DA (2000) Ultrasound biomicroscopy of sclerotomy sites after pars plana vitrectomy for diabetic vitreous hemorrhage. Ophthalmology 107(9):1729–1736
30. Shimada H, Nakashizuka H, Mori R, Mizutani Y, Hattori T (2006) 25-gauge scleral tunnel transconjunctival vitrectomy. Am J Ophthalmol 142(5):871–873
31. Oshima Y, Ohji M, Tano Y (2006) Surgical outcomes of 25-gauge transconjunctival vitrectomy combined with cataract surgery for vitreoretinal diseases. Ann Acad Med Singapore 35(3):175–180
32. Yanyali A, Celik E, Horozoglu F, Oner S, Nohutcu AF (2006) 25-Gauge transconjunctival sutureless pars plana vitrectomy. Eur J Ophthalmol 16(1):141–147
33. Shimada H, Nakashizuka H, Mori R, Mizutani Y (2005) Expanded indications for 25-gauge transconjunctival vitrectomy. Jpn J Ophthalmol 49(5):397–401
34. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou TJ (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 112(5):817–824
35. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 139(5):831–836
36. Cho YJ, Lee JM, Kim SS (2004) Vitreoretinal surgery using transconjunctival sutureless vitrectomy. Yonsei Med J 45(4):615–620
37. Fujii GY, de Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 109(10):1814–1820
38. Chalam KV, Shah VA (2004) Successful management of cataract surgery associated vitreous loss with sutureless small-gauge pars plana vitrectomy. Am J Ophthalmol 138(1):79–84
39. Gupta OP, Weichel ED, Regillo CD, Fineman MS, Kaiser RS, Ho AC, McNamara JA, Vander JE (2007) Postoperative complications associated with 25-gauge pars plana vitrectomy. Ophthalmic Surg Lasers Imaging 38(4):270–275
40. Amato JE, Akduman L (2007) Incidence of complications in 25-gauge transconjunctival sutureless vitrectomy based on the surgical indications. Ophthalmic Surg Lasers Imaging 38(2):100–102
41. Scartozzi R, Bessa AS, Gupta OP, Regillo CD (2007) Intraoperative sclerotomy-related retinal breaks for macular surgery, 20- vs 25-gauge vitrectomy systems. Am J Ophthalmol 143(1):155–156
42. Byeon SH, Chu YK, Lee SC, Koh HJ, Kim SS, Kwon OW (2006) Problems associated with the 25-gauge transconjunctival sutureless vitrectomy system during and after surgery. Ophthalmologica 220(4):259–265
43. Okuda T, Nishimura A, Kobayashi A, Sugiyama K (2007) Postoperative retinal break after 25-gauge transconjunctival sutureless vitrectomy: report of four cases. Graefes Arch Clin Exp Ophthalmol 245(1):155–157
44. Patelli F, Radice P, Zumbo G, Frisone G, Fasolino G (2007) 25-gauge macular surgery: results and complications. Retina 27(6):750–754
45. Riemann CD, Miller DM, Foster RE, Petersen MR (2007) Outcomes of transconjunctival sutureless 25-gauge vitrectomy with silicone oil infusion. Retina 27(3):296–303
46. Miyahara T, Ohta K, Yamamoto Y, Ueno A, Murata T (2007) 25-gauge vitrectomy to treat ocular complications of familial amyloid polyneuropathy. J Glaucoma 16(1):169–170
47. Gonzales CR, Boshra J, Schwartz SD (2006) 25-Gauge pars plicata vitrectomy for stage 4 and 5 retinopathy of prematurity. Retina 26(7 Suppl):S42–S46
48. Lakhanpal RR, Javaheri M, Ruiz-Garcia H, De Juan E Jr, Humayun MS (2005) Transvitreal limited arteriovenous-crossing manipulation without vitrectomy for complicated branch retinal vein occlusion using 25-gauge instrumentation. Retina 25(3):272–280
49. Scott IU, Flynn HW Jr, Dev S, Shaikh S, Mittra RA, Arevalo JF, Kychenthal A, Acar N (2008) Endophthalmitis after 25-gauge and 20-gauge pars plana vitrectomy: Incidence and outcomes. Retina 28(1):138–142
50. Inoue M, Shinoda K, Shinoda H, Kawamura R, Suzuki K, Ishida S (2007) Two-step oblique incision during 25-gauge

vitrectomy reduces incidence of postoperative hypotony. Clin Exp Ophthalmol 35(8):693–696
51. Kunimoto DY, Kaiser RS (2007) Incidence of endophthalmitis after 20- and 25-gauge vitrectomy. Ophthalmology 114(12):2133–2137
52. Lommatzsch A, Heimes B, Trieschmann M, Spital G, Pauleikhoff D (2008) Long-term results after pars plana vitrectomy with 25-gauge technique. Ophthalmologe 105:445–451
53. Shinoda H, Nakajima T, Shinoda K, Suzuki K, Ishida S, Inoue M (2008) Jamming of 25-gauge instruments in the cannula during vitrectomy for vitreous haemorrhage. Acta Ophthalmol Scand 86:160–164 [Epub ahead of print]
54. Keshavamurthy R, Venkatesh P, Garg S (2006) Ultrasound biomicroscopy findings of 25G Transconjuctival Sutureless (TSV) and conventional (20G) pars plana sclerotomy in the same patient. BMC Ophthalmol 6:7
55. Kapamajian M, Gonzales CR, Gupta A, Schwartz SD (2007) Suprachoroidal hemorrhage as an intraoperative complication of 25-gauge pars plana vitrectomy. Semin Ophthalmol 22(3):197–199
56. Inoue M, Noda K, Ishida S, Nagai N, Imamura Y, Oguchi Y (2004) Intraoperative breakage of a 25-gauge vitreous cutter. Am J Ophthalmol 138(5):867–869
57. Moreno-Montañés J, Barrio-Barrio J, García-Layana A (2007) Combined cataract surgery and 25-gauge sutureless vitrectomy for posterior lentiglobus. J Cataract Refract Surg 33(3):380–382
58. Cardascia N, Boscia F, Furino C, Sborgia L (2007) Gentamicin-induced macular infarction in transconjunctival sutureless 25-gauge vitrectomy. Int Ophthalmol 16 October [Epub ahead of print]
59. Robaszkiewicz J, Wójcik E (2006) 25-gauge technology in vitrectomy: pro and con. Klin Oczna 108(10–12):467–470
60. Chen E (2007) 25-Gauge transconjunctival sutureless vitrectomy. Curr Opin Ophthalmol 18(3):188–193
61. Mason JO III, Colagross CT, Vail R (2006) Diabetic vitrectomy: risks, prognosis, future trends. Curr Opin Ophthalmol 17(3):281–285
62. Augustin AJ, Offermann I (2007) [Scope and limititions of innovative vitrectomy systems.] Klin Monatsbl Augenheilkd 224(9):707–715
63. Chong LP, McCormick M, Deboer C, Barnes A (2007) A self-stabilizing lens ring for 25-gauge vitrectomy surgery. Am J Ophthalmol 143(2):350–351
64. Tei M, Shimamoto T, Yasuhara T, Komori H, Oda H, Kinoshita S (2005) A new non-trocar system for 25-gauge transconjunctival pars plana vitrectomy. Am J Ophthalmol 139(6):1130–1133
65. Taylor SR, Aylward GW (2005) Endophalmitis following 25-gauge vitrectomy. Eye 19:1228–1229
66. Er H (2004) Successful management of cataract surgery associated vitreous loss with sutureless small-gauge pars plana vitrectomy. Am J Ophthalmol 138(6):1090–1091
67. Stewart JM (2006) Wound integrity and the conjunctiva in prevention of endophthalmitis following sutureless 25-gauge vitrectomy. Eye 20:1490
68. Shah VA, Shah GY, Chalam KV (2006) Reply to endophthalmitis following 25-gauge vitrectomy. Eye 20:735–736
69. Martidis A, Chang TS (2007) Sutureless 25-gauge vitrectomy: risky or rewarding? Ophthalmolgy 114:2131–2132
70. Banker AS, Freeman WR, Kim JW, Munguia D, Azen SP (1997) Vision-threatening complications of surgery for full-thickness macular holes. Vitrectomy for Macular Hole Study Group. Ophthalmology 104:1442–1452
71. Heier JS, Topping TM, Frederick AR Jr, Morley MG, Millay R, Pesavento RD (1999) Visual and surgical outcomes of retinal detachment following macular hole repair. Retina 19:110–115
72. Michels RG (1984) Vitrectomy for macular pucker. Ophthalmology 91:1384–1388
73. Park SS, Marcus DM, Duker JS, Pesavento RD, Topping TM, Frederick AR Jr, D'Amico DJ (1995) Posterior segment complications after vitrectomy for macular hole. Ophthalmology 102:775–781
74. Theocharis IP, Alexandridou A, Tomic Z (2007) A two-year prospective study comparing lidocaine 2% jelly versus peribulbar anaesthesia for 25G and 23G sutureless vitrectomy. Graefes Arch Clin Exp Ophthalmol 245(9):1253–1258
75. Oliveira LB, Reis PA (2007) Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. Retina 27(8):1054–1058
76. Tan CS, Wong HK, Yang FP, Lee JJ (2008) Outcome of 23-gauge sutureless transconjunctival vitrectomy for endophthalmitis. Eye 22:150–151 [Epub ahead of print]
77. Augustin AJ, Offermann I (2007) Scope and limititions of innovative vitrectomy systems. Klin Monatsbl Augenheilkd 224(9):707–715
78. Koch FH, Luloh KP, Singh P, Scholtz S, Koss M (2007) 'Mini-gauge' pars plana vitrectomy: 'inside-out view' with the GRIN solid rod endoscope. Ophthalmologica 221(5):356–362
79. Hubschman JP, Gonzales CR, Bourla DH, Gupta A, Schwartz SD (2007) Combined 25- and 23-gauge surgery: a new sutureless vitrectomy technique. Ophthalmic Surg Lasers Imaging 38(4):345–348
80. Fine HF, Iranmanesh R, Iturralde D, Spaide RF (2007) Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. Ophthalmology 114(6):1197–200
81. Hilton GF, Josephberg RG, Halperin LS, Madreperla SA, Brinton DA, Lee SS, Gordon SF (2002) Office-based sutureless transconjunctival pars plana vitrectomy. Retina 22(6):725–732

82. Kim MJ, Park KH, Hwang JM, Yu HG, Yu YS, Chung H (2007) The safety and efficacy of transconjunctival sutureless 23-gauge vitrectomy. Korean J Ophthalmol 21(4):201–207
83. Mason JO III, Colagross CT, Vail R (2006) Diabetic vitrectomy: risks, prognosis, future trends. Curr Opin Ophthalmol 17(3):281–285
84. Peyman GA (1990) A miniaturized vitrectomy system for vitreous and retinal biopsy. Can J Ophthalmol 25(6):285–286
85. Kellner L, Wimpissinger B, Stolba U, Brannath W, Binder S (2007) 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. Br J Ophthalmol 91:945–948

Chapter 26

Pearls from Experts

M. Ohji, S. Huang, P. Kaiser, P. Tornambe, S. Gotzaridis

26.1 25-Gauge System

M. Ohji

26.1.1 Displacing the Conjunctiva

The straight conduits of the scleral wound and the conjunctival wound may increase the risk of postoperative infection. Therefore, it is extremely important to displace the conjunctiva when trocars are inserted into the sclera through the conjunctiva to prevent straight conduits. The conjunctiva is pressed a couple of millimeters from the limbus; it is then pulled and the trocars are inserted at the center of the pressure plate ring. This pressure plate was developed for 23-gauge sutureless vitrectomy; however, it also can be used in 25-gauge vitrectomy. We developed forceps with scale marks that are used in a similar fashion. The forceps are 8 cm long, 1 cm wide, and bent 6 mm from the tip and have special features, i.e., two scale marks on the top surface and a serrated undersurface of the tip (Figs. 26.1 and 26.2). The distance between the two scale marks is 4 mm. At the start of sutureless vitrectomy using the 25-gauge vitrectomy system, the forceps are positioned 2–3 mm from the limbus and then moved toward the limbus to pull the conjunctiva until the proximal scale mark reaches the limbus. The trocar is inserted at the other scale mark, that is, 4 mm from the limbus. When the needle inside the trocar is withdrawn, the collar of the trocar can be grasped with the forceps. The forceps also can be used for intravitreal injection of drugs and for conventional 20-gauge vitrectomy in a similar fashion. In 20-gauge vitrectomy, the forceps can be used to grasp the conjunctiva using the teeth at the tip of the forceps, as well as during the creation of a sclerotomy.

26.1.2 Lower Aspiration

Because of the lower infusion and aspiration rate in the 25-gauge system, more time is needed to remove a substance injected into the vitreous cavity, including ICG. Therefore, it may be safer to take a longer time to evacuate sufficient ICG from the vitreous cavity.

26.1.3 Bright Illumination

An endoilluminator is one of the most important instruments among many used during vitreous surgery, and very bright endoillumination without light hazard is extremely important. The light pipe in the 25-gauge vitrectomy system is narrower than that in the 20-gauge vitrectomy system, and the 25-gauge light pipe connected to the regular illumination source offers dim illumination and does not allow visualization of the details of the fundus lesions. A brighter endoillumination system is essential to allow surgeons to see the details of the fundus lesions when using the 25-gauge system. Recently, very bright illumination systems have been introduced by Synergetics and Alcon (Fig. 26.3). Both systems have a xenon light source, and provide very bright illumination through a narrow 25-gauge light pipe that facilitates visualization of the details of the fundus lesions (Fig. 26.4). This advance makes the 25-gauge vitrectomy system easier, more efficient, and safer, and expands the indications for 25-gauge vitrectomy.

The chandelier system has been available for a long time; however, its usefulness is limited because of insufficient illumination. The 25-gauge chandelier illumination system, another instrument that became useful after the introduction of the bright xenon light source (Fig. 26.5), allows surgeons to remove peripheral vitreous or to apply laser to the peripheral retina with scleral indentation by themselves without assistance. A chandelier illuminator inserted into the trocar in the 25-gauge system is also available.

I believe that the new very bright xenon illumination system is a major innovation in vitrectomy, and might change surgical techniques during vitrectomy.

26.1.4 Instrument Flexibility

The new-generation 25-gauge instruments are now stiffer than the previous-generation 25-gauge instruments, and shorter instruments might be another option for stiffer instruments.

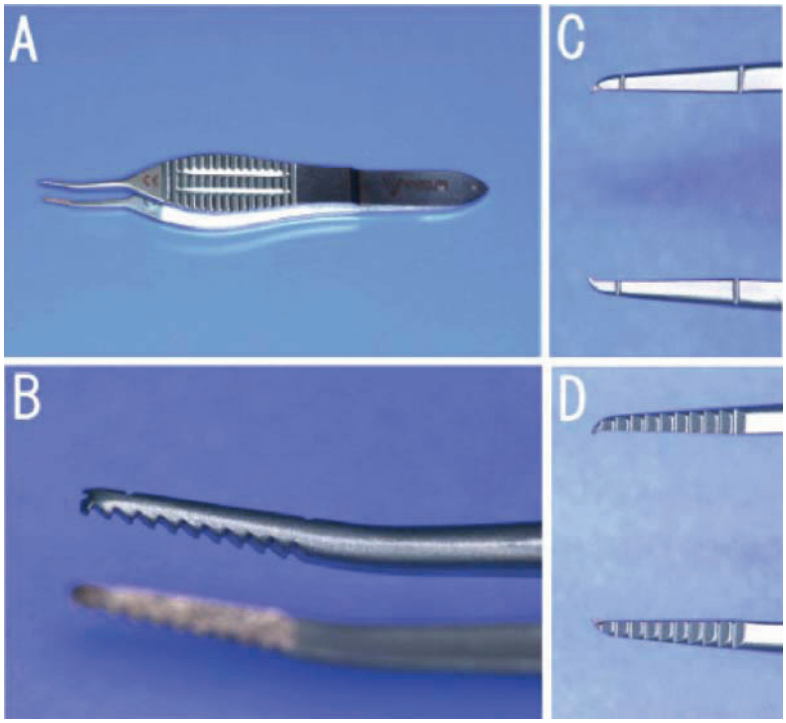


Fig. 26.1 Forceps with scale marks

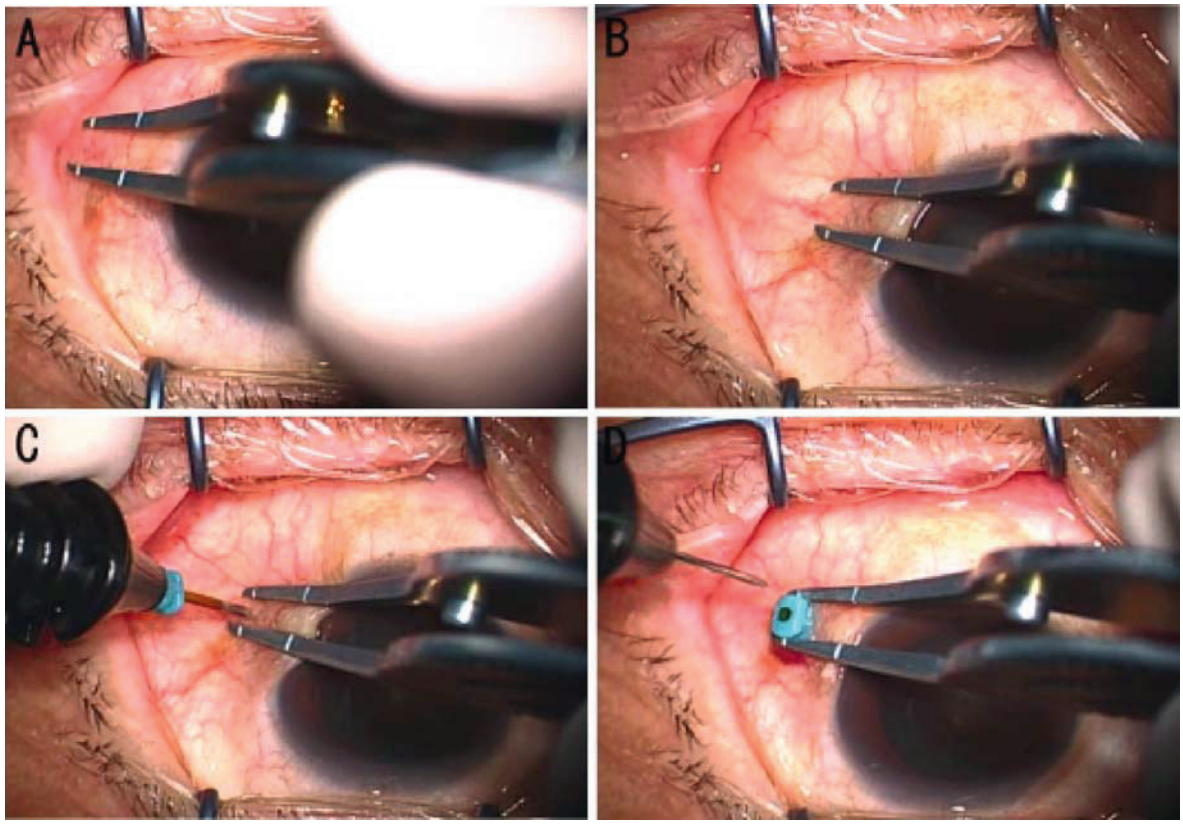


Fig. 26.2 How to use the forceps with scale marks

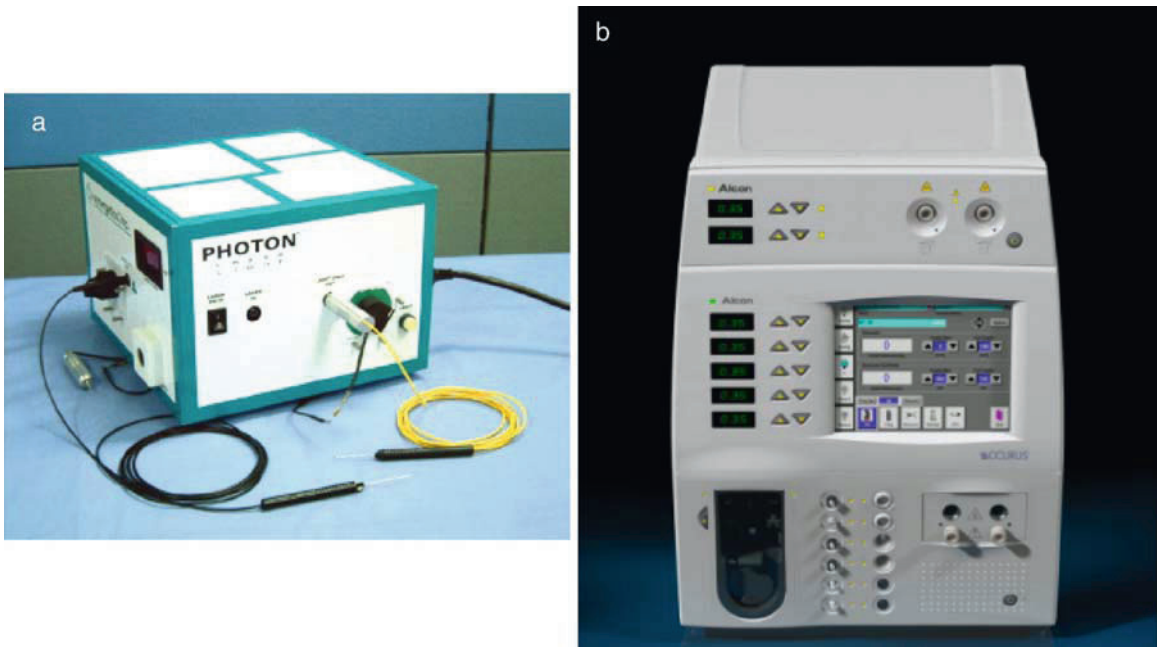


Fig. 26.3 Xenon illumination. Synergetics (**a**) and Alcon (**b**)

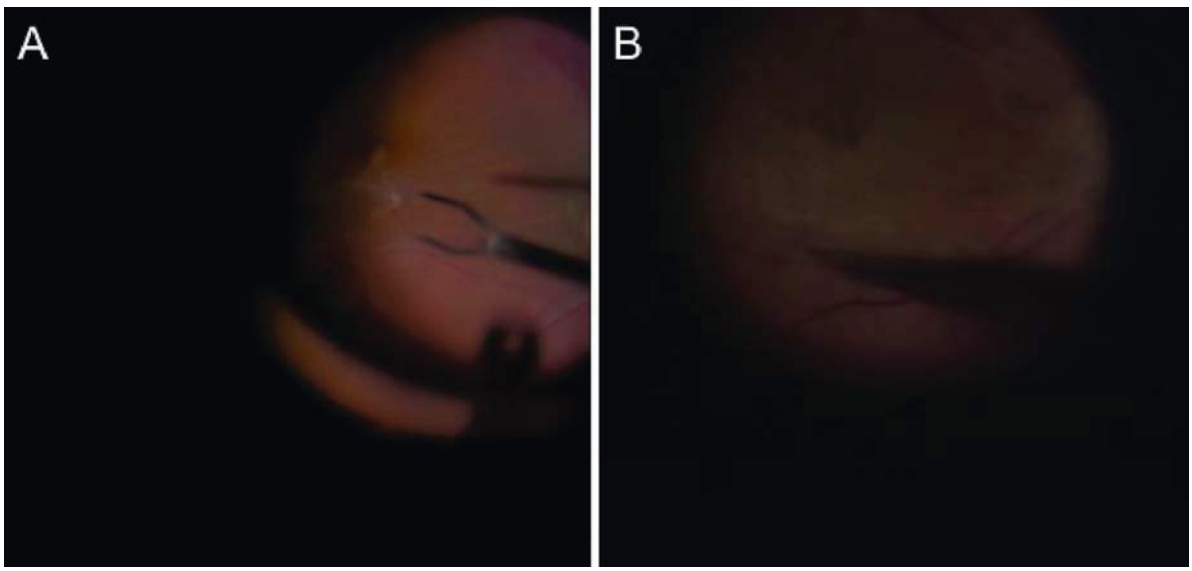


Fig. 26.4 Comparison of xenon illumination and halogen illumination

When using 25-gauge instruments, it might be difficult to rotate the eyeball because of the softness of the instruments. The 25-gauge instruments have become stiffer and likely will become more so in the future, and they can probably be used just like 20-gauge instruments in the near future.

26.1.5 Simultaneous Cataract Surgery

When surgeons perform simultaneous cataract surgery through clear corneal incision during small-gauge vitrectomy, the trocars should be inserted first before cataract surgery is performed. If surgeons perform cataract surgery

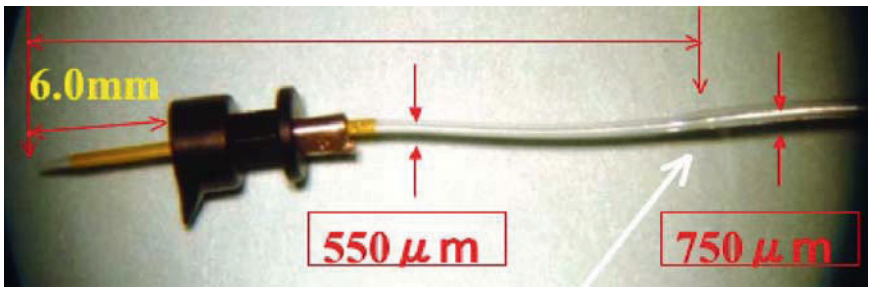


Fig. 26.5 25-gauge chandelier

first and then attempt to insert trocars, iris prolapse through the corneal incision or even through the sclerocorneal wound may occur because of elevated intraocular pressure during insertion of the trocars. A clear cornea incision may be preferable for simultaneous cataract surgery combined with small-gauge sutureless vitrectomy, because a conjunctival incision is not required.

26.1.6 Preventing Fluid Leakage

Two techniques can prevent fluid leakage. One is injection of air at the end of surgery; an air bubble injected into the vitreous cavity efficiently prevents fluid leakage, and it is a simple and useful technique. The second technique is oblique insertion of trocars. An oblique wound through the sclera and the choroid has a longer pathway than that made during the standard insertion perpendicular to the sclera when using the 25-gauge system.

26.1.7 Case Selection

Case selection may be the most important factor contributing to the success of small-gauge vitrectomy. The 25-gauge system is suitable for treating epiretinal membranes because a great deal of vitreous does not have to be removed and complicated maneuvers are not performed. Vitrectomy to treat macular edema due to diabetic retinopathy and branch or central vein occlusion could be the second best indication for small-gauge vitrectomy, because removal of peripheral vitreous is not essential. The internal limiting membrane can be removed during small-gauge vitrectomy. A simple vitreous hemorrhage caused by branch vein occlusion may be the third best indication for small-gauge vitrectomy; peripheral vitrectomy is not essential and fluid–air exchange is not required. A macular hole is also one of the best indications for small-gauge vitrectomy; removal of vitreous from the far peripheral is not essential; however, it is better to remove a certain amount of peripheral vitreous. A simple retinal detachment could be treated with small-gauge vitrectomy; however, complicated PVR or severe PDR might preclude small-gauge vitrectomy.

Surgeons may be able to complete some complicated vitrectomy cases; however, there are some limitations to the indication. Horizontal scissors that are very useful for delamination cannot be used in the small-gauge vitrectomy system, because of the shape of the trocars in the small-gauge vitrectomy system. It is possible to complete the vitrectomy even in these complicated cases without using the horizontal scissors; however, a bimanual technique may be needed, or the surgery may take longer. Scleral indentation is useful to remove vitreous from the far peripheral. It is difficult to indent the sclera with an intact conjunctiva, compared with eyes in which a conjunctival incision has been made. Therefore, small-gauge vitrectomy seems to have some limitations in surgeries that require vitrectomy in the far peripheral, even though surgeons could complete vitreous surgery with the small-gauge system. "Can be performed" and "can be comfortably or efficiently performed" are two different things.

26.1.8 Contact Lenses

Observation is another important factor in vitrectomy. There are many options, including floating lenses set inside the lens ring, a wide-angle viewing system including a contact lens such as mini-Quad contact lens, and a non-contact system including the binocular indirect ophthalmoscope (BIOM) and Peyman–Wessels–Landers non-contact wide-field viewing system. An important feature of the small-gauge vitrectomy system is sutureless surgery, and sutures for the lens ring secured to the limbus are cumbersome. One solution is the sutureless ring for floating lenses. The sutureless ring is set on the cornea using a rubber band or a silicone band bridging the speculum and the ring (Fig. 26.6). Another solution is a self-retaining contact lens made of silicone or polymethylmethacrylate. Using a self-retaining contact lens is easy; it is placed on the cornea and then removed, and no suturing is needed.

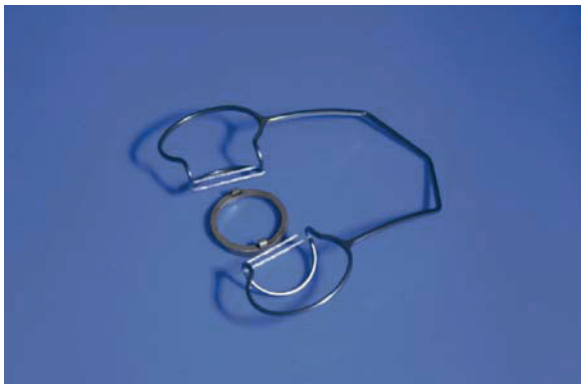


Fig. 26.6 Sutureless ring

Combining the self-retaining contact lens or sutureless ring for fine manipulation in the macular area with a wide-angle viewing system for maneuvers at the peripheral fundus area is especially useful.

26.2 25-Gauge System

Suber Huang

Case selection – transitioning to 25-gauge surgery

- Just starting out — PVD present with asteroid, vitreous opacities, floaters, vitreous hemorrhage.
- Experienced — no PVD, small retained lens fragments, macular pucker, macular hole, retinal detachment, traction retinal detachment, endophthalmitis.
- Thin ice — if limited by instruments or difficult pathology, make a limited peritomy and convert one or more sclerotomies to 20-gauge.
- PVR, dislocated lens nucleus, IOFB, silicone oil.

Fluidics management

- Choose the appropriate combination of aspiration pressure and infusion pressure.
- Use only the necessary pressures to achieve surgical goals, to reduce chance of iatrogenic retinal tear.

IOP management

- Lower bottle height when not suction not engaged (membrane peeling, exchanging instruments, indirect exam, etc).
- Observe the nerve for pallor.
- Be watchful for sudden decompression of eye when performing AFX, low suction or passive.
- If a sclerotomy is widened, be mindful of its effect on IOP and infusion pressure.

Sclerotomy management

- Anterior displacement of conjunctiva, not lateral, for a more posterior conjunctival entry site.
- Limit instrumentation changes.
- Use a forceps underneath the cannula to provide counter pressure on the sclera when removing from the eye for a smooth exit and undistorted globe.

Complications management

- Turn infusion off prior to removing cannulas from eye.
- Prior to removing the infusion cannula, briefly turn on the infusion to re-pressurize the eye to normal IOP then turn off before final removal.
- If active fluid wound leak is suspected, use a sterile air or gas bubble to re-pressurize the eye and to provide internal tamponade.
- If sub-conjunctival gas is seen, perform a limited peritomy and suture sclerotomy.

Post-op management

- Antibiotic ointment at bedtime may speed healing and provide a physical barrier to block ingress of exogenous bacteria into conjunctival/scleral incisions.
- Specific instructions to shield and avoid pressure to the eye.
- Patients often feel so good that they wish to resume full activities immediately – stay conservative.

26.3 25-Gauge System

Peter Kaiser

1. *Beveled incision*. The use of a beveled entry has almost completely eliminated hypotony and wound leak in my patients. The entry is started by displacing the conjunctiva away from the entry site with forceps or a cotton-tipped applicator. The trocar is advanced bevel up. The trocar is then inserted at a 45° angle until the edge of the trocar meets the scleral surface. The trocar is then inserted straight in. This forms a beveled incision that is considerably more watertight than the typical straight entry.
2. *Slow trocar removal*. Although it is a natural tendancy to quickly remove the trocars at the end of the case, this may lead to vitreous incarceration and wound leak. Instead, very slowly remove the trocars to allow enough time for the sclera to close the surgical wound. I then put pressure over the spot with a cotton-tipped applicator to further avoid any negative pressure and incareration. This technique appears to decrease wound leak considerably.

3. *Move the infusion cannula*. Since all the trocars can accept the infusion line, do not be afraid to move the infusion line from its normal inferior position to the superonasla trocar and operate from a temporal position like our cataract colleagues. This is especially useful in patients with deep-set eyes, or in whom laser treatment with a straight laser probe is required in the superior quadrants.
4. *Depress without plugging the trocars*. I scleral depress in all my cases. The less rigid instruments make this a little tricky in 25-gauge cases. In addition, plugging the trocars is difficult without re-inverting the wide-angle viewing system, which is often difficult to remove without also removing the trocar. To overcome these limitations, I scleral depress without plugging the trocars and with a slightly higher infusion pressure. This technique makes scleral depression fast and efficient.
5. *Xenon light source*. The new xenon light sources are almost a necessity in 25-gauge surgery. Although the light pipes have improved considerably, the addition of the bright, white xenon lights is the difference between driving through a tunnel with a headlamp vs high beams.
6. *25-gauge needle*. I like to use a pick to start my ILM and ERM peels. I have found that bending a 25-gauge needle makes an effective and cheap pick to perform these peels. It is also useful as a quasi "MVR" blade in cases where one is needed.
7. *Tap and inject*. Darius Moshfeghi, MD and his colleagues at Stanford gave me a great tip for performing a tap and inject procedure for endophthalmitis. After inserting a 25-gauge trocar, the tap and injection of antibiotics can be performed throught the trocar. This technique allows for a large-gauge needle to perform the tap, and easy access for the intravitreal antibiotics.

26.4 23-Gauge System

Paul Tornambe

1. 23-gauge surgery is not 'training wheels' for 25-gauge surgery. I prefer 23-gauge surgery because the feel of 23-gauge instruments is more like 20-gauge instruments. There is no significant learning curve for the 20-gauge surgeon, it is plug and play.
2. The best way to start 23-gauge surgery is to set up a case for 20-gauge instruments, then try one or more 23-gauge instruments. If there are parts of the procedure you are not comfortable with, you can simply switch back to your 20-gauge comfort zone.
3. Infusion cannula

   (a) The sharp, disposable 23-gauge self-retaining, self-sealing cannula can be used with 20-gauge instruments. The infusion keeps up with 20-gauge cutters and aspiration. Set the infusion level at 35 mm Hg.
   (b) The sharp cannula is inserted through the conjunctiva and sclera; there is no need to open the conjunctiva or pre-place sutures for the cannula is self-retaining. When the cannula is removed it is self-sealing, so if you use no other 23-gauge instruments than the infusion cannula, you have decreased the number of suture-closed wounds by 33%.
   (c) The insertion is performed 3.5–4 mm from the limbus. Conjunctival forceps are used to grasp the cannula to push the sharp tip through the conjunctiva and sclera. Insert the cannula to its platform so that the step-off collar of the cannula fully penetrates the sclera. Although the tip is sharp, I have had no complications with it in the eye.
   (d) To remove the cannula, use two conjunctival forceps. Grasp the cannula with one forceps wedged between the sclera and platform and gently press down, and with the other forceps grasp the cannula above the platform where the tubing inserts into the cannula and pull it out of the eye.
   (e) A blunt, reusable cannula is also available. One version has the usual opening at the tip; another has two side ports which direct infusion currents of fluid or air away from the retina. This may prevent postoperative scotomas. This cannula is more difficult to insert because it requires two steps. Grasp the conjunctiva and sclera with a 0.12 forceps, or use the Eckhart conjunctival stabilizer. Make the transconjunctival/scleral incision away from a blood vessel with a 23-gauge needle, then insert the cannula. Don't push down on the eye with the 0.12 forceps, or vitreous will present at the wound and balloon the conjunctiva, making it harder to see the wound.
4. *23-gauge Vitrector*: The 23-gauge vitrector (pneumatic/DORC) has a smaller port opening, which is closer to the tip of the instrument than 20-gauge cutters. This permits lower trans-orifice flow, which does make for

slower aspiration of vitreous than the 20-gauge vitrector. However, it also permits more safety and control than 20-gauge vitrectors at similar cutting rates. It also permits surgery on some membranes which would require scissors if a 20-gauge vitrector were used.

5. *23-gauge scissors, forceps, picks:* Unlike 25-gauge instruments, these don't bend. Compared with 23-gauge instruments, the smaller size really makes a big difference. Even if you don't do 23-gauge virectomy, you should try some of these smaller-gauge instruments.
6. *23-gauge focused light probes:* Unlike 25-gauge focused light probes, 23-gauge light probes provide adequate illumination, and the 23-gauge probes don't bend.
7. *Chandelier lights:* Chandelier lights such as the 25-gauge Torpedo provide excellent pan illumination of the retina. The main drawback of chandelier lights is that unfocused light sources do not show vitreous gel well, and one loses the reflexes created by focused probes on the retinal surface. To improve visibility, the vitreous can be stained with triamcinalone acetate, fluorescein, or ICG, or a focused light probe can be used when needed. Chandelier lights permit bimanual surgery and beautiful full-field views of the retina, excellent for video recording. The Torpedo2 permits one step transconjunctival/trans-scleral insertion of the chandelier light. For other chandelier systems, use the same technique described for blunt insertion of the infusion cannula [see 3 (e)].
8. *The Eckhart 23-gauge cannula system:* A non-manipulated 23-gauge wound is self-sealing. However, a 23-gauge sclerotomy is challenging to work with if instruments must be passed in and out of the eye many times during a case. Also, if multiple entries are made, the 23-gauge wound enlarges and is no longer self-sealing. The Eckhart cannula system is a novel device, easy to use, which permits multiple instrument entry for self-sealing 23-gauge, sutureless vitrectomy. The conjunctiva is stabilized with a ring device, and a shelved circumlimbal incision is made with a very sharp blade, permitting non-traumatic entry into the eye. The cannula is then inserted into the shelved wound. With this system, 23-gauge instruments can be inserted and removed easily during the case. The cannulas are usually directed inferiorly where most pathology lies. If there is superior pathology, one cannula is directed in that direction. All 23-gauge instruments, including curved forceps, pass through the cannula. When the cannula is removed, the wound does not leak. The cannula system may also be used for infusion, although I prefer the infusion instruments described previously (see 3e).

26.5 20-Gauge Sutureless System

Stratos Gotzaridis

Sutureless 20-gauge pars plana vitrectomy is a modified technique that upgrades the conventional 20-gauge vitrectomy to a minimal technique.

Tips:

It needs the use of a short neck – wide tip diathermy probe. With this probe, an extensive burn over the conjunctiva needs to be created. The diathermy has to be broad and intense. The probe presses and stretches the conjunctiva over the sclera. The conjunctiva becomes thin or very thin, and sometimes creates an opening with gradually thinning rim that is sealed with the underlying sclera. The visible end point of the conjunctival burn is a white circle, the size of which must be large enough (4–5 mm diameter). This is an extremely important point of the technique. Adequate diathermy provides convenience in introduction of the instruments, especially at the very beginning. The preferable end point is the creation of a very thin layer of the conjunctiva, or even better the opening of it with the gradually thinning end sealed with the sclera rim. That will provide easier access to the entering tunnels. Also the adhesion between conjunctiva and sclera prevents later bleeding and inflation of the subconjunctival space with infusion fluid.

1. A 20 G MVR blade is used in a bevelled, almost tangential way to create a combined conjunctivoscleral tunnel incision in the inferotemporal quadrant. The blade is directed vertically just before entering into the vitreous cavity, in order to create better wound sealing at the end of the operation.
2. That creates a scleral tunnel that functions as a valve during the operation (when the instruments are out) with no need of plugs.
3. A 4 mm self-retaining (spirals on the metal tip) anterior chamber maintainer (Lewicky) without suture can be used as an infusion cannula. That provides the adequate stability to the infusion line. Superotemporal and superonasal conjunctivosclerostomies are then made.
4. The light pipe and the vitrector, as well as other instruments (such as micro forceps, micro scissors and fragmatom), are easily introduced through these incisions.
5. There is a minor difficulty during the introduction of the instruments at the initial entering to the tunnels. First touch and push the sclera with the instrument

just before the opening of the tunnel, in order to create a slight opening of the tunnel, and then forward the instrument in.

6. Unnecessary exchange of the instruments through the tunnels must be avoided. This will prevent enlargement of the scleral tunnels and finally avoid wound leakage.
7. At the end of the operation, just before pulling the instruments out, keep the intraocular pressure low and remove the instruments slowly out of the tunnels. That will prevent vitreous incarceration to the wounds. Immediate massage with a cotton tip over the ports will allow the scleral walls of the tunnel to collapse one over the other (they are mildly expanded due to maneuvers of the instruments). That will stop wound leakage. In a case where the intraocular pressure is slightly higher and a vitreous incarceration exists at the end of the operation, that will return to normal as soon as the pressure returns to normal too. The absence of suture-tight closure of the tunnels allows the vitreous bands to slide into the eye after the IOP returns to normal.
8. The pressure of the eye at the end of the operation is either normal or slightly low. In case where hypotony is noticed, additional air or fluid can be injected through pars plana with a syringe and 27-gauge needle.
9. Subconjunctival antibiotics and corticosteroids are used at the end of the procedure. Conjunctival chemosis that occurs after the antibiotic injection is beneficial in the closuring of the scleral tunnels.

Index