Ferenc Kuhn

Vitreoretinal Surgery

Strategies and Tactics

Springer

Vitreoretinal Surgery: Strategies and Tactics

Selected wisdoms for the aspiring VR surgeon

Vitreoretinal surgery: the easy thing that is hard to do (paraphrasing Bertold Brecht).
Even a journey of a thousand miles begins with a single step (Chinese proverb).

Anyone who has never made a mistake has never tried anything new (Albert Einstein).
The reception of outlandish ideas: First, "it's completely impossible." Second, "It's possible but not worth doing." Third, "I said all along that it was a good idea". (Sir Arthur C. Clarke).
If I had had listened to my customers, I would have improved the horse and buggy (Henry Ford).
You can resist an invading army, but no power on earth can stop an idea whose time has come (Victor Hugo).

The important thing is not to stop questioning. Curiosity has its own reason for existing (Albert Einstein).
The difference between good and almost good is like the difference between the lightning bug and lightning (Mark Twain).

Everything should be made as simple as possible, but not simpler (Albert Einstein).
Simplicity is the ultimate sophistication. It takes a lot of hard work to make something simple (Steve Jobs).

What you see is what you get. What you don't see gets you.

Hobson's choice is a free choice in which only one option is offered.
Decisions are easy when no options are left (Narasimha Rao).
Doubt is not a pleasant position but certainty is absurd (Voltaire).
The surest sign of insanity is being certain without having any doubt (Andrew Feldmar).
Self-delusion is the first step towards disaster (Raghuram Rajan).
Having a bad strategy is better than not having a strategy at all (Sir Winston Churchill).
No battle plan survives the first contact with the enemy (Helmuth von Moltke).
We either find a road or we build one (Hannibal).
They said it couldn't be done, but that doesn't always work.
Insanity is doing the same thing over and over again and expecting different outcomes (Albert Einstein).

Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric (Bertrand Russell).
What was yesterday's gold standard is today's dogma; what was yesterday's craziness is today's gold.
You are neither right nor wrong because the crowd disagrees with you. You are right because your data and reasoning are right (Benjamin Graham).

You cannot learn to play the piano by going to concerts.

Don't pay attention to the critics. Don't even ignore them (Sam Goldwyn).

Care more particularly for the individual patient than the special features of the disease (Sir William Osler).

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Ferenc Kuhn, MD, PhD
St. Johns, FL
USA

Helen Keller Foundation
for Research and Education
International Society of Ocular Trauma
Birmingham, AL
USA

Consultant and Vitreoretinal Surgeon
Milos Eye Hospital
Belgrade
Serbia

Consultant and Vitreoretinal Surgeon
Zagórskiego Eye Hospital
Cracow
Poland

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Preface: Read me First[1]

Even in the digital age, books printed on paper remain popular with readers.[2] They are a great collection of knowledge presented in a concise, edited format. Scientific books in particular offer a single source of expert opinion, typically richly illustrated, and they continue to provide the reader the magic of holding a physical copy in his hand. A book can be carried around and be accessible even in areas with no internet service.[3]

Today's scientific books are typically written by multiple authors, typically with very limited editing.[4] With occasional exceptions, each chapter in each book ends with a long list of references,[5] seemingly providing support for every major claim the chapter makes. While such books have obvious merit, *Vitreoretinal Surgery: Strategies and Tactics* is different.

This book was written by a single author, reflecting his over-30-year experience in the field. Crucially, this author claims neither that his approach to vitreoretinal (VR) surgery is the *only* nor *the* best option; many surgeons will find parts of this book objectionable or have a different (better) solution to a particular problem than the one described here.[6]

Why this author has chosen to present that particular option for a particular pathology at this particular point in time,[7] however, does have a reason. It is the

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[1] See the **Appendix**, **Part 2**.

[2] They do not necessarily compete with electronic versions either, as this book proves.

[3] This is true even though an online (electronic) version has its own advantages, such as being fully searchable. A hybrid between a printed and an online book is one available on an electronic reader (iPad, Kindle), which is easy to carry around.

[4] It is rather common to have the same topic addressed by more than one author in an edited book, and the information is all too often contradictory.

[5] Sometimes a chapter has more pages dedicated to the references than to the main topic itself.

[6] Let me illustrate this point with one example: reoperation in eyes with silicone oil tamponade and the need to keep the oil after surgery. I used to do the membrane removal under oil, but abandoned this because, among others, I want to see the true ("oil-free") anatomy of the retina in order to address all abnormalities and because with the silicone oil freshly implanted, the "emulsification clock" is reset. Other surgeons, perhaps just as reasonably, will argue in favor of working under the original oil.

[7] The solution to a specific problem evolves over time; what has been true for a number of years may not be true tomorrow as new options, techniques, and technologies emerge.

author's responsibility to describe not only *what* he does, *how* he does it, and *when* he does it; above all, he must explain *why* he does it. The reader will then have an opportunity to contemplate that "why" and make a conscious decision as to whether he agrees and so will employ it himself or, again based on a conscious thought process, decide against it – just as well, as long as the decision against is not a random one.

This book has no references, only a few important publications are listed as "Further Reading." References in the internet age are nowhere near as important in a book as they once were. Besides, the statements made, the issues emphasized, the surgical solutions offered in this publication represent a synthesis of the author's experience. What is described here may have as its birthmother his own brain, that of a colleague during an informal conversation, a publication, or a presentation at some meeting; either way, the original idea has surely evolved over time.

This is a very practical-oriented book, presenting the reader with both strategic and tactical questions about VR surgery (and the surgeon himself). Everything in this publication serves as an agent provocateur to incite the reader to develop his own, individualized approach to each patient, to each surgery. It is *not* the goal of the book to create copies of the author-surgeon; it *is* a goal of the book to encourage the reader to make conscious decisions before, during, and after surgery,[8] to develop his own, unique method for working as a VR surgeon. The author recommends spending a few minutes by listening to a wonderful song[9] that so beautifully, so elegantly describes this singular approach (the lyrics are also published at the end of the Preface).[10]

The format of this book is rather unusual. The reader will find few lengthy paragraphs; these are mostly replaced by bullet points, tables, and text boxes such as *Pearls* and *Q&A*. This format hopefully makes it easier to read the book and find the necessary information fast. Furthermore, the book is partially written in the first person[11] and refers to the surgeon and the patients as "he"[12] – for no reason other than simplicity.

I tried to mimic as much as possible the most ideal teaching situation: an experienced surgeon actively assisting the fellow. This requires providing specific advice as the fellow progresses with the case and questions/issues arise. My own approach to VR surgery is a very conscious one. This helps me foresee many of the problems

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[8] A good example is a recent lecture the author heard: the speaker described a diabetic patient receiving 36 monthly injections into a single eye with macular edema. Obviously, the treatment became an automated process, and the ophthalmologist forgot to stop at some point during the 3 years to look at the big picture, and ask: Isn't there something wrong here if the patient must come back for the very same thing every single month for 3 years and the pathology recurs every time?

[9] https://www.youtube.com/watch?v=6E2hYDIFDIU

[10] An honest speaker asks his audience of trainees not to believe *a word* he (or anybody else) tells them. They should carefully listen to what they are told, test the teaching in their own practice, and then decide whether they accept, reject, or modify it.

[11] Rather than, as is typical, the author referring to himself in the third person.

[12] Except the OR nurse, who is a "she." I have worked, throughout my career, very closely with 17 nurses, each a female.

that emerge as surgery is performed by the fellow (or myself). I tried to construct this book as if addressing these questions while assisting a younger colleague. Naturally, not all situations can be anticipated and thus described in the book, but I believe the most common ones will have been.

I attempted to structure the contents so that they follow a rational order and avoid repetition as much as possible. However, I am aware that this is an impossible task.[13] I also made an effort not to present information a well-trained, past-residency-training ophthalmologist (aspiring to be a VR surgeon) is supposed to already know.

The opening part is a rather unique one since it discusses issues that are virtually never raised: who should and who should not be a VR surgeon, and how to train to become one in a country without a formal fellowship. This part is followed by two parts about the basic rules the surgeon must keep in mind before the actual surgery; the fourth part deals with the fundamentals of VR surgery, while the fifth is dedicated to tactical issues per indication.

I do not recommend that the reader go straight to a chapter in the last two parts of the book without reading (all) the prior parts first; the chapters in **Parts 4** and **5** were written with the assumption that the reader had gone through all preceding chapters.

The book is based on the "standard 3-port" approach to vitrectomy, using the microscope and the BIOM (macular contact lens) for viewing. One chapter (17) briefly describes the alternative approaches. All issues discussed relate to 23 g trans-conjunctival vitrectomy, unless otherwise indicated.

The book is not written for fellows residing in any specific country. While VR surgeons in countries with an advanced health-care system may find certain aspects of what is discussed here superfluous,[14] young surgeons in many, less advanced countries are likely to have to deal with such issues. Furthermore, even in advanced countries it is still helpful for the fellow to consciously address every possible component of VR surgery, from the correct posture during surgery to using the forceps in the most ideal way.[15]

The primary target audience of this book is the ophthalmologist who is either contemplating whether to become a VR surgeon or who is already in training, whether as part of a formal fellowship or, more commonly, an informal one. I sincerely hope, however, that the book will also be useful to my very experienced colleagues: the training of the VR surgeon is never complete. Throughout these 3 decades I have visited numerous ORs and without exception found some "trick" that was interesting so that I have decided to try it myself – or something that made me murmur to myself: "thank God I never tried this." Either way, the visit proved

[13] Eventually, a choice has to be made between "vertical" and "horizontal" structuring. For example, one cannot group everything that concerns the lens in a single location; the lens has to be mentioned in the chapter on visibility as well as in several chapters dealing with strategy and tactics.

[14] Describing the characteristics of "the" ideal chair for vitrectomy, setting up the vitrectomy machine etc.

[15] At what angle should I peel the ILM in an eye with severe macular edema?

useful: whatever it is that forces a surgeon to make conscious, rather than automated, decisions during surgery is a positive thing. The most important is for the surgeon never to be on autopilot; he must avoid making decisions and surgical maneuvers based on reflex or custom.

In summary
Scientific books are impersonal – this book is not. They typically have multiple authors – this book has only one. They contain page after page of references – this book presents none, only a list of "Further Reading". They usually address larger issues, not technical details – this book attempts to do both.

My Way lyrics:

And now, the end is near;
And so I face the final curtain.
My friend, I'll say it clear,
I'll state my case, of which I'm certain.

I've lived a life that's full.
I've traveled each and ev'ry highway;
And more, much more than this,
I did it my way.

Regrets, I've had a few;
But then again, too few to mention.
I did what I had to do
And saw it through without exemption.

I planned each charted course;
Each careful step along the byway,
And more, much more than this,
I did it my way.

Yes, there were times, I'm sure you knew
When I bit off more than I could chew.
But through it all, when there was doubt,
I ate it up and spit it out.
I faced it all and I stood tall;
And did it my way.

I've loved, I've laughed and cried.
I've had my fill; my share of losing.
And now, as tears subside,
I find it all so amusing.

To think I did all that;
And may I say – not in a shy way,
"Oh no, oh no not me,
I did it my way."

For what is a man, what has he got?
If not himself, then he has naught.
To say the things he truly feels;
And not the words of one who kneels.
The record shows I took the blows –
And did it my way!

Yes, it was my way.

(by Jacques Revaux and Gilles Thibault)

Ferenc Kuhn, MD, PhD
Birmingham, AL, USA
Belgrade, Serbia
Cracow, Poland

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Without continual support, a VR surgeon cannot become one or function as such. The complete list of individuals who stood behind and with me in this endeavor is too long to include here: I am able to provide the names of only a selected few.

I am very grateful to my wife, Maria, and my two daughters, Sophia and Judit, who graciously accepted that I was away so much and that my professional life shortchanged them in many ways, and still gave me nonstop encouragement. Without my parents' support I would never have made it to medical school and certainly not into ophthalmology.

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Last but not least, I need to thank my patients whose feedback has served as a recharge for my often depleted emotional battery.

Abbreviations and Glossary

AC	Anterior chamber
Air-test	F-A-X to examine whether the detached retina is shortened or wrinkled
AMD	Age-related macular degeneration
Anomalous PVD	Areas of VR adhesion remain although some or most of the cortical vitreous has separated from the retina posteriorly
Anterior vitrectomy	Removal of the vitreous from the frontal part of the vitreous cavity (*not vitrectomy in the AC or vitrectomy performed via an anterior approach*)
BIOM	Binocular indirect ophthalmo-microscope
BRVO	Branch retinal vein occlusion
BSS	Balanced salt solution
C_3F_8	Perfluoropropane gas
Cannula	Unless otherwise indicated, this is the 23, 25, and 27 g (rarely 20 g) transscleral, metal tube that is inserted through the conjunctiva and sclera to provide access to the vitreous cavity during vitrectomy. In routine surgery, one of these is for the housing of the infusion cannula; the others are for the light pipe and instruments such as the probe. The infusion cannula is referred to as such; it is a "cannula within the cannula" when in place
Cellophane maculopathy	The earliest stage of EMP development: no membrane is visible on the retinal surface, but the ILM is wrinkled
CEVE	Complete and early vitrectomy for endophthalmitis
CNV	Choroidal neovascular membrane
Combined RD	Combined tractional and rhegmatogenous RD
Complete PPV	Total PPV
cpm	Cut per minute
CRVO	Central retinal vein occlusion
cst	Centistokes

Dropped nucleus	Even if the lens material found in the vitreous cavity is cortex, not nucleus, this is the term used for lens particles that got lost posteriorly during phaco
EAV	Endoscopy-assisted vitrectomy
ECCE	Extracapsular cataract extraction
ECH	Expulsive choroidal hemorrhage
EMP	Epimacular proliferation (a.k.a. macular pucker, epimacular membrane, epiretinal membrane, macular epiretinal proliferation etc.)
FA	Fluorescein angiography/angiogram
F-A-X	Fluid-air exchange
IBO	Indirect binocular ophthalmoscopy
ICCE	Intracapsular cataract extraction
ICG	Indocyanine green
ILM	Internal limiting membrane
IOFB	Intraocular foreign body
IOL	Intraocular lens
IOP	Intraocular pressure
IPM	Interphotoreceptor matrix
IR	Infrared
IRMA	Intraretinal microvascular abnormality
IU	International unit
LCD	Liquid crystal display
Lens	Crystalline lens
Lens (IOL) luxation	The lens (IOL) is completely dislocated. It may be in the AC, vitreous cavity, subretinal space, suprachoroidal space
Lens (IOL) subluxation	The lens (IOL) is decentered but does not completely leave its normal position
LP	Light perception
ME	Macular edema
MIVS	Transconjunctival vitrectomy (the term stands for micro[minimal]-incisional vitrectomy surgery)
MVR	Micro-vitreo-retinal (blade etc.)
N/A	Not applicable
Nurse	OR nurse, the VR surgeon's assistant
Oil	Silicone oil; "normal" if its viscosity is 1,000–1,300 cst and the density is <1
OR	Operating room
P-A	Posterio-anterior
PDR	Proliferative diabetic (vitreo)retinopathy
PFCL	Perfluorocarbon liquid (any type of heavier-than-water intraocular fluid used as a temporary tamponade)
Phaco	Phacoemulsification
Phacologist	A cataract surgeon for whom the eyeball is a superfluous attachment to a capsular bag. The latter demands the implantation of the IOL into it, at any cost

PK	Penetrating keratoplasty
Posterior cortical vitreous	Posterior vitreous face, posterior hyaloid face, posterior vitreous cortex
PPL	Pars plana lensectomy
PPV	(Pars plana) vitrectomy
Probe	Vitrectomy probe/vitrector/cutter
PVD	Posterior vitreous detachment. PVD means separation of the vitreous cortex from the retina in the posterior pole, usually understood as up to the equator
PVR	Proliferative vitreoretinopathy
Q&A	Question and answer
RD	Retinal detachment (rhegmatogenous unless mentioned otherwise)
ROP	Retinopathy of prematurity
RPE	Retinal pigment epithelium/epithelial
RVO	Retinal vein occlusion
SB	Scleral buckle/buckling
Scleral indentation	Scleral depression
Scraper	Tano diamond-dusted membrane scraper
SDI	Stereoscopic diagonal inverter (BIOM)
SF_6	Sulfur hexafluoride gas
Steroid	Corticosteroid
TA	Triamcinolone acetonide (Kenalog)
TKP	Temporary keratoprosthesis
tPA	Tissue plasminogen activator
TRD	Tractional RD (diabetes, PVR, etc.)
Trocar	The tool (“MVR” blade) used for creating the conjunctivo-scleral incision for cannula-placement in transconjunctival surgery
UV	Ultraviolet
VA	Visual acuity
VEGF	Vascular endothelial growth factor
VH	Vitreous hemorrhage
Visco	Viscoelastic material
Vitreous base/retinal periphery	The area around the ora serrata where the 10-layer neuroretina and vitreous gel normally terminate
Vitreous cushion	A layer of vitreous lining the retina (typically exceeding the thickness of the cortex)
VMTS	Vitreomacular traction syndrome
VR	Vitreoretinal
vs	Versus
YAG (laser)	Neodymium-doped yttrium aluminum garnet laser

Contents

Part I

Becoming a VR Surgeon

Introduction

This part deals with the two most fundamental issues an aspiring VR surgeon faces.

An ophthalmology resident should choose to become a specialist in VR surgery only if he truly understands what such a career entails – otherwise he will not live a happy life as a VR surgeon. He must have a personality that feels comfortable with the daily challenges and more-than-occasional failures the VR surgeon faces, but also be able to recharge his often-depleted emotional batteries by the daily miracles in restoring sight in diseases that not so long ago would have led to blindness. The first chapter offers guidelines for the aspiring resident in making the right choice.

Many of those who, after careful consideration, made the conscious choice to indeed become a VR surgeon will not be able to join a formal training program because the country's health care system does not offer one. The second chapter provides a road map on how to train "on your own."

Should *You* Become a VR Surgeon? 1

The simplified answer is: it primarily depends on your personality. Most people prefer living a life that is mostly a series of routine activities and feel uncomfortable if they are constantly exposed to challenges, especially if these vary in nature and severity. Such people would have an unhappy life as a VR surgeon.[1] **Table 1.1** compares the life of the cataract surgeon with that of the VR surgeon.

In a classic joke, a car dies and the owner visits the mechanic. The mechanic opens the hood, takes a lengthy look around, then picks a hammer and whacks something under the hood – and the engine roars back to life. When asked how much his intervention costs, he says: “$100.” The owner becomes agitated, how can you charge $100 for a hammer blow? “No”, the mechanic says, “that’s $1. But to know what to whack, that’s $99.”

VR surgery is rather similar. When an experienced surgeon operates, everything looks easy and straightforward to the observer, but when it is the beginner who is sitting at the operating table and tries to proceed with the case, even the simplest maneuvers appear complex and difficult. It is crucial for the ophthalmologist who is considering becoming a VR surgeon to understand that the learning curve is steep[2] and long – in fact, the learning process never stops. New indications, techniques, and technologies keep emerging, and even the experienced surgeon must constantly adapt. For those considering the VR subspecialty, it is therefore highly advisable to understand all its implications for their professional and personal lives *before* they enter the training program.

I remember a colleague with exceptional dexterity in removing cataracts and implanting IOLs but no regard for the rest of the eyeball.[3] He once asked me to assist him in surgery: he wanted to perform vitrectomy for a macular hole on his former cataract patient. He saw ILM removal in a couple of videos and assumed that

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[1] Even worse, their patients will be unhappy: a chronically unhappy surgeon is not able to perform.

[2] When I completed my fellowship with my initial mentor, the late Klaus Heimann, his farewell message was: “Don’t be discouraged, but your first 50 surgeries will end up as failures.”

[3] The typical phacologist.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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Table 1.1 Life as a cataract vs as a VR surgeon*

Variable	Cataract surgeon	*VR surgeon*	Comment
Learning curve	Moderate	*Very steep*	*For a VR surgeon the learning process is intense and it remains forever so*
Sleepless nights before or after surgery	Almost never[a]	*Occasionally*	*Preoperatively because the surgeon is not sure what the best surgical approach would be* *Postoperatively because the surgeon now knows he made the wrong choice and it resulted in an irreversibly poor outcome*
Difficulty in preoperative decision-making	Minimal	*Moderate to extreme*	For the cataract surgeon, the diagnosis brings an almost automatic solution, phaco and IOL implantation, and the timing is also obvious: as soon as feasible. *For the VR surgeon, this can raise extremely difficult questions; just think about a one-eyed patient who has retinitis pigmentosa and develops an EMP. If something goes wrong during surgery, the patient instantly loses (some) central vision in an eye that is already losing its visual field; then there is the risk of postoperative complications. Conversely, if surgery is not done, the central vision will gradually and irreversibly decrease*
Consequences if the preoperative decision-making was erroneous	None to minimal	*None to extreme*	*Just think of a patient with an injury that has a high risk of endophthalmitis; you decide to do early PPV but a catastrophic ECH occurs intraoperatively*
Physical challenge intraoperatively	Minimal; mainly determined by how many cases the surgeon decides to perform on a given day	*Can be significant*	*My longest case (TKP-PPV for a severe injury in a young boy) lasted* 6 h *and* 23 min

(continued)

Table 1.1 (continued)

Variable	Cataract surgeon	*VR surgeon*	Comment
Mental challenge intraoperatively	Moderate	*Moderate to intense*	During cataract surgery the need to make a unique, major decision relatively rarely emerges, but in certain instances real challenges do exist (children, pseudoexfoliation etc.). *In VR surgery, even in "easy" cases* (*VH, see* **Sect. 62.1**), *many decisions are required, and some of them, if they prove to have been wrong, result in irreversibly negative consequences*
Difficulty in intraoperative decision-making	Minimal to moderate	*Minimal to severe*	Cataract surgery has to a large extent been standardized. The inter-case variability is typically limited, and even if the tissue reacts differently to that expected, the solution is usually a readily available one. *Even in an "easy" case, the VR surgeon must make several decisions that are individualized to that particular patient/eyeball. In more difficult cases the number of decisions can be almost infinite*
Tissue reaction to the surgeon's action	Typically as expected	*As expected or very different*	The nucleus may be as soft as predicted or much harder. *During vitreoretinal separation the retina may prove as resistant to traction as assumed – or it may tear at the weakest traction force*
Consequences if the intraoperative decision-making was erroneous	Minimal to moderate[b]	*Minimal to extreme*	*Certain errors can easily be corrected* (*an equatorial retinal tear has been caused during too forceful PVD*); *others can result in irreversible loss of vision* (*tearing the fovea during EMP removal*)

(continued)

Table 1.1 (continued)

Variable	Cataract surgeon	*VR surgeon*	Comment
Expected success rate/prognosis	Very high/excellent	*Low to high/good to poor*	The cataract surgeon is disappointed if full vision is not restored[e] or not restored rapidly[f] *In certain pathologies (macular hole, EMP etc.) excellent visual recovery can be expected if surgery is done well* and *early. In others (PVR, submacular hemorrhage etc.) the success rate is low and/or the recurrence or complication rate high (see* **Fig. 11.1**)
Apparent success rate	Very high	*Low*	*This is a bias, although it may not be obvious to the VR surgeon: his patients are much less likely to come back for longer-term follow-up if surgery was successful. His failures, on the other hand, keep returning*
Intraoperative complication rate	None to low	*None to moderate*	For the cataract surgeon, these complications are rare and mild, and even if they occur, the solution is usually at hand *The VR surgeon faces an endless list of potential complications, some of which may be rare or severe enough not to have a readily available solution*
Postoperative complication rate	None to low	*None to infinite*	*A stand-alone booklet can be written about the list of potential complications following VR surgery (see* **Chap. 64**)
Severity of early postoperative complication(s)	None to low[c]	*None to extreme*	For the cataract surgeon, the only truly vision-threatening risk is endophthalmitis *The list of even the very serious complications after VR surgery is rather long: endophthalmitis, high IOP due to gas expansion, severe VH, RD, PVR etc.*

(continued)

Table 1.1 (continued)

Variable	Cataract surgeon	*VR surgeon*	Comment
Reoperation(s)	Very rare[d]	*Rather common*	*For the VR surgeon, this is true even if his initial job was well done*
Patient satisfaction	High	*Low to high*	*For the VR surgeon, this is one of the reasons why preoperative counseling is so imperative: the patient should know* before *surgery what to reasonably expect and why his cooperation with the surgeon's instructions is so crucial*
Threat of lawsuit against the surgeon	Very low	*Low to moderate*	*For the VR surgeon, this is one of the reasons why preoperative counseling is so imperative: the patient should know* before *surgery what to reasonably expect and why his cooperation with the surgeon's instructions is so crucial; he must also understand and appreciate how difficult the surgeon's task is*
Intellectual reward	None to high	*None to extreme*	This is a personality-dependent issue. The phacologist looks at how many cases he did during the day; the cataract surgeon proudly looks at how many patients had their sight restored by him *Saving vision even in "routine" VR cases means great satisfaction. Nothing is as rewarding for the VR surgeon than improving the patient's chances for being able to see (or even keeping the eyeball) in cases where everybody has given up hope*

(continued)

Table 1.1 (continued)

Variable	Cataract surgeon	*VR surgeon*	Comment
Financial reward	Decent	*Lower then decent*	This, of course, depends on many factors: health care system in the country, the type of practice, the number of cases performed etc. *The VR surgeon may be more rewarded than his cataract colleague per case, but his caseload is much lower*

[*]Nothing in this book implies that the VR surgeon has any type of supremacy over the cataract surgeon; cataract removal with IOL implantation is the most successful surgery on the human body and with good reason: great cataract surgeons have perfected it beyond expectation. My already high personal appreciation was only increased when I underwent, on both eyes, cataract surgery myself, done by an excellent cataract surgeon. Conversely, I do harbor hard feelings for that minority of cataract surgeons whom some call "phacologist": those for whom the patient is a lens walking on two legs, waiting for extraction and in-the-bag IOL placement. Such phacologists do not recognize that "there is life behind the posterior capsule" and thus have no respect for the retina or the eye in general (see the **Appendix**, **Part 2**).
[a]One of the exceptions is a major intraoperative bleeding from the choroid (ECH) and consequent loss of the eye.
[b]Provided the cataract surgeon makes the correct choice: he does not fish for lens particles (see **Sect**. **44.1.1**) lost into the vitreous or he does not carry on with the surgery even though a choroidal hemorrhage is occurring (see **Sect**. **40.1**).
[c]Except: endophthalmitis.
[d]YAG capsulectomy is not considered as a reoperation.
[e]Which is rarely the result of the cataract surgery but due to some VR pathology such as AMD.
[f]Corneal edema due to increased phaco time because of a hard nucleus.

this is exactly like a capsulorhexis: you take a forceps and tear off a membrane.[4] What he did not understand is that success in VR surgery is primarily determined not by the hand (dexterity) but by the brain, which gives instructions to the hand (see **Sect**. **4.2**).

Pearl

Whatever instruction the brain gives to a trained VR surgeon's hands, it is very likely that the hands will be able to execute that decision and without causing significant iatrogenic mechanical damage. Conversely, one may have the most delicate hands, but if the instruction is false, failure is inevitable. An obvious example is ILM removal: the surgeon must be aware of how to grab the membrane, recognize via visual feedback how deep the jaws are biting, how to pull on the membrane (vectors), at what speed etc. (see **Sect. 32.1**). All trained VR surgeons should possess the hands to carry out any maneuver with relatively little difficulty.

[4]Similarly, an inexperienced VR surgeon should not, unless assisted by an experienced mentor, undertake removal of an EMP – I have seen eyes after such attempts with an intact EMP but with central retinal tears as the inexperienced surgeon grabbed retina instead of epiretinal tissue.

Aspiring VR surgeons must understand what their future life will be like, but also how complex the training is (see **Chap**. **2**), and not embark on this road unless they are prepared to accept the hardship.[5]

One of the peculiarities of the VR surgeon's life is the relatively high number of returning patients. They usually come back because of a complication. (Those, and this is the majority, who had been cured forever with one operation are much less likely to return.) The VR surgeon is therefore exposed to a "selection bias" on his outpatient (clinic) days: there will many more patients to be seen with "a problem" than without.

The VR surgeon occasionally sees patients who arrive with a condition that other colleagues deemed inoperable, but the patient does not want to give up hope and keeps searching for a surgeon who is willing to try. Successful intervention in such a case is what helps the surgeon recharge his drained emotional battery.

A VR surgeon is not a surgeon of the retina and vitreous; he is a surgeon of the eyeball.[6] To be able to properly deal with posterior segment problems, he must also be able to treat corneal diseases, perform a PK, suture the iris, remove the lens and implant an IOL, recognize the causes of secondary glaucoma etc.[7]

Ophthalmologists who understand these caveats and accept their implications will have a richly rewarded emotional and spiritual life as VR surgeons. If they do not, will they be very unhappy – and so will their patients.

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[5] I know of several fellows who entered into a program only to give up after a few months; more was lost for them than the time wasted.

[6] More precisely, surgeon of a *person* (see **Chap. 5**).

[7] Some, although not all, of these are therefore discussed in this book, even if such topics do not regularly get detailed in publications dedicated to VR surgery.

2 How to Train as a VR Surgeon Outside a Formal Fellowship

Ophthalmology residents who decide to become a VR surgeon have at least some experience in performing anterior segment surgery, mainly cataract extraction. Such a background provides a good basis for specializing in posterior segment work – but no more than a foundation for it.

Training for VR surgery is a long, indeed never-ending, process. If the ophthalmologist is fortunate enough to live in one of the few countries in which formal schooling (fellowship) is available, his path to becoming a trained VR surgeon is charted. Most residents, however, will not have access to such tried-and-tested programs and must design their training program themselves. This chapter provides guidelines for such an endeavor.[1]

Pearl

For someone aspiring to become a VR surgeon, the importance of proper training cannot be overemphasized. Without such training many operations will end in failure for the surgeon and visual loss for the patient. Repeating the same erroneous intravitreal maneuvers will predictably result in the same tragic outcome. Facing failure after failure, these surgeons will eventually give up VR surgery, at the cost of blind patients and the loss of self-confidence.

[1] All trainees are called *fellow* in this book.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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2.1 The “To-Do” List[2]

The fellow should do all of the following:

- Select an experienced *and* willing VR surgeon[3] at the fellow’s institution, who will serve as a mentor for the entire training period (see the **Appendix**, **Part 1**).
- Read the most important books and articles on VR surgery – the mentor should help with the selection process.
- Attend meetings where peers, preferably from the international community, discuss the latest development in the VR field.[4]
- Spend the maximum possible time with the mentor,[5] examining patients in the outpatient department. Many a pathology will be seen and you should understand how the decision whether the condition in that particular patient is amenable for surgery is made.[6]
  - Follow the patient after PPV, preferably long term. This helps recognizing complications and their treatment, and also, in retrospect, to see whether the decision to go to surgery was correct.
- Assist in surgery as often as possible.[7] Assisting, again, must never be spent by passively staring at the microscope or monitor (see **Table 2.1**). As always, the more experience gained, the easier and more useful such observing/assisting becomes.[8]
- It is highly advisable to learn from more than a single surgeon, however good he is. Different surgeons have different approaches to the same problem, and, optimally, the fellow is exposed to a variety of options. Even when the fellow sees something “horrifying,” it is helpful: he now definitely knows that he will never do *this* in his own practice.

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[2] Taking notes throughout the entire training process is crucial, for two reasons. (1) The human brain is not a storage facility. Instead of trying to memorize the received information, whether major strategy-related issues or useful surgical tricks, it is best to preserve them electronically, in an organized system that best suits the fellow’s own logic and allows searching. (2) There is a huge difference between active and passive knowledge; taking notes makes the learning process active, as opposed to just listening or reading, both of which are passive.

[3] Do not expect that everybody around you will treat you well (see the **Appendix**, **Part 2**).

[4] Obviously, some of the lectures will at the beginning be way above the level of the fellow. This difficult initial period will not last very long, and the fellow should not be discouraged if he has problems understanding all he hears (or reads). If the information is conflicting, it may simply be due to the complexity of the field, not a sign of his incompetence.

[5] Shadowing. You should bombard him with questions, and while remaining respectful, do not hesitate to challenge him (see the **Appendix**, **Part 2**).

[6] The mentor’s decision is to some extent subjective; others may choose a different option in the same situation (see the Preface, **Sect. 11.4**, and **Chaps. 8**, **9**, and **10**).

[7] If this is not allowed or possible during a visit, at least observe closely, as if you were assisting.

[8] Imagine two people being taken by a football fan to a game: one of them understands it, the other has never seen one. Even though these two people will see exactly the same events unfolding in front of their eyes, one will be able to share exciting moments after the game with the fan (“Did you see how player X passed the ball in the 40th min with his heel?” – “Yes, it was fantastic”). The inexperienced person will have no idea what the other two are talking about. The image of that heel-pass was cast on his retina, but his brain did not register it.

Table 2.1 The rules of assisting/observing in VR surgery[a]

Element	Comment
Talk to the surgeon before the operation	Explain to him that you came to learn and that you are very interested in what he is going to do; ask him if he is comfortable with you asking lots of questions[b]
The condition of the eye	Note the anatomical relationships; formulate a strategic goal (what the eye's condition at the end of the operation should be) and then the tactical goals (the tissue manipulations needed to achieve that final anatomical condition). Of these two basic categories, initially the second is more obvious; as the experience grows, the strategic issues will gain importance[c]
The surgeon's next move	Try to expect what this move will be (what you would do in this situation). There are *two possibilities*, *detailed next*
Move is what you expected	*Be proud of yourself*
Move is not what you expected	*This is the moment of truth*: *if you are able to figure out why his move was not what you expected*, *you learned something* *If you cannot determine why the surgeon acted differently from your expectation*, *you must ask him why he did what he did*[d]
Asking the surgeon "why"	Most surgeons will not be willing to answer you during the operation. You must make a mental note (if you are assisting) or a quick written one (if you are observing) about the exact situation and how the surgeon's action diverged from your expectation, and ask him after the operation A few surgeons are willing to answer the question right there and then. These are the surgeons you will benefit from the most since you can instantly learn something A few surgeons actually encourage you to comment, not simply answer your questions; this is the absolute best option since it makes your newly gained experience a truly active one. These are the surgeons you should often revisit Conversely, some surgeons will not answer you at all or give you an obviously bogus answer. Leave him

[a]The distinction is that during observation the fellow follows the surgery on the monitor or, if he is able to have access to it, through the microscope. If he is allowed to scrub in and actually act as an assistant, the experience is enhanced.
[b]Make sure you select your words very carefully if the patient is awake during the operation (see **Chap.** 15).
[c]These goals are discussed in **Parts IV** and **V**.
[d]See **Sect.** 3.4.

- The best possible scenario is to visit numerous surgeons/institutions over time.[9] The fellow does not have to spend a lot of time with/at each; a week or 2 usually suffices. Ideally, he arrives with lots of questions, gets answers, goes home, and continues the learning process in his own practice; with time he will have more questions and then visit another surgeon for answers and for a different experience.

[9] See **Sect.** 3.4 about the behavior of the fellow in the ORs he is visiting.

Q&A

Q *How should the fellow select which other surgeons to visit and observe*?

A The surgeon should obviously be knowledgeable – but it is equally important for him to be willing to help, answer all questions, and explain things; in short, he must not only be an experienced surgeon but also be a decent person.

The process of observing is not restricted to what is happening inside the eye. It is also crucial to take note, among others, of the following:

- The surgeon's posture and seating arrangement (see **Chap. 16**).
- How he holds the instruments with three, not with two, fingers (see **Sect. 20.1**).
- How he hands instruments to, and accepts instruments from, the nurse while he never looks outside the microscope (see **Fig. 35.1**).
- How he supports the actions of the hand performing the maneuver with his other hand (see **Fig. 2.1**).

- Watching *unedited* videotapes of surgeries performed by the fellow himself as well as by other surgeons is a great teaching tool (see **Sect. 11.3**).
- Once you gained some experience performing surgery yourself, find a mentor who is willing to observe you (ideally, assist you), serving as your coach. Nothing is as valuable as an experienced surgeon who shares his practical expertise with you this way – as long as he does it in optimally (see the **Appendix**, **Part 1**).

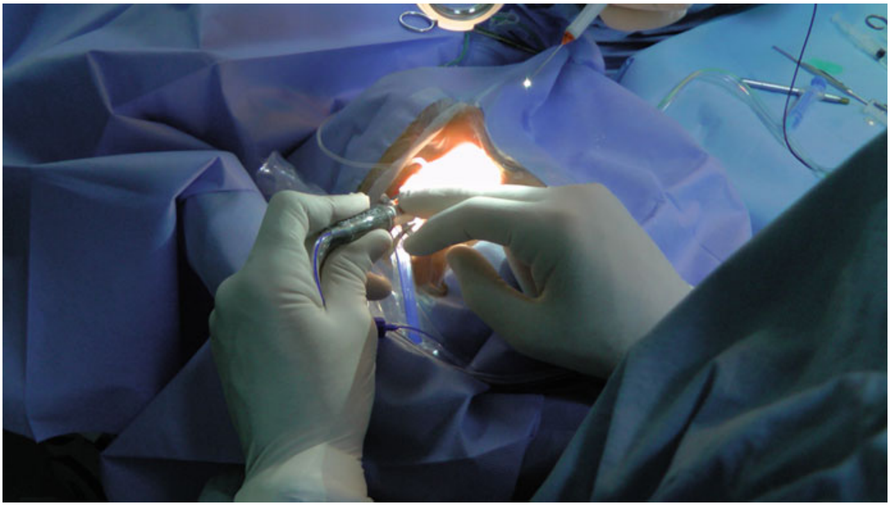

Fig. 2.1 **One hand supported by the other**. The surgeon is performing maneuvers in the AC: the probe must be inserted through a temporal paracentesis because it has to be held in the horizontal plane. In this particular case it means that the probe is held in the surgeon's nondominant hand; his dominant hand is used to provide extra stability and increased precision for maneuvering with the probe

Table 2.2 provides a brief summary to help the fellow design his own training program.

Table 2.2 The elements of a self-designed VR fellowship program*

Element	Comment
Books, articles	These represent a readily available source that should often be consulted
Internet	It is useful to know "what's out there"; however, websites that are not written by *professionals for professionals* in a verifiable manner should never be used as a source for learning
Attending VR meetings	The usefulness of such meetings increases as the fellow gains experience. The meetings, even at the onset of the training program, however, provide physical access to, meeting with, potential mentors. Exchange of ideas with peers is another benefit, whether related to information/knowledge about VR surgery or the training process
Active participation in own institution's VR activities	Examining patients, assisting in surgery, following patients who underwent PPV, postgraduate courses, clinical research
Observing/assisting in surgery	This should never be a passive observation but an active one: the fellow should think along and try to predict the surgeon's next step (see **Table 2.1**). Furthermore, observation is not restricted to intraocular manipulations; everything must be noticed from anesthesia to how the nurses assist the surgeon or how the surgeon holds the instruments in his hand
"Why?"	The fellow must develop an attitude so that he never accepts *anything* he is told without consciously contemplating it, and, if he has doubts or disagreements, is ready to voice these – regardless of who the "authority" that told him that particular thing is (see the **Appendix**, **Part 2**)
Note-taking	This is a nonstop process; the notes must be kept in a single place (one electronic file, one booklet) and be arranged logically and constantly updated. The electronic version has the advantage of being searchable
The messenger	It is a common problem that speakers/tutors are unable to place themselves in the shoes of the audience or the fellow, and try to explain things on a level that is far above the one that the audience/fellow is able to perceive. Even if the fellow finds a knowledgeable and helpful surgeon, if this person is unable to communicate in a manner that is "on level," the fellow is better off not spending time with him
Visiting other surgeons	To select which surgeon to visit is not an easy task. The surgeon must not only be a respectable expert but one who is willing to help; one who explains things and does so on a level that the fellow actually understands (see above); one who does not give bogus answers to the fellow's questions just so that all questions are answered, regardless of the answers' truthfulness; and one who is willing to maintain a long-term relationship with the fellow: he remains available to be consulted via email, SMS, or the telephone (Skype)

(continued)

Table 2.2 (continued)

Element	Comment
Multiple visits to multiple surgeons	As the fellow starts to perform surgery on his own, the number of his questions will not diminish but multiply. It is preferable to spend several shorter visits at different time points with different surgeons than returning to the same surgeon over and over again. The most effective way of developing one's own way of doing VR surgery (the ultimate goal) is a synthesis of everything the fellow has seen and experienced
Start own operations with a helpful expert assisting	Nothing is as valuable as an expert's advice that pertains to the particular case, the specific issue, and the emerging problem during the operation done by the fellow. The advice can easily solve a problem the fellow may otherwise feel as insurmountable or it can prevent a complication that otherwise may result
Never undertake a case that is above your level of training	Once the fellow has a few successful cases, especially if no serious complications have occurred, there is a tendency to take on cases that are too complex. This can have horrible consequences for the patient and for the fellow as well. VR surgery must never be done by a surgeon who lost his confidence (see **Chap. 11**)
Reviewing surgical videotapes	Watching unedited tapes, if done by undivided attention, can provide valuable lessons about surgical maneuvers and unbiased information about what works and what should be avoided or done differently. Such a review is of utmost value not only to the fellow but even to the most experienced surgeon (see **Sect. 11.3**)

*Most of what is listed here takes place simultaneously, not in a rigid sequence.

2.2 A Word of Caution

Those who are outside a formal fellowship program have less supervision and scrutiny over their progress assuring that they always take the next step gradually (see also **Sect. 11.1**). This laxity may lead to a dangerous chain of events.

- Failures, some resulting in blind eyes, accumulate. To compensate, the fellow may choose to operate on more and more such cases, which lead to more failures, which seems to reinforce the need to do more cases, a vicious cycle.
- A corollary to this rule is a fellow who is forced to take on complex trauma cases, which are way above his level of expertise, because nobody else at the institution is willing to do them (see **Sect. 63.12**). The fellow will (have to) try operating in these cases not because he wants to but because he is told to.
  - With each successful surgical maneuver,[10] the fellow's ego gets a boost, and the motivation to do more and more complex maneuvers grows.[11]
  - Successful completion of surgical maneuvers can subconsciously make the fellow view VR surgery as a sum of surgical maneuvers. This is normal but very dangerous and must be consciously fought, not the least by the fellow himself. VR surgery is much more than the sum of individual surgical maneuvers – it is strategy first, and tissue tactics only second (see **Table 3.1**).

[10] Such as peeling an epiretinal membrane.

[11] All this is also normal.

Part II

VR Surgery: Basic Principles

Introduction

There are many issues that are rarely if at all discussed in textbooks, even though they have great significance for the VR surgeon in training. These issues include, among others: the rationale for preparing an individualized plan for the entire treatment process and for each operation; a number of "everything-you-always-wanted-to-know-about-vitrectomy-but-were-afraid-to-ask" type of questions (such as the importance of tremor or the length of surgery); the thought process involved in designing one's own surgical philosophy; the criteria for selecting the personnel that form the VR team; the surgeon's relationship with his nurse; choosing the equipment, instruments, and materials for VR work; the importance and technique of communicating with the patient; the decision-making whether and when to operate and on which eyeball if the condition is bilateral; the order of cases on a day when multiple vitrectomies are scheduled; and the need for the surgeon to conduct periodical self-examinations.

Fundamental Rules for the VR Surgeon

3

3.1 Plan (Not Trial and Error)[1]

No VR surgeon should operate on a patient without first designing a plan, which is to be based on the characteristics of the condition in general and the characteristics of the condition in that specific person's eye in particular.[2] The plan involves three levels, the first two of which are strategic and the third tactical (see **Table 3.1**).

No VR surgeon should begin the treatment process without knowing three basic things:

- The condition of the eye at the onset – point A.[3]
- The expected condition of the eye at the termination of the intervention (the ideal, hoped-for outcome) – point B.
- How to get from point A to point B.

To sit down to the operating table and address each tissue pathology as it comes into view and deal with the technical challenges only as they emerge without first designing a plan is ineffective in its process and suboptimal in its outcome. Amazingly, the very surgeon who practices such a re-active type of surgery[4] would never himself consider driving in an unfamiliar city from his current location (point A) to his destination (point B) without first consulting a map or GPS device to plan the route.

[1] As described in **Chap. 5**, all strategic decisions are to be made *together* with the patient.

[2] Behavioral economics provide an excellent example of the difference between reflective (autopilot-like) action vs one based on conscious consideration. Answer the following question: if the ball and the racquet together cost $11 and the racquet costs $10 more than the ball, how much does each cost? The reflective, rapidly given answer is $10 and $1; the considerate one says $10.50 and $0.50.

[3] This may be a very accurate diagnosis such as a visible macular hole or, less commonly, a vague one such as in an eye with a massive VH.

[4] "Let's go step by step and see what happens."

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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Table 3.1 The three levels of planning in VR surgery

Level	Comment
One: The *strategy* of the entire treatment process from the end of the evaluation to the final follow-up visit. Prevention of possible complications is incorporated in the plan	This is the most fundamental part of the plan: What number of surgeries appears to be ideal to allow reaching the most optimal final outcome?[a] It may be preferable to forego a *comprehensive* (all-in-one) reconstruction and instead choose a *staged* approach with multiple surgeries. In the latter case (for instance, for an eye with a severe rupture that caused lens extrusion, vitreous hemorrhage, major retinal damage, and iris retraction), the surgeon must also develop a plan regarding the *timing* of each intervention. If a single surgery is sufficient to deal with the pathology,[b] planning on level one and level two merges into a single strategy, which includes the preoperative, perioperative, and postoperative medical treatment as well as the operation itself plus its timing
Two: The *strategy* concerning the upcoming operation. Prevention of possible complications is incorporated in the plan	The surgeon should know what he intends to achieve during that particular surgery (see the text for more details). To close a macular hole, for instance, the main surgical steps[c] include vitreous removal (with a preoperative decision regarding the amount of vitreous to be removed; see **Sect.** 27.2), ILM peeling, and gas tamponade
Three: This is the *tactical* level. Prevention of intraoperative complications is incorporated in the plan	The VR surgeon must make several[d] intraoperative decisions related to the actual surgical technique (tissue tactics). Should a proliferative membrane, for instance, be bluntly dissected or sharply cut, and if the latter, whether with the probe or scissors, and if the latter, which type of scissors? Exactly where should the membrane be cut? At what angle should the scissors be held when the handle is finally squeezed?
One to three: No part of the plan must be in stone	As the treatment progresses, whether it relates to strategy such as staging and timing or tissue tactics such as the technique of ILM peeling, the surgeon must carefully observe how the tissue, the eyeball, and the person react to his actions (feedback on multiple levels). If the outcome of his activity differs from the expected,[e] he must modify the plan accordingly, on any or all three levels. If for instance the original plan called for two surgeries but during the first operation the surgeon realizes that all his original long-term goals can be accomplished in this sitting, the second surgery becomes superfluous

[a]The surgeon must also have a rough idea about what that most optimal outcome can be, both anatomically and functionally (prognosis).
[b]Which is the majority of the cases.
[c]There are other, less crucial steps, which are not listed here.
[d]It can range from the high teens to literally hundreds during a complex trauma case.
[e]This is rather common in VR surgery, see **Table** 1.1.

Pearl

Just as a driver who encounters a roadblock or traffic sign that forces him to alter his planned route, a surgeon who finds an unexpected pathology or tissue behavior must change his original plan according to what the new findings dictate.

As in the driving example, the surgical plan cannot be formulated without the surgeon having a clear idea about the desired anatomical outcome of that particular operation. Instead of making ad hoc decisions as pathologies emerge, the surgeon's tactical decisions are in harmony with the strategy.[5] This *long-term thinking* has multiple advantages (see **Table 3.2**).

Table 3.2 Long-term vs short-term planning for a patient requiring VR surgery

A 48-year-old male presents with a 6-day history of vision loss; he has 3 D of myopia. He has a macula-off RD with a large tear at the equator inferotemporally. The vitreous is full of pigmented cells, and the tear's edge is curled			
Treatment selection	Plan A, focusing on the *short* term	Plan B, focusing on the *short* term	Plan C, focusing on the *long* term
Rationale for choosing that particular option	Without surgery, the eye will go blind There is a risk of PVR, but both the RD itself and the risk of PVR can be taken care of by traditional SB surgery. The break has to be lasered. Gas tamponade is needed to temporarily cover the break	Without surgery, the eye will go blind There is a risk of PVR; while the RD could be taken care of by traditional SB surgery, the PVR risk requires vitreous removal. The break is inferior; therefore adding a SB increases the chance of success. The break has to be lasered. Gas tamponade is needed to temporarily cover the break	Without surgery, the eye will go blind. The PVR risk is high, surgery therefore must be complete PPV to relieve the current traction and address the one on the horizon: PVR. For the latter, silicone oil is needed. The laser must surround the break but also be circumferential (cerclage) to provide additional support. The lens will become cataractous and is better removed now
Actual treatment plan	A *radial SB* after external drainage of the subretinal fluid and *laser* around the break to seal it. An additional *encircling band* against any future traction and 0.5 ml of pure *SF6* for tamponade	*Vitrectomy*, *SB* (*segmental or circumferential*), *laser*, and 30% *SF6* tamponade	*Cataract extraction with IOL implantation*, *capsulectomy*, *total vitrectomy*, *endolaser cerclage*, *silicone oil implantation*

- It requires careful consideration whether an eye that is likely to develop PVR requires primary in-the-bag IOL implantation.
  – An eye at high PVR risk may be better off with removal of both lens capsules during the primary surgery, especially if the patient is young (see **Sect. 38.5**). The implantation of an iris-claw IOL is the *last* step of the management process (see **Sect. 38.6**).[6]

[5] Another analogy to describe the difference between the two approaches is the example of two football coaches who have the purse to buy new players. One coach buys famous players with the hope that their talent will naturally give birth to a team system; the other one buys players who he thinks will fit his existing coaching philosophy. The second coach should have a higher chance of creating a winning team.

[6] The implantation is performed months after the silicone oil has been removed.

- Suture-constricting a pupil too early makes subsequent VR surgery more difficult (see **Sect.** 48.1.2).[7]
- The surgeon should try to anticipate complications such as PVR, which may arise due to the condition itself or as a result of his own intervention. He must try to reduce the risk (prophylactic chorioretinectomy; see **Sect.** 33.3).

Pearl
A good surgeon is akin to a defensive driver who not only drives carefully but is constantly on alert: keeping watch over all the other drivers around him and trying to anticipate what those drivers may do. A surgeon must never be on autopilot and never do maneuvers as a matter of reflex or custom – there must be a reason for everything he does (or does not do).

- A pseudophakic eye requires a capsulectomy.
  - With the probe it is possible to create a capsulectomy regardless of the thickness of the capsule and without the risk of damaging the IOL; in addition, the capsulectomy is precisely of the desired size.
  - Performing capsulectomy assures instant and permanently excellent visibility for both patient and ophthalmologist.
  - True, YAG laser will probably also allow opening the posterior capsule at any time postoperatively, but the opacified capsule will interfere with visualization until then. The laser also produces a large, permanent floater that may be bothersome to the patient, a consequence that could easily have been avoided by planning ahead.
  - Leaving the posterior capsule intact has one, intraoperative, advantage: no risk of IOL fogging during F-A-X (see **Sect.** 25.2.3.4).

Finally, it must be emphasized that as technology evolves, surgical techniques improve, new materials become available etc., the surgeon must also change. The same condition that a few years ago would have required a certain plan to treat may require a very different plan today.[8]

Figure 3.1. is an illustrative example of planning. It is from “civilian life,” outside ophthalmology, but it shows the mindset that the VR should develop to replace “instinct” with thinking ahead.

[7] Another example of long-term thinking is a patient with PDR: the VA is full but the tractional detachment is progressively approaching the fovea. A surgeon with short-term thinking simply hopes that the TRD never progresses that far and defers surgery until the fovea does detach. A surgeon with long-term thinking explains to the patient what is likely to unfold, but also the risks of the surgery, and, with the patient’s informed consent, operates before the fovea detaches.

[8] One illustrative example: In severely injured eyes I used to preserve the anterior capsule and implant, as the very last step of the treatment process, a sulcus-fixated IOL. In recent years I switched to removing both capsules and implanting an iris-claw IOL (usually possible even if the iris had also been injured and required suturing; see **Sect.** 38.6).

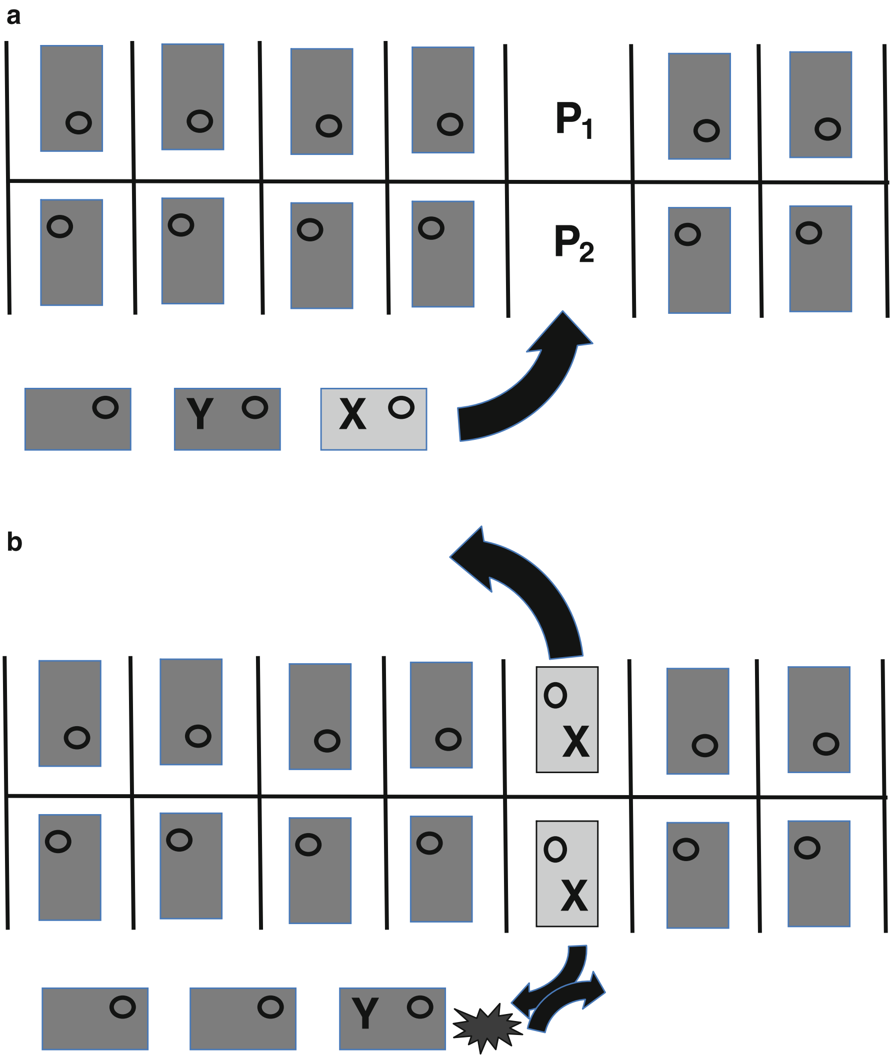

Fig. 3.1 Planning to park a car. (**a**) All cars are parked in a way that reflects their owners' lack of planning before they had parked their vehicle (peer pressure may also have played a role for those who arrived later). The question is: how will the driver of car X, just arriving, park? This parking lot provides the opportunity to pull through (leaving the car in space P_1 instead of P_2). Space P_1 has numerous advantages: upon leaving, there will be no need to first go in reverse. (**b**) Backing out not only wastes fuel and wears out the breaks and the gear mechanism earlier, it also makes it impossible for the driver to see, at least initially, whether there is oncoming traffic (such as car Y). If that driver does not pay attention, a crash can easily occur. Furthermore, driver X will be forced to wait until all traffic clears before he can proceed. Parking in space P_2, in short, has absolutely no advantage. A VR surgeon, planning ahead, should immediately pull through to space P_1

3.2 Control (as Opposed to Playing Russian Roulette)[9]

By carefully planning the treatment on levels one and two, it is the surgeon, not chance, that controls the strategic aspects of the treatment. Control intraoperatively[10] is also very important; it means that the surgeon has a clear idea about the consequences of each of his maneuvers, how the tissue will (should) react. Instead of "let's cut into the retina and hope it will not bleed," control translates to "I will diathermize the retina before cutting into it so that there will be no bleeding."

Pearl
Ideally, everything that unfolds inside the eye during VR surgery does so because of *choice*, *not chance*. Grabbing an EMP in the *center* and pulling it away from the retina translates into a traction force that acts on the retina at each location where there is adhesion between scar tissue and retina – and the surgeon has no way of knowing where these adhesion points are. By attacking the membrane at its center, the surgeon gives up *control* over subsequent events and replaces it with *hope* (centrifugal peeling; see **Sect. 32.2.2.5**).

3.3 Do Not Try to Adapt the Eye to Your Own Preferences

Certain conditions permit, even encourage, a cure by employing against them exactly the same type of surgery, performed in an identical fashion and repeating the same surgical steps; VR pathologies must never be in this category. Each case deserves individual attention and management, on all three levels of planning and executing the plan. **Table 3.3** shows the differences between the two approaches.

Trying to force the surgeon's favorite technique on the eye irrespective of the condition's unique attributes is wrong and dangerous. The *surgeon* must adapt to the eye's condition and not the other way around. He must be able to see the forest, not just the tree, and develop the best possible treatment option in the particular situation. If he is unable or unwilling to modify his approach based on what the eye's condition demands, he must forego surgery and refer the patient.

3.4 The "What, When, How – and Why" Questions

The VR surgeon must always know *what* he is doing or planning to do, *when* he plans to do it (timing), and *how* he intends to do it (tissue tactics). It is equally important for him to always know *why* he does it, and this is true for all three levels of planning, including every single tissue maneuver during surgery.

[9] A corollary to this issue is a surgeon who never had binocular vision. In real life it is not a problem: he may not even know this, and no binocularity test is required of a potential VR surgeon. Those who used to have binocular vision but then lost it should not be discouraged either: EAV proves that the human brain is able to cope, even if the learning curve must be respected (see **Sect. 17.3**).

[10] Level three, tissue tactics.

Table 3.3 Adapting "eye to surgeon" vs "*surgeon to eye*"*

Example	Adapting eye to surgeon	Comment	*Adapting surgeon to eye*	*Comment*
Cataract in a eye of 20 D myopia	Phacoemulsification with in-the-bag IOL implantation; the IOL power is 0 D	Because the posterior capsule must be preserved so that an in-the-bag IOL implantation can be performed	Removal of the lens in toto[a] and not implanting an IOL at all; total or subtotal PPV[b]; prophylactic endolaser cerclage	No vitreous, no traction, which, along with the laser treatment, virtually eliminates the RD risk. Preserving the capsule(s) brings no benefit
Traumatic cataract in an eye that suffered a contusion; there is mild phacodonesis, the lens is slightly dislocated (tilted posteriorly in one quadrant), and the vitreous has prolapsed into the AC	Anterior vitrectomy; phacoemulsification; capsular tension ring; in-the-bag IOL implantation	The situation usually results in a perfect anatomical situation at the completion of surgery. However, the condition of the remaining zonules is unknown intraoperatively: there is a risk of postoperative IOL dislocation. Furthermore, the long-term RD risk has not been addressed	Pars plana lensectomy and anterior vitrectomy; removal of the lens capsules; prophylactic endolaser cerclage; implantation of an iris claw lens	While this is a more complex surgery than the one described in the second column, the long-term risk of IOL dislocation as well as the RD risk have been properly addressed – even if the latter risk is not going to be zero
RD with rather central breaks at 2, 5, and 9 o'clock	Three radial buckles; cryopexy or laser; gas tamponade	Even if the anatomical outcome is excellent, the surgery has significant morbidity	PPV; endolaser cerclage; gas or silicone oil tamponade	The PVR risk is not negligible; treatment without prevention is inadequate

*Shortened terms describing a surgeon who applies, pretty much unchanged, his usual approach regardless of the individual circumstances vs a surgeon who changes his approach according to what the individual situation demands.

[a]To keep the eye "compartmentalized" was an extremely important issue in the ICCE era when combined surgery was performed but no laser therapy was available – many eyes were lost to neovascular glaucoma. Compartmentalization has lost its significance since.

[b]See **Table 27.2.**

Pearl

Just as it is unwise to initiate therapy without a diagnosis, it is wrong to perform surgery or any surgical manipulation as a reflex or instinct. The surgeon must make *conscious* decisions concerning all strategic issues and every tissue manipulation prior to any action.

In my many visits to many operating rooms as a trainee, I found surprisingly few surgeons who honestly answered my "*why*?" questions. Several surgeons were clearly annoyed and did not give an answer at all. Many of those who did answer gave useless ones,[11] answers that clearly told me: I do not have a rational explanation for why I'm doing what I'm doing (see **Table 2.1**).

I encourage every visitor in my operating room to ask me the most fundamental question: "Why did you do that?"[12] It is extremely rare that I cannot give a rationale for my action.[13]

3.5 Don't Start What You Cannot Finish

Typically, the first surgery has the best chance of success, and with each successive operation the prognosis gets poorer. If a surgeon cannot complete the intervention because he reached the limit of his expertise or the equipment is lacking,[14] the eye's condition may have worsened.

Removal of a VH in an eye with complete PVD is perhaps the easiest indication for PPV.

However, if the PVD in incomplete and there is VR adherence in an area of no-PVD, even an experienced surgeon can cause a retinal break and even intraoperative RD (see **Sect. 58.2**).

Q&A

Q *Which are the easy cases for the inexperienced fellow to operate on*?

A It is impossible to say. What may look easy preoperatively can quickly turn into a disaster in the hands of a surgeon who lacks the proper expertise. This is why the fellow needs to assist in VR surgery for extended periods before gradually being guided into the surgeon's role. Unsuccessful surgeries early into one's career are not "only" harmful for the patients but also for the surgeon's self-confidence (see **Sect. 4.7**). This is especially true if the stakes for the patient are exceptionally high, such as when he is monocular (see **Sect. 8.4**).

[11] "Because I always do it this way"; "because that's what I was taught"; "what do you mean?"

[12] Why did you use a bent needle and not a forceps to lift that membrane? Why did you cut the subretinal strand rather than take it out? Why did you just change the direction of peeling the ILM? The fellow must behave in the OR as a young child who is constantly "pestering" his parents with "why?" questions.

[13] If I cannot answer a visitor's "*why*?"question, it forces me to reconsider the issue in question to either find the rationale for it or look for a more effective option.

[14] Another evidence in favor of planning all aspects of surgery well in advance.

3.6 Common Sense vs Dogma

Common-sense thinking is a must-have attribute of the VR surgeon.[15] One's approach to the treatment of a condition must have a rational basis, and this rational does not tolerate dogmas – even if that dogma seems to have a solid scientific foundation.[16] First, not all scientific questions are amenable to an answer by a study with level 1 evidence. Second, even if such a study exists and its results seem to have an obvious answer to a particular problem, it still must pass the "smell test," that of: "Does it make sense to do this?"[17] Third, just because a study's conclusions are statistically valid, there is great variability in how an individual responds to the same therapy.[18] This is another reason for each surgeon to develop his own "my way" philosophy (see **Sect. 11.4**).

3.7 Maximal Concentration During the Entire Operation

- Once you are sitting at the operating table, you must have your undivided attention to be focused on the eye and do so throughout the entire procedure.[19]
- It can lead to tragedy if you lose concentration, regardless of why.
  - External factors (e.g., overhearing two nurses gossiping about a colleague).
  - Internal factors (e.g., the manipulations are easy and straightforward,[20] and the operation is proceeding smoothly with no apparent risk of intraoperative complications).

Unexpected events can rapidly occur, making a problem of minor significance (e.g., during that "easy" EMP removal the surgeon comes across a small area of strong VR adhesion) into a disaster (the peeling force/direction is not changed in time and an easy-to-avoid retinal tear is caused).

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[15] I recently heard a presentation by a well-known retina specialist about a patient with diabetic macular edema. He received 36 monthly intraocular injections (at ~$2,000 each); the plan was to continue the treatment. Common sense tells you that if a therapy is expensive *and* does not work, you do not "blindly" follow a study's blanket recommendation but switch therapy.

[16] This principle extends to include studies that are "evidence-based." Just because such proof of the efficacy of a certain treatment option once existed, it does not necessarily mean that years after the publication of that study it still holds water.

[17] The British Medical Journal published a sarcastic article in December 2003 about the "effectiveness of [the] parachutes," stating that this "has not been subjected to rigorous evaluation by using randomized controlled trials… everyone might benefit if the most radical protagonists of evidence-based medicine organized and participated in a double-blind, randomized, placebo-controlled, crossover trial of the parachute."

[18] In other words, Mr. A. will do fine with therapy X, but Mr. B. is better off with therapy Y.

[19] The football (soccer) coach's cliché warning to his players is that the game lasts 90 min; whether the other team wins by scoring in the first or last minute does not matter, you still lose.

[20] Such as panretinal endolaser treatment, which requires very little "brain work." A surgeon who delivers over 2,000 spots is at risk of losing focus and venturing too close to the fovea (see **Sect. 30.3.2.**).

A corollary to the "maximum concentration" rule is for the surgeon to never take his eye off the operating field as long as any instrument is inside the eye. If he needs an instrument to be exchanged, he must blindly hand it to the nurse and accept blindly what she places in his hand (see **Chap. 6** and the **Appendix**, **Part 2**).

3.8 Make Life as Easy for Yourself as Possible

I often hear surgeons stating that they do not need any extra help (such as mechanical support for their hands, staining of the ILM, support from a well-trained assistant). I do not question these statements: I am also able to remove an unstained ILM without hand support or do scleral indentation myself. However, I still prefer having wrist support (see **Sect. 16.2**), stain the ILM (see **Sect. 34.3**), and often ask my assistant to do scleral indentation (see **Sect. 28.4**) because it makes the operation safer and easier.

Pearl
The surgeon should try to reach his strategic and tactical goals via the least complicated and most effective, safest, and fastest way possible.

3.9 Under Peer Pressure: To Yield or Not to Yield

There will be moments when the surgeon feels pressured by his peers, his patients, the industry, or the medical bureaucracy to abandon his own idea ("my way") and "go mainstream" instead.

Every surgeon must make an individual decision whether to bow to such outside pressure.[21]

Q&A

Q *Should the VR surgeon bow to peer pressure*?

A It is not possible to entirely neglect the outside world. Some of this pressure, for whatever reason, is absolutely overwhelming: the "disposable everything" trend is unstoppable. Some of the pressure can be resisted but is still futile: 20 g PPV will sooner or later disappear as companies will not manufacture the tools for it. The pressure, however, should be resisted if the surgeon feels strongly about it (e.g., using scissors, not the probe, to cut proliferative membranes on the retinal surface). An example why to resist peer pressure is given in **Sect. 13.2.3.2**.

[21] Or insist on his "my way" approach.

3.10 Referral of the Patient

Referring a patient must not be a simple instruction for him to "go and see someone at institution X" or ask the assistant to "send the patient to Dr. Y." A detailed description of his condition must accompany the referral, which also has to be timely and very specific about why it is made; furthermore, the patient must be made aware of all these details.[22]

Pearl
VR surgery must never be about the surgeon's ego ("if my peer could do it surely I also can"), only about the patient. The surgeon must be aware of his own limits and never try to stretch it into unchartered territory. If he, for whatever reason, is unable to do an optimal job, he should neither unnecessarily delay surgery nor should he do an incomplete job but refer the patient to a colleague/institution where all elements of success are available. If something truly unexpected emerges during surgery and the surgeon is unable to deal with it, it is best to stop surgery and not force it, but refer the patient as the lesser of two evils.

If the ophthalmologist, for whatever reason, is not willing to perform a surgery that the patient desires, referral is the only acceptable option (see **Sect. 46.1.1**).

3.11 The Rest of the Eyeball…

As the knowledge base is growing,[23] ophthalmologists are becoming highly specialized. A specialist, the joke goes, knows more and more about less and less; a highly specialized expert knows everything about nothing.

The VR surgeon must never fall into this trap. He does not have to be an expert in cataract or glaucoma surgery, but he must be knowledgeable in these fields[24] so that he can complete his surgery even if issues not strictly related to VR surgery emerge.

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[22] While writing this book, I saw a patient who was injured while chopping wood. He suffered a scleral rupture, traumatic cataract, and a VH. His wound was sutured and the ophthalmologist immediately had his assistant refer the patient to a well-equipped institution. Unfortunately, the assistant making the phone call failed to mention that the referral is for a fresh injury and simply asked for an appointment; the receiving institution also failed to ask the reason for the referral. The patient was scheduled for the next available date, which was 4 months later. He arrived with LP vision and an incarcerated, totally detached retina with severe PVR.

[23] I remember a cornea book with over 1,500 pages – and that was in 1978. Imagine a book today on the same topic and with the same detail: how long would it be?

[24] As well as in many other subspecialties such as uveitis or the cornea.

Frequently Asked Questions About the Basics of VR Surgery

4

4.1 What If the Surgeon Has Tremor?

The less experienced a fellow, the more he is worried about his tremor: will it interfere with surgical success? Below are a few thoughts about tremor:

- It is exceptional that a surgeon has absolutely no visible tremor – and even then it may simply escape easy detection.
- Tremor is not a constant phenomenon. Whether it is present during a particular operation depends on several factors.
  - The surgeon's mental status. Tremor may not appear under certain circumstances[1] but readily manifests itself if the stakes are assumed to be higher.[2]
  - Acute sympathomimetic reaction due to increased caffeine intake, medications, or unexpected news.[3]
  - Straining.[4]
  - Lack of rest the previous night (length, quality, alcohol consumption).
  - The setup at the operating table: wrist or hand support (see **Sect. 16.2**).
- Even if tremor is present, it need not necessarily interfere with the hands' ability to properly execute the brain's commands. The negative implications of the same amplitude of tremor depend on the surgeon's experience.

Pearl
The more experienced the surgeon, the less the tremor interferes with surgical success.

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[1] Such as during a typical operation in a familiar environment.

[2] Such as live surgery or a patient who is a VIP or a well-known malpractice attorney.

[3] Such as when the surgeon finds out just prior to the operation that his wife wants a divorce.

[4] Such as lifting heavy objects the hours preceding the operation.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_4

- The surgeon is able to reduce the level of tremor by having proper hand (wrist) support and by consciously and constantly paying attention to not squeezing the instruments he is holding.
  - Squeezing non-squeezable instruments (see **Sect. 13.2**) such as the light pipe obviously serves no purpose, yet inexperienced surgeons do this instinctively. It should be part of the fellow's training to fight this reflex.
- Not all squeezable instruments are the same.[5] A good example is the disposable vs the permanent VR forceps (see **Fig. 13.5**). To operate the forceps the surgeon must squeeze its handle. The permanent forceps requires minimal force because (1) the traveling distance of the handle from "jaws completely open" to "jaws completely closed" is short and (2) its resistance to the squeezing is low. Neither is true with the disposable forceps.[6]

Q and A

Q *What can the surgeon do if, despite his best efforts, tremor seems unstoppable and appears to prevent successful execution of a maneuver?*

A An individual decision is necessary whether the risk of attempting vs abandoning the maneuver is greater. Alternatively, the surgeon can try to switch the order of maneuvers and return to the delicate one (e.g., ILM peeling) later during the operation, first performing tasks that require less dexterity (e.g., scleral indentation and peripheral vitrectomy).

A final issue regarding tremor concerns its impact on the surgeon's lifestyle. Can he repeatedly strain his hands/arms with hard physical work (daily weight lifting in the gym) or must he refrain from such activities?[7]

Again, the answer varies based on the individual surgeon. Some people are able to perform fine intravitreal work perfectly even after hard physical work; others have a major increase of tremor even after mild physical activity.[8] Keep in mind, though, that *repeated* hard physical work *does* reduce the ability of one's fingers to carry out fine manipulations. VR surgeons should not do heavy weight lifting on a long-term basis.

[5] It is the industry's responsibility to design, based on surgeon feedback, squeezable instruments so that minimal force is necessary to operate them.

[6] A careful observer will notice that while at the onset of a difficult (long) ILM peeling the surgeon's hands are steady, with time tremor develops. This is due to the force needed to squeeze the handle of the *disposable* forceps.

[7] My very first chief held an extreme view on this: "On the day of performing surgery the surgeon must not use his hands for *anything* strenuous." He was a giant of a man with a petit wife; on the morning when he was scheduled to operate, his wife accompanied him to work and carried his briefcase for him. This was in the age of ICCE, light years from the era of ILM peeling.

[8] The same is true for caffeine intake.

4.2 How Important Is Good Dexterity?

Again, it must be emphasized that the brain is the boss; the hands simply execute the instructions coming from the cortex. No matter how good a surgeon is with his hands: if the command is erroneous, the outcome is poor (see also **Chap. 1**).

Very few people have two hands with equal dexterity; it is no different with VR surgeons. Typically, the surgeon is right-handed and would not be able to do the finest of maneuvers[9] with his left hand unless undergoing rigorous, lengthy training.

- Typically, the surgeon's nondominant hand is used for performing maneuvers that require only limited dexterity.
  - In monomanual surgery, the nondominant hand usually holds the light pipe only. It may, however, be also needed for vitreous removal in the periphery in a phakic eye but also during laser cerclage (see below).
  - In bimanual surgery, the nondominant hand is used for grasping a membrane, which the surgeon then cuts with an instrument operated by his dominant hand.
- Occasionally, the intraocular target area cannot be approached from the nasal side, even if this is where surgeon's dominant hand is. Several options are possible.
  - The task *must and can* be accomplished with the nondominant hand.[10]
  - The task *should but cannot* be accomplished with the nondominant hand. In such cases some type of a compromise must be sought. For example, the patient has an extensive network of subretinal strands, including in the submacular area, which require removal because they do not allow retinal attachment (as clearly proven by a carefully performed air-test [see **Sect. 31.1.2**]). The surgeon may leave some of the subretinal membranes behind, alternate between use of the dominant and nondominant hands, use multiple retinotomies for access, or switch to a 20 g system.

Pearl
The surgeon himself may be surprised to realize how much he is able to accomplish with his nondominant hand. He should train the nondominant hand and thus improve its capability.

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[9] Mostly, ILM peeling.

[10] One such scenario is lensectomy/phacofragmentation; this cannot be accomplished from the nasal side – the nose is in the way (see **Sect. 38.2.1**).

4.3 Mono- or Bimanual Surgery Is Preferable?

This is one of those questions to which there is no definite "this is better than that" answer.

- Most (experienced) surgeons can accomplish most tasks using only one working hand.
- Most surgical maneuvers can be performed using only one hand, with occasional help by the nondominant hand: the light pipe as an ancillary tool.[11]
- Using a fixed light source[12] and having two working instruments in the eye has obvious advantages but also some drawbacks.
  - Fixed lighting can never match the variety of illumination options the surgeon-held light pipe can provide by changing the location (switching hands), angle (shadows), and distance from the field (illumination power).
  - The assistant can help by changing the angle of illumination via grabbing and redirecting the permanently fixed light. However, this makes rotating the eyeball more cumbersome.
  - Self-illuminating instruments can eliminate or reduce the effects of these difficulties, but they introduce new ones: light reflex and additional shadow/s from the instruments themselves.
- Having two working instruments in the eye requires very close coordination between the two hands.[13] Such coordination is as important an issue as the dexterity of the dominant hand.
  - The surgeon is able to practice coordination between his two hands in many ways, outside the OR, by designing tasks that require fine bimanual movements.
  - A great "live" test, with only a small risk of causing significant iatrogenic damage, is "window cleaning" of the dirty anterior surface of an IOL (see **Sect. 25.2.3.2**).

Pearl
Whether the VR surgeon uses one or two working hands to accomplish a certain task is an individual decision, not one that should be influenced by peer pressure (see **Sect. 3.9**). A surgeon who is unable to have the required close coordination between the two hands should stay with the monomanual technique.

[11] For example, separating the vitreous from the retina anterior to the equator (see **Sect. 27.5.2**).

[12] Light such as chandelier, twin, bullet etc.

[13] And, of course, between the two feet.

4.4 Which Gauge?[14]

No patient ever asks the surgeon about the gauge he used during surgery; the one thing the patient is interested in whether the operation was successful or not. Selecting the gauge (20, or MIVS: 23, 25, 27) is an individual choice: whatever the surgeon feels most comfortable with to achieve the desired outcome. The crucial difference is not related to gauge size but to whether transconjunctival or conjunctiva-dissecting (traditional 20 g) surgery is performed (see **Table 21.1** for more details).

- It may be advisable to mix the gauges in certain situations (see **Sect. 32.4.1**).
  - An IOFB whose every dimension exceeds the inner diameter of the cannula (see **Sect. 63.7.1**).
  - Intravitreal instruments with long blades are needed (PDR, subretinal membranes).
- The smaller the gauge, the higher the flow (vacuum) required to achieve tissue attraction.
  - Tissue attraction means movement of the tissue toward the port.[15] Conversely, at a given flow rate and at a given distance between retina and port, the risk of biting into the retina is higher with larger gauge probes.
- In general, the smaller the gauge, the slower the vitreous removal.[16]
  - A probe with a smaller gauge also involves a higher chance of blockage by the aspirated material (such as lens, synchysis, hard membranes). The blockage requires flushing of the probe by the nurse or even replacement of the probe.
- Sutureless, spontaneous closure of the wound (and thus the prevention of postoperative hypotony), and healing (and thus prophylaxis of wound reopening) are proportionally faster with smaller gauges.
- In principle, the smaller the gauge, the less risk of causing a retinal break at the sclerotomy site, which risks the development of a postoperative RD.

I use almost exclusively 23 g because this offers most of the advantages of the 20 g instruments without significant compromise regarding functionality and the speed of the removal of vitreous, membranes, or lens material.[17] Unless otherwise indicated, 23 g transconjunctival cannulas and instruments have been used throughout this book.

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[14] The outer diameter of a 20 g instrument is 0.89 mm; 23 g, 0.72 mm; 25 g, 0.55 mm; 27 g, 0.40 mm. The scleral incisions need to be slightly longer than the diameter of the instruments inserted through them (diameter vs. surface area of the tool).

[15] The speed of movement also depends on the duty cycle (see **Sect. 12.1.2.5**).

[16] It also depends on machine characteristics (pump, flow/aspiration, duty cycle etc.) and setup (see **Sect. 12.1**).

[17] Exceptions include certain complex trauma cases or situations where instruments with a longer blade are preferred (see above).

4.5 Combined Surgery or Cataract Surgery Separately?

Technically, aphakia provides the least difficulty for a VR surgeon: there is no lens to interfere with visualization or to protect when working in the anterior part of the vitreous cavity. Aphakia, though, is very rare today, which leaves the VR surgeon to face a patient who is either phakic or pseudophakic. Both conditions present their own challenges; these are listed in **Table** 4.1.

Performing cataract and VR surgery in one setting has multiple advantages and a few disadvantages and challenges; these are shown in **Table** 4.2.

A few strategic and tactical issues are discussed below; the rest are found in **Chap.** 38.

Table 4.1 Phakia vs pseudophakia as a challenge to the VR surgeon

Variable	Phakia	Pseudophakia
Visibility	*Completely clear lens*: no challenge to surgeon *Some cataract present*: minimal to moderate challenge to surgeon. For most maneuvers, this is easily overcome by BIOM use (see **Sect.** 12.3); during macular work, tissue staining (see **Chap.** 34) helps *Substantial cataract present*[a]: may make VR surgery impossible. The surgeon should remove the lens and then complete the VR surgery	*Both the bag and the IOL are clear*: no challenge to surgeon *The bag contains cortical material or the capsule is opacified*: minimal to significant challenge to surgeon. Through a capsulectomy[b] the bag can usually be cleaned; the opacified capsule often needs to be incised with vitrectomy scissors before it can be trimmed with the probe
Iatrogenic damage by surgeon	*Broken posterior capsule*, *severe intraoperative cataract developing for other reasons*[c]: the surgeon should remove the lens and *then* complete the VR surgery	*Loss of posterior capsule or sufficient zonular support*: extremely rare[d] but may require removal of the capsule-IOL complex. This can be rather challenging and often a rather long incision is needed (see **Sect.** 44.2.2)
Additional issues	Removal of the anterior vitreous face: may be a significant challenge to the surgeon (see **Sect.** 27.5.3)	Rarely,[e] the capsule-IOL complex must be removed

[a]Or true lens damage (not lens touch, see **Sect.** 25.2.3.1) is inadvertently caused by the surgeon.
[b]Which can be performed with the probe in a much more controlled fashion than with YAG laser (see **Sect.** 3.1).
[c]Lens feathering, gas cataract etc.
[d]Broken zonules, IOL instability etc.
[e]Phacodonesis because of weak/damage zonules; IOL damaged during YAG capsulectomy; chronic endophthalmitis etc.

Table 4.2 Combined vs staged cataract/PPV surgery

Cataract/PPV surgery	Combined	Staged[a]
Advantages	Single procedure for the surgeon: saves time	Cataract surgery can be optimally planned (this includes IOL calculation)
	Single procedure for the patient: saves anxiety	If no crystalline lens is present, PPV can be performed under ideal visualization
	Single procedure for the health service: saves cost	Deferring lens removal well into the postvitrectomy period is preferred by patients who still have accommodation at the time of the PPV
	Cataract surgery is more complicated and has a higher risk of intraoperative complications in the vitrectomized eye	
	PPV may have to be unnecessarily delayed if cataract surgery must be performed as a separate prior procedure	
	Unhindered, instant access to the retinal periphery, ciliary body etc.	
Disadvantages[b]	The cornea may become too hazy during cataract surgery to allow safe accomplishment of fine tasks such as ILM removal	More OR time is required for that one patient
	Not all insurance plans provide full reimbursement for both parts of the surgery	The nucleus may be very hard after PPV, especially if silicone oil has been used
	If the cataract surgery was not planned and the surgeon intraoperatively decides to do it, proper IOL calculation may be impossible[c]	If silicone oil is in the eye, it may leak into the AC during lens removal, interfering with visualization; there may be significant loss of the oil

[a]Cataract surgery precedes the VR surgery unless indicated differently.
[b]I tried to avoid repeating the obvious counterpart of what is mentioned in the other column (e.g., combined surgery saves money, but the opposite statement is not listed among the disadvantages of staged surgery).
[c]Preempt this problem by doing the calculation prior to the PPV.

- Even if the surgeon's plan calls for preserving the lens,[18] it makes sense to do the IOL calculation preoperatively.
  – The lens may be damaged during PPV, requiring removal that was not planned originally.[19]

[18] It needs to be emphasized that *every* patient undergoing PPV will eventually develop cataract.

[19] Intraoperative lens feathering (see **Sect. 25.2.3.1**), whether due to the long duration of surgery or lengthy/repeated air tamponade, rarely interferes with visualization to the extent that lens removal becomes necessary.

  - Silicone oil may have to be used, whose presence can make IOL calculation somewhat uncertain, especially if the cataract is very dense.[20] Cataract progression is usually faster when silicone oil is present; therefore, preemptive lens removal should be considered.
- If combined surgery is performed, it is recommended to place the infusion cannula first.
  - Opening of the infusion is rarely necessary until after the completion of the cataract surgery.
- Lens removal may be very difficult in the absence of a red reflex (significant VH is present).
- I try to avoid hydrating the corneal incisions – this requires constructing the wounds so that they are self-sealing (see **Sect. 39.1**).
  - If the tunnel incision is leaking, a single 10-0 nylon suture is used to close it (see **Sect. 63.4**). The suture is left in place for at least a couple of weeks.
- It is preferable to use an IOL with a large optic.
- Once the IOL has been placed and the wounds are leak-free, the infusion is opened, the two working sclerotomies are prepared, and a standard PPV is carried out.
  - I always perform a capsulectomy in the pseudophakic eye (see **Sect. 25.2.3.4**).

4.6 Is It Acceptable That Financial Decisions[21] Override the Medical Ones?

It is a sad reality, but one that all surgeons must accept: the funds available for VR surgery are limited. How to select the patients for operation so that the greatest possible number of those needing VR surgery have access to, and benefit from, it is not easy. Below are a few thoughts (not absolute rules!) to help making the triaging decisions.[22]

- Emergencies should have priority; in this definition of the term, an RD *is* an emergency.
- One-eyed patients should have priority.
- Those with very poor prognosis should be left toward the end of the waiting list.
- Those with good prognosis should be moved up on the waiting list.[23]
- Those with a condition that progresses slowly[24] or do not cause permanent early damage[25] should be placed somewhere in the middle of the list. Obviously, these

[20] The LenStar (Haag-Streit AG, Koenitz, Switzerland) is able to provide rather accurate readings.

[21] These are not made by ophthalmologists but by insurance companies, administrators, politicians, lawyers, businessmen etc.

[22] This is an incomplete list; those who often do triaging will have much to add to it.

[23] This is against the typical rationale in triaging. However, in VR surgery, delay almost always results in a progressively worse outcome, and the progression can be rather rapid.

[24] For example, EMP.

[25] For example, ME.

persons must have regular checkups to detect any rapid deterioration of vision early, in which case they are moved up the list.

- Those also requiring cataract surgery should undergo separate operations. This is because reimbursement is probably full for both operations if done independently – and the budget for cataract and VR operations is separate.
  - If the VR surgeon performs many combined surgeries but the reimbursement does not cover the cataract/IOL part, the facility can go bankrupt.[26]
- If the functional and anatomical conditions are identical in the two eyes, the much younger person should have the advantage.
- With similar functional and anatomical conditions, patients who are keen on having their pathology treated should be placed higher on the list than those who hesitate despite extensive counseling.

Pearl

The cost of a single surgery is, to a certain extent, up to the surgeon: certain maneuvers may be performed at very high cost but also at low expense and without compromising success. A good example is *routine* PFCL use in RD surgery: it definitely makes drainage through an anterior retinal break easier, but PFCL is very expensive. In the vast majority of cases, the drainage can be completed without PFCL use, even if it takes extra effort (see **Sect. 54.5.2.3**).

4.7 How Much Confidence in Himself Should the VR Surgeon Have?

You can err on either side, and both are dangerous.

- *Overconfidence*: After a series of successful cases or a few exceptional "victories," the surgeon may think that now he knows everything.
  - Humility about his own limitations and respect for the tissue he is handling are crucial parts of the VR surgeon's personality – and must remain so.
- *Loss of confidence*: If the surgeon starts to believe that he is now incapable of solving problems that he used to solve (or should be able to deal with), a vicious circle may result. Failures accumulate, prompting the surgeon to commit more errors, which then exacerbates the situation (see **Sect. 2.2**).
  - It is best *not* to lose confidence in the first place; once lost, it is much more difficult to regain it. In any case, the key is to gradually increase the level of difficulty of the problems he is tackling (see **Sect. 3.5**) and to constantly reevaluate his results.

[26] The surgeon, of course, will hear from the financial department first.

4.8 How Long Do Vitrectomies Take?

Another issue that fellows (as well as inexperienced nurses and anesthesiologists) often ask about is the length of the procedure.

Q and A

Q *How long does an average VR surgery last*?

A There is no answer to this question. The duration depends on many factors: The particular indication, the type of equipment used, the quality of the instruments, the experience of the surgeon, the experience and attitude of the nurse, the expected and unexpected complications during the operation, the extra maneuvers that may become necessary etc. If I encounter no surprise, I usually need no more than 10 min for an uncomplicated VH with PVD, a little less than 15 min for an eye with a macular hole, but I have had numerous complex TKP-PPVs that lasted for more than 5 h.

Finishing surgery in the least amount of time should *not* be a goal of any surgeon for any procedure. The reason to nevertheless try to do so is not for the surgeon to have extra "free" time[27] but to reduce the time the patient (and his family) spends worrying about what is happening in the OR.

Pearl

No award is given to finish a VR surgery in record-breaking time. The award goes to those who consistently do a perfect job.

4.9 Was Surgery Successful?

Obviously, this is a crucially important and obviously most relevant question; it is, and always should be, asked by the patient, his friends, relatives – and the VR surgeon himself. However, the answer is not as straightforward as it may first seem.

For a cataract surgeon, if no intraoperative complication occurs, the answer is almost always a "yes": the anatomical success is there for all to see, and the risk of postoperative complications is small; the functional success is virtually never determined by the lens operation[28] but by the condition of the posterior retina.[29]

[27] Not that there is anything wrong with this concept.

[28] Except perhaps if an IOL of the wrong power was implanted.

[29] To avoid the "unexpected outcome of no visual improvement," the fundus should always be checked prior to cataract surgery: is there an old RD or an end-stage AMD?

For the VR surgeon, however, the issue is much more complex, due to the complexity of the operation and/or to the body's reaction to the operation; the original condition may also be a progressive one.

- *Was the vitrectomy an anatomical success*? Often, everything looks perfect at the conclusion of surgery, but by the next morning, there is blood in the AC or in the vitreous, or the retina may be detached.
  - Even if complete anatomical success has been achieved, scar formation or some other undesirable complications may later destroy what has been achieved intraoperatively.
- *Was the vitrectomy a functional success*? Success in restoring the anatomy does not necessarily lead to functional improvement. There are several possibilities.
  - The vision may not improve initially but do so subsequently.
  - The vision improves initially but deteriorates or is even lost longer term as the anatomical condition of the eye turns for the worse (i.e., the retina detaches).
- *The vision does not change substantially* – but an otherwise hopeless situation (loss with natural history) has been prevented.

The VR Surgeon's Relation to His Patient: Counseling

5

Counseling should be the basis of any patient-physician relationship. The more complex the patient's condition,[1] the more complex the relationship and the greater the need for *proper* counseling. Counseling is a two-way communication,[2] during which the VR surgeon provides information to the patient, who then asks questions to clarify what he heard and, finally, makes the final decision regarding treatment – with the surgeon's help.

Counseling is not easy to master since it is not usually taught in medical school but has a steep learning curve. There is little feedback about the VR surgeon's progression in mastering it,[3] and both the learning of and practicing it are very time-consuming.

5.1 The "Target" of Counseling

The VR surgeon's life is busy; during the daily routine, it is easy to miss the tree (the branch) for the forest (see **Table 5.1**) and focus on the tissue or the eyeball, instead of the person.

One very often seen example of how some surgeons concentrate on the tissue pathology rather than the person is the way the timing of surgery for a macular hole is determined. A surgeon who declares that "I do not operate on a macular hole until

[1] Such as VR surgery and ocular traumatology.

[2] As opposed to a sadly all-too-often-seen monologue: the physician telling the patient what he will do to him to cure his disease (see the **Appendix**, **Part 2**).

[3] One measure the VR surgeon can use to monitor his own progress in mastering the art of counseling is the percentage of his patients asking, after being told to make the treatment selection based on the information the VR surgeon gave him about his condition: "Okay, and what would choose if *you* had this same condition?" If counseling is done right, very few patients will ask this question – but it may take several years for the VR surgeon to reach this stage of expertise.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_5

Table 5.1 Why the indication for surgery should be made by the patient, not by the surgeon

Example	Selected outcome options[a]	Comment
A pregnant woman toward the end of her term presents with full vision in an eye that has 7 D of myopia. Her VA is full but there is a chronic inferior RD, which almost reaches into the fovea. She is unable to determine whether there has been progression lately (the retina has high-water marks) and no documentation is available	If you recommend surgery[b]: All may go well: she maintains good vision, and her baby does not arrive prematurely *There may be intraoperative complications, the vision remains worse than preoperatively, and her baby arrives prematurely, possibly while she is on the operating table* *There may be postoperative complications, the vision is severely compromised, her baby arrives prematurely, and the baby is not healthy* If you do not recommend surgery: All may go well: she maintains good vision, and her baby does not arrive prematurely *Her fovea detaches before the baby is born, in which case:* *VR surgery is performed, but she still loses some vision* *It is now too late to operate on the retina because the baby is due, and she loses some or a lot of vision by the time VR surgery becomes possible* *She loses some vision but before VR surgery could be done the baby arrives prematurely*	Options in *italics* spell some type of disaster for the patient and for the VR surgeon. There will be willing lawyers who try to hold the surgeon legally (and financially) responsible for any imperfection the baby may have if VR surgery was performed and the baby arrived prematurely – or for not having done VR surgery and she loses some vision If it had been the surgeon who talked the patient into surgery (rather than the two of them coming to an agreement based on the patient's decision), it would be very difficult for him to escape the moral and legal responsibilities should there be any visual loss due to a surgical complication. The surgeon faces the same issues if he decided on his own to decline surgery because he expected no progression of the RD but the fovea nevertheless detaches
A middle-aged man presents with a macular condition that is typically progressive, likely to destroy the central vision with time. At the moment, however, his vision is almost full and he is not bothered by any symptom. VR surgery is able to prevent the risk to vision, but only if done early	If you recommend surgery: All may go well: he maintains good vision, and he accepts that early cataract development is an unavoidable side effect *There may be intraoperative complications, and the vision remains worse than preoperatively* *There may be postoperative complications, and, despite reoperations, the vision is severely compromised* If you do not recommend surgery: All may go well: he maintains good vision forever or at least for an extended period *The disease progresses rather fast, and by the time the patient undergoes surgery his vision cannot fully be restored* *His visual acuity starts to drop, surgery is performed, but intra- or postoperative complications develop and the vision will never be restored to its original level*	The risk-benefit ratio must always be the primary, decisive factor determining whether the surgeon agrees to perform the operation (see **Sect. 8.1**). This is usually a rather straightforward decision if the condition has already caused functional loss. Most people, however, have a great difficulty appreciating the benefits of a prophylactic procedure. If complications occur and the postoperative vision is even slightly worse than the preoperative vision, they will not feel relieved that the surgery prevented the much worse outcome that was likely with "natural history" but feel betrayed by the surgeon who talked them into the operation

[a]Many other possible scenarios are not included here, all of which would be in the "complication/failure" category in both of the examples.
[b]Which in this case would be PPV and, probably, silicone oil implantation.

VA drops to 20/40" has no consideration for the individual patient. Several *questions* immediately come to mind about this:

- *Why 20/40, and not some other level of VA* (e.g., *20/50*)?
  - Indeed, the very fact that there is no consensus about the cutoff VA level shows that such an artificial distinction has no merit.
- *Is the patient informed that a delay of surgery can cause permanent visual loss*?
  - The lower the initial VA, the smaller the chance of regaining full vision.
- *Are patients robots so that the same artificially chosen cutoff VA is applicable for everybody*?
  - Some people are extremely bothered by minor visual disturbances while others tolerate much worse ones.[4]

Pearl

The decision when/whether to operate must not be decided by a random VA value but by the desires of the patient – based on the information he receives from his physician about his condition.

Another example to show the "tissue vs person" thinking is a patient who undergoes cataract surgery and the nucleus is dropped (see **Table 9.1**). The visual outcomes in the literature are fairly similar whether PPV is performed immediately or delayed by days or even a few weeks.

- The cataract or VR surgeon who leaves the timing up to convenience[5] looks at the problem on the "tissue level": since the outcomes are similar, it does not matter when the PPV will be done.
- The cataract or VR surgeon who wants the PPV to be done immediately[6] looks at the problem as one of a person who expected a complication-free cataract operation with a rapid visual rehabilitation. Now that the complication has occurred, this has all changed, and the patient should not be exposed to days or weeks of anxiety about the final outcome.

[4] If this was not enough to convince the reader why an artificial cutoff VA must never be the deciding factor when indicating or deferring surgery, think about *yourself*, the VR surgeon, having a vision problem that greatly bothers *you* during surgery. *You* go to your colleague who finds that you have 20/25 vision and a barely visible EMP, and he tells *you* that no surgery is justified because *your* vision is not yet "bad enough." Will you accept this verdict?

[5] Surgeon, OR time availability etc.

[6] In the same surgical session.

5.2 The Patient Does Not Know Most of What Is so Obvious to the Surgeon

Once the surgeon makes the diagnosis, he must inform the patient (and, preferably, his family) about the following:[7]

- *The eye's normal anatomy and physiology*. Without this, it is impossible to explain to the layperson what is wrong with the eyeball.
- *The current condition*, describing the pathology that requires a decision whether to treat it.[8]
- *The options to choose from*. Barring untreatable conditions, there are always at least two choices: do nothing (elegantly called observation or "watchful waiting") or do something; typically, the "do something" is not a singular option but can be subdivided into several choices.
  - Briefly, and as appropriate, each surgical procedure should be described.
  - Presenting the options, the surgeon should try to provide numbers (percentages) for each:[9] prognosis, intraoperative, and early and late postoperative complications.[10]
  - Counseling is not about one particular tissue lesion only. For instance, if a patient who presents with a macular hole is found to also have a subluxated IOL, he needs to be asked about how much the IOL's position interferes with his visual functions. If the patient considers it a major hindrance, the VR surgeon should offer repositioning or replacing the IOL during the PPV (see **Sect. 38.5.1**).

Counseling is not restricted to a preoperative discussion; it may continue intraoperatively if the patient is awake (see **Table 15.1**) and certainly must continue postoperatively, from "the day after" to the very last follow-up visit.

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[7] The information must be as short as possible but as detailed as needed so that the patient can have the final say in the decision-making process. Making the patient read and sign a sheet of paper called "informed consent" is insufficient, even if accompanied by a video explaining the operation for the patient's condition. There is no substitute for personal interaction and explanation.

[8] For example, I usually describe an RD as a wallpaper, which has peeled off the wall and is now found in the room. To make it a wallpaper again – to allow the film of tissue, the retina, to work and not lose its function permanently – the wallpaper must be put back on the wall. If SB is performed, the wall and the wallpaper are joined again by pushing the wall in; in PPV the surgery is performed inside the room, pushing the wallpaper back onto the wall. However, the latter is a technical issue that I explain only if the patient asks about the surgical technique.

[9] In the case of an RD: a roughly 80–90% initial success rate. If PPV is performed, there are rare complications such as ECH or endophthalmitis, which occur in less than 1 in 1,000 operations; the main long-term issues are cataract in the phakic eye and re-RD in ~15% of the cases. An RD can occur early, due to a break, or several weeks later, due to PVR.

[10] Once the patient made his choice, he must be informed about the recognition of the complications.

5.3 Communicating with the Patient

Counseling is not a monologue but a dialogue, even if the surgeon is the "primary speaker"; the patient is encouraged to ask questions and voice comments and concerns. While talking, the surgeon must read his patient's face and tailor his message according to the patient's facial expressions.

Q&A

Q *How do you adapt your message or choose your words for that individual patient*?

A Knowing the patient's educational level and intelligence and whether the patient seems to have common sense is very helpful. The surgeon must also learn to decipher the direct (verbal: the way the patient phrases his questions) and indirect (metacommunication) feedback of how his message gets across. These signals of the latter include, among others, whether the patient's face reflects understanding or being at a loss and whether the patient's metacommunication is in agreement with his verbal message.

The surgeon should be able to read the patient's metacommunication but must also know that most patients will read his own metacommunication. It is crucial for the surgeon not to show contradiction between his verbal message and facial expression, body language, and hand gestures. Even if pressed for time, he should not be caught looking at his watch while the patient talks.

5.4 Coaching vs Trying to Be Objective

By diagnosing the disease, the surgeon knows what his own preferred management option would be. **Figure 5.1** helps the surgeon navigate so as to avoid the trap of coaching, unequivocally influencing the patient to choose the surgeon's preferred option.[11]

Pearl

The negative consequence of coaching may never surface; however, if something goes wrong, in today's litigious environment, a lawsuit may follow. The patient's lawyer will argue that had the patient not been told what the surgeon's preferred treatment option is, he would have chosen something else, which surely would have been more successful.

[11] Coaching may be done in a way that while all that is said is true and there is an apparent choice for the patient, in reality the selection of the words makes one option very suggestive.

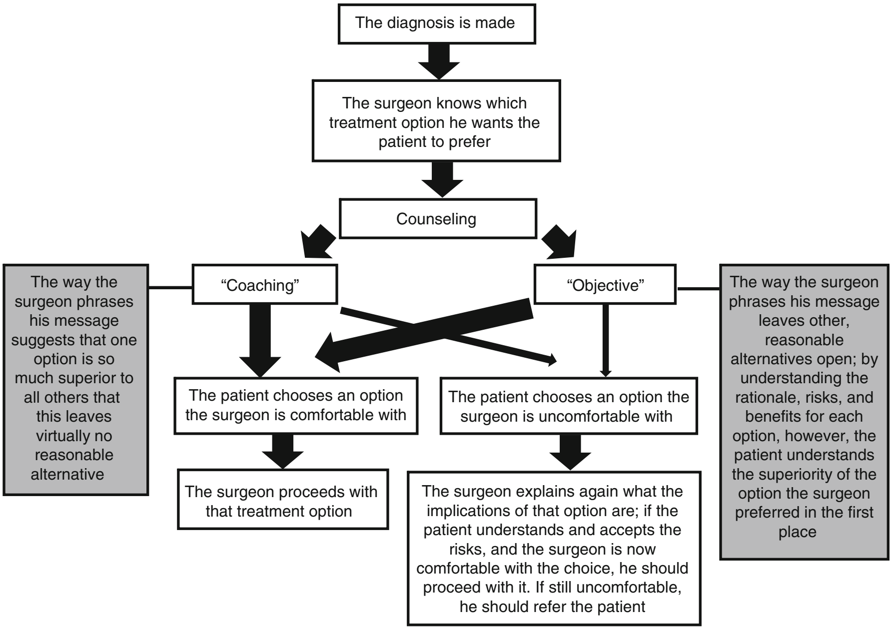

Fig. 5.1 **Influencing the patient's choice of treatment**. With the "coaching" option the surgeon, directly or indirectly, tells the patient which option he should choose. If one treatment option is clearly superior to all others (such as vitrectomy, as opposed to intravitreal antibiotics alone for traumatic endophthalmitis [see **Sect.** 45.3]), this is perfectly fine. In many cases, however, there are several options available, and with each the surgeon can reasonably argue in favor of or against. In such cases he should try to remain as objective as possible and describe the options so that the patient can make the choice. If the patient chooses an option that the surgeon truly feels uncomfortable with, he should re-explain the options and clearly state the disadvantages of that option. If the patient does not change his mind and the surgeon remains uncomfortable with the choice, he should refer the patient, rather than do something against his own conviction. The *thick arrows* represent the likely and the *thin arrows* the unlikely chain of events

Counseling is done correctly when the surgeon informs his patient in an objective manner, presenting options without making the patient feel that the surgeon prefers one option over the other/s. If the consequences of each option are presented properly, the reasonable patient will still make the right choice.

5.5 The Ultimate Treatment Decision: "Whose Eye Is It?"

In my view the eyeball belongs to the patient and thus he has the right to make the final choice regarding treatment. The surgeon's job is to supply the information so that the choice rests on a rational foundation, and both surgeon and patient feel comfortable with it (see **Table** 5.1).

Once the selection has been made, the patient should be given additional, more detailed, written information about it (informed consent). The document should discuss the following:

- The procedure itself: what actually happens during surgery. This is especially important if the surgery is under local anesthesia (see **Sect. 15.2**).
- The list of postoperative complications and their recognition, and what the patient should do if they occur.
- The patient's responsibilities postoperatively, including medications and physical activities.
  - It is unacceptable if the patient with a macular hole is told only *after* the operation that he needs to be facedown for several days.

Pearl
I try to not repeat it throughout the book, but in every case when the treatment is described for any condition, it is based on the VR surgeon's reasoning. The ultimate decision, however, whether to go ahead with that option is the patient's.

5.6 Which of the Two Eyes to Operate on First?

Rather often patients are seen with the same chronic condition (e.g., ME or EMP) involving both eyes, even if the condition is more advanced in one eye. The question, once both eyes are determined to need surgery, is which eye should be operated on first.

- Operating on the eye with worse vision is what most surgeons recommend.[12]
- My suggestion to the patients – and I explain the rationale for this – is to select the eye with the *better* vision first. There are two reasons for doing this:
  - If the worse eye is operated on first and vision does not improve according to the patient's expectations, the incentive to subsequently operate on the better eye (with the better prognosis) may be destroyed ("why would my left eye improve if the right did not?").
  - The prognosis in the eye with better vision may worsen if surgery is delayed.

5.7 What if the Eye Has Two Diseases?

If a patient is referred with, say, visual deterioration in an eye that has both dry AMD and EMP, it is impossible to determine which of the two diseases – one clearly an indication for surgery, the other not[13] – is responsible for how much of the visual loss. I heard surgeons advising patients in such situations against having surgery.

[12] And patients intuitively prefer.

[13] Even though there are some early data that PPV may help in certain cases of dry AMD; my own experience is that if traction is found on the OCT, surgery *can* improve vision in dry AMD.

Proper counseling and not an outright rejection should be the VR surgeon's answer. The patient must be told that surgery has risks and cannot promise to bring improvement – but that there is a chance, if the operable condition was the main culprit[14] causing the visual deterioration. Again, it should be the patient's decision whether to opt for surgery or not.

5.8 What if the Eye Has Severe Visual Loss and the Chance of Improvement with Another Surgery Is Low?

Performing another operation – say, on an eye that had multiple surgeries for PVR and has an inferior RD despite a previous retinectomy and a circumferential SB – raises serious questions.

- The new operation may not improve the situation.
- Even if anatomical success is achieved, vision may not improve.
- The patient may have to endure a long operation and the inconvenience of pain, irritation, need for topical and probably systemic medications, and a very small risk of sympathetic ophthalmia (see **Sect. 63.9**).

Conversely, the only way to give the eye and thus the patient a chance is via another operation.

Q&A

Q *What if the patient refuses to even consider another operation because, based on his previous experience, there is no hope – but the surgeon is more optimistic?*

A I tell my patients: "Do not give up until I give up; as long as I see reasonable hope for improvement, I am willing to offer a chance unless you categorically refuse."

5.9 Empathy: The Single Most Important Component of Counseling

One definition of empathy is "the ability to understand and share the feelings of another." It means that the VR surgeon sees before him a person, not a disease, but it also means a lot more. He must appreciate what is going through the patient's mind at the time of the examination and during the decision-making process (see **Table 5.2**). The patient:

[14] Which is largely unknown at the time of decision-making. I tell my patients that there *may be* a chance for improvement with surgery but no chance without.

- Is anxious, worried, and nervous about whether the eye will go blind.[15]
- Has doubts about whether he is making the right choice regarding the therapy.
- Is scared of how a "blind eye" will impact his and his family's life.[16]

Throughout the entire duration of the patient-physician relationship, the VR surgeon must help the patient deal with these hard issues; no person should become a physician if lacking empathy *and* being able to show it. Feeling empathy is either part of the personality or it is not; demonstrating it properly is a learned skill.

The VR surgeon rather often has a patient who is in a grave situation: vision in one eye is already lost and the prognosis in the fellow eye is very poor. Such a scenario presents a unique challenge regarding surgeon behavior.

Table 5.2 The person vs the condition as the target of counseling*

Example	Comment
A 19-year-old professional boxer presents with a trauma-related RD. He undergoes PPV with laser cerclage and gas tamponade. Once the gas absorbs and he is deemed cured[a], he wants to know whether he can continue his boxing career. Laser cerclage has also been applied to the fellow eye	I once polled an audience of over 300 ophthalmologists about what they would tell this patient. With the exception of two (who said they did not know what they would say), everybody in the lecture hall said they would "forbid" this. The problem is twofold First, we do not know whether the eye that now underwent vitreous removal and prophylactic laser treatment (see **Sect. 30.3.3**) has an increased, identical, or lower risk of RD than preoperatively or than the untreated fellow eye, if again exposed to the direct and indirect trauma that boxing represents Second, the boxer earns his *living* by boxing; it is not a hobby for him. It is easy for the VR surgeon to categorically declare "no boxing anymore," and the surgeon himself will certainly sleep better at night – but his brief sentence changes forever a young person's life, dreams, and livelihood
A 70-year-old female farmer came to see one of my colleagues with an acute, macula-off RD. He told her that she needed immediate surgery; the lady said she couldn't stay because nobody would take care of her chickens. He screamed at her that her retina was more important than her "stupid chicken"	For her the chickens are crucially important not only as a food source and as a way to make a living but also because she is emotionally attached to them. Furthermore, she has no idea what a retina is or what the implications of the treatment or its delay would be The VR surgeon must appreciate her side of the story and explain to her in a language that is clear to her the essence of her condition, the risks and benefits of early treatment, and the consequences of the delay. If she understands these, she can go home, find someone to take care of her chicken while she is in the hospital, and then come back for the treatment as soon as possible

*Both examples are taken from my own experience; they are used to illustrate the point of why the person and not a tissue, the eyeball, or the anatomical abnormality should be the primary focus of the VR surgeon's attention.
[a]Minus the very small possibility of RD due to unaddressed traction (see **Chap. 54**) or a more pronounced risk of PVR (see **Chap. 53**).

[15] People rarely ask: "Will the *eye* go blind?" They typically ask: "Will *I* go blind?", as if the condition were bilateral, even when the fellow eye is healthy. Perhaps this choice of words reflects the extent of the patients' anxiety level.

[16] Job, financial support, everyday activities etc.

Pearl
Empathy can easily turn into a paralyzing force if the surgeon cannot find the right balance between his empathy toward the patient vs his emotions about the patient's sad fate. Empathy should not be allowed to prevent the surgeon from doing his job.

Physical touch – squeezing a patient's hand or hugging him – can convey warmth, understanding, and togetherness; it shows how much the physician understands what the patient must go through. Such gestures can go a long way in reassuring the patient that the surgeon is "with him all the way," but it can be offensive in certain cultures.[17]

5.10 The Prognosis with the Chosen Surgical Option

Every patient's most important question is, whether he voices it or not, the expected final outcome. Even if hard numbers are available from the literature or the surgeon's own clinical practice, and the prognosis is good, it is advisable for the VR surgeon to be cautious and never promise success.

Pearl
When informing the patient about the expected outcome (success rate, final visual acuity), it is best to be *slightly* on the *pessimistic* side. *Pessimistic*, because it is psychologically more preferable to have an outcome that is better than expected, than the other way around; and *slightly*, because too much pessimism may deter the patient from surgery when in fact it has a reasonable chance of success.

Deciding for surgery is relatively easy when the prognosis is good or surgery can arrest a condition's otherwise inevitable worsening.

Q&A
Q *What if the prognosis of the condition is poor*?
A The question is primarily decided by the difference between outcomes based on the natural history vs with surgery. If with surgery "there is nothing to lose" but there is at least some hope, and the complication risk is acceptable, surgery to the willing patient should not be denied. The patient must, however, understand that the loss of vision may be slow if nature takes its course but rapid or even instantaneous with surgery (due to complications).

[17] Forbidden in the Muslim world if the surgeon is a male and the patient a female.

5.11 If the Patient Chooses to Undergo Surgery

The surgeon should give a brief but proper explanation of the surgery itself. This is especially important if the operation will be under local anesthesia: the patient must appreciate why any movement during surgery can have deleterious consequences. As an example, it is impossible for a layperson to understand that "the ILM is 2 μ thick," but they immediately perceive the implications if the ILM thickness is compared to that of the human hair (see **Sect. 15.2**).

5.12 The Benefits of Proper Counseling

As described above, proper counseling is difficult to learn and practicing it is very time-consuming. It does, however, offer several advantages for the surgeon, making it a rewarding experience:

- The patient becomes a partner and remains one during the entire treatment process.
  - He understands the difficulties the surgeon constantly faces practicing his profession and how little this leaves for having a personal life.
  - He is more likely to follow instructions, cooperate in positioning and taking his medications, and return for follow-up visits.
  - It is more likely that he will return for a follow-up visit not only when problems arise but also if surgery was successful.
- If a patient was treated like a partner, like an individual, and not a tissue pathology, he is less likely to sue his doctor if something goes wrong.

It must be emphasized again and again that the reason I am arguing in favor of letting the patient – rather than the surgeon – "indicate" surgery is *not* due to a desire to escape the responsibility of making a decision. It *is* difficult to make decision, but the surgeon makes hundreds of decisions every day. However, to make the patient a true partner, it is best to let him make the most difficult decision: to operate or not.

5.13 To Say It[18] or to Keep Quiet[19]

A 70-year-old patient with severe diabetes arrives; his parents also had the disease. He comes with his 40-year-old son who is very fat. Are you going to tell the son, who is technically not your patient, that he is also at risk of developing the disease and that he must lose weight and exercise to do his part in reducing the risk he faces? (Personally, my answer is: Yes, I will.)

[18] Because you are a *physician*, who sees the forest, not only the tree.

[19] Because you should not poke your nose into how other people live their life (see the **Appendix**, **Part 2**).

5.14 The Dogmas

There are many dogmas that have absolutely no scientific or even empiric basis, yet they have been around for ages and do not seem to disappear. This may be because in the daily routine, we do not stop to re/consider them or because we think we sleep better if we do not challenge them, do not go against "mainstream," and do not take on extra responsibility which, who knows, may have even legal implications. Some of these dogmas are simply stupid, others outright devastating, but all may have some negative impact on a person's life (see **Table 5.3**).

Table 5.3 An incomplete list of dogmas in the VR field[*]

Dogma	Comment
If you had VR surgery, do not lift objects heavier than 5 kg	Would the scleral wound rupture or a VH occur? And why would the limit be 5 kg? What needs to be discussed with the patient is the risk associated with Valsalva maneuvers
If you have high myopia, you must have cesarean delivery	Would straining during vaginal delivery cause a retinal tear and then RD?
If you have a corneal erosion, do not use topical steroids	True after the first week, but during the first days postoperatively, the beneficial effects of the steroids far outweigh any potential risk
Your other eye is okay; therefore it is unwise for you to suffer through a difficult operation with poor prognosis in the affected eye	May be a valid argument if someone could guaranty that the fellow eye's condition will never worsen. If something happens to that eye in the future[a], it may then be too late to save any vision in the affected eye
Because of the risk of sympathetic ophthalmia, we should instantly remove your injured eye	The risk of sympathetic ophthalmia mandates extensive counseling, not enucleation[b]
Your eye is getting smaller, the best option is to remove it *now*	This is a cosmetic issue, and the decision is up to the patient
We will wait with the operation until your vision is (much) worse	So that the prognosis is also likely to get worse
Let's go ahead and remove the IOFB now, and we can decide later, based on what happens in the eye, whether we need to do a second operation for the damage caused by the IOFB	IOFB removal is not *the* goal of the surgery; it is part of a comprehensive procedure to deal with the mechanical injuries the IFB caused
Unless your retina detaches, and we'll see this on ultrasonography, let's wait 3 months until we decide whether to remove the blood from your vitreous	Why risk an RD when removal of the VH is likely to prevent RD development, restore your vision instantly, and is a very low-risk procedure? And if wait, why 3 months?
We will remove the blood from your vitreous when we see on ultrasonography that the tissue starts to organize	In other words, we will wait until PVR starts to develop

[*]Only those dogmas are sampled here that originate with the physician; those that the patients devise are not included.
[a]Remember Murphy's law.
[b]Always keep in mind when enucleation is discussed that this an amputation, which has very significant psychological implications for the person.

6 The VR Surgeon's Relation to His Nurse

The VR surgeon never works alone at the operating table: as a minimum, there is a nurse assisting him. Although the relationship between the two is crucial, it is not discussed in publications.

> **Pearl**
> The VR surgeon is only as good as his nurse is. Without a nurse who is a true *assistant*, the surgeon cannot dedicate his undivided attention to the patient.

Surgeons who do not treasure their nurse do so at their own peril as well as their patient's.[1] Even the slightest problem – an instrument is not immediately available, the vitrectomy machine's settings are different from what the surgeon expects etc. – will force the surgeon to unnecessarily divert his train of thought from the intraocular task to an "extraocular" problem. When this happens and especially if it does so regularly, it is frustrating – and the frustrated VR surgeon is at an increased risk of committing errors (see the **Appendix**, **Part 2**).

A good nurse should pay attention, among others, to the following:

- Always hand the proper instrument to the surgeon (see **Sect. 3.7**).
  – This is not as straightforward as it sounds: many companies do not "color-code" their forceps or scissors, and it may be too dark in the OR for the nurse to see the tip of the tool. The surgeon does not examine the instrument handed to him before he inserts it into the eye; realizing only then that he was given the wrong forceps, or scissors instead of forceps, is very frustrating.

[1] I have been blessed to work throughout my career with absolutely excellent nurses. I cannot overemphasize how grateful and indebted I am to all of them.

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- The instrument is placed in the surgeon's outreached hand correctly (see **Fig. 54.7**).
  - I have seen nurses in various ORs neglect this rule, forcing the surgeon to turn the instrument around before being able to use it. I have also heard frustrated surgeons scream at the nurse when this happens – but this only poisons the well.[2]
- Learn how to do scleral indentation well (see **Chap. 28**).
  - If the nurse does not look into the microscope[3] while indenting the sclera, she may not realize that the height of the indentation changes, greatly increasing the risk of retinal injury.
- Pay close attention to what the surgeon is doing and learn his individual habits.

Q&A

Q *Is a good nurse supposed to anticipate the surgeon's next move?*

A Yes. A good nurse does much more than fulfill the surgeon's verbal requests. She observes the surgeon's every move, becomes familiar with the particular surgeon's customs, and tries to prepare for the next surgical maneuver in advance. She also voices her opinion if she thinks something is not right or could be improved (see below).

To closely follow the operation, the nurse must be able to continually see what the surgeon is doing inside the eye. Preferably, she can look into the microscope, or at least view it on a high-resolution, properly placed monitor connected to the video camera (see **Sect. 12.4**).

- Remain with the surgeon for the duration of the entire operation.
  - I have seen ORs where multiple nurses assisted the surgeon during the same, relatively short operation. They did not even announce when one would replace the other. The reason for the changes was not due to some kind of emergency[4] – simply a local custom. Nurses have different personalities; their style of assisting is different: it *does* matter to the surgeon whether he works with the same person throughout. Continually adapting to different nurses' personality is another potential source of frustration for the surgeon.

[2] Neither is it a solution if the surgeon totally avoids the conflict and does not address the problem at all. But instead of screaming and shaming her in public, he should privately sit down with the nurse, identify the problem, and find a solution.

[3] Or at least follow it on the monitor, see below.

[4] Such as a bathroom break or a crisis phone call.

Pearl
VR surgery is a teamwork. There are many actors on the team, but none is more important than the nurse. It is therefore highly recommended that the surgeon work with the same nurses.

- Help guide the surgeon's hand if he is presbyopic and has difficulty finding the opening of the cannula to enter the eye.
  - It is a suboptimal option to repeatedly turn on the microscope light for cannula entry, nor is it really helpful to leave the room light, even if it is red, on.[5] The nurse who gently holds the surgeon's hand and helps it introduce the instrument through the cannula is doing a great service.
- Prepare for the particulars of the case as much as these can be anticipated, but also be ready to quickly get and supply whatever unexpected tool or material is needed.
  - During PPV for RD, the flute needle, endodiathermy, endolaser, and gas are always needed, but silicone oil, PFCL, cryopexy, ICG etc., may also be required. These needs differ from surgeon to surgeon,[6] which is one reason why it is so important that the surgeon-nurse team works together long term and during the entire case (see above).
- Keep all the necessary instruments and materials, but only those, on her table (see **Sect. 16.11**).
  - When working in room light, some surgeons prefer grabbing the instrument from the nurse's table themselves.[7]
- Pay very close attention not only to the "case" but also to the surgeon. If the nurse has an idea to solve a problem or a suggestion to improve on what the surgeon is doing – she should not be shy (or discouraged) to voice her suggestion (see **Fig. 36.2**).[8]
  - This, of course, requires that the surgeon be a person who is willing to listen. Often it is not the surgeon who comes up with a unique solution: the "outsider" looks at the issue from a different perspective.[9]
  - I appreciate the nurse as the active, crucial other part of the surgical team, and not as a passive handler of surgical instruments.[10]

[5] It is useful for the surgeon to maintain his dark-adapted status.

[6] Not only case by case.

[7] Some nurses do not like if the surgeon "touches their table." The surgeon should respect this.

[8] I permanently changed certain maneuvers in my own practice based on the advice of the nurse.

[9] Remember, the idea of the IOL is not Sir Harold Ridley's; a medical student, Peter Choyce, who was observing Dr. Ridley in surgery, suggested it.

[10] Much like the role of the-official-with-the-flag in modern football; there is a reason why he is not called as "linesman" anymore but as "the referee's assistant".

- Keep a description at hand of the most commonly used medication-dilution rules.
  – It is extremely aggravating when a surgeon needs, for instance, antibiotics injected into the infusion bottle, but nobody remembers the correct concentration, and surgery must be stopped to calculate the dosage. Calculating the concentration in such an ad hoc manner, under time pressure, is also a potential source of errors – and the incorrect concentration of an intravitreal medication can have blinding consequences.
- Is very careful in cleaning and handling the delicate intraocular instruments.
  – For instance, membrane fragments are caught in-between the forceps jaws, which require instant, in-the-dark cleaning so that the surgeon can carry on with the operation (see **Sect.** 13.2).

If the surgeon is able to find a nurse who fits what is described above, he has the best possible chance of succeeding in the OR. If, however, the nurse is not a willing partner, whether because of personal or professional reasons, the surgeon should request the OR director to never assign this nurse to his cases.

Q&A

Q *What if the inexperienced fellow is paired with an experienced and dominant nurse?*

A Occasionally the nurse's personality is such that she wants to boss the fellow around. The surgeon must not allow this to happen; he has to hold his line firmly (remaining the "captain in the OR"; see **Sect.** 16.13). Conversely, he must avoid completely alienating the nurse by becoming too aggressive. A private conversation to identify the problem and find a mutually acceptable compromise is the best way to defuse the situation and prevent future conflicts.

Examination

7

This chapter will neither provide detailed descriptions of examining the patient for VR surgery, nor will it detail the findings in various conditions.[1] Instead, a few important, perhaps less commonly emphasized points are presented in **Table 7.1** about each diagnostic procedure.

> **Pearl**
> The VR surgeon must examine the entire eyeball, not simply the vitreous and retina.

When the examination is completed and the surgeon dictates the findings, it is extremely helpful to do a schematic (retinal) drawing as well.[2] I am not recommending a drawing that looks like a piece of art, but a sketch indeed speaks a thousand words: the location and extent of an RD or height of the hypopyon is easy to illustrate and is very informative to a colleague. The drawing also serves as a baseline image for later comparison.

> **Q&A**
> Q *Does the finding on examination determine the therapy?*
> A Sometimes: an RD makes surgery unavoidable, unless the patient categorically refuses (see **Chap. 5**). In most cases, however, the diagnosis is the "basis for negotiation" with the patient: whether and when surgery is optimal to be performed.

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[1] Such information can be found in many excellent publications, which the readers are encouraged to consult.

[2] The iPad with the appropriate software, such as the one being developed by Dr. Klaus Lucke (Bremen, Germany), may be a huge advancement in this area.

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Table 7.1 Examining the candidate for VR surgery

Variable	Comment
History	The VR surgeon should never rely on the referring physician's or a nurse's notes but personally ask the patient about his current complains, past ocular and systemic history, current general condition etc. Certain conditions such as vitreous floaters may be difficult for the VR surgeon to visualize, which makes asking the proper questions especially pertinent
External inspection	This is crucial mostly in cases of injury, but can reveal other abnormalities such as hypopyon or cataract[a]
Visual functions (VA, reading ability, Amsler)	The VA must be taken in both, not just in the affected eye In many macular conditions (see **Sect.** 50.1) the patient's difficulty reading with the affected eye or the abnormalities found on the Amsler test, especially if these can be compared to a normal fellow eye's, are more important than the VA level[b]
Slit lamp/60–90 D lenses[c]	While such lenses provide a small field of view, they have high magnification and resolution, allowing the surgeon to detect minor abnormalities in a three-dimensional view. The eye's external surface, the anterior chamber and the tissues surrounding/constituting it, the vitreous/cavity, the posterior retina, the optic disc, and to a certain extent the choroid can and should be examined This method is often employed in determining whether a PVD is present. Unfortunately, what is diagnosed as PVD often proves to be vitreoschisis (see the comments below, under ultrasonography) The exact location of the retinal break in an eye with RD is much less important to determine if PPV, not SB, is planned (see below and **Sect.** 54.5.1)
Slit lamp/three-mirror and/or 170° lens[d]	The former lens has a very small field of view but allows the surgeon to visualize the chamber angle and the peripheral retina as well. Enlarging the field of the lens reduces its resolution
IBO[e]	This is a great diagnostic tool, which is less utilized today than it deserves. Its strong light is able to penetrate even advanced media opacities, gives an excellent three-dimensional view, and allows dynamic examination. With scleral indentation[f], the surgeon can also examine the retinal periphery Many surgeons stand during the ophthalmoscopy while the patient is sitting. This does not allow full viewing of the periphery, especially superiorly, and is very taxing for the surgeon's lower back. Ideally, the patient is in the supine position during the examination and the surgeon is standing over him, with a straight back The exact location of the retinal break in an eye with RD is much less important to determine if PPV, not SB, is planned[g]
IOP	It should always be measured and recorded
OCT	This is a relatively new field and an increasingly important diagnostic tool. Its primary focus is the macular area, but it also provides important information about the retina elsewhere, the choroid, the optic disc etc. It allows the surgeon to actually see things that used to be somewhat of a guesswork before[h]. Being a noninvasive tool, it can readily be used during repeated follow-up visits, providing the surgeon with a longitudinal view of the condition in question The OCT findings do not always reflect reality. When the diagnosis of PVD, for instance, is made, it may actually be a vitreoschisis – it is the particular machine's resolution that limits how much the finding can be trusted (see the comments below, under ultrasonography)

(continued)

Table 7.1 (continued)

Variable	Comment
Ultrasonography	This test is very useful in eyes with opaque media, primarily to detect the presence of an RD. However, it is very important to understand that it may be impossible to definitely determine whether the retina is detached, especially in severely traumatized eyes with dense VH[i]. The surgeon who, based on ultrasonography, is convinced that the retina is attached can easily cause major iatrogenic retinal damage during surgery[j] Although it is also often employed to determine whether a PVD has occurred, ultrasonography can be misleading as it is unable to detect the thin vitreous layer on the posterior retina. Erroneously diagnosing vitreoschisis as PVD can lead to erroneous therapeutic decisions (see **Sect.** 26.1.2)
Electrophysiology	It is extremely rare that the VR surgeon needs the results of this test
Fluorescein angiography	It is much less common than in the past that the VR surgeon needs the results of this test. Nevertheless, this is the only method to show retinal ischemia
Documentation[k]	Drawing, fundus photography, and written and electronic records of all findings can and should be part of the examination (see the text for more details)

[a]A nuclear cataract can be highly transparent and therefore easier to detect with a penlight than at the slit lamp.
[b]The pathologies causing reading difficulties or metamorphopsia point to foveal involvement, even if the underlying disease is outside the macula. A deep IOFB impact, even if rather distant, can cause retinal folding that reaches into the center.
[c]These lenses are noncontact.
[d]These are contact lenses and thus should not be used immediately prior to surgery.
[e]Keep in mind that the image the surgeon sees is upside down.
[f]Remember, this is rather unpleasant to the patient.
[g]The advantage of the 90 D lens over IBO in identifying a retinal break and the traction forces acting upon it is its higher resolution; the disadvantage is that it, unlike the IBO, does not allow a proper dynamic examination.
[h]Is it a partial-thickness macular hole, a pseudohole, or a true hole?
[i]Conversely, in up to a fifth of the cases the presence of an RD is incorrectly diagnosed in an eye with VH (see **Sect.** 62.1).
[j]This is partially a psychological phenomenon. The surgeon is subconsciously prone to proceed with less caution during vitrectomy if under the impression (conviction) that he will not encounter detached retina with his probe.
[k]This is not examination in any sense of the world, but should be part of the process of working up the patient.

A final caveat about examining the patient. Do not order tests that will not fulfill at least one of the following criteria:

- Influences therapeutic decisions.
- Serves as a baseline for monitoring progression.
- Helps determining the technique or success of therapy.
- Preserves the record for medicolegal purposes.
- Is necessary for a scientific study.

The Indication Whether to Operate

8

The list of conditions amenable for VR surgery is long and growing. Each condition has its own arguments in favor of and against surgery, which need to be discussed with the patient so that he, together with the surgeon, can come to a decision (see **Chap. 5**). In this chapter only a few basic thoughts regarding indications are discussed, strictly from a medical standpoint.[1]

8.1 The Argument in Favor of Surgery

Why surgery should be done is rather obvious: it promises the chance of visual improvement, the prevention of its worsening, or, as a minimum, the preservation of the globe.

Q&A

Q *Can the surgeon promise functional success?*

A Never. With certain indications such as floaters, the chances of improvement are excellent, but still not 100%. All the surgeon can promise is to try his very best to help. Surgeons cannot restore function; they restore anatomy, with a reasonable hope that function will follow. It is also not possible to predict how much improvement will occur. Statistically, one can give a general prognostic figure, but the surgeon must always emphasize that the statistical average or range is not necessarily true for that particular person or operation.

[1] In other words, what the surgeon might prefer if the final decision were not up to the patient. Sadly, in real life often this is what happens, as if the eye were owned by the physician.

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- Every time a medical intervention, whether surgical or not, is considered, one of the key questions is the risk-benefit ratio. No intervention should be performed, even at the specific request of the patient, if the former is greater than the latter (see **Table 5.1**).
  - Usually it is relatively easy to determine whether the chance of improving (preserving) function is indeed higher than the risk of deterioration due to a complication (or natural history).
  - There are exceptions to this general rule. Think about a patient who has retinitis pigmentosa, has lost vision in one eye, and develops an EMP in the only eye (see **Table 1.1**).[2]
- The benefits a successful surgery brings[3] are obvious: an attached retina's function should improve, a vitreous is no longer opaque, the macula is smooth again etc.
  - Often the patient "sees the difference" the next day; in other cases he is warned that his vision may be even worse than preoperatively but that this is temporary (e.g., gas tamponade, see **Sect. 35.2.2**).
  - More difficult to appreciate is an operation that does not improve function, "only" preserves the current status; such an indication requires even more extensive counseling than usual.

Pearl

A somewhat similar question is whether to perform a certain surgical maneuver (e.g., laser around a posterior retinotomy, see **Sect. 30.3.1**) if it is done not because it has proved to be necessary but because the surgeon will "sleep better if he did it." This argument is not totally wrong: as long as the maneuver has a rationale (at least some scientific merit) and its risk is low, the surgeon can claim, should the disease course turn for the worse, that he tried everything (instead of having to say: "If only I had done that maneuver in the first place…").

- "Beauty" should in general not serve as a justification for VR surgery[4] or for an intraocular maneuver. The goal is not to restore perfect anatomy but to improve function via restoring (enough) anatomy. A membrane in PDR need not be removed in its entirety so as for the fundus to look perfect; leaving harmless[5] membrane stumps on the retina often makes more sense than risking iatrogenic retinal breaks by forced "beautification" (see **Sect. 32.3.2**).

A special case is an eye with full visual acuity but with a distinct anatomical and functional abnormality; this is discussed in **Chap. 46**.

[2] This is also a good example why the patient, not the surgeon, should have the final say indicating the operation. Imagine if it was the surgeon who convinced the patient that he should accept surgery and something goes wrong. The surgeon will feel guilty and the patient may sue him.

[3] And every surgery starts with the premise that as a minimum, it has a chance of success.

[4] Exceptions do exist. Removal of a calcified, white lens from a blind eye is absolutely justified if the person is bothered by it.

[5] That is, deprived of any traction potential.

8.2 The Argument Against Surgery[6]

Q&A

Q *What if the patient wants a "guaranty" of success?*

A None can be offered. If a patient asks me for a guaranty, I ask them the following: *Do you have a guaranty that as you exit the building after the examination, a brick would not fall and hit you in the head?* Most people are shocked to hear this first, but then realize that no such guaranty is possible. It is highly unlikely that a brick would hit them, but it is not entirely impossible.

It is very uncommon[7] today that a major *intraoperative* complication, causing permanent visual loss, occurs. Most of the serious complications present in the early or late *postoperative* period, but these complications should always be on the surgeon's mind before undertaking the operation.

Pearl

The reason why the surgeon *should* operate is very obvious *before* the operation; the reason why he *should not* have becomes obvious only *after* the operation. Still, for a surgeon to choose "observation" for a condition that is amenable to surgery is more difficult than to opt for the intervention.

Observation is nevertheless a perfectly acceptable option in many cases – except when it is chosen as a convenience to the surgeon,[8] not because this is the most reasonable alternative for the patient.

8.3 The Age of the Patient

Some surgeons are much more willing to forgo surgery if the patient is "old."[9]

Pearl

Old age of the patient should, as a general rule, not be used as an excuse to disqualify him from surgery. Acceptable arguments include his systemic condition and life expectancy.

[6] As Hippocrates warned: "First, do no harm."

[7] What "very uncommon" means is that the chance is more than zero.

[8] A famous American humorist was once asked why he stopped writing his syndicated weekly newspaper column. His answer was: "I realized that it's much easier not to write the column than to write it."

[9] Of course, the definition of "old" is very subjective. A surgeon in his 30s may deem so a 60-year-old patient; for a surgeon in his mid-50s, a 70-year-old patient is still "relatively young".

On the other side of the spectrum is the very young patient.[10] Children with conditions that, if untreated, invariably lead to amblyopia[11] should be offered surgery as early as possible, and the family/guardian must be advised about the need for anti-amblyopia treatment.

8.4 The Condition of the Fellow Eye

For many surgeons, this can be an important, even decisive, factor: they are much more reluctant to offer surgery, for instance, to a patient with tractional diabetic RD involving the macula if the other eye has decent vision.

My personal issue with this attitude is its inherent assumption that some type of a warranty is in effect for the fellow eye: it will never develop a sight-threatening disease.[12]

- Do not deny PPV just because the fellow eye is healthy or has good function.
- Conversely, do not recommend PPV if you do so *only* because the fellow eye has poor (no) vision.
  - The prognosis for the *eye* undergoing PPV is the same whether the patient is monocular or not. However, the prognosis for the *person* is very different if he is monocular: the stakes are much higher.

Pearl

Operating on a monocular patient does have certain implications for both the patient and surgeon (see **Sect. 3.5** and **18.2**), and these must be seriously considered when the decision whether to operate is made.

[10] As described in **Chap. 41**, surgery on young patients is generally more difficult than on adults; the fellow should therefore not “jump into” operating on a child’s eye without proper experience.

[11] Persistent hyperplastic primary vitreous, *Toxocara*-related chorioretinal scarring, late stages of ROP etc.

[12] In real life Murphy’s law applies: if a serious condition develops, it occurs in the “good eye” and at a time when it is too late to attempt repair of the first eye. It is very sad for the surgeon and patient to face their guilty feeling; the remorse cannot reverse what had been so casually given up earlier.

9 The Indication When to Operate (Timing)

Of all the pieces on the surgeon's decision-making palette, the easiest to influence is the time when the surgery is to be done. In many conditions delaying the operation means that the vision will gradually worsen, and the worse the visual acuity at the time of the operation, the less likely that the improvement will fully restore what has been lost.[1]

> **Pearl**
> As a general rule (exceptions exist), the earlier surgery is performed, the easier the procedure technically is and the better the prognosis.

Still, it is impossible to issue blanket advice about the urgency of VR surgery,[2] and every decision should be an individualized one tailored to the particular circumstances. **Table 9.1** shows the decision-making process in various conditions and **Fig. 9.1** the strategic thinking in timing decisions.

One issue to consider in each case if the surgery is elective is whether certain systemic medications need to be suspended or modified preoperatively. This is briefly discussed in **Sect. 40.1**.

[1] The surgeon can describe this to the patient by comparing the situation to climbing a ladder (with the steps representing visual acuity levels). If you have the strength to climb only a limited number of steps (representing the functional improvement one can hope to achieve) and you start at the bottom of a rather tall ladder, you will never be able to get to the top again. However, if you start climbing when you are down from the top by only a few steps, you can reasonably hope to be able to make it fully back up again.

[2] As mentioned in **Chaps. 5** and **8**, the final decision should rest with the patient anyway.

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Table 9.1 Indication-specific considerations related to timing

Indication[a]	Comment
BRVO	This is mostly a macular edema indication, even if the case is amenable to sheathotomy
Cataract	True urgency, even emergency, is present if the lens is swelling and causes high IOP[b]; in the presence of a broken capsule, this is rather common in children and very uncommon in older patients The opaque lens should be removed very early if there is suspicion/confirmed presence of a retinal condition requiring urgent PPV
Cellophane maculopathy	This is not an urgent indication, the timing is primarily determined by the severity of the patient's complaints
CRVO	The rationale for early surgery is to remove the VH so that the retina can be visualized; otherwise, it is basically a macular edema indication
Dropped nucleus	The issue is less medical than psychological and one of empathy. Delaying the reconstructive vitrectomy increases patient anxiety without any benefit regarding functional outcome. If a VR surgeon is available at the time when the complication during cataract surgery occurs, it is best to perform immediate PPV
EMP	This is not an urgent indication; the timing is primarily determined by the severity of the patient's complaints. Increased thickness of the membrane and its tractional consequences can make surgery more urgent
Endophthalmitis	For me this is an urgent indication: as soon as the diagnosis is made, I prefer performing complete and early PPV (CEVE)[c]
Glaucoma	If the high IOP is caused by ghost cells[d], early PPV is recommended
Hyphema	Clotted blood is best removed by the VR surgeon experienced in using the probe. In general, it is not urgent to remove the hemorrhage – most of the time it absorbs spontaneously – but there are exceptions: Elevated IOP, especially if the clot is large[e] There is suspicion/confirmed presence of a retinal condition requiring urgent PPV
Macular edema[f]	It is not an urgent indication, regardless of the etiology – the macula can tolerate being "wet" for weeks, even months, without serious and permanent damage. However, such damage *will* occur with time and will become irreversible if PPV is not performed
Macular hole	The more recent the hole, the more urgent the PPV
PVR	A rare exception to "the earlier the better" rule. Provided there is silicone oil in the eye, it is usually unwise to operate while the PVR process is in its active phase If the macula is threatened, surgery is recommended even when the PVR cycle is incomplete If there is no silicone oil in the eye or the PVR presents in an eye with no prior surgery, early/urgent PPV is recommended[g] The thicker/more numerous/more mature the membranes, the earlier PPV should be done All other things being equal, surgery can be deferred for longer in case of sub- rather than preretinal membranes

(continued)

Table 9.1 (continued)

Indication[a]	Comment
RD	This is a very complex question; only a few scenarios are presented here: *Macula on*: PPV is rather urgent[h] if the macula is threatened Superior RDs are riskier than inferior ones, as are temporal ones *Macula off*: surgery needs to be timely but it is not urgent *Staphyloma-spanning posterior RD in a highly myopic eye*: this is a special case; I prefer operating early if there is no macular hole present, to prevent its development. Nevertheless, surgery can be delayed for weeks since this condition is likely to have persisted for a rather long period of time *Bullous*: regardless of location, more urgent than a flat one *Vitrectomized eye*: more urgent than in an eye with no prior PPV *Tractional RD*: urgent only if the macula is under acute threat of detaching. This is true whether the proliferative membrane/strand is pre- or subretinal *Exudative RD*: this is not a surgical indication with the rare exception of the macula being under acute threat of detaching[i] *Hemorrhagic RD*: the more acute and thicker the hemorrhage, the more urgent the PPV[j]
Retinoschisis	If surgery is unavoidable – the retinal splitting is fast approaching the macula – PPV should be done immediately
Suprachoroidal hemorrhage[k]	PPV is not urgent unless at least one of the following is found: Kissing choroidal detachments High IOP Direct retinal damage Submacular location of the suprachoroidal blood
Trauma	Immediately to (almost) never; this is detailed in **Chap. 63**
Uveitis	It is rarely an urgent indication: PPV is typically aimed at complications such as vitreous opacity and macular edema. However, RD may also develop, in which case the timing recommendation changes appropriately (see under RD)
VH	PPV is urgent if a retinal tear caused the bleeding; trauma is another indication for immediate or very early surgery. In all other cases the surgeon may wait – just remember that blood in the vitreous is not inert and can lead to secondary complications[l]
VMTS	The key is to rely not on a *single* OCT image but on: History (progression) Visual function (VA, metamorphopsia) *Serial* OCT images (progression) Condition of the vitreous (less formed/more syneretic: more urgent surgery due to the risk of increased vitreous movement) Pseudophakia (more urgent since the vitreous gel has more room for movement and can thus exert greater traction on the macula)

[a]Unless otherwise indicated, more information is found in the relevant chapters in **Part V**. The conditions are in alphabetical order.

[b]If pupillary block occurs, the IOP can rapidly become so high that irreversible optic nerve damage threatens.

[c]As opposed to the much limited role for surgery, and a limited one at that, in the Endophthalmitis Vitrectomy Study.

(continued)

Table 9.1 (continued)

[d]Degenerated, swollen, rigid red blood cells that have difficulty exiting through the trabecular meshwork because of their size. They have a khaki color and can actually be seen in the AC at the slit lamp at high magnification. AC irrigation brings only temporary relief since the vitreous gel is the reservoir of the ghost cells.
[e]Risk of corneal "blood staining".
[f]I do not discuss here the nonsurgical treatment options.
[g]Whether the macula is off or on, although there is more urgency in the latter scenario.
[h]For example, a delay until Monday morning is acceptable if the patient presented on Friday afternoon, but bedrest is recommended.
[i]Even then, the subretinal fluid's composition is different (two examples include optic pit and central serous chorioretinopathy) from that seen in other RDs, and the macula is able to tolerate having been detached for extended periods.
[j]Or an alternative treatment such as tPA and gas injection.
[k]Drainage of the blood is not discussed here.
[l]Not to mention that it means loss of vision for the patient.

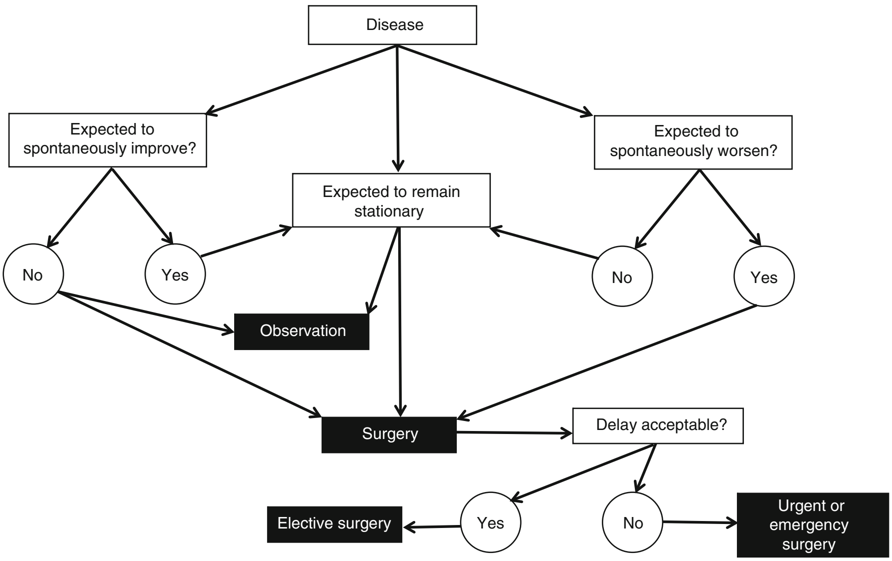

Fig. 9.1 Strategic thinking regarding the timing of surgery in VR diseases. If a condition is not expected to improve spontaneously, the surgical option should always be considered. The risk of rapid worsening makes the surgery urgent; otherwise, there is a reasonable argument for some delay, but how long this should be depends on many factors (not listed here). I typically tell my patients to look at the issue in a rational way: if we know that eventually surgery will become necessary, is there any gain by delaying it, or is there potential harm? In the latter case delaying the intervention has only risks but no benefit

10 The Order of Cases If Multiple Surgeries Are Performed

Many VR surgeons perform several operations a day. What is the most optimal order to follow?

There are certain rules that should be broken only if a strong reason to do so exists.

- Patients with an infectious *systemic* condition[1] should be operated as the final case of the day.
- Patients with an infectious *ocular* condition (endophthalmitis) should be operated as the final case of the day.[2]
  - If the endophthalmitis requires immediate surgical intervention, the OR must be thoroughly disinfected before the normal daily schedule can be resumed.[3]
- Patients freshly arriving with open globe trauma[4] may require very early surgery (if the risk of ECH is high) or can wait until the end of the day. Among the many factors determining the timing are the risk of endophthalmitis; the type, length, and location of the wound; and the age and systemic condition of the patient, including his willingness to cooperate.
- Diabetic patients, especially if they have unstable or severe systemic conditions, should have priority.
- Children and young adults in general should have priority, even if local anesthesia is used.
- Patients with high anxiety should have priority.

Beyond these caveats, it is up to the surgeon to compile the list according to his preferences. The options are:

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[1] Sepsis, HIV, hepatitis etc.

[2] Proper antibiotic treatment, including intravitreal antibiotics, must be given immediately, not be delayed until the surgery commences.

[3] This may take up to 8 h.

[4] See **Table 63.1** for more details.

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- Go gradually from the easiest to the most complex.[5]
- Go gradually from the most complex to the easiest.
- Make a random list (or leave the decision about the order up to the assistant).
- Anesthesiologists and nurses may prefer leaving one or two "easy" case/s towards the very end so that they can predict when they can finally go home. Unless the surgeon has a very strong argument against it, he should oblige.[6]

Pearl
Making the list of surgeries should not be a random act – unless the surgeon made a conscious decision that this is what he prefers ("surprise me").

I prefer going from the easiest to the most complex. The rationale is that the human brain likes to "slack off" once the difficult task has been completed. I may struggle concentrating during a straightforward case if I just finished a very complicated one, but I do not have issues concentrating during a difficult case once the straightforward cases have been completed, even if the complex case is done late into the evening. Again, this is a strictly personal preference.

[5] Of course, life has many surprises and the case, which promised to be easy and fast, turns out to be the opposite; the reverse may also occur, but this is less common. A Hungarian proverb accurately describes this: Man plans, God executes.

[6] Remember, though, that the patient has understandable anxiety before the operation and has been preparing himself for it; postponing it has obvious mental implications for the patient so do not take such a postponing lightly.

The Surgeon's Relation to Himself

11

The robot never doubts itself nor has ego issues. Both can, however, happen to the VR surgeon; there are certain things that he must subconsciously keep in mind while other things need conscious reevaluation on a regular basis. Why the surgeon should periodically face himself in the mirror is best discussed before the need to turn to a psychiatrist emerges.

11.1 Self-Confidence Versus Overconfidence

Without proper belief in his own capabilities, the VR surgeon may be overcome or even paralyzed by the task ahead. Conversely, a complete lack of self-doubt can lead him to readily undertake jobs that he is yet unqualified for and then blame somebody else (or the circumstances[1]) when something does go wrong.

It is not easy to find the right balance between these two opposing extremes, yet this is one of the key ingredients in being a VR surgeon who can justifiably feel as satisfied with himself as his patients can with him. Those who during the training do not neglect the "only gradually" rule (see **Sect. 2.2**) have a higher chance of finding the right balance.

11.2 A Series of "Bad-Luck Cases"

No surgeon, and certainly no VR surgeon, has a 100% success rate. Even if he always does a superb, error-free job, nature interferes: the human body does not accept part of what took place during surgery and surely not all the time. If eyes

[1] The nurse gave him the wrong instrument, the vitrectomy machine was not set correctly, the retina was unexpectedly "weak" etc.

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with poor outcome cluster,[2] it is not necessarily his fault, yet he eventually feels guilty and starts to doubt himself: maybe he has indeed erred.

As an example, **Fig. 11.1** shows several possible outcomes in a person presenting with an EMP. In extremely rare instances, the patient may even die during surgery (see the **Appendix**, **Part 2**), and compared to this event the original scar on the macula is so insignificant that the surgeon seriously blames himself for offering/indicating vitrectomy in the first place.

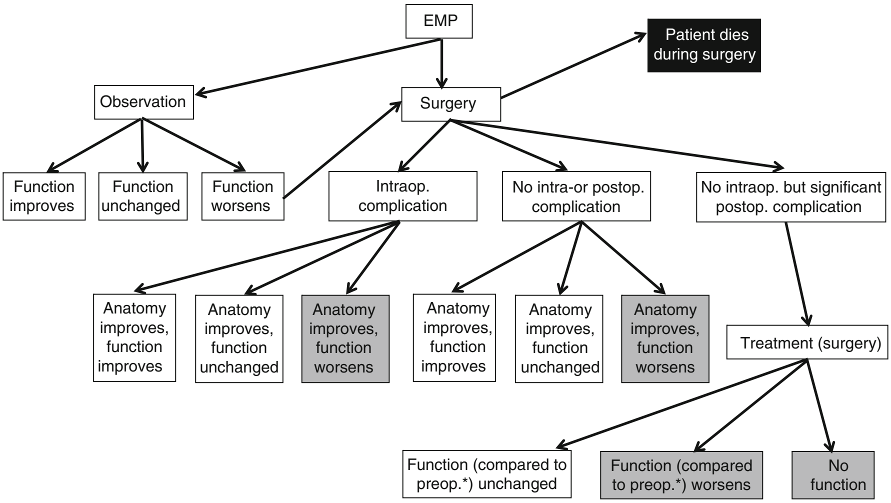

Fig. 11.1 **Possible outcomes after PPV for macular pucker**. Not all potential options are shown here; see the text for details. *Preop* preoperatively, *intraop* intraoperatively, *postop* postoperatively, * compared to before the initial surgery

Occasionally an intra- or postoperative complication occurs and makes the patient's final vision worse than the preoperative one (or at least prevent improvement). If there is an accumulation of such failures in a short period of time, however unrelated they are, it naturally suggests to the surgeon that he is at fault.

It must be understood that such a series of unexpected failures can and do occur. The surgeon must thoroughly examine each such occurrence (see below, **Sect. 11.3**) and objectively determine whether he is guilty.[3] If he is not, then, and only then, should he move on (without losing confidence, see above, **Sect. 11.1**).

[2] When you flip a coin, it is either head (H) or tail (T). If you flip it 10 times, you do not always end up with 5 Hs and 5 Ts; neither will the order be a neat H/T/H/T, but something random like T/T/T/H/H. Similarly, you may have 30 cases with no complication, and then all of a sudden in the next two cases the very same complication occurs. It is only natural to start blaming yourself: surely, this is not a chance event.

[3] Doing something he should not have or not doing something he should have.

Q&A

Q *How should the surgeon deal with his own feeling of guilt due to a significant complication that is his fault?*

A There are several ways a surgeon can react to a significant complication he caused. Not feeling guilty at all and not contemplating what happened and why is the worst possible scenario. Feeling guilty to the point of being paralyzed by the event and considering giving up surgery all together (lack of self-confidence) is also a misguided response, unless such cases regularly occur. Initially feeling guilty and giving serious consideration to why the complication occurred and how it can be avoided next time is the optimal response.

11.3 Self-Examination

It is very useful if the surgeon periodically analyzes his results.[4] Such a statistical analysis provides feedback mostly on the *strategic* level (see **Table 3.1**).

A great opportunity for the surgeon to review his intraoperative activities (*tissue tactics*) is to record all his operations and dedicate time to actually watch them (see **Table 2.2 and Sect. 12.4**), especially if this can be done at a later date (when the memory is not so fresh) and by watching multiple tapes one after another.[5] Reviewing unedited videos is an indispensable teaching tool even for the experienced surgeon.

- Every surgeon[6] has a mental image of how he does certain maneuvers.
- When facing the mirror, which is what the videotape provides, there may come a shock, showing that the memory is selective and pliable.[7]
  - What the surgeon thinks he has been doing and what he actually does, whether it concerns the surgical technique or the number of attempts to achieve a certain goal, can be vastly different. Watching the videotape and thereby realizing the difference between the mental image and reality[8] helps reconcile the conflict and improve performing the maneuver in question.[9]

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[4] Even better if he has a resident or colleague who does it for him so that the review is absolutely unbiased.

[5] Conversely, it is very misleading to watch your own *edited* videotapes (or ones shown at scientific meetings). These are sterilized to the point of uselessness: they never show complications or failures; every maneuver is immediately successful and all attempts work effortlessly. Nothing is further from real life.

[6] Except the very beginner who, understandably, focuses too closely on the "tree branch," not the tree, much less the forest.

[7] This is not a conscious process to artificially improve the surgeon's image of himself; it is identical to what happens when eyewitnesses try to remember an event. Even though they all saw the same thing, their brain makes them recall very different things.

[8] The surgeon is convinced that when he says: "I always do it this way and it always works," it is true. However, the recording may show that he does not always do it that way and it does not always work.

[9] In the classic joke, the surgeon has three wishes. First, that he has as much money as his colleagues think he has. Second, that he had as many girlfriends as his wife thinks he had. Third, that he is as good a surgeon as he claims he is.

11.4 My Way

As mentioned in the Preface, the surgeon should develop his own, individualized way of performing VR surgery, whether this relates to strategic or tactical questions. The "doing things my way" philosophy, however, must never mean rigidity: as a result of technological advances and the self-examination process, the actual execution of the my-way technique should undergo a perpetual change, a constant strive for improvement.

Part III

The VR Surgeon in the OR

Introduction

This part presents a systematic review of the most relevant characteristics of the equipment, instruments, and materials that are employed on a daily basis in VR surgery, and analyzes their use by the surgeon. It also addresses the selection criteria for, and application of, anesthesia for a particular patient and operation, and discusses numerous issues the surgeon should consider in the OR before actually sitting down to start the case. These issues include, among others, the implications of incorrect surgeon posture during the operation; the setting and adjusting of all equipment to maintain maximum efficiency, safety, and comfort; the acceptability of music and the quality of the air in the OR; the physical arrangement of all major equipment and furniture; and who the "captain" in the room must be.

Major Equipment, Their Accessories and Use

12

In **Chap. 6**, I stated that the VR surgeon is only as good as his nurse. This is almost[1] equally true regarding the armamentarium at the surgeon's disposal.

An entire book could be written about the equipment used by today's[2] VR surgeon. Only a selected few items are discussed here and even those to only a certain extent.

12.1 The Vitrectomy Machine and Its Components[3]

The key factor determining the quality of the machine is how precisely the surgeon can control what happens inside the eye as a consequence of his maneuvers, i.e., how little traction the probe exerts on the retina during vitreous removal.

12.1.1 The Pump

12.1.1.1 Peristaltic Pump: Flow Control

This is the pump used in the original, early machines; it now lives its renaissance because it allows precisely controlled removal of material from the vitreous cavity,

[1] "Almost" is the key word. A dedicated and experienced surgeon can be successful even when some of the tools he otherwise considers necessary are unavailable or their quality is suboptimal.

[2] When I started VR surgery, the probe was "multifunctional": a single handpiece that cut/aspirated and provided infusion and light. The cut rate was very low, unavoidably exerting traction on the retina – especially because the cutter was rotating, not guillotine. The light pipe slid over the cutter, and the vitreous was often caught between them, with disastrous consequences; finally, the light was very weak. Surgery was monomanual (through a single sclerotomy, which was almost 3 mm long). There were no scissors, forceps, intraocular gas, silicone oil, endodiathermy, endolaser, air pump (A-F-X!), and PFCL (I treated the giant tear by lying on the floor and injecting air into the eye of the patient who was turned facedown on the operating table) – and this is an incomplete list.

[3] The characteristics are individually analyzed here, but the surgeon has to understand that many of these features are interconnected.

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regardless of whether the probe's port is submerged in fluid or gel (see below, under Venturi pump).

The amount to be removed has an upper limit, set by the surgeon.[4] This amount cannot be exceeded unless the settings are changed on the console. This increases the control the surgeon has over his actions, reducing the risk of the probe inadvertently biting into the retina[5] when working in its proximity.

12.1.1.2 Venturi Pump[6]: Vacuum Control

Due to the much lower resistance to flow of fluid (BSS or aqueous in syneresis lacunae; see **Sect. 26.1.2**) compared to gel vitreous, the machine's settings must be calibrated to fluid removal.[7] This not only slows down the speed of surgery but also makes vitreous removal in the vicinity of (especially detached) retina riskier.

12.1.1.3 Combination Pump (e.g., VacuFlow[8])

Combining the advantages of both pumps, this design virtual eliminates flow pulsation, therefore minimizing the risk of retinal injury while allowing fast gel removal.

12.1.2 The Probe

A fair number of characteristics are important.

12.1.2.1 Size/Gauge[9]

In principle, the smaller the size, the better for the patient; however, this is different for the surgeon; it is true that "size matters."

> A significant downside of smaller-gauge instrumentation is the bending of the tools as the surgeon rotates the eyeball or maneuvers the instruments into certain intraocular positions. The smaller the diameter, the higher the tendency of the tool to bend, which may be frustrating and divert attention away from the task itself (see **Sect. 3.7**). With experience, the surgeon is able to overcome this shortcoming (or switch to a larger gauge as a last resort).

Despite claims to the contrary by some in the industry and the profession, smaller instrument size *does* mean slower surgery, and with today's technology certain tasks can either not be completed at all or are more difficult (such as phacofragmentation, implantation/removal of 5,000 cst silicone oil).

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[4] The decisive variable is the amount of material to be removed in a given time period (flow, ml/m); the vacuum is used to achieve that flow rate. If the vacuum reaches its maximum but the flow has not, the flow cannot be increased until the surgeon resets the vacuum value.

[5] Especially if it is detached and highly mobile.

[6] Its only real advantage is an instant reaction time when activated by the surgeon.

[7] If set for gel removal, the eye immediately collapses once the probe is submerged in fluid: the infusion supply cannot instantly adjust and replenish the amount of BSS just removed.

[8] EVA by DORC (Zuidland, the Netherlands).

[9] See **Sect. 4.4**.

12.1.2.2 Port Location

The more distal the port[10], the better (see **Fig. 12.1**): this makes work in close proximity to the retina safer and more effective (e.g., shaving the vitreous over detached retina). With more distally placed ports, the surgeon relies less on scissors for cutting epiretinal membranes.

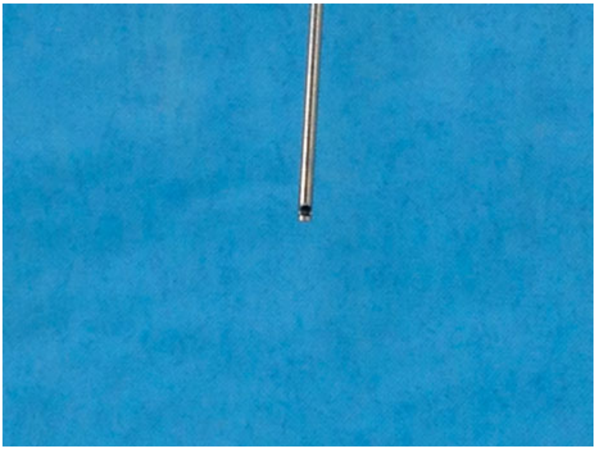

Fig. 12.1 **Distal, large port on a 23 g vitrectomy probe**. See the text for details

12.1.2.3 Port Configuration and Size

A probe with a slit-shaped opening, especially if with a double slit, is able to remove vitreous with increased speed and safety: there is higher fluid flow but decreased fluid/gel acceleration that could drag the retina into the port.

The port size is obviously limited by the diameter (gauge) of the probe, which in turn is one factor in the speed of vitrectomy.[11]

12.1.2.4 Cut Rate

The probe (vitrectomy machine) should provide for:

- Single cuts: the pedal needs to be activated before the next (single) cut is made.
- High[12] cut rate: some machines[13] double the cut rate by making the guillotine cut in both the proximal and distal directions.
- Minimal or no drop in the flow rate even when the cut rate is high.

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[10] That is, the closer the probe's opening is to its tip. Probes are now available with a port at only 0.43 mm (20 g) and 0.23 mm (23 g) from the tip.

[11] Todays' surgeon can find a 20 g probe with a 0.45 × .66 mm port and a 23 g probe with a 0.33 × 0.47 mm port.

[12] A cut/minute rate of 600 used to be called normal and 1,500 c/m high only a few years ago. The cutoff value is unspecified, but today a "high" cut rate is generally understood as >5,000 cpm.

[13] DORC (Zuidland, the Netherlands), Geuder (Heidelberg, Germany).

Q&A

Q *Is the probe's cut rate truly so important in VR surgery?*

A Yes. In principle, the higher the cut rate, the less likely that the probe will inadvertently bite into the retina, whether detached or attached. (The duty cycle also plays an important role in the fluid "surge" at the aspiration port.) Conversely, higher cut rates also mean that, in the true sense of the word, less "vitr*ectomy*" than "vitreous *shaving*" occurs: the tissue is released before the actual cut. Just think of performing lensectomy in the vitreous cavity: the cut rate must be low to avoid the fluid surge pushing the material away from the port (see **Sect. 38.2.2**).

12.1.2.5 Duty Cycle[14]

The higher, the better; this reduces the risk of drawing retina to the port. Probes with a port that is always open (continuous flow) are becoming available and greatly reduce the risk of iatrogenic retinal injury.

12.1.2.6 Probe Length

In highly myopic eyes, most probes are unable to reach the posterior retina. The surgeon usually compensates for this by indenting the eyewall, which unfortunately distorts the image. This is an especially important issue if a contact lens for high-resolution viewing is used.

The ideal probe is long enough to readily reach the posterior pole in the highly myopic eye (see **Table 42.1**) as if it were an emmetropic one.[15]

12.1.3 The Light Source/Pipe

The light provided by the vitrectomy machine must be bright enough to allow safe execution of any surgical maneuver. It should be color-adjustable with no harmful UV/IR rays. At least two bulbs should be housed in the console, so if one burns out, the other can be instantly switched on.

Most surgeries are performed with the surgeon holding the light pipe in his non-dominant hand. This tool must be:

- Shielded (blocking light on one side so as to prevent blinding the surgeon with direct light).[16]
- Wide angle (simultaneous illumination of most of the retina).

[14] Proportion of time when the port is opened vs closed.

[15] Obviously, this is true for all hand instruments as well.

[16] Light reflected from instruments or white intraocular surfaces requires adjustment of the angle of illumination.

There are definite benefits for the surgeon if he can use two active hands (bimanual surgery; see **Sect. 4.3**), which requires a different concept of lighting, even if the "chandelier" type of illumination has its own disadvantages (see **Table 12.1**). Certain manufacturers provide a 20 g light pipe equipped with a pic, which allows performing surgery with "one-and-a-half" hands.

More is found on endoillumination in **Chap. 22**.

Table 12.1 Illumination options for the VR surgeon

Illumination option	Benefits	Disadvantages
Traditional light pipe	The light can be shown from different directions The light pipe can be held in either hand The light pipe can be used as a blunt dissecting instrument[a]	The surgeon does not have two working hands
"Chandelier"[b]	The surgeon has two working hands	It is difficult, although not impossible[c], to adjust the angle of illumination More than one light may have to be used to provide adequate illumination or avoid shadowing
Illuminated instruments	There is no need to have separate scleral entries for the light: it is either built into the infusion cannula and/or the working instruments	The issues of shadowing and the inadequacy of lighting are still not completely resolved

[a]If equipped with a hook (pic), even for sharp dissection.
[b]This category includes, regardless of the name of the device, all lights that are fixed externally: bullet, twin etc.
[c]Requires a trained, attentive nurse.

12.1.4 The Infusion Supply

Gravity-fed systems[17] are no longer acceptable. Automatic resupply (infusion compensation) is the optimal solution, in which the vitrectomy machine instantly reestablishes and continually maintains the preset IOP value, irrespective of how much material and how fast a material is removed from the eye.

> **Pearl**
> The bottle height is about as specific an indicator of the IOP as the tachometer is about the car's speed. It is only a rough estimate.

[17] If this is the surgeon's only choice due to the vitrectomy machine's characteristics, at least he should place the drip chamber of the infusion bottle at the height of the patient's eye and connect the infusion bottle with the vitrectomy machine's air pump. The infusion pressure created in the vitreous cavity then equals the air pressure set by the surgeon on the vitrectomy console. This setup eliminates the unreliable guesswork of having the "bottle height" determining the IOP.

12.1.5 The Trocar

- It should require a low piercing force to avoid major IOP elevation during insertion.
- Its shape should be slit-like to allow spontaneous closure of the scleral incision at the conclusion of surgery.
- The one-step system is preferable to the two-step one.

Q&A

Q *What are the disadvantages of the two-step entry system?*

A Both the transconjunctival and the scleral openings may get lost during the switch from the blade to the trocar. This is frustrating, and if the scleral opening is not found by blindly poking under a conjunctiva that bled or is swollen due to the fluid leaking from the vitreous cavity, the conjunctiva may have to be incised.

12.1.6 The Cannula

- The cannula should be valved to avoid fluid loss when no instrument is inserted in the cannula. Having a plug in the cannula is better than having neither, but the valve is the ideal option.
  - Occasionally,[18] the surgeon *does* want free flow through the cannula. Preferably the valve can temporarily be removed (and replaced if necessary)[19]; otherwise, either the valve is permanently eaten by the probe or a cannula without valve must be inserted (see **Fig. 35.9a**).
- Even in the OR's dark environment, it should be easy for the surgeon to find the entrance of the cannula (so that even a presbyopic surgeon does not need the nurse's help; see **Chap. 6**).
- The cannula should be color-coded, based on its size (gauge).

12.1.7 System to Inject/Extract Viscous Fluid

- The drainage connection for silicone oil removal should be internal, not external: a blunt needle inserted through the cannula into the vitreous cavity, rather than a silicone sleeve that is held over the cannula's head.
  - The latter can easily aspirate outside air, not silicone oil, if the fit is not watertight.

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[18] For example, passive silicone oil removal.

[19] DORC (Zuidland, the Netherlands; see **Fig. 21.2b**).

- The needle should be long enough to reach any remnant silicone oil bubble, even if it is stuck at some distance from the cannula's internal port. The needle companies provide with their machine is typically too short.
- Ideally, the plunger head of the syringe used for oil extraction does not get stuck (making it impossible for the vitrectomy machine to create vacuum and start oil removal).

12.1.8 The Pedal

- Its switches (buttons) should be programmable so that they can be set according to the individual surgeon's preferences.
- It should allow for linear, dual linear, and "3D" modes (see **Sect. 16.3**).
- Having a wireless pedal avoids the accumulation of wires/cables under the surgeon's feet.
- One of the most crucial functions of the pedal is the "backflush" option, similar to that with the flute needle (see **Sect. 13.2.2.1**): if the retina is inadvertently caught in the probe's port, the surgeon must be able, with a readily available button, to immediately reverse the flow and blow the retina away.

12.1.9 Integrated Laser[20]

It is very important for the laser probe to be curved. There is no location in the eye that cannot be reached with a curved probe; conversely, some areas are risky or impossible to reach with a straight one; a straight probe prevents doing proper endolaser cerclage[21] in the phakic eye.

12.1.10 Endodiathermy Probe

- The ideal probe's tip has a nonsticky surface.
- There should be two tip designs to choose from: one with a sharp, pointed tip and one with a blunt tip that has a large surface.
  - It is the latter one that is ideal for chorioretinectomy (see **Sect. 33.3**).
- The power of the cautery should be highly adjustable.[22]

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[20] Typically argon. The laser may also be a stand-alone equipment.

[21] See **Sect. 30.3.3**.

[22] At high power (which is also used in chorioretinectomy), the liquid blood, which otherwise hides the exact location of the hemorrhage, will evaporate when the probe is activated just over the blood pool. The source of the bleeding is thus identified and can be treated (at a lower power). This maneuver is often needed in PDR.

12.1.11 The User Interface of the Vitrectomy Console

Being the vehicle through which the user instructs/programs the machine, it is crucial for the LCD interface to be user-friendly: simple and intuitive. The designers of the software must resist using too many or too few colors as well as a menu showing too limited or too numerous options.[23]

Ideally, the interface should satisfy the following criteria.

- Every crucial piece of information is displayed.
  - Selecting one function should then bring out the options of that function while graying out the others (see **Fig. 12.2**).

Fig. 12.2 **An optimized display on a vitrectomy machine**. All the important information is readily visible, but only the currently used application (endolaser) is highlighted. Nothing that is crucial is missing and everything needed is visible; the use of colors is sufficiently helpful without being overwhelming

- The information should be easy to find and read.
- The arrangement should be rational and the programming logical so that the user need not study the instruction booklet to understand how the touch-screen display is to be operated.[24]

[23] I once saw an advertisement in which the company was proud that its remote control for the TV had 65 buttons. Which human being would remember all the functions of all those buttons?

[24] I once had a camera that had four modifier buttons; operating them allowed the user to access a multitude of functions. The problem was that the camera's capabilities in the booklet were listed by *button* (e.g., "if you push button A once and button B twice, you can take photos in macro

Pearl
A vitrectomy machine should provide some type of audio feedback to the surgeon about a number of characteristics, such as whether the probe is in vitreous or fluid and the actual flow/aspiration level, and confirm any intraoperative change to the machine parameters. The feedback should be moderately conspicuous and its audio level adjustable – the surgeon should also be able to turn it off if he finds it bothersome.

My personal settings for the vitrectomy machine are described in **Table 12.2**. The software should allow these settings to be programmed into the memory and recalled per user.

12.1.12 Troubleshooting

There are many things that can go wrong with the vitrectomy machine and its accessories; an incomplete list of these and their solution is provided in **Table 12.3**.

12.2 The Microscope

Looking for the ideal microscope, here are a few things to consider:

- Floor-mounted microscopes have the advantage of being mobile and easier to handle if they need to be repaired; they are also less expensive than a ceiling-mounted one.
  - Conversely, ceiling-mounted microscopes cut down on the clutter in the OR.
- Regardless of the type of mounting, the microscope must remain firm (shake-resistant) when its wheels are locked.
- The microscope should provide an excellent 3D view and have built-in UV and IR filters.
- The view must easily be switchable between coaxial and non-coaxial.[25]
  - It is highly advantageous if slit illumination is also possible (see **Sect. 17.2**).
- It should have both high and low magnification. The latter is also important because the surgeon may want to see a large field when working externally.[26]
- All functions, including the speed of the X/Y movement, must be adjustable.
  - If the pedal functions are not programmable, at least the buttons should be arranged logically (**Fig. 12.3**).

mode"), not by *function* ("if you want to take photos in macro mode, push button A once and button B twice"). Is the user looking for a function or a button?

[25] Occasionally it is preferable for the reflected light to arrive at the surgeon's eye at an angle.

[26] Just think about suturing the iris with a double-armed Prolene suture (STC-6; Ethicon, Livingston, Scotland). The suture is long, the (other) needle easily gets lost, and it is hard to find if the microscope has a small field of view.

Table 12.2 Settings for the vitrectomy machine in 23 g PPV[*]

Variable	Probe-retina distance	Setting
Aspiration[a]	Probe far from (peripheral and/or detached) retina	600 mmHg
	Probe close to (peripheral and/or detached) retina	<<600 mmHg[b]
Flow[c]	Probe far from (peripheral and/or detached) retina	20–25 ml/s
	Probe close to (peripheral and/or detached) retina	1–5 ml/s
Cut rate[d]	Probe far from (peripheral and/or detached) retina	1,200–3,000 cpm
	Probe close to (peripheral and/or detached) retina	5,000–8,000 cpm ("shaving")
Infusion pressure	Irrespective of probe-retina distance	30–35 mmHg[e]
Light (illumination power)	Irrespective of probe-retina distance[f]	Only as much as needed for safe intravitreal maneuvers
Pedal arrangement	N/A	Cut rate: set (but changed manually according to probe position as needed; see above) Aspiration/flow, linear (thus no need to force the foot to do double motion: (1) press pedal down for cutting and then (2) turn pedal sideways for aspiration; see **Sect.** 16.3)
Silicone oil[g] injection	N/A	30–40 mmHg
Silicone oil extraction	N/A	500–600 mmHg

[*]These figures relate to certain machines; different machines require slightly different settings. PVD requires different settings, see **Sect. 27.5.1.**
[a]Venturi pump.
[b]Pedal setup: linear (the actual value employed is adjusted according to tissue reaction such as retinal movement).
[c]Peristaltic pump. The aspiration value set on the machine simply determines the value above which the machine will not increase the vacuum to allow achieving the required flow rate.
[d]With either pump.
[e]There are advocates of setting the IOP at 50 mmHg. This may be dangerously high in long cases or in eyes with poor circulation (e.g., diabetic ischemia).
[f]Still, the light should be held as far away from the retina as consistent with sufficient lightning.
[g]≤1,300 cst.

Table 12.3 Vitrectomy machine-related troubleshooting*

Symptom	Cause and possible solution
Machine will not work or display any information	Connection to power source loose No electricity (a blown fuse is the most common reason) Software malfunction (restart necessary)
No aspiration	Vitrectomy machine's compressor not turned on/working[a] Water got into the machine during the previous surgery or testing Probe clogged because of the nature of the aspirated material (lens, hard membrane etc.)
No cutting	Vitrectomy machine's compressor not turned on/working Guillotine mechanism inside the probe is stuck[b]
Vitreous removal too slow	Cut rate set too high (low flow) Aspiration/flow set too low Vitreous composition[c]: occasionally seen in diabetics and in a relatively high percentage of eyes with VMTS. It takes a lot of extra time to remove such a gel
Eye collapses during aspiration	Infusion still closed (multiple locations possible: stopcock, bottle, line etc.) Too high vacuum[d]
Silicone oil implantation: no intraocular flow ("oil does not arrive" or flow stops)	Machine setup erroneous, e.g., not calibrated for 5,000 cst oil Oil is lost at the tube's connection to the syringe Oil is lost at the tube's connection to the cannula
Silicone oil explantation: no flow	Machine setup erroneous, e.g., not calibrated for 5,000 cst oil Syringe full Plunger stuck System not closed (air is aspirated)
The trocar requires extra pressure to penetrate the sclera	Mishandled trocar: bent tip Scar tissue is underneath the sclera (previous surgery, PVR etc.) Eye too soft
Cannula repeatedly gets loose/removed during instrument exchange	The instrument (less commonly, the inside of the cannula) has microscopic material stuck to its surface, and as the intraocular instrument is withdrawn, it takes the cannula with it Thin sclera (high myopia, autoimmune disease etc.) Reoperation with the cannula placed in the same area as before Surgeon withdrawing the instrument at an angle to the axis of the cannula Repeated changes during the operation to the cannula's position, loosening its snugness in the sclera Surgeon not readjusting the instrument before withdrawal (forceps in open position, a memory-material curved laser probe not pulled back)
Infusion outflow through cannula	Damaged valve Wrong (valveless) type cannula in the package
Pedal does not work	Speed (e.g., X/Y) set to slow Battery dead/cable damaged/contact loose

(continued)

Table 12.3 (continued)

Symptom	Cause and possible solution
Endolaser probe does not work[e]	Cable broken Laser filter not on[f] Connection to machine loose
Endodiathermy probe does not work	Cable broken/contact loose The power is too low Material that during usage got stuck to the tip dramatically decreases and then stops the function

[*]Related to the machine itself and its major accessories; the list is not a comprehensive one. The cause may also be different with different machines.
[a]Used to be a problem with older machines.
[b]It can lead to severe iatrogenic complications. This is why the surgeon (not just the machine) should test the probe outside the eye, by looking at the port through the microscope and seeing if the guillotine action is visible. The higher the cutting frequency, the more difficult it is to actually see the motion so the blade's movement may have to be felt by hand (tactile feedback).
[c]I am not aware of a commonly accepted terminus technicus. The vitreous appears more structured than normal and has increased resistance to flow.
[d]Should not happen if a peristaltic pump is used; in reality, it is still possible with older machines.
[e]Common, not accessory-related reasons include material stuck to the tip (retina was touched with it, blood etc.) or an air bubble that is adherent to it.
[f]Be very careful; in some older machines the laser will function even when the filter has not been activated; a very unpleasant and dangerous experience for the surgeon and the OR personnel.

- The pedal must satisfy the same criteria as that for the vitrectomy machine (see **Sect.** 12.1.8).
- The eyepiece must be highly tiltable to adapt to the surgeon's comfort (see **Sect.** 16.7.1).
- It should be easy to mount/intraoperatively add/change various attachments: eyepiece for two assistants + an additional viewing tube, BIOM+SDI, laser filter, and digital video camera. All these must be arranged so that they do not unduly increase the working distance between the eye and the surgeon's eyepiece.
- The user interface must satisfy the same criteria as that for the vitrectomy machine (see **Sect.** 12.1.11).
- There should be a digital video camera attached. It has to be of great quality to allow high-definition recording with as large a field as possible (see **Sect.** 12.4 below).

Regardless of the type of microscope, the surgeon should always keep in mind two inherit characteristics of the operating microscope:

- By increasing the zoom (magnification[27]), the resolution[28] will not increase.[29]
- Zoom (magnification) and field of view are also inversely proportional.
- During the operation, the surgeon must constantly search for the best compromise between these two opposing pairs of characteristics by adjusting the zoom using the buttons on the pedal.[30]

[27] Image size.

[28] Ability to tell two objects apart.

[29] See "pixeling" on the computer monitor.

[30] In theory, if the focus (image sharpness) has been set at high zoom at the beginning of the setup (see **Chap.** 16), the microscope will keep the focus throughout the entire operation.

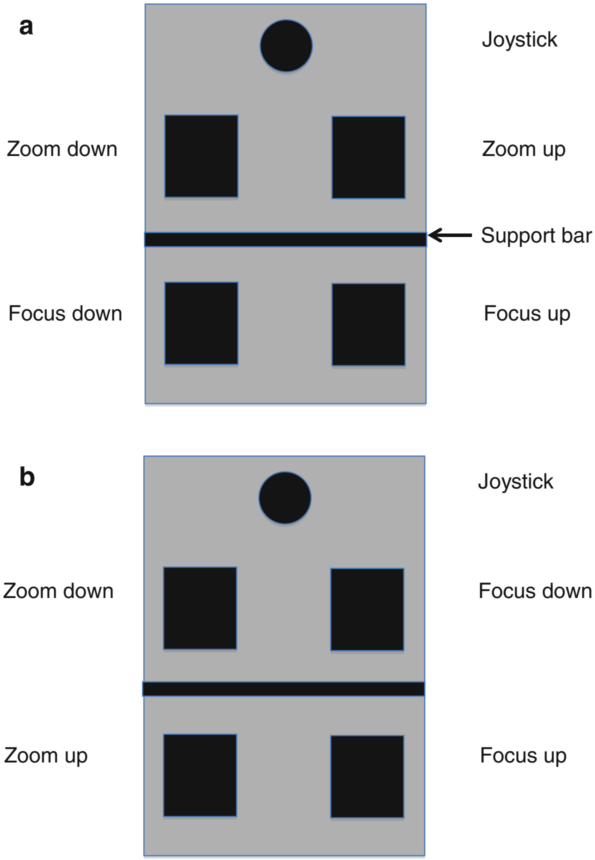

Fig. 12.3 Arrangement of the function buttons on the microscope pedal. (**a**) For most surgeons, it is not logical if their foot must move horizontally to achieve opposite actions of the same function: the foot must be repositioned every time to change between "focus down" and "focus up." (**b**) The surgeon's foot, when the focus function is to be activated, is positioned so that its palm is placed over the "focus down" and the heel over the "focus up" button: he can switch between the two functions without having to make a major change in foot position

12.3 The BIOM[31]

Of all the wide-angle systems, I found the BIOM to be the one offering the most to the surgeon.

- It is noncontact, eliminating corneal trauma and the need for an assistant/sutures to hold it in place[32]; it also gives unhindered access to all cannulas/sclerotomies.
- Even in the presence of significant corneal or lens opacities, the view is sufficient to allow safe VR surgery.
- Most of the fundus is visible even through a pupil as small as 3 mm.
- The field can be as wide as 125°, with excellent depth perception.

[31] A more detailed description of this device is given in **Sect.** 16.5.

[32] As opposed to a "contact" system, which is indeed in constant contact with the cornea, requires assistance to maintain its position, and has a higher risk of causing damage to the epithelium.

- With minor adjustment of the focus,[33] equally fine visualization is provided in the gas-filled eye.

Pearl
How easy it is to get used to the BIOM and the numerous advantages it offers is best demonstrated if the surgeon is forced to go back, after having switched to the BIOM many surgeries ago, to a contact lens (see **Chap. 13**). The surgeon will feel lost as he is not able to see the "big picture" in the vitreous cavity (see **Chap. 17**).

12.4 The Video Camera[34] and the Recording of Surgeries

The camera should be digital and of the highest quality. It may require a rather significant initial investment, but as technology advances, a less-than-high-resolution camera will rapidly become outdated.

Q&A
Q *Should every operation be recorded?*
A Yes. If nothing remarkable occurs during the case, the digital recording can easily be erased. This is much preferred to the often-heard exclamation: "What an idiot I was not to record this!" That special moment during the operation may prove "unrepeatable."

Recording even "routine" surgeries has an additional benefit: The surgeon can periodically set time aside and review them (see **Sect. 11.3**).

It is also crucial to have a large, high-quality display in the OR so that the surgeon can check whether what he assumes to be recording is indeed visible.[35] The nurse must also be able to see the monitor, especially if she is unable to view the operation through the microscope.

For the surgeon, the recording should be of *good* quality for his own viewing and of *excellent* quality if he intends to use videofilms for teaching or scientific purposes. Here is a list with a few recommendations:

- Make sure you set up the microscope and the BIOM properly (see **Sects. 12.2** and **12.3** above, plus **Sects. 16.4** and **16.5**).

[33] Up.

[34] See **Sect. 12.2** above.

[35] He may be out of focus or outside the field of the camera, or there is too much light reflex.

- Once the light pipe is in the vitreous cavity, use the highest magnification of the microscope, and use the up/down pedal so that the image seen on the monitor is absolutely sharp.
  - If the image in your microscope is not sharp, do not adjust the microscope height but adjust your eyepieces to account for your refraction.
- On the console that controls the camera functions, adjust the white balance and the auto iris.
- Test the reflection in the eye from a white surface (proliferative membrane, optic disc). If there is too much reflection and the image has high contrast (e.g., white reflex centrally and darkness surrounding it), the auto iris is not working properly.
  - If this cannot be fixed, reduce the amount of light on the vitrectomy machine to the lowest level that is still compatible with safe surgery.
- The way the camera is fixed to the microscope is rather permanent.[36] The image may be slightly off-center, and certain areas[37] may not be visible on the monitor/recording at all.
- Realize that even the best camera has a smaller field of view than what you see in the microscope: What you can comfortably see in the microscope may be invisible on the monitor.
- Ask/nominate someone (the "watchman") in the OR to constantly monitor the display and immediately tell you when something is not perfect. Reassure this person you will get angry with her not if she repeats the same thing a hundred times but if you do not record something because she did not warn you. She does not have to be polite; short communications are sufficient: "center," "focus," and "reflex" (too much light).

> This is a straightforward request for something that is very easy to do. The sad reality is, though, that nobody wants a perfect recording as much as the surgeon does. Expect the watchman's initial enthusiasm to drop during the case. You will need to constantly encourage her and thank her for her efforts.

[36] That is, further adjustment is not possible.

[37] Especially the superior retinal periphery. The company's local representatives occasionally may be able to help adjust/readjust the camera's position.

Instruments, Tools, and Their Use 13

13.1 The Contact Lens[1]

Even if a high-resolution "macula lens" of a wide-angle viewing system[2] is used, the plano-concave ("flat") contact lens provides superior resolution for fine work on the posterior pole (see **Fig. 13.1**). The field of view is 36° with the contact lens and there is no magnification.[3]

It is not advisable, however, to use a contact lens for manipulations outside the posterior pole. Even the "wide-field" contact lens will not provide a field greater than 48°,[4] and these actually shrink the image size (0.45× magnification) due to their concave anterior surface. The prism lens (30°) allows work in the periphery, 360° if rotated, but the individual field of view is only 33°.

13.2 Hand Instruments[5]

One of the benefits of working with intravitreal hand tools is that they have a fixed outer diameter: the distance between their business end to the entry port is irrelevant. This advantage becomes evident when the surgeon wants to cut a membrane in the AC with traditional scissors: the further the fulcrum of the tool from the paracentesis, the wider the wound must be (see **Fig. 13.2**).

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[1] See **Sect. 32.1.1** for additional information about the use of the contact lens.

[2] Which is the ideal viewing tool (BIOM, see **Chaps. 12** and **16**) for all areas and tasks other than the finest manipulations on the central retina. Still, since the noncontact, high-resolution macula lens of the BIOM also allows maneuvers such as ILM peeling or separation of proliferative membranes, it is the individual surgeon's personal choice whether he uses it or the contact lens.

[3] Magnifying (1.5×) contact lenses, with an even smaller field of view (30°), are also available.

[4] That is, restricting the field to the posterior pole.

[5] More about the use of these instruments can be found in various parts of **Parts IV** and **V**. Not the entire armamentarium of tools is discussed here.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_13

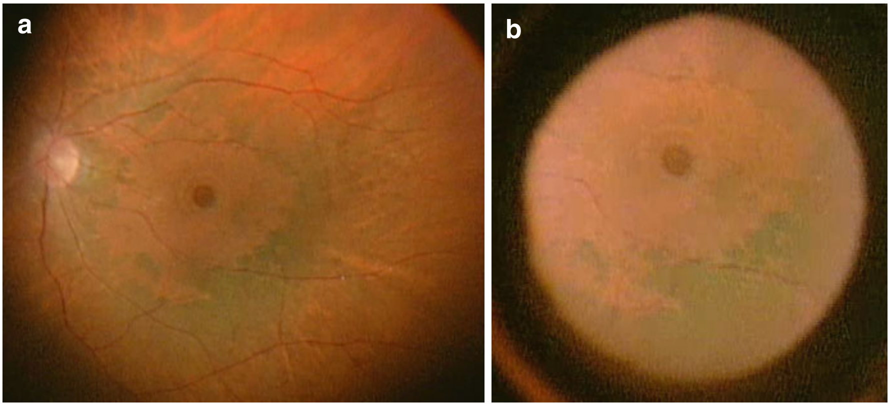

Fig. 13.1 **Comparison between the image seen through a high-resolution macula lens and the contact lens**. (**a**) A large field and decent resolution with the BIOM high-resolution macula lens is achieved in this patient who had ICG-staining before removing the ILM for a macular hole. The EMP causes a "negative staining," mostly in the vicinity of the hole. (**b**) At the same magnification of the microscope in the same patient, the field is noticeably smaller, but more details are visible when viewed through the plano-concave macular contact lens

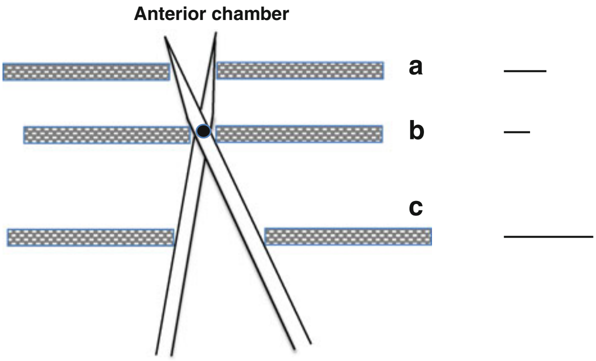

Fig. 13.2 **Schematic representation of the use of a fulcrum-type scissors**. The distance of the fulcrum's position (*dark circle*) from the wound (*patterned lines*) (the distance of the object to be cut from the wound is also important) determines the length of the incision needed to operate the instrument. The wound is the smallest when the fulcrum itself is at the incision (**b**). When the fulcrum remains outside the eye (**a**), the incision must be longer, while the longest incision is required with the fulcrum being in the AC itself (**c**). This is the most common clinical scenario (because most objects are further away from the point of entry than the length of the blade), demonstrating the advantage of VR microinstruments, where the wound length is the same regardless of how far away the tool (i.e., the object to be cut) is inside the eye (see **Fig. 13.3** for the single exception to this rule). The *black lines* on the right of the image show the required wound length

Vitrectomy hand instruments can be classified into the following categories.

- *Squeezable tools*. It is the squeezing of a handle that initiates the action. Forceps and scissors[6] belong to this category.
- *Non-squeezable tools*. The surgeon's hand manipulates these stationary tools in toto, without the need for the fingers to separately activate parts of them. Blades, needles, spatulas, and pics belong to this category.
- *Hybrid tools*. Either minor finger activation (flute needle) or a one-time manipulation (pushing out retractable tools such as a magnet, laser probe, or scraper) is needed.

This distinction is more important for safety than whether the instrument is sharp or blunt (see below): squeezable tools require more dexterity since their operation demands much more complex maneuvers. The use of such instruments underlines the need for firm wrist support (see **Sect. 16.2.1**) to avoid inadvertent movements of the instrument's tip, which would risk injuring the retina.[7]

There is a paradox regarding the use of sharp vs blunt instruments.[8]

Q&A

Q *How can a blunt instrument (such as a spatula) be less safe in manipulating epiretinal membranes than a sharp tool (such as scissors)?*

A The answer lies in what was described under **Sect. 3.2**: control by the surgeon. Separation between two tissues is determined by the strength of two forces: *adhesion* (attachment of one tissue to another) and *cohesion* (tensile strength of a single tissue – how easily it tears). If the adhesion is stronger and a *blunt* tool is used for separation, the tissue tears in the area where its cohesion is the weakest. The surgeon's control over what happens is rather limited. With the use of a *sharp* instrument, it is the surgeon who decides where to separate (cut the connection between) the two tissues, perhaps more difficult technically, but certainly more controlled (see **Sect. 39.3**).

[6] Certain vitrectomy machines allow the blades to be operated by the footpedal, without the need for the surgeon to squeeze the handle.

[7] Remember the obvious: you are manipulating the instrument *extraocularly* to achieve an effect *intraocularly*. You have visual feedback of the latter but only tactile feedback of the former. The less you need to manipulate the extraocular part, the better.

[8] A *careful* chef will have a smaller chance of cutting his fingers when slicing meat with a sharp than with a blunt knife: the blunt blade requires more force to be effective, thereby reducing the chef's control over the process.

13.2.1 Squeezable Instruments[9]

13.2.1.1 General Concepts of Working with Squeezable Instruments

How the instrument reacts to the surgeon's squeezing action differs according to the design of the tool, and the surgeon must understand this so that he can use the instrument in the most optimal way. There are two main design types, depending on what happens upon squeezing the handle.[10]

- The outer shaft forces two metal rods together; the movement of the two (occasionally three) endpieces is identical[11] (forceps, most scissors; see **Fig. 13.3a**).
- Only one of the endpieces is mobile; the other one is stationary (vertical scissors; see **Fig. 13.3b**).

13.2.1.2 The Handle

- Choose a handle with a short travel route: on **Fig. 13.4** "X" should not be more than 2 mm. Increasing the distance results in decreasing stability.

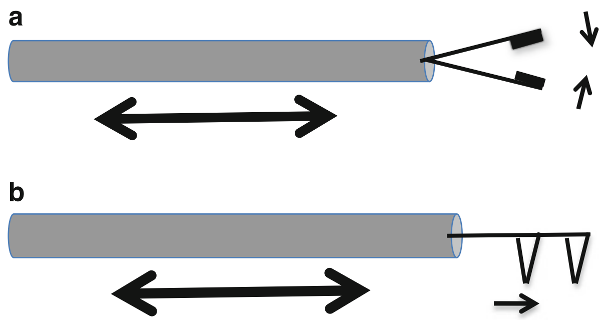

Fig. 13.3 Schematic representation of the workings of squeezable instruments. (**a**) The outside shaft slides forward (*double arrow*), forcing the jaws to close (*single arrows*). In the "fully open" position, the distance between the rods (or blades, depending on the design) exceeds the diameter of the outer shaft. This may cause difficulty when an object is too close to the small wound so that the instrument cannot be fully opened (this is the exception referred to in **Fig. 13.2**). A classic clinical example is a transcorneal iris suture (McCannel type), where the thread needs to be "fished out" from the AC through a paracentesis: the surgeon is often forced to either use a hook instead of a VR forceps or enlarge the paracentesis. (**b**) The outside tube slides forward (*double arrow*), but only the proximal blade moves (*singular arrow*). With this design, any maneuver is doable, irrespective of wound length or the distance of the target from it (in real life, unlike on the image, the tip of the blade does not reach beyond the imaginary extension of the shaft – otherwise, the tool cannot be inserted through the same size of cannula)

[9] The design of the handle ("squeezability") makes a huge difference in how user-friendly they are.

[10] The default position of the tool is "open": it is the surgeon's action that forces the tool to "close." There are also tools that work with "reverse" action: the default option is the "closed" position.

[11] They move simultaneously, along mirrored paths and equal distances – even if one blade is longer than the other.

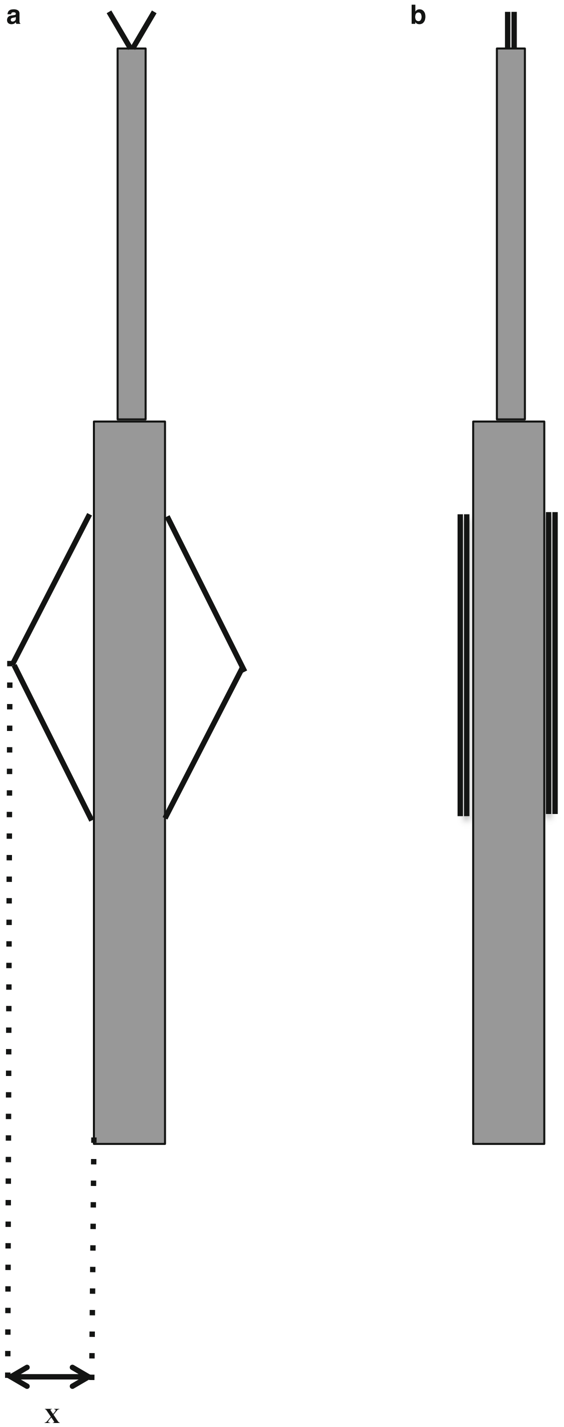

Fig. 13.4 **Schematic representation of operating a squeezable instrument**. (**a**) The forceps in the "open" position. The distance each of the surgeon's fingers must travel to completely close the forceps jaws (**b**) is indicated by X. The longer X is, the more chance for unintentional movement of the blades to occur, therefore increasing the risk of iatrogenic tissue damage. The way the surgeon can compensate for this is to partially squeeze the handle before actually grabbing the tissue: this reduces the travel distance and thus the risk of undesirable movement of the instrument's tip (see the text for more details)

  - The longer the physical distance the surgeon's fingers must cover to move the forceps jaws from "fully open" to "fully closed," the more the risk of the jaws making inadvertent movement. This can cause grabbing a membrane too deep (retinal damage) or too superficial (no purchase).[12]
- The resistance to squeezing (i.e., the force needed to operate the instrument; see **Sect. 4.1**) is also important. Ideally, there is minimal resistance[13] – and it must also be a smooth, even one.
- A handle that can be operated in a circular fashion (see **Fig. 13.5**) means that the surgeon is able to rotate the tool and easily maneuver the jaws/blades into the most optimal position.[14]

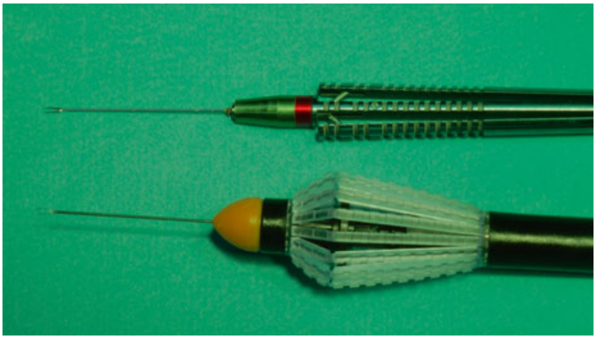

Fig. 13.5 Different handle designs on a permanent and a disposable ILM forceps. The *permanent* one (above) has two semicircles to squeeze; these have minimal resistance and a short travel distance. The only disadvantage is that occasionally the position of the semicircles and the grasping plane of the jaws are not aligned as demanded by the task, forcing the surgeon into holding the forceps in a somewhat awkward position. The *disposable* forceps (below) eliminates this problem because its circular handle can be squeezed with the same ease, regardless of the position of the jaws. However, the handle has a bit longer travel distance and, more importantly, requires a greater force of squeezing. The undesirable consequence of this is obvious if the forceps needs to be used over extended periods (an ILM that easily tears and needs to be regrasped frequently): the surgeon who had no tremor initially may develop fine shaking toward the end of the peeling

[12] To compensate for this, the surgeon should squeeze the handle *before* engaging the membrane. The aperture (distance between the blades/jaws) must be slightly larger than the tissue to be attacked. This is, however, still not an ideal solution since the fingers must now simultaneously fulfill two functions: squeezing the handle plus positioning the jaws on the target tissue. If the ILM forceps has a default opening of 1 mm, squeeze it by ~80% before any grabbing attempt.

[13] Think about a driver and the resistance of the gas pedal in the car. On a long trip, it is great to have a pedal with high resistance because the driver can simply rest his foot on it. When doing a fine maneuver such as starting to move a stopped car, however, and this is what describes the forceps analogy, the driver wants minimal resistance so that the car transitions from "stop to go" smoothly and the engine neither dies nor revs.

[14] The alternative is a reusable handle that allows the rotation of the jaws/blades into the ideal position before the handle is actuated (see **Sect. 44.2.2**).

13.2.1.3 Forceps

The surgeon should have a large variety of forceps available for different tasks since their design greatly influences their functionality.[15]

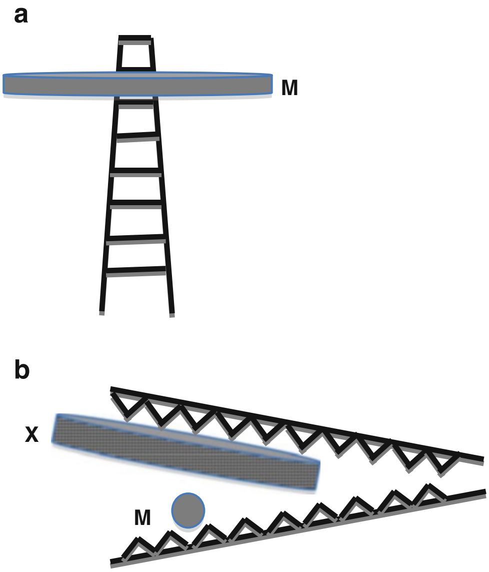

Fig. 13.6 **Schematic representation of the serration on the forceps jaws**. (**a**) Current designs have the serration perpendicular to the axis of the forceps (the lower jaw is shown from above). The area of contact with the membrane (*M*) is small. (**b**) From a side view, it is even more obvious that only a single tooth is grabbing the membrane (*M*). If the membrane could be grabbed along the membrane's long axis (*X*), the contact area increased greatly. Since this is rarely possible in real life, the serration in this case should be turned by 90°. The ideal serration angle would be at 45°, allowing decent grabbing in all membrane positions

- Pointed tips can pick up finer membranes but increase the risk of tissue damage, and they are more prone to tear the grasped membrane since they have a small contact area.
- Serration on the jaw surfaces increases the firmness of the grab.
- "End-gripping"[16] forceps (see **Fig.** 13.7) come in a wide variety (see also **Sect.** 32.1.1).
  - In general, the finer their tip, the better visibility the surgeon has of what exactly the jaws are coming into contact with.

[15] Unfortunately the so-called "crocodile" (serrated) forceps has the serration edged perpendicularly to its axis; this limits the surface of contact to be small in most cases and may allow the subretinal membranes that are directly underneath the retinotomy or in close proximity to it to slip from the forceps jaws (see **Fig.** 13.6).

[16] End-gripping means that the jaws close only at their very tip.

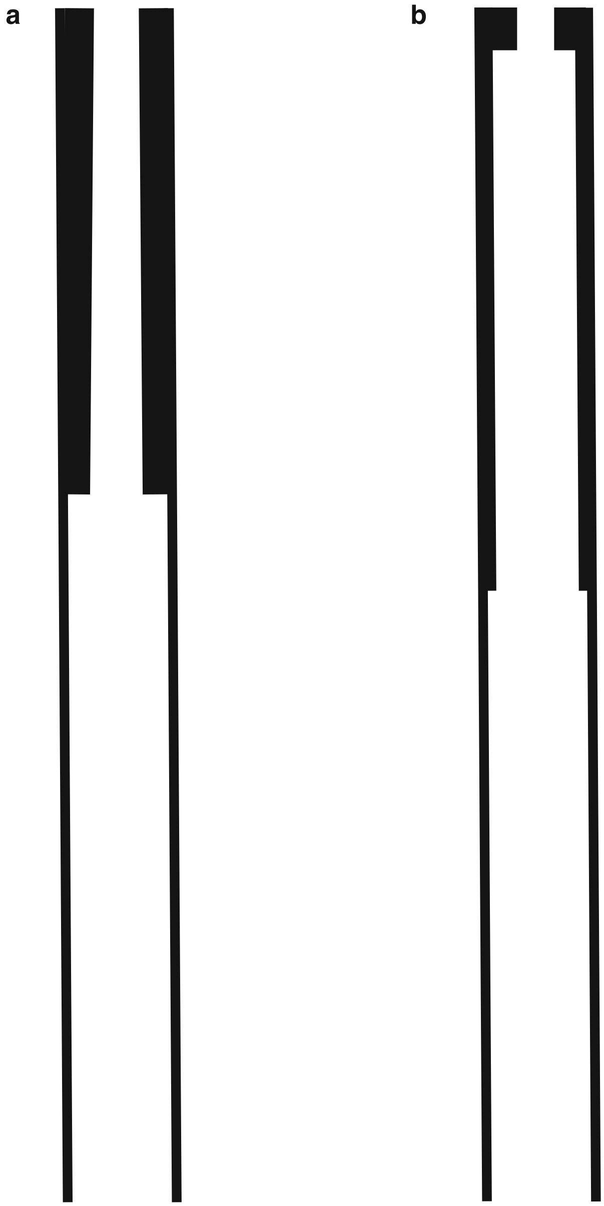

Fig. 13.7 **Schematic representation of standard vs end-gripping forceps designs**. Cross-sectional view, forceps in the open position. (**a**) When the standard type of forceps is closed, the entire surface of the jaws will come into contact: a relatively large area. (**b**) In the closed position of an end-gripping forceps, only the tips will touch each other; an open space is left behind them, which may increase the visibility of the tip when it is in action

– The larger the tip, the easier it is to grab the membrane and the smaller risk of tearing it – but it is more difficult to have decent visual feedback of what exactly is being grabbed.

Q&A

Q *Why does a forceps lose its ability to grab fine membranes?*

A Apart from the obvious (damage sustained during sterilization), the nurse may damage the tip intraoperatively as she tries to clean the jaws (remember, she does it in relative darkness and without the use of the microscope; see **Chap. 6**); the actuating mechanism may get stuck (silicone oil helps), or a piece of the membrane may remain caught between the jaws (see **Sect. 32.1.3**). The surgeon can also be responsible: serially grabbing thick membranes will destroy the fine-grasp capability of any forceps, not allowing it to grab delicate tissues anymore.

13.2.1.4 Scissors

- Scissors with long blades allow the surgeon to see the tip of the blade emerge from under the membrane on its far side. This enhances safety – otherwise, the surgeon can never be absolutely sure that he is not cutting retina underneath the membrane.
  – Another advantage of the long blade (of a vertical scissors; see below) is that if the surgeon keeps the forceps in the closed position, the blades can be used as a blunt spatula.[17]
  – A further disadvantage of the short blades is the membrane's tendency to be pushed away (distally) as the forceps is actuated; with long blades the risk of the membrane slipping out of the blades is much smaller.
- The blade angle has 3 basic variations: vertical, straight, and curved.[18] Each has some advantages, but by far the vertical is the most versatile one. It is also the least risky (causing iatrogenic retinal damage) as its sharp tip does not directly point toward the retina.[19]
  – In the open position, the vertical scissors can act as a bent needle (see below, **Sect. 13.2.3.1**). In most cases, with careful maneuvering, even the lower blade with a sharp superior edge can act on the already lifted membrane as a spatula would.[20]

Pearl

In an experienced surgeon's hands, a sharp but non-squeezable tool is more precisely controllable and thus less risky than a blunt instrument that requires squeezing.

---

[17] The disadvantage is that the surgeon has to pay attention to keeping the handle squeezed – which also interferes to some extent with how delicate his finger movements can be.

[18] The blade is perpendicular to the axis, is a linear continuation of it, or is in-between. The first two have straight blades. The vertical may also be asymmetrical: the lower blade is longer than the proximal one.

[19] Although occasionally the tip of the vertical blades must be turned toward the retina to pick up a membrane, which is then dragged toward the surgeon. Keep in mind that this is a risky maneuver.

[20] In other words, the blade will not cut the membrane while it is manipulating it.

- If the membrane to be cut is rather far from the retina, straight or curved scissors are fine.
- The blade of the vertical scissors should be as long as possible.[21]
- There are two very separate actions in play[22]; the surgeon must never merge the two into one.
  - Positioning the blades: carefully select the location where the cut is to be made and place the blade there.[23] Make sure that you have firm wrist support (see **Sect. 16.2.1**).
  - When you cut, remember that your fingers must execute two actions simultaneously: *hold* the scissors blades securely in the same position,[24] while your fingers must *squeeze* the handle.
  - With vertical scissors,[25] you insert the lower (stationary) blade underneath and the upper (active) blade atop of the membrane that you want to cut. When you squeeze the handle, the upper blade travels downward; you must not make any movement with the lower blade.

Pearl
That the lower blade of the vertical scissors is stationary is not intuitive. The less experienced surgeon, while activating the scissors, tends to lift his hand and thus the forceps. A conscious learning process is needed to strictly keep the lower blade in situ while cutting.

- If possible, avoid making multiple short cuts; try to make each cut as long as possible. This avoids the need for constant blade repositioning with its inherent risk.

13.2.2 Hybrid Instruments

13.2.2.1 The Flute Needle[26]

The surgeon often uses this simple but extremely useful tool, e.g., to evacuate air or fluid,[27] passively, from the vitreous cavity or the subretinal space. Active aspiration is also possible with certain types (see **Fig. 36.2**).

---

[21] The cannula in MIVS limits blade length, unless retractable blades of memory material are used.

[22] This is equally true for forceps use.

[23] Remember the carpenter's primary rule: measure twice before cutting (once). Cutting is a one-way street.

[24] Unless the membrane moves during cutting, which adds to the complexity of the maneuver.

[25] Which is by far my preferred type.

[26] More details about flute needle use are provided under **Sects. 25.2.7** and **31.1.2**. Always use a back-flush type, which also allows *blowing away* materials and offers an escape route when you catch retina with the tip (see below). The flute needle is known in many countries as Charles needle, after its inventor. The name is misleading: it is not just a needle but an entire device. The German name (Staubsauger, vacuum cleaner) is more accurate and certainly more descriptive.

[27] Such as blood (in a previously vitrectomized eye), BSS (during A-F X), PFCL.

Unlike the probe, which has a side opening, the flute needle's port opens in front of the instrument. This means that the flow generated is primarily anterior to the needle's shaft.

- The default position for the surgeon is to keep his index finger over the silicone chamber's aperture to block any flow.
  – Lifting the finger results in an outflow since the IOP is higher than the atmospheric one.
- Lift the finger only when you are certain that the cannula's tip is positioned correctly.
- If the detached retina is very mobile and retina is caught in the tip's aperture, forcefully press on the silicone chamber so that the fluid contained within pushes the retina away from the tip.
  – Since the tip is blunt, such a capture/release, while undesirable, does not cause measurable retinal damage – unless the retina is very fragile.[28]
  – If fluid is drained through a (hopefully preexistent) macular hole, always use a "soft-tip" cannula to avoid damaging the RPE. Otherwise, do not employ the soft-tip version because its internal diameter is smaller and there is more internal friction.[29] Drainage may be completely impossible, especially if the subretinal fluid is thick.[30]
- If the retina needs to be "massaged" under air or PFCL and the scraper is not available, the soft-tip flute needle is an acceptable alternative.

Q&A

Q *How safe is it to "massage" the retina?*

A A detached but intraoperatively just reattached retina, which is at the moment devoid of the effects of the IPM (see **Sect. 26.3.2**), is relatively easy to move around with a soft tool, under, for instance, PFCL. What the surgeon must remember, though, is that while manipulating the retina, it is unavoidable that he also puts pressure and shearing on the RPE and choroid (see below, **Sect. 13.2.3.2**).

13.2.2.2 Retractable Instruments

The external shaft houses the working part of the tool, which is either made of a memory material (e.g., a curved laser probe) or hidden to block the function of the tool until it is needed (permanent magnet). In either case, the surgeon inserts the instrument into the cannula and then pushes an external slide with his index finger. Proportional to this movement, the business end of the tool then appears in the vitreous cavity.

[28] High myopia, diabetes etc.

[29] That is, the drainage is slower.

[30] As a historical note, in the "pre-TA" era the soft-tipped cannula has been used to determine whether the posterior hyaloid is still on the retinal surface ("fish strike" phenomenon).

With a memory material, it is important for the surgeon to retract the tool back into the shaft before the tool is withdrawn (see **Sect. 21.7**).

13.2.3 Non-squeezable Hand Instruments

As mentioned above, there are instruments that do not require complex extraocular maneuvers; the surgeon' fingers are used for a single maneuver: moving the entire tool around.

13.2.3.1 Bent (Hooked, Barbed) Needle

Epiretinal membranes can be picked up (see **Chap. 32**) with forceps, a membrane scraper, (vertical) scissors, or a needle[31] with a small hook at its tip (see **Fig. 13.8** and **Table 13.1**.). The barbed needle is a very versatile tool, among others for the following purposes.

- Creating a PVD by carefully scratching the retinal surface (see **Sect. 27.5.1**).
- Slicing open, even lifting, an elastic preretinal membrane (see **Fig. 13.9**).
- Separating scar tissue from the retina, whether in the macula or elsewhere and irrespective of how thick (thin) the membrane is. The technical difficulty presents when working over detached retina (see **Sect. 53.2**).
- Identifying and then lifting invisible membranes off the retinal surface.
- Incising the ILM reduces the potential risk of direct forceps grabbing (see **Sect. 32.1.2.2**).[32]

Fig. 13.8 **The barbed (hooked) needle**. (**a**) If 23 g surgery is performed and the needle is 25 g, it is better to create the hook outward: this improves the visibility of the tip during the delicate maneuvers of picking up tissue without damaging what lies underneath. (**b**) If 23 g surgery is performed and the needle is 23 g, the hook must face inward; otherwise, it may not slide through the cannula – or even if it can be forced in, it will likely remove the cannula upon withdrawal (see **Sect. 21.7**). (**c**) Preparation of the hook: the needle is gently pressed against a smooth, flat metal surface and only for a split of a second. It is very easy to "overdo" this, and create a hook that is too large or at too much of an angle. (**d**) The ideal appearance of the barb. It is visible, even at this high magnification, mostly because of the different light reflex (which is in turn due to the angle). (**e**) A proliferative membrane, which has caused a large tractional retinal break, has been hooked with the needle and is being separated from the retina. The hook is turned toward the retina. (**f**) In this case, the hook faces away from the retina; this is recommended only after the membrane has been identified and partially separated from the retina (i.e., there is now space between them). The needle can then act as a spatula, but in case the membrane is lost or the surgeon seemingly reached the end of the membrane, the barb can again be turned toward the retina and continue the search for separation elsewhere. If the needle's hook is covered by tissue, the surgeon need not remove the tool but "twang" it intravitreally (see **Sect. 32.1.3**) and then continue with the membrane work

[31] In lieu of a bent-tip MVR blade, this is my favorite tool to start lifting fine, often even thick, epiretinal membranes and identifying invisible ones in proliferative diseases such as PVR or PDR.

[32] Other potential uses outside the vitreous cavity (e.g., see **Fig. 13.3**) are not listed here.


a
b

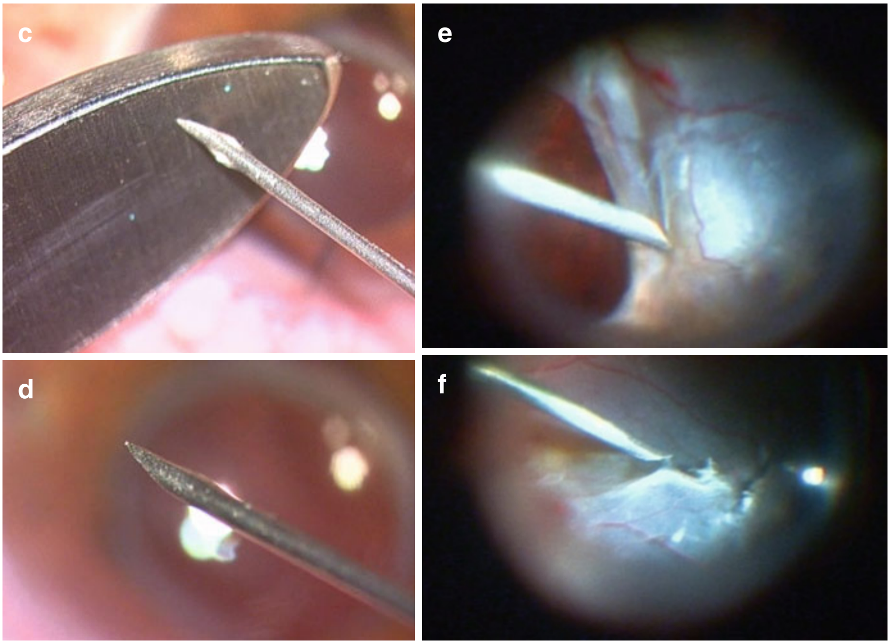

Fig. 13.8 (continued)

Table 13.1 The bent (hooked) needle for the removal of *epiretinal* membranes[*]

Variable	Comment.
General advantages of the bent needle	Being a tool that requires no squeezing, it provides maximal control for the surgeon The hook is small and is unlikely to cause significant retinal damage even if pressed too deep The hook can be turned downward to find and lift the membrane then upward to continue with the lifting and extend the separation sideways (acting as a spatula) Having decently sharp edges, the needle can cut adhesions of the membrane to the retina, provided the adhesion is weak
Advantages over forceps use	The ILM on which the epiretinal membrane rests has no edge; gently scraping on its surface will not break the ILM; therefore, it is easier with the needle than with forceps to identify the correct depth (i.e., identify the true thickness of the EMP) so that the separation does not create a "membranoschisis"[a] but occurs between the EMP and the ILM
Advantages over scissors use	Because of the angle of the blade, it may be difficult or even dangerous to start the separation of the membrane. As described above, it is easier and safer to the find the correct cleavage plane with the hook on the needle
Advantages over scraper use	The vector of the scraper in use is partially downward, unavoidably putting pressure on the retina, which in turn is pressed against the hard sclera underneath. The downward pressure decreases the surgeon's control over the maneuver. This is not a contraindication to scraper use, but the pressure on the retina (and choroid) represents a potential risk that the surgeon must appreciate, even if the tool's advocates rarely mention it. Again: the needle is indeed a sharp tool but gives the surgeon much more control over what happens

[*]The epiretinal membrane is quite often multilayered (see **Sect. 32.2.2.3**).

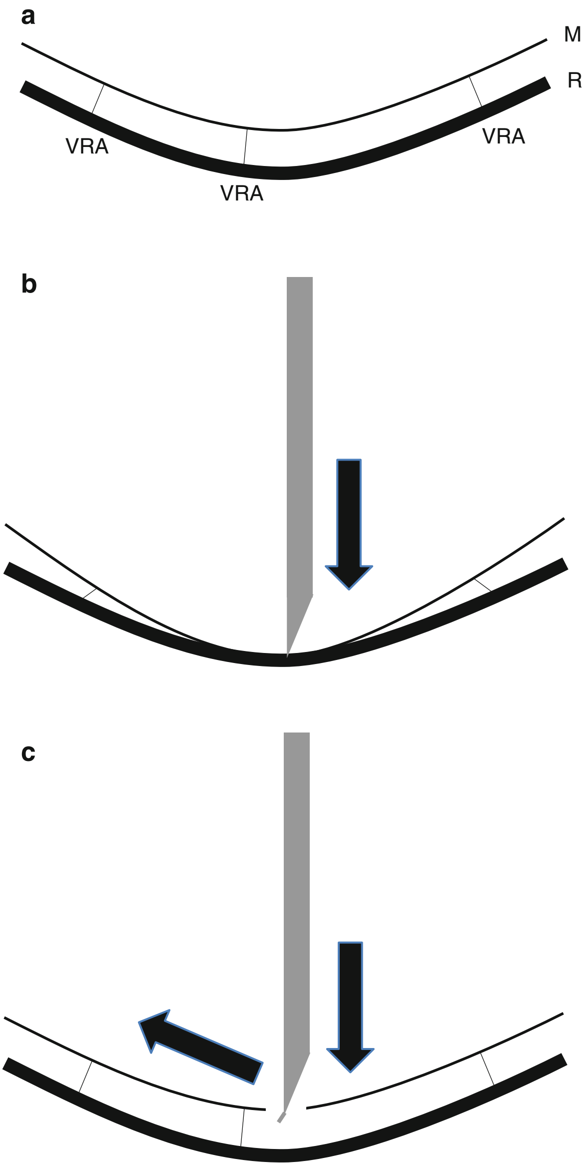

Fig. 13.9 **Schematic representation of using the barbed needle to open an elastic preretinal membrane**. (**a**) The membrane (*M*) may be an anomalous PVD or a newly formed one in diabetes, and it may or may not have attachments (*VRA*) to the retina (*R*); the space between it and the retinal surface may be extremely tight (as on this image) or virtually nonexistent. The surgical goal is to open and then to remove the membrane without damaging the retina. (**b**) If the surgeon tries to incise the membrane with a sharp (not barbed) needle or blade, he has to sink the tool into the membrane; in other words, he pushes the sharp tip toward the retina, more or less perpendicular to it (*arrow*). The membrane, however, is elastic: instead of opening up, it gets forced against the retina. The risk of direct retinal injury is considerable since the surgeon is not absolutely certain how deep his tool is (how much he must push toward the retina as opposed to moving the needle sideways). (**c**) Conversely, if a barbed tool is used, the vector of the tip's movement is a combination of a retina-perpendicular and retina-parallel one (*arrows*); eventually the membrane opens, without undue risk to the retina, and can safely be lifted with the barbed needle or a forceps

The tip must be small[33] and have an angle of ~30°. The needle can be used with the hook turned toward or away from the retina (see **Fig. 13.8**).

13.2.3.2 Membrane Scraper

Whether retractable[34] or not, the small flap (the working part) of these tools has two sides.

- They bend easily in one direction (perpendicular to their flat surface). This side should be used over attached retina, especially near the fovea. The surgeon must make sure that he keeps the (unavoidable) downward pressure to the minimum.
  - When the flat surface is held parallel to the retina and moved tangentially, the thin edge of the silicone flap can be used to break the VR adhesions.
- The scraper has a much higher resistance perpendicular to its thin edges. This side can be used over detached retina when the retina cannot easily be pressed against the sclera.
- The scraper is the ideal tool to move the retina (typically done under PFCL) in an eye that just underwent a large retinectomy. Massaging the retina in this fashion, however, does have some caveats.
  - Understand that the typical goal of using the scraper is to lift a membrane off a surface that is (and should remain) stationary: EMP off the retina (ILM); both the EMP and the retina are rather soft. Damaging the EMP to be lifted is not a concern, but damaging the underlying surface is.
  - However, when the scraper is used for massaging, a "membrane" (retina) is to be relocated, dragged over a hard and immobile surface (sclera; the choroid in this respect is irrelevant). Both the mobile (retina) and the stationary (in this respect the choroid) tissues require atraumatic handling.
  - Never turn the thin edge toward the retina (see above).
  - Use the scraper only on the side of the entry (e.g., over the temporal retina if the superotemporal cannula is used). For the opposite half of the retina, you must switch hands; otherwise, the main vector of the scraper's movement will be perpendicular to the retina, not parallel with it. Attempts to cross over and caress the retina on the side opposite of the entry risk tearing the retina or damaging the choroid.

Pearl

The surgeon must also remember that the scraper is dusted with diamond crystals; dragging them over retina denuded of the ILM means inevitable tearing of nerve fibers. I do not recommend using it for ILM peeling, even if technically this is possible (see **Sect. 32.1.2.2**).

---

[33] Barely visible; this is why the barb is never prepared by *hitting* (bumping) a metal surface with it.

[34] Which is the preferred option, to avoid the difficulty of pushing the tool past the cannula's valve.

13.2.3.3 Spatula/Pic

These blunt instruments can be used to pick up and dissect epiretinal membranes. The tool must have a bent profile: this allows the surgeon to hold it at two different angles relative to the retina. The membrane needs to be rather mature for such a blunt instrument to be effective.

- If the retina is *attached*, the initial movement of the spatula is a careful, slow forward thrust (away from you; the main direction of the tool is along its main axis). Hold the tool fairly parallel with the retinal surface. As much as this is possible, try to do all this in the middle section of the membrane.
  - The initial separation affects only a small area. Avoid "going deep" and inadvertently pushing, the tip of the tool into the retina.
  - Separate the membrane from the retina, keeping the membrane "hooked" by the spatula the entire time. While holding the spatula parallel with the retinal surface, move alternatively toward both endpoints (periphery) of the membrane. If you go "all the way" in one direction, you lost the grip: further separation with the spatula becomes impossible,[35] and forceps must be used to complete the procedure (see **Fig. 13.10**).
- If the retina is *detached*, a forward motion is usually ineffective: the tool is initially pulled backward, as if it were a rake.[36] The tool is held at an angle to the retinal surface.
  - The force of the tool's action is spread over a larger area, and thus there is less of a risk of going too deep with it (i.e., through the retina).
- Once the membrane is hooked, the instrument is moved along two vectors: lifting the membrane somewhat (perpendicular to the surface) and separating it from the retina by moving the spatula sideways (parallel with the surface, perpendicular to the tool's main axis).

13.2.3.4 Intraocular Magnet

By introducing the magnetic pole into the eye, this instrument virtually eliminates the risk of inadvertent/uncontrolled IOFB movement inside the eye. Unlike with an extraocular electromagnet where the IOFB travels (rockets) toward the magnet's pole and the surgeon has very little, if any, control over its flight path, with the permanent intraocular magnet the surgeon has absolute control over what happens since he moves the magnetic pole toward the IOFB.[37]

---

[35] As discussed under **Sect. 32.2.2.5.**, the "centrifugal" peeling of an EMP appears similar, but, due to the different characteristics of the tools used (forceps vs spatula), the effect is also different. The forceps, if used to grab the membrane in its central part, causes traction over large area; the spatula has a much more local effect. By moving it sideways and in both directions, the surgeon separates the membrane from the retina in a controlled fashion.

[36] Similar to what was described above with the vertical scissors (see **Sect. 13.2.1.4**).

[37] The surgeon must always make sure that the IOFB is completely freed of all its VR connections before being approached with the intraocular magnet.

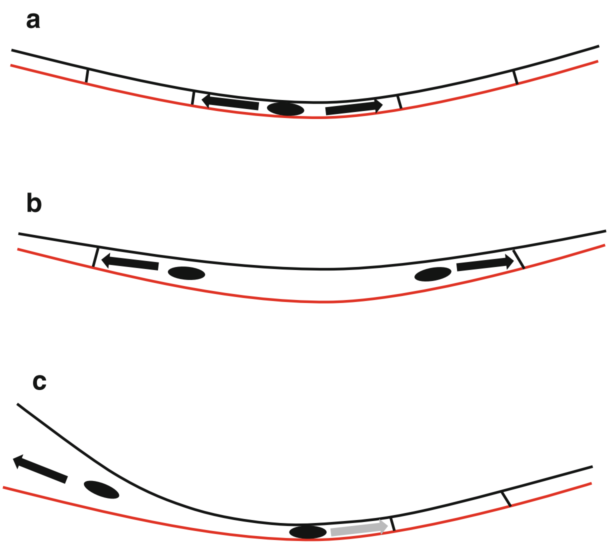

Fig. 13.10 **Use of a spatula to separate epiretinal membranes from the retina**. (**a**) The spatula (*dark oval shape*) must be placed between the membrane (*dark line*) and the retina (*red line*), then moved in both directions (*black arrows*), starting from the membrane's central area. Roughly equal distances must be covered toward both endpoints of the membrane and only gradually approaching the membrane's periphery. The breaking of the connections (*short black lines*) between membrane and retina is in a somewhat symmetrical or mirrored pattern. (**b**) If the surgeon follows this rule, the membrane is gradually separated from the retina in each direction. (**c**) However, if the surgeon went all the way in one direction, it becomes impossible to complete the separation in the other direction (*gray arrow*): there is nothing holding down, and giving resistance to, the membrane from the other direction

13.3 Viscoelastics as an Intravitreal Instrument[38]

Viscoelastic material can be used in the vitreous cavity in different ways.

13.3.1 Membrane Dissection ("Viscosurgery"): Viscoelastics as a Spatula

Delamination is possible with viscoelastic use if the cannula is pushed far enough between membrane and retina before injection; however, there are several caveats that the surgeon must keep in mind.

- A cohesive type of visco should be used; it is easier to remove after use.
- Once the viscoelastics started flowing, the "push effect" is of equal strength in a 3-dimensional shape in front of the cannula's tip.

[38] Keep in mind that viscoelastics, unlike watery fluids, have a high internal resistance. The stronger the surgeon's initial push of the plunger of the syringe, the more resistant the material becomes against the push.

- Avoid pushing "too hard" to avoid a viscoelastic flow that would be at high pressure.
  - Even at low pressure on the plunger, once the viscoelastic material leaves the cannula, the surgeon loses control over its effect (see **Sect. 3.2**) until he stops pushing the plunger.[39]
  - The effect at any given flow rate (injection force) is determined by the strength of adhesion between retina and membrane and the cohesion of each membrane. If the adhesion between membrane and retina is weak, you get gradual separation, exactly as hoped. If the adhesion is strong, the viscoelastic may initially flow around it and separate the membrane from the retina in the vicinity – but eventually tear the retina at the adhesion site.
  - If the cohesion of the retina is weak, the retina will tear.
  - If the cohesion of the membrane is weak, the visco will break through.
- The visco is easy to remove with the probe; the flute needle with its passive flow will not work.

13.3.2 Opening a Closed Funnel

Contrary to common belief, PFCL is not the proper tool to help the surgeon open a retina that is completely detached, and its anterior "entrance" is closed. See **Sect. 32.3.1.5** on how viscoelastics can be used to open a closed funnel.

[39] In fact, because the material is not only viscous but also elastic, the flow does not stop immediately.

Materials and Their Use

14

14.1 Air[1]

Air is a great intraoperative tool for several reasons:

- It forces to the deepest point of the eye the intravitreal/subretinal fluid, allowing its drainage.
- It provides instant tamponade for a retinal break.[2]
- It keeps the retina attached, even if the IPM has been broken.
  - Once the probe is submerged in it, air allows visualization[3] and safe removal of the (peripheral) vitreous. The air pushes the retina against the RPE and thus permits gel removal even in areas of very strong VR adhesion (pneumovitrectomy, see **Sect.** 27.3.2).
- It acts as a lens, providing the surgeon a wider field of view than under fluid.
- In the AC, it has the following benefits:
  - Instant deepening of the AC.
  - Prevention of the formation of anterior synechia.
  - Highlighting the presence of prolapsed vitreous[4].
- Air helps demonstrate the presence of vitreous behind the posterior capsule (see **Sect.** 27.5.3).

[1] Additional information about most of these materials is found in **Chap.** 35.

[2] In RD surgery, the tamponading effect of the gaseous material is less important than its space-occupying function (see **Sect.** 54.5.2.6). The benefit of the air (gas) is that it prevents the shearing effect of the intravitreal fluid on the retinal edge around the break.

[3] Air thus acts as a diagnostic tool so that the surgeon can detect the presence of residual vitreous. The "skirt" of peripheral vitreous is typically invisible in BSS, even under air. However, once an instrument, such as the probe, is submerged in the vitreous skirt under air, the light reflex immediately changes and the parallaxis becomes more evident (see **Figs.** 14.1 and 27.2).

[4] The normally symmetrical/even shape of the air bubble is deformed where the vitreous "cuts" into it.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_14

Complications[5]: When A-F X is performed in the presence of RD, there is a danger of small air bubbles ("fish eggs") getting under the retina or the air tearing a retina that is under severe traction or is shortened (similar to that seen with gas use, see **Sect. 54.4.2.9**).

The risk of high IOP or cataract is less pronounced with air than with gas (see below) because it is nonexpansile and gets absorbed in a few days.

> **Pearl**
> A rarely mentioned side effect of the use of intravitreal air and gas is that most patients cannot see through them. If they are not told about this in advance, it may be a very scary experience – another example of the importance of proper counseling (see **Chap. 5**).

14.2 Intravitreal Gas

Gases are used to provide tamponade that lasts several days to a few weeks.

- Depending on their concentration, gases can be nonexpansile or expansile. They are assumed to work via their tamponading effect ("covering the retinal break") in eyes with an RD (see the remark above) or macular hole.
  - SF_6: It doubles its volume if pure gas is used. The typical concentration is ~30%, which lasts for up to 2 weeks.
  - C_3F_8: It increases its volume 4 times if pure gas is used. The typical concentration is ~15%, which lasts for up to 2 months.[6]
  - With the patient being at reduced atmospheric pressure,[7] even a gas with a nonexpansile concentration expands, and this effect is proportional to the outside pressure; IOP elevation results.
  - Such an IOP elevation would also occur during general anesthesia as the N_2O used enters the vitreous cavity. The vitrectomy machine prevents this pressure rise by automatically adjusting the IOP, but if the anesthetic gas is not allowed to escape[8] from the vitreous before surgery is completed, the gas tamponade will be short-lasting because that gas escape occurs postoperatively.
- Gases can also be used in the AC in eyes with severe hypotony. They increase the IOP for a few days if a nonexpansile, or even weeks if expansile, concentration is used.

[5] Only selected complications are mentioned in this chapter.

[6] I do not use this gas at all: if longer-term tamponade is necessary, I prefer silicone oil.

[7] Such as flying or being on a mountain.

[8] This typically requires ~10 min.

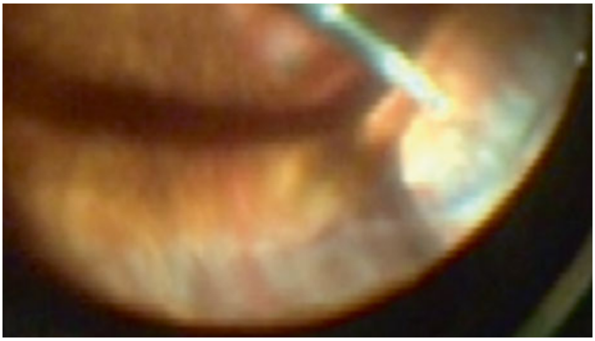

Fig. 14.1 **Pneumovitrectomy for the "vitreous skirt" in the periphery**. The image is slightly different in the air-filled eye if vitreous is still present. On the left side, pneumovitrectomy has already been done and the remaining vitreous skirt is greatly trimmed; to the right, where the probe is held, the skirt is still rather thick. All this is readily visible under air; if BSS is used, the remaining vitreous is largely unnoticeable

Complications[9]: High IOP (see above) and cataract; the latter ("gas cataract") may be temporary (see **Fig. 14.2**). Rarely, a visual field defect develops.[10] Gases may also enter the subretinal space, but this is less common than with air, due to the high surface tension of the gas.

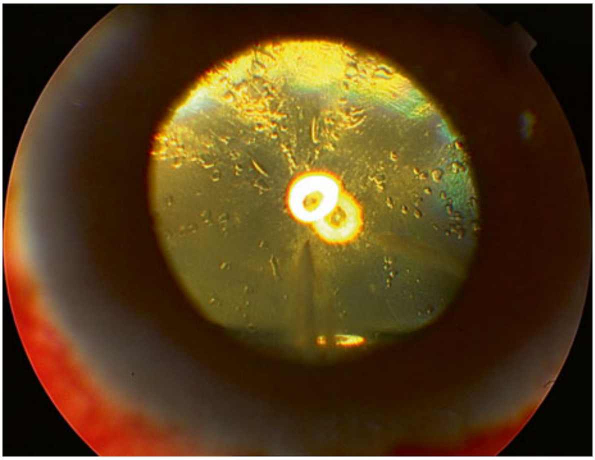

Fig. 14.2 **Gas cataract**. Typical image of the lens feathering due to long vitrectomy or gas implantation. With very rare exceptions, the condition resolves spontaneously with time

14.3 Silicone Oil

Providing long-term[11] tamponade, the oil can be both a prophylactic and a therapeutic tool.

[9] Employing gas of erroneous concentration (see **Chap. 6**) is a complication due not to the gas but to the nurse (just remember, it is still the surgeon who is ultimately held responsible for it).

[10] Probably due to the drying of the retinal surface.

[11] Weeks, months, or permanent, depending on the indication and the eye's condition, see **Table 14.1**.

Table 14.1 Duration options of silicone oil tamponade

Duration	Common conditions[a]	Comment
Weeks	Macular hole	This period should be sufficiently long to achieve hole closure[b]; if the hole remains open after a month or so, it is unlikely to close even if the silicone oil is retained for longer
Months[c]	RD	Large (giant) or multiple breaks, unsuccessful RD surgery on the fellow eye Typical duration of tamponade: at least 3 months
	PVR present	The most effective weapon to keep the retina attached. Having significant amount of pigment in the vitreous is an indicator of more severe PVR to develop (see **Fig.** 53.1) Typical duration of tamponade: 3–6 months
	PVR expected (prophylaxis)	The silicone oil acts as a space-occupying tool Typical duration of tamponade: ~3 months
	PDR	The most effective weapon to keep the retina attached; the oil also helps prevent VH Typical duration of tamponade: 3–6 months
	Endophthalmitis	If the retina is detached or damaged (break/s, necrosis) or if, due to the reaccumulation of debris, postoperative visibility of the retina is expected to be poor Typical duration of tamponade: ~3 months
Permanent (forever)[d]	Recurrent/nontreatable RD	The oil is the only tool that may be able to prevent further deterioration of the condition (RD, recurrent VH). Periodically, the silicone oil must be exchanged
	Severe hypotony, phthisical eye	The oil is the only tool that may be able to prevent further deterioration of the condition. Periodically, the silicone oil must be exchanged It is best to make the eye aphakic and the "100% fill" means 100% for the entire eyeball, not only the vitreous cavity[e]

[a]Only a selected few examples are included here.
[b]There is no need for positioning as long as the fill is 100%.
[c]It is rather common that, due to the recurrence of the condition, "oil exchange" is necessary, extending or multiplying the periods with silicone oil fill.
[d]On a personal note: This is my only indication to use 5,000 cst oil.
[e]See **Sect.** 13.3.1 for more details.

14.3.1 Types of Silicone Oil

- Viscosity: The two typical options are 1,000/1,300 cst and ≥5,000 cst.
  - Higher viscosity is assumed to delay the time to emulsification.[12]
  - The higher the viscosity, the more difficult to inject, and especially extract, the oil.
- Molecular weight: Standard vs "heavy" silicone oil.
  - The standard oil[13] has a specific gravity of 0.97: it floats on water (BSS, aqueous).
  - The "heavy" oil has a specific gravity of 1.02–1.06: it sinks in water (BSS, aqueous).

14.3.2 Achieving a 100% Fill[14]

The oil is supposed to be in contact with the retina,[15] ciliary body, zonules, and the posterior capsule (iris in the aphakic eye) over their entire surface. To achieve this, the surgeon needs to do the following.

- A meticulous exchange between the current intravitreal content (typically air) to silicone oil.
  - In fact, the goal is a slight overfill, as measured by the IOP,[16] to compensate for the postoperative increase in the volume of the vitreous cavity.[17]

Q&A

Q *What is the true benefit of a 100% silicone oil fill?*

A In principle, cells cannot accumulate and proliferative membranes cannot form: the risk of PVR development is reduced.

- Prevention of silicone oil loss at the time of cannula removal (see **Fig. 14.3**).
  - A second reason for this is to prevent oil accumulation under the conjunctiva.[18]

---

[12] The key word here is "assumed." Emulsification depends on many other factors as well, and it is not uncommon to see early emulsification even with higher viscosity oils.

[13] 37 kDa molecular weight as opposed to the 74 kDa molecular weight of a heavy oil.

[14] The technical details are provided in **Sect. 35.4**.

[15] A scleral buckle represents too great a change in the curvature of the eyewall for the silicone oil to follow; in an oil-filled eye there is always a small ring of aqueous at the bottom of the central slope of the indentation.

[16] I typically aim for 30 mmHg.

[17] The temporary, intraoperative "loss" of the volume of the vitreous cavity is caused by increased choroidal thickness due to increased blood flow. Additional factors may include epiretinal blood, posterior dislocation of the iris/lens diaphragm (e.g., due to air or viscoelastics in the AC) etc.

[18] Which can give foreign-body sensation to the patient; young women also often complain about the eye "looking ugly" (see **Sect. 35.4.4**).

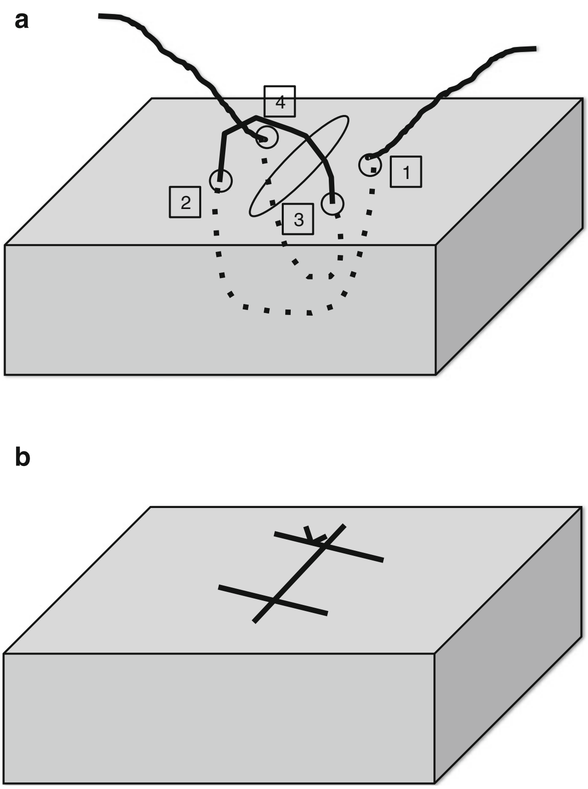

Fig. 14.3 **The double-loop suture to close the sclerotomy to avoid silicone oil loss**. (**a**) Entry (*1*, *3*) and exit (*2*, *4*) points of the needle; the numbers represent the proper sequence. (**b**) The appearance of the suture once the threads have been cut

If the fill is incomplete, a crescent of aqueous is found, in the erect patient, at the bottom of the eye.[19] Inflammatory debris collects in this pool of fluid, increasing the risk of PVR.

Pearl
The use of heavy silicone oil shifts the pool of fluid superiorly. With the use of standard oil, the PVR starts inferiorly; it is shifted superiorly with heavy oil (see **Table 14.2**).

With silicone oil use, there are important questions related to the lens[20] (see **Table 14.3**).

[19] Depending on the degree of the underfill and the size of the pupil, the oil meniscus can actually be visible at the slit lamp.

[20] The surgeon must keep in mind that an unexpected complication can always force him to implant silicone oil, even if this was never in the original plan.

Table 14.2 Clinical implications of an underfill with silicone oils of different weight

Variable	Standard oil	Heavy oil
Consequence: always	Fluid pooling inferiorly	Fluid pooling superiorly
Consequence: potentially	Cell proliferation, membrane formation inferiorly PVR/RD inferiorly with a relative visual field defect superiorly	Cell proliferation, membrane formation superiorly PVR/RD superiorly with a relative visual field defect inferiorly
Reoperation for PVR/RD[a]	Retinectomy (+silicone oil reimplantation)	Retinectomy (+silicone oil reimplantation)
Reoperation: Implications for patient	Partial loss of the upper visual field (less important in everyday life, but the loss may be rather extensive due to multiple retinectomies)	Partial loss of the lower visual field (more important in everyday life, but the loss may be less extensive if the previous retinectomy was inferior)
Reoperation: Implications for surgeon	Technically, access to all of the inferior retina is rather easy	Technically, access to the superior retina is more difficult
Removal of the oil	Technically easy	Technically more difficult

[a]Adding an SB is not considered here

Table 14.3 Silicone oil and the lens

Issue/question	Comment/answer	Rationale
If the eye is (to remain) phakic, should you nevertheless do biometry prior to the PPV?	Yes	The need for silicone oil use may become necessary only during, not before, surgery Biometry is less reliable in the silicone oil-filled eye[a]
Should you remove the lens in each eye undergoing PPV if you know that silicone oil will be implanted?	Yes/no	*Yes* if the eye does not have useful accommodation[b] or the silicone oil is likely to be needed forever *Yes* if cataract is expected to develop while the oil is in the eye *No* if the patient is young with useful accommodation
Should you leave the eye aphakic?	Yes/no	*Yes* if there is a very high risk of postoperative PVR or the eye is highly myopic.[c] A 6 o'clock iridectomy must always be performed (see **Sect.** 35.6) *No* in every other case
If you do implant an IOL, should you perform a posterior capsulectomy?	Yes	The capsule may opacify prior to oil removal, which may be as much a hindrance to visualization of the retina as cataract development would be
If you do implant an IOL, what calculation do you use: assuming oil retention or removal?	An eye without silicone oil, unless	You are certain preoperatively that you will never be able to remove the oil. The possibility of this, however, must always be discussed with the patient preoperatively (see **Chap.** 5)

[a]See **Sect.** 4.5.
[b]Emmetropic eye and a patient over 45–50 years of age; different answers apply in cases of hyperopia or low myopia, and younger age; the patient should decide.
[c]Not needing refractive correction. This may be controversial suggestion, but I fail to see the benefit of implanting a 0 D IOL (see **Sect.** 42.1).

14.3.3 Complications Related to Silicone Oil Use

- High IOP (see above).
- Cataract (see **Table 14.3**).
  - In diabetics, cataract development appears to be delayed.
- Silicone oil prolapse into the AC. This may occur:
  - Intraoperatively because of weak/torn zonules, more commonly in highly myopic eyes.
  - Intraoperatively because of overfill.
  - Postoperatively if the oil is being pushed forward by detaching[21] retina (see **Fig. 35.4**) or, less commonly, a severe hemorrhage.

> **Pearl**
> If at the follow-up visit the surgeon finds in the AC silicone oil that was not there at the last visit, he must first determine whether RD is developing.

- Silicone oil under the retina if the retina detaches and the traction forces tear it.
  - The typical appearance of such a tear is one of a characteristically oval shape (see **Fig. 14.4**). It is rather large and centrally located.
- Hyperopic shift in the phakic or pseudophakic eye, ~+5 D.[22]
- Band keratopathy if the silicone oil is in almost constant or recurring contact with the endothelium for extended periods of time.
  - This is caused by calcium-hydroxyapatite deposition in the superficial corneal layers. Paradoxically, if the AC is completely filled with silicone oil (the

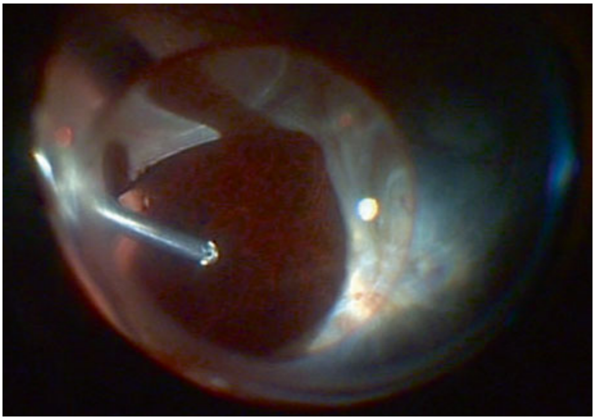

Fig. 14.4 Secondary tractional retinal tear under silicone oil. The shape of the tear is typical, almost pathognomonic: it is oval and often follows the course of the nerve fibers in the area

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[21] If the retina tears and the silicone oil enters the subretinal space, there may be no oil prolapse into the AC at all or the progression of the prolapse is halted.

[22] In the aphakic eye, a similar-sized decrease in the corrective diopter power is seen due to the shape of the oil bulge; in a myopic eye, the myopic correction will be reduced.

contact is not intermittent but permanent and the entire surface of the endothelium is involved), the development of band keratopathy is markedly delayed. This is why a phthisical eye needs to be made aphakic with a 100% oil fill,[23] preferably with 5,000 cst oil (deferring emulsification, see above).

14.3.4 Complications Related to Silicone Oil Use Removal

- Oil sticking to the retina if during the original surgery PFCL was directly exchanged with heavy oil: an easily avoidable problem.[24]
- RD, occurring in up to a fifth of the cases (see **Sect. 35.4.6**).[25]
- VA loss upon silicone oil removal: a fortunately rare occurrence. Why vision drops after oil extraction and does not recover remains a mystery.

14.4 PFCL

Unlike the true tamponades, the heavy fluid is an intraoperative tool, not intended to be retained after PPV. It is an extremely useful "third hand" in many situations, but it should not be overused (see **Table 14.4**).

Complications:

- PFCL has a high tendency to evaporate.
  - The nurse should not keep it in an open container or it will rapidly disappear "into thin air."
  - This evaporation is the reason why, upon intraocular injection, it is virtually impossible to avoid implanting a small air bubble into the vitreous, even if the nurse carefully pushed all the air out of the cannula.[26] This bubble is usually stuck to the anterior (i.e., superior) surface of the enlarging PFCL bubble and remains centrally located (see **Fig. 33.1**).
  - In the air-filled eye, the evaporation continues: small bubbles gather on the back surface of the posterior capsule/IOL. This interferes with visualization (the bubbles can easily be aspirated but will reaccumulate if the air is not replaced with fluid) and causes loss of PFCL in the back where it would be needed.
- A PFCL bubble inadvertently left in the subretinal space is potentially toxic. Unless it is under the fovea, however, it is not justified to perform surgery just to remove the bubble.

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[23] The oil is in permanent contact with the endothelium, making it impossible for the little remaining aqueous to enter the corneal stroma. Even then, corneal complications are inevitable.

[24] A hyperviscous solution that makes subsequent silicone oil removal very difficult. It is best to prevent this by exchanging the PFCL to air first, not directly to heavy oil.

[25] The figure depends on many factors such as the original indication, the type and quality of the original and subsequent surgeries, and intraocular events since the last operation.

[26] Caused by the evaporation of the PFCL from the inside of the cannula used for the injection.

Table 14.4 Examining the *routine* use of PFCL in various conditions*

Condition	Routine PFCL use justified?	Reasoning
Giant tear-related RD, especially if the retina is flipped over	Yes	It is possible, but very difficult, to flip the retina back if heavy fluid is unavailable
Stabilizing a mobile or completely detached retina	Yes	Without PFCL there is a high risk of the probe biting into the retina, especially toward/at the periphery but even centrally
Control of acute intraocular bleeding	Yes	It tamponades the bleeding and does not mix with the blood
Expulsion of liquefied suprachoroidal blood	Yes	It helps in pushing the blood anteriorly and toward the sclerotomy (i.e., externally)
Full opening of a closed funnel/360° retinectomy performed	No/yes	*No* if the circumferentially cut and collapsed retina is supposed to be opened/unfolded by PFCL *Yes* if PFCL is injected *after* the funnel's partial opening by viscoelastics and the removal of traction forces
Extensive subretinal manipulations are required and the retina is difficult to keep away	Yes[a]	Easy access to the subretinal space/retinal back surface is created, but all the PFCL must meticulously be removed once the subretinal work has been completed
Relaxing retinotomy/<360° retinectomy	Yes/no	*Yes* only if the retina does not reattach under air
Central RD where ILM peeling is planned[b]	Yes/no (judgment call)	*Yes* since the PFCL reattaches the retina, even if it does not prevent movement of the retina under the bubble (see **Sect. 32.1.6.1**) *No* since with a special ILM-peeling technique, there is no need for PFCL use (see **Sect. 32.1.6.2**)
Bringing to the surface a dropped nucleus	Yes/no	*Yes* if the lens is so hard that phacofragmentation would threaten with corneal/retinal damage *No* in all other conditions[c]
Nonmetallic IOFBs	Yes/no	*Yes* if the IOFB is very large or has a shape/surface that makes it impossible to safely grab it with forceps *No* in all other cases: expensive and unnecessary
Metallic IOFBs	No	The permanent intraocular magnet is the right tool. In addition, there is always a possibility that the PFCL will cover the IOFB, rather than lift it up
Bringing to the surface a dropped IOL	No	The haptic of the IOL is easy to grab with forceps (see **Sect. 44.2.2**)
Expulsion of still-clotted suprachoroidal blood	No	It does not work

(continued)

Table 14.4 (continued)

Condition	Routine PFCL use justified?	Reasoning
"Normal" ("average") RD	No	Expensive and unnecessary. There is also the risk of leaving small PFCL bubbles behind[d]. PFCL should be used only when the retinal break is too peripheral to allow complete draining of the subretinal fluid
TRD/PVR	No	Elimination of the traction forces is the key to success, which does not require routine PFCL use. PFCL is used only when all traction is relieved and the retina will still not reattach with air or there is a retinal break too peripheral to drain through
TRD/PDR	No	

[*]Defined here as PFCL used not because the condition of the eye *demands* it but because of peer pressure or because of a surgeon who does not consciously weigh the benefits/downsides of PFCL use in each case.
[a]The PFCL is injected into the subretinal space (i.e., behind the retina).
[b]See **Chap. 56.**
[c]The smaller the PFCL bubble, the more it resembles a real sphere; with a partial fill, the lens particles tend to slide toward the bubble's equator, i.e., close to the retina. To keep the particles centrally, either viscoelastic needs to be injected in a ring form or the entire vitreous cavity filled with PFCL.
[d]It is not so uncommon to find, during reoperation following surgery done by a less experienced surgeon, large intravitreal PCFL bubbles or smaller ones in the AC or subretinally.

Q&A

Q *Must you use a 2-way cannula (Chang) for PFCL injection?*

A No. Even the valved cannulas used in MISC usually leak enough to let the excess BSS/air out. The surgeon must monitor the optic disc during PFCL injection, and if it starts to turn pale must stop the injection and drain the BSS/air before continuing with the injection. The major downside of these exchanges is the repeated reimplantation of that ubiquitous air bubble.

14.5 Viscoelastics[27]

These materials can be used, among others, for the following purposes:

- Create space: separation of two tissues (see **Sect. 13.3.1**) or deepening an existing space between them (see **Sect. 32.3.1.5**).
- Maintain space: keep the retinal funnel open or the AC deep.

[27] Let me avoid the use of the term "ophthalmic viscosurgical device." I prefer calling the automotive device with 4 wheels: a car. See **Sect. 13.3** for additional details on visco use.

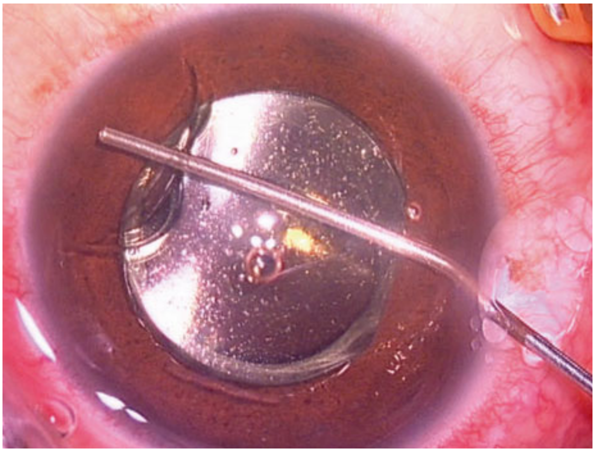

Fig. 14.5 **Use of viscoelastics to press the silicone oil out of the AC**. The cannula is entered into the AC through a paracentesis on the temporal side, then advanced to the furthermost point of the chamber. The visco is *slowly* injected while the lower lip of the wound is pressed downwards. The cannula is held perpendicular to the paracentesis incision so that the force of the visco has an equal effect on both sides (in fact, 360°). (If the cannula is obliquely held, more oil will be left behind on the side of the larger angle, and eventually an oil bubble will break off, requiring additional maneuvers to press out.) The visco pushes the oil in the opposite direction of its own flow and the oil readily escapes through the gaping wound (see also **Fig. 35.3**)

- Stop or isolate a fresh bleeding.
- Direct/channel fluid flow: raise the IOP by reducing aqueous outflow or force silicone oil out of the AC (see **Fig. 14.5**).
- Block/prevent fluid flow: prevent silicone oil from entering the AC or aqueous escaping through a wound.
- Block/prevent tissue movement: iris prolapse into a traumatic wound or paracentesis.
- Prevent water condensation on a surface (see **Sect. 25.2.3.4**).[28]
- Mechanical protection: a plug in the macular hole to prevent dye entry or when a sharp epiretinal IOFB must be grabbed by forceps.

14.6 Sutures

A few of the most basic guidelines are presented here regarding needles, sutures, and their employment by the surgeon.

- Never grab needles at their tip.
  - One common error is to have the needle cut too long a path, making it difficult to avoid grabbing the needle's tip at the exit point.

[28] For this purpose, it is the "viscous," not the "elastic" component of the material that is utilized.

- The channel (suture track) created by the needle is always larger than the suture material that occupies the channel.
  - Intraoperative leakage along the track in case of a 100% deep corneal suture (see **Fig. 63.2b**) is therefore unavoidable, but this ceases as the tissue swelling compresses the channel.
- Do not grab the cornea when suturing it (see **Table 63.3**).
  - It is unnecessary because the needle is sharp enough to enter, pass through, and exit the tissue: it will not push the tissue away.[29]
- All sutures work by tissue compression. In most tissues, there is no untoward consequence of too much compression.
  - In the cornea, too much compression results in tissue deformation, which distorts the view for both patient and ophthalmologist.
- In the cornea, all suture knots must be buried.
  - Too large a knot makes it impossible to pull the knot into the suture channel.
  - The suture should be cut short.

Pearl

A blade is preferred over scissors to cut the thread (**Fig. 14.6**). This gives the surgeon more control by increasing the visibility (the scissors may block the view) and precision (the suture is moved to the blade, not the other way around).

Even if the VR surgeon never in his life needs to place corneal sutures,[30] closing scleral wounds will surely be necessary in MIVS or trauma (see Sects. 21.8.3 and 63.5).

Q&A

Q *When do you have to close the sclerotomy in MIVS?*

A The default option is not to use sutures – this is what makes small-gauge PPV more comfortable for the patient than the traditional 20 g option. However, if the wound is leaking or silicone oil is used, it is advisable to suture-close it to avoid postoperative hypotony or subconjunctival displacement of the oil.

To close a sclerotomy, typically 7/0 vicryl (or silk) is used. The former is absorbable[31]; the latter is not, which is a strong argument in favor of the former.

[29] In all other tissues, the resistance against the advancing needle is high so the tissue tends to move *with* the needle in the same direction. The forceps is employed to counteract this movement: the surgeon pulls the tissue *against* the movement of the needle.

[30] Which is indeed difficult to imagine.

[31] I.e., the vicryl suture does not require removal, irrespective of whether it is in the conjunctiva or sclera.

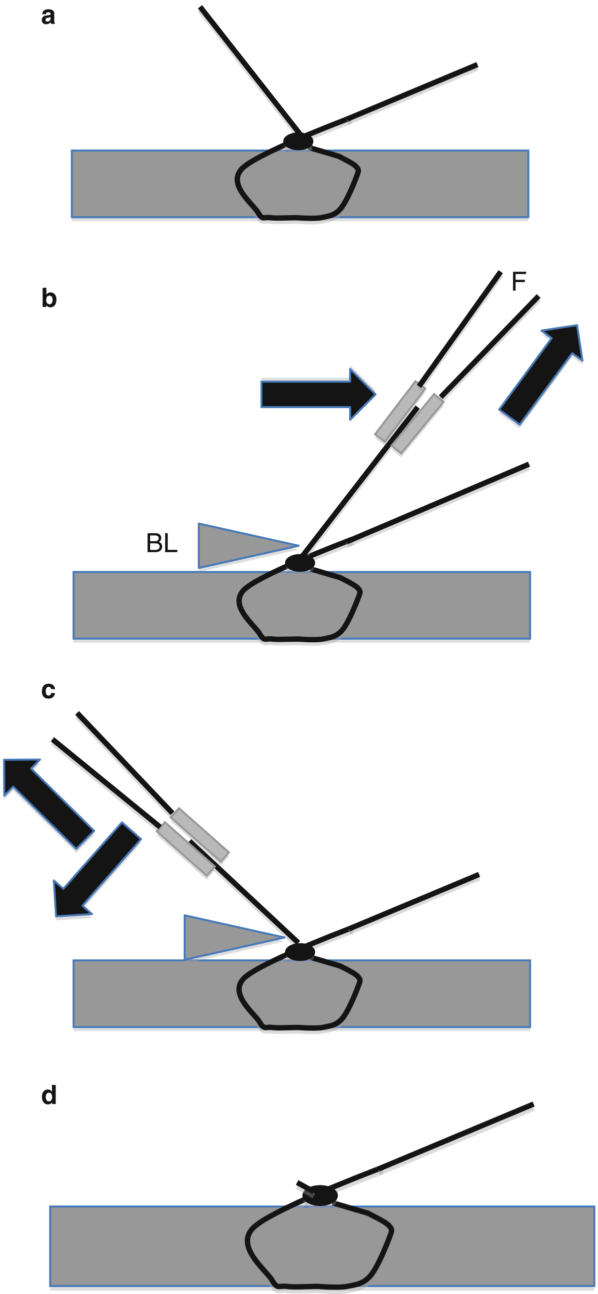

Fig. 14.6 **Cutting the suture thread short with a blade**. (**a**) Suture in place and knot complete. (**b**) One of the threads is grasped with forceps (*F*) and the blade (*BL*) positioned at the desired location (where the suture will be severed). The thread is pulled upwards and away from the blade (*arrows*). (**c**) While continuing to pull the thread upwards, it is moved toward, and onto, the blade. The blade is then slightly moved against the thread, which is stretched so that it does not get pushed away by the blade (these movements are not shown for simplicity). (**d**) The result is a cut that is short enough to allow the knot to easily slide into the suture channel but not too short to threaten with getting untied. The second thread has not been severed yet

The difficulty of closure comes from the fact that many times neither the conjunctival nor the scleral wound is visible.

- If silicone oil has been used:
  - The surgeon grabs, with his nondominant hand, the sclera with teeth forceps,[32] and lifts the sclera slightly up.
  - The surgeon removes the cannula with his other hand.
  - The nurse places the needle holder into the surgeon's outreached palm, making sure that the needle is facing the correct direction (away from or toward the surgeon, see **Fig. 54.7**).[33] Meanwhile the surgeon keeps the wound lips pressed together with his nondominant hand.
  - A double loop is created so that the incision is instantly closed when the suture itself is pulled up (**Fig. 14.3**).

If the scleral wound is not visible because of bleeding or chemosis, the conjunctiva may have to be incised.

[32] A colibri-type forceps with small teeth is the most optimal option.

[33] Another example of why a good nurse is so important.

15 Anesthesia

For the VR surgeon to have "peace of mind" during the operation,[1] the patient must feel no pain and the eyeball may not move (akinesia, "block"). An anesthesia that permits the sensation of pain or significant eye movement is inadequate for VR surgery.

> **Pearl**
> Minimal eye movements are tolerable since the surgeon has rather firm control over the eye by having two instruments inside it. Nevertheless, when fine manipulations are performed, the surgeon should not be forced to divide his attention between the surgical task ahead and the struggle to keep the eye immobile.

There are two types of anesthesia, local and general; both have advantages and disadvantages (see **Table 15.1**). Either way, the surgeon must have absolute confidence in the anesthesiologist (see the **Appendix**, **Part 2**) and look at him as a partner on the team (see **Sect. 16.1**).

One of the benefits of local anesthesia is that the surgeon can communicate with the wake patient during the operation. For instance, I rather often do this in cases of delayed surgery for severe injury. In such an eye some of the pathologies or their extent may be discovered only intraoperatively,[2] and each of the possible treatment options has different implications for the patient; it is preferable to make the decision jointly.

[1] Allowing him to concentrate on the surgery rather than on the patient who complains of pain or moves because of it.

[2] Hence the original plan may have to be drastically changed (see **Sect. 3.1**).

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Table 15.1 Anesthesia in VR surgery: types and their advantages

Anesthesia type[a]	Advantage	Disadvantage
Local	Inexpensive	The akinesia may be imperfect
	Possible to communicate with the patient during surgery[b]	The patient may move[c] or fall asleep due to the intravenous sedation. The latter is not a problem until the patient suddenly wakes up and then inadvertently moves
	Easy to change the position of the patient's head: just ask him to do so	The patient is able to hear everything that is being said in the OR during the operation[d]
	Short turnover time[e]	Risk of peribulbar hemorrhage or severe chemosis
	Patient can lie down on the operating table on his own and enter and leave the OR on his own foot or in a wheelchair – only rarely is an extra person needed to move the patient	Risk of needle penetration into the globe
	The wonders of VR surgery: a few patients describe an incredibly beautiful experience as they can see even minute details of what is being done inside their eye[f]	Reinjection may be necessary if the operation is very long
		An anesthesiologist should be on the premises "just in case"
General	Patient feels absolutely no pain	Expensive equipment needed
	Patient will not move body or eyeball during the operation[g]	An anesthesiologist and an extra nurse are needed (and paid for)
	The patient's systemic condition is closely monitored	There is an issue with N_2O diffusion into the intravitreal gas (see **Chap. 14**)
	The systemic blood pressure is relatively easy to adjust[h]	There is a risk of a coughing attack after the tube has been removed; an ECH may result
	If for some reason the machinery breaks down or the operation is unexpectedly long, there is no extra pressure on the surgeon to finish it	The turnover time is often more than 30 min
		Longer postoperative recovery

[a]The patient's systemic condition is another factor that may be decisive in determining which option to choose. In countries with excellent medical care problems, such as patients showing up with poorly controlled diabetes or blood pressure, almost never occur, but in most countries it is a rather common issue.
[b]See the text for more details.
[c]Often due to back or neck pain. If fine work is being done, such as ILM peeling, movement of even the patient's leg may lead to movement of the head.
[d]Not necessarily cursing (although that happens, too) but, for instance, the machine breaking down or the surgeon mentioning last night's football game ("*he is not fully concentrating on* me*!*").
[e]In one of the ORs where I work, the average time between finishing one and being able to start the next operation is 7 min. If the facility is equipped properly, this is also achievable when using general anesthesia, but it requires a lot of expensive extra equipment.
[f]Obviously, this does not represent an indication for, or justification of, local anesthesia, but it nevertheless awards these patients a memory they will never forget.
[g]The anesthesiologist must not start waking the patient up until hearing the verbal confirmation from the VR surgeon.
[h]Mostly reduced to the normal range; hypotony in PPV for choroidal melanoma.

15.1 How to Decide the Type of Anesthesia

The patient and the surgeon should decide the type of anesthesia.[3] General anesthesia,[4] however, is needed or should be considered in the following cases:

- Young patients.[5]
- Immature, unreliable, mentally challenged, and malicious patients or those who have claustrophobia.
- Patients who undergo repeat PPV, especially if multiple or recent surgery/surgeries.[6]
- Patients who cannot lie in the supine position for extended periods because of a systemic condition such as a hump or lower back pain.
- A special type of requirement is in place (such as artificial systemic hypotony), which demands tight control and might be unpleasant for the wake patient.
- The operation may require extended or repeated maneuvers that can be difficult to anesthetize locally (360° scleral indentation, cryopexy, disinsertion/hooking of extraocular muscles etc.).
- Patients who request it.

If intraocular gas tamponade is used, certain caution is needed to avoid a postoperative drop in the fill percentage (see **Sect. 14.2**).

Fig. 15.1 Preparing the patient for general anesthesia. Especially if the patient's head is correctly positioned (see 16.6), discharge from the nose may find its way to the conjunctiva and thus into the eye. The nostrils should be tamponaded to eliminate the endophthalmitis risk from this source

[3] Sometimes the facility preserves the right to determine it.

[4] Which also means special preparation by the person draping the patient (see **Fig. 15.1**).

[5] It is not strictly a question of biological age. A 17-year-old may be mature enough to undergo an operation in local anesthesia, while a 30-year-old may still be "too young" to do the same.

[6] In inflamed, edematous tissues the efficacy of the anesthetics is reduced.

15.2 If Local Anesthesia Is Chosen

Local anesthesia is preferred for most of the cases.[7] The surgeon can choose from several potential options, which are discussed in **Table 15.2**.

Table 15.2 The type of local anesthesia in VR surgery

Anesthesia type	Comment
Topical (surface)	Even if the surface of the eye is fully anesthetized, certain intraocular manipulations will cause pain. Furthermore, the eye remains mobile, and this is a problem the surgeon must face even if complete anesthesia is maintained throughout the operation *Summary: this kind of anesthesia is not recommended for VR surgery*[a]
Sub-Tenon (parabulbar)	The irrigation of the posterior globe surface (through an opening in the conjunctiva and Tenon's capsule) results in immediate anesthesia and after a few-minute delay in akinesia. The medication can be delivered through a blunt metal cannula or a flexible silicone tube *Summary: this is a safe and effective technique, but it is usually employed as a supplementary, not primary, option*
Peribulbar[b]	The procedure is very effective while keeping the risk of damage to the optic nerve or a major orbital vessel to the minimum. The needle should not be longer than 18 mm *Summary: this is the preferable option in local anesthesia*
Retrobulbar	Deep penetration of the needle into the orbit always has a risk of injury to the optic nerve (especially if the patient is directed to look *away* from the injection site) or a major orbital vessel. The needle should not be longer than 31 mm *Summary: if possible, avoid this technique, but if you must apply it, have the patient look* toward *the needle or maintain the primary position*
If peribulbar anesthetics need to be added during surgery, remember that the volume of the orbit is limited, and there will be (additional) pressure on the globe. The elevated IOP can be dangerous if the globe is open: make sure the valves of the cannulas do not leak, all incisions are closed, inject gradually, and be careful when reopening the eye If the PPV is done as a continuation of a cataract surgery (dropped nucleus) that was done in topical anesthesia, place a suture in the phaco wound before the peribulbar injection. Inject no more than 2 ml and then use parabulbar anesthesia to complement it.	

[a]Some surgeons insist that in "short cases" topical anesthesia is acceptable. However, a "short" case can quickly turn into a long one if a complication occurs. I have seen quite a few operations when during the "short case" the surgeon was forced to switch, intraoperatively, to a more robust type of anesthesia.
[b]Both the peri- and the retrobulbar injections are given at an inferotemporal location, and the anesthesia is accompanied with intravenous sedation.

[7] With rare exceptions (see above), I do all my cases in local anesthesia.

Q&A

Q *Who should administer the peribulbar injection: the surgeon, his assistant, or the anesthesiologist?*

A There is no rule, as long as the person is well trained. The only advantage of the surgeon himself giving the injection is that if a complication occurs, he has nobody else to blame. Conversely, it takes away time that he could otherwise use to rest between cases.

It is very important for the surgeon to extensively talk to the patient before, and during, surgery about not moving. I tell my patients the following:

- "No movement" means just that. Not with your head, not with your hands, and not with your feet.
- If you do need to move (because your back hurts or you need to sneeze, cough etc.), tell me in advance. I will then take out the instruments from your eyeball and wait until you tell me that I can continue.
- Keep your other eye closed. Do not squeeze and do not try looking left and right. The eye will be covered with a drape so you will not see anything anyway.
- Extra oxygen will be supplied under the drape so you will not be in danger of suffocating. If you feel you need more oxygen, let me know, and we will increase its flow.
- I may have to do a particularly delicate maneuver during surgery[8] when you must be even more motionless, as if you were frozen. From the surface of your retina, the thin film of vision, I have to remove a membrane, which is so thin that if you stack 40 of them on top of each other like bricks in a wall, it is still only as thick as a human hair.[9]
- You are welcome to ask me any question during the operation, but when you ask the question, make sure that only your lips and tongue move. I will answer you, even if not immediately.

Having performed well over 10,000 surgeries under these conditions, I had only two cases when I was not able to complete a maneuver because of patient movement and no case when I had a serious complication due to patient movement. One important caveat for those operating on patients who are awake: if something goes wrong and you loudly voice your frustration,[10] even if the issue is a minor one, the patient will hear you…

[8] Such as ILM peeling.

[9] Most patients are unable to envision what "2 μ thick" truly means.

[10] "Oops!" – or one of those unprintable cusswords.

15.3 Medications If Local Anesthesia Is Used

Table 15.3 provides different drug regiments for local anesthesia in VR surgery.

Table 15.3 Medication options for local anesthesia in VR surgery

Medication	Option A	Option B
Peribulbar	6 ml of the following mixture: 4.8 ml bupivacaine 0.5% 1.2 ml lidocaine HCl 2% 0.024 ml adrenaline 1% 9 IU hyaluronidase	4–8 ml of the following 50–50% mixture: Bupivacaine 0.5% and lidocaine HCl 2%
Intravenous	Midazolam 1–2 mg Fentanyl 0.05–0.1 mg	Midazolam 0.5–1 mg/kg.
If sedation during surgery needed	Fentanyl 0.05 mg	Propofol 0.3–0.6 mg/kg/h in infusion.
Topically	Oxybuprocaine plus mydriatics: Cyclogyl, cyclopentolate, tropicamide, neosynephrine.	

The Surgeon at the Operating Table 16

The preparations for performing VR surgery are time-consuming initially, but they become much less so with time: some of the activities need a one-time effort; others become routine. However, the initial preparations are indeed necessary to reduce the unavoidable tension associated with performing complex and high-stake surgery.

Pearl
Inadequate preparation for VR surgery increases the surgeon's stress level, the complication rate, and is, long term, threatening the surgeon's physical health as well.

16.1 The OR Personnel

- The surgeon should work with a well-trained, well-intentioned, and attentive *nurse* (see **Chap. 6**).
- A *circulator*[1] must be present during the entire time. This person must know where to find:
  - All the equipment, instruments, tools, material, supplies, spare parts etc. that may become necessary during the operation, even if these are rarely used.[2]
  - Any other personnel[3] who may be needed.
- *Anesthesiologist*: if surgery is done under local anesthesia, the anesthesiologist need not be in the OR all the time, but must be available in case the patient's systemic condition requires his intervention.

[1] A knowledgeable nurse who is not scrubbed in.

[2] Spare light bulbs and other parts, extension cord, battery charger, flashlight etc.

[3] Other VR surgeon/s, cleaning person, electrician, on-hand repair technician for the equipment.

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Both the nurse and the circulator need to be familiar with the location and details of a list[4] that must have been compiled earlier with vital information regarding:

- How to mix the intraocular (for injection or infusion) and local (fortified topical, periocular, subconjunctival) medications such as antibiotics and steroids.
- How to mix intraocular gases to achieve the required concentration.[5]
- The contact information (name and mobile phone number) for at least two representatives of all companies whose major equipment (vitrectomy machine, laser etc.) is used.[6]

Pearl
It is highly advisable to have a backup vitrectomy machine available, even if this is an older and less sophisticated one. It is solely for emergency purposes, in case the standard machine breaks down and cannot instantly be brought back to life.

16.2 The Operating Table and the Surgeon's Chair

16.2.1 The Operating Table

You should be able to adjust the following:

- Height.
- Inclination angle in either direction.
- The head part's inclination angle (separately; see below, **Sect. 16.6**).

Ideally, a U-shaped wrist support[7] is securely fixed to the table, and its height should also be adjustable (see **Fig. 16.1**).[8] The table's supporting mechanism must be far enough back from to leave space for the surgeon's feet to have unhindered access to all three pedals.[9]

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[4] This list must exist in a readily accessible electronic form plus as a poster on the OR wall. The electronic version should be on a computer that is not password protected.

[5] I once had a series of cases where the intraocular gas absorbed rapidly. For a while we were unable to identify the cause: the manufacturer changed the gas concentration in its bottles.

[6] This is especially critical if only a single machine is available, a rather risky situation.

[7] A VR surgeon uses his hands and fingers while operating, not his arms as general surgeons do.

[8] Some surgeons argue that they have so great dexterity and so little tremor (see **Sect. 4.1**) that they do not need wrist or lower-arm support. This may be so, but the question is why anyone would decline using a device that is inexpensive yet extremely useful since it increases the safety of intraocular manipulations.

[9] Microscope, vitrectomy machine, laser (see below, **Sect. 16.3**).

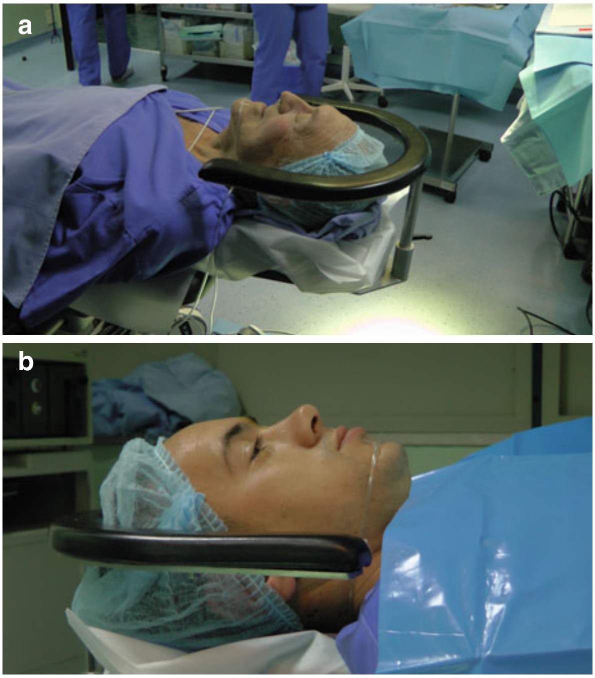

Fig. 16.1 **The U-shaped wrist support on the operating table**. (**a**) The "U" should be close enough to the patient's head so that when the surgeon's instruments are held in the vitreous cavity, the "U" is supporting the wrist and far enough so that the plastic bag collecting the waste fluid remains accessible (this means that the U's shape and size need to be optimized to achieve these goals). The "U" must be padded to avoid hard counterpressure on the surgeon's wrist. (**b**) The "U" must also be at the correct level as it relates to the eyeball. The most optimal height is for the top of the "U" to be just below the level of the lateral canthus: the one on this image is too low. Placing the "U" lower reduces its efficacy in providing support; if too high, it interferes with access to the eye. The latter is especially obvious when manipulations are needed in the anterior parts of the eye, such as hyphema removal or lensectomy

16.2.2 The Surgeon's Chair

A well-designed chair should satisfy the following criteria (see **Fig.** 16.2):

- Wheels so that it can easily be rolled.
  – Small "footprint": the legs do not reach too far out, which would prevent the surgeon from moving close to the operating table.
- Locking mechanism against rolling and shaking.
  – The surgeon himself should be able to activate/deactivate the break with a central pedal, and the break should work simultaneously on all wheels.
- Batteries to help unclog the OR floor.
- Electric, surgeon-operated height adjustment.

Fig. 16.2 The surgeon's chair: the good, the bad, and the barely acceptable. (**a**) A chair that satisfies all demands [SurgiLine (UFSK-International OSYS GmbH, Heidelberg, Germany)]: it easily rolls but has a surgeon-activated break acting on all legs; the legs do not protrude outward; it has a battery to operate its height adjustment; the surgeon has easy access to the pedals for the chair's up or down movement, yet these pedals are never in the way; the back support is ideally placed; the support for the lower arm is padded and completely mobile in all directions. (**b**) An acceptable compromise, except that the chair has no breaks, the height adjustment upward is easy for the surgeon to accomplish and to do so in small increments but the down movement is possible only by uncontrolled and large movements, and the armrest is not padded in the back (this becomes a significant issue during a long case or day). (**c**) A terrible chair, which is shaky, has no breaks, and the height adjustment requires manual work

Fig. 16.2 (continued)

- Easy-to-adjust arm support that can be moved in several dimensions (up-down; forward-backward; inward-outward both in whole and its distal end). The armrest should easily be secured.
- Comfortable padding on the armrests, which also provide support for the lower arm.
- Back support, which is adjustable in height and not positioned too far back.

16.3 The Vitrectomy Machine,[10] Its Footpedal, and the Arrangement of All the Pedals

- Different surgeons prefer different parameters (pump type, aspiration/flow values etc.). Yours should be stored in the machine under your own name.
  – Always make sure that the display shows *you* as the surgeon.

The pedal can be programmed, on modern machines, to work in a linear, dual linear, or 3D mode.[11]

- When pressing down with the pedal, the aspiration/flow starts and gradually increases, and eventually cutting kicks in (linear).
  – Many surgeons use a modified option: they activate the aspiration/flow function by pressing *down* with the pedal, and they turn the pedal *sideways* to add cutting as well.[12]

[10] The parameters are discussed under **Sect. 12.1**.

[11] Things are best when simplified; 3D mode is not the simplest option.

[12] This is, of course, an individual preference; as long as it is the surgeon's *conscious* decision to use this setup, it is fine. The reason for this setup is, however, usually not a conscious decision but simply the "blind" following of the previous surgeon's (mentor's) "footsteps." For me the turning of the foot leads to an unnatural, uncomfortable position.

- When pressing down with the pedal, both the aspiration/flow and the cutting start and gradually increase (dual linear).
- With pressing down with the pedal, both the cutting and aspiration/flow rates change, but in opposite directions (3D).

As indicated in **Table 12.2**, I prefer a set cut rate and liner aspiration/flow (linear).

Some vitrectomy machines allow more functions[13] to be operated by the surgeon via the footpedal. He has to make an individual decision whether he prefers this option or choose instead the minimalistic one, asking the nurse/circulator to make the adjustment on the machine interface as needed.

- You have to work using two pedals.[14] It is rational to place the microscope pedal under your dominant and the vitrectomy machine's under your nondominant foot (see **Fig. 16.3**).[15]

Q&A

Q *Why place the microscope pedal under the dominant foot?*

A Because the foot operating the microscope will be much more active during PPV than the foot used to drive the PPV machine. It makes sense to employ the dominant (in 90% of the surgeons the right) foot the active one. This foot must control the X-Y joystick (see below), and the two focus and two zoom pedals. The nondominant foot basically controls the cutting/aspiration functions – with a single movement in my setup version. Both feet, of course, will have additional functions (such as the diathermy by the nondominant and the microscope's light switch by the dominant foot), but even here the dominant foot will remain more active.

Unlike pretty much everything else in VR surgery, operating various pedal functions via the pedals should be completely automated.[16] Switching the two pedals around requires "reprogramming" the surgeon's brain.[17]

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[13] Such as the regulation of the IOP.

[14] Actually, a third one should also be preplaced ("just in case"), the laser pedal, which is best placed in-between the two main pedals.

[15] Most surgeons arrange the pedals the other way around. When asked "why," the common answer is a surprised stare first, followed by (see **Sect. 3.2**): "Because that's how I found it [after the previous surgeon/s]" or "this is how it's always been at our institution".

[16] I.e., the surgeon must not be forced to stop and think about which of his feet is about to do what to achieve what kind of function on which equipment.

[17] This is why the initial setup in the OR is so crucial: have the pedals placed from your very first surgery the way you will always want them. If a surgeon operates in multiple ORs, the "customary" pedal arrangement may be different per OR. Some OR personnel prefer making the surgeon accept the local custom (for them it is easier than switching the pedals around). Insist on your own preference.

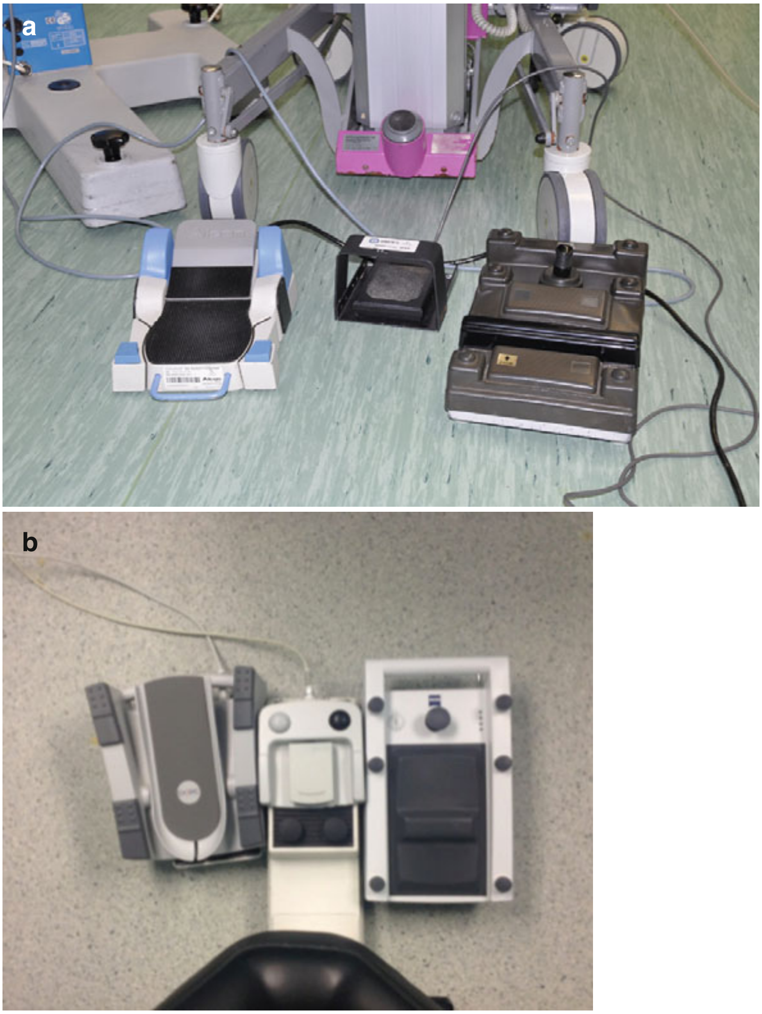

Fig. 16.3 **The arrangement of the pedals under the surgeon's feet**. (**a**) A right-footed surgeon should have the microscope pedal placed on the right and the vitrectomy pedal on the left; the laser pedal is in the middle (to be operated by the left foot). The pedals are angled outward, not parallel with each other. (**b**) Some surgical chairs come with a built-in anterior platform so that all pedals can (in fact, must) be placed on this. A somewhat cumbersome option, especially if the pedals are too large for the platform, and their position is not secure

16.4 The Microscope

- Before starting the operation or before scrubbing in, adjust the X-Y, zoom, and focus speed.[18]

[18] Obviously, higher speed makes the operation somewhat faster, but it may also make precise intraoperative adjustments more difficult.

- Adjust the power of the illumination. The brightness level should be the lowest that still allows you to work on the eye surface.[19] You will need to turn on/off the microscope light several times during the operation, even after you have already reached partial or full adaptation. It is unwise to get blinded by the reflection of too bright a light from the sclera or the contact lens.

16.5 The BIOM

For practical reasons, most of the information about using this indispensable tool is presented here (see also **Sect. 12.3**).

16.5.1 BIOM: The Advantages

See **Table 16.1**.

Table 16.1 The advantages of the BIOM*

No	Corneal damage since there is no physical contact
	Contamination by blood from the operative field[a]
	Assistant required to hold the lens/system in place
Easy	Mounting of the adapter plate
	Removal of the reduction lens
	Focusing with a wheel that is in a permanent position
	Exchanging of the front lenses
Large selection of	Front lenses for different viewing options
Superior	Observation angle/surgical field (wide, magnified, combined)
	Resolution
	Depth of focus
Unhindered	Mobility of eyeball during surgery
	Access to eyeball around the swung-in front lens
No/little interference from[b]	Hazy media (cornea, AC, lens, vitreous)
	Small pupil
Microscope mounting and operation	Permanent and easy
	Available for most types of microscopes
	No interference with the use of microscope-mounted other devices (video camera, laser filter)
	Automatic SDI activation

*Fifth generation.
[a]Unless the BIOM front lens is extremely close to the epithelium. Conversely, the lens may be dirtied if the cornea is squirted with too much force and the fluid droplets splash back.
[b]Obviously, there is a limit to the BIOM's capability to compensate for the interference.

[19] This is also true for the room light.

16.5.2 BIOM Use: Practical Information

See **Table 16.2**.

16.5.3 BIOM: Setting Up for Daily Use

Follow these steps to optimize the use of the BIOM (see **Table 16.3**).

16.5.4 BIOM: Checklist

There are numerous practical tricks to maintain excellent visualization throughout the operation (see **Table 16.4**).

Table 16.2 Useful hints for BIOM users

Working with (switching to) the BIOM requires some getting used to[a]	Do not give up after the initial frustration during the first few cases[b] The benefits soon become obvious if you are persistent, and soon you could not imagine operating without it[c]
Microscope's focus pedal	This is one of the most important adjustments the surgeon must make. Once the BIOM is swung in place, the microscope's focus pedal does not control the focus anymore, it now changes the field of view: going down makes the field larger[d] The focus is adjusted using the BIOM's focusing wheel
The ideal working distance from the cornea	The front lens should be at ~2 mm from the cornea. This avoids dipping into the visco yet provides the largest possible field If the cornea has to be recoated with visco, it is best to lift the front lens first, but it is not necessary to swing it out
Scleral indentation	Even when using the widest-angle front lens, scleral indentation is recommended to view the vitreous base
Working in close proximity to the posterior capsule in phakic eyes	Unless there is substantial cataract to clearly show the border between lens and vitreous, swing out the BIOM to avoid biting into the lens (see **Sect. 27.5.3**)
Fine work on the posterior pole[e]	Use a contact lens instead of the BIOM, unless you are a very experienced surgeon (see **Sect. 13.1**)
Do not turn the microscope light on while the BIOM is swung in	The light reflex is blinding. Condition your brain to follow these sequences: (1) Microscope light off; (2) BIOM in (1) BIOM out; (2) microscope light on (see also **Sect. 16.4**)

[a]Not an issue if the fellow starts his career using the BIOM.
[b]Just as you often fell off the bicycle when you started to learn cycling or had difficulty wearing a new prescription glass.
[c]The best comparison between performing vitreous surgery using a contact lens vs the BIOM is when you compare cataloguing the inside of a room from the outside. You can do it with the door shut, through the keyhole (contact lens) vs with the door wide open and your head in the doorway (BIOM).
[d]I.e., the more peripheral part of the fundus/vitreous to be viewed, the closer the BIOM front lens should be to the cornea.
[e]E.g., ILM peeling.

Table 16.3 Basic setting up of the BIOM

Variable	Make sure that:
View through the microscope	The view is sharp for the surgeon's either eye, even at high magnification[a]
BIOM adapter plate	It is securely fixed to the microscope and the screw is tightened
BIOM reduction lens	The lens is not too hot and it properly clicked in place
BIOM	It is securely fixed to the adapter plate
BIOM front lens	The desired type of lens has been selected It is pushed all the way into its slot The focusing wheel is at the lowest position[b]
Imaging	With the light pipe inside the vitreous cavity, the image is sharpened at the highest magnification of the microscope. The position of the front lens is then appr. 20% higher than the lowest possible point
Corneal surface	After squirting, it is coated with visco (see **Table** 16.4)
The microscope	It is lowered to be close to the eye so that the BIOM front lens is ~2 mm from the surface of the visco; this process is checked by the surgeon viewing it from the outside, not by looking through the microscope (see **Fig.** 16.4)

[a]And the video camera also captures a highly focused image.
[b]i.e., the front lens will be in its closest possible position to the cornea. This prevents accidentally dipping into the visco where the focusing wheel turned in the wrong direction.

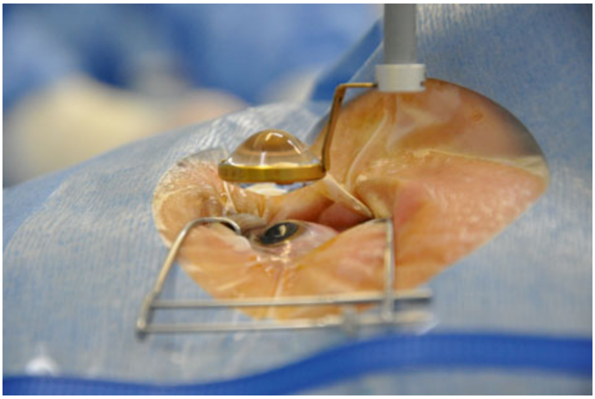

Fig. 16.4 **The BIOM front lens**. When in position, the lens should be about 2 mm from the top of the visco on the cornea. Note that the distance is measured not from the rim of the lens but from the apex of its inferior dome, which is much closer to the cornea

16.5.5 BIOM: Troubleshooting

The BIOM is a highly reliable tool, but the image quality may still be suboptimal. The causes and their fixes are listed in **Table** 16.5.

Table 16.4 The BIOM checklist per operation

Make sure that you[a]:	Comment
Have properly secured all attachments	Pushed all the way in, with screws tightened[b]
Selected the front lens you want to use	Choose from the following lenses: 60° (macula), 70°, 90°, 120°, 60–125° (wide field, high definition). In general, the wider the field, the worse the resolution
Cleaned both the reduction and front lenses, and they have cooled off	The lenses must be carefully wiped before, occasionally during, the operation; the reduction lens usually only before, the front lens sometimes during the operation[c]
Firmly pressed the draping onto the patient's skin, 360° around	To prevent endophthalmitis from contamination on the skin (or discharge from the nose, see **Fig.** 15.1) and avoid breath-related fogging
Gently squirted the corneal epithelium with BSS and then coated the cornea with visco before swinging the BIOM into position	You must avoid splash back from the corneal surface or coating the front lens itself (see **Sect.** 25.1.4)
Lowered the microscope to reach the proper working distance	See **Table** 16.3
Set the focus	With the BIOM in position, use the lowest zoom of the microscope and focus the retinal image with the BIOM wheel[d]. Zoom then to the highest magnification and reset the BIOM focus. This should allow you to work throughout the entire operation[e] without having to adjust the wheel – until F-A-X is needed
Do not use the BIOM for fine macular work	Although doable with the high-resolution/wide-field lens, it is best done with a contact lens because of the higher resolution. You will be able to see very fine details that were hidden before
Do not use the BIOM anterior to the posterior lens capsule[f]	Working here is viewed through the microscope without the BIOM swung in

[a]Or the nurse, as appropriate.
[b]Avoid overtightening it: this not only makes the eventual unscrewing more difficult but wears out the mechanism earlier.
[c]Because of fogging, touching the visco, or splashed-back BSS droplets.
[d]If the vitreous is not clear, perform vitrectomy until you have a clear view of the retina and do the setup then.
[e]Although occasionally, for example, when working high in the vitreous cavity on a detached retina, the focus may have to be readjusted (focus down in this case).
[f]Lens proper, iris, AC etc.

16.6 The Patient

If the operation is performed under local anesthesia, it is crucial that the patient:

- Has a comfortable position[20] lying on the operating table.
- Is able to maintain this position for extended periods.[21]

[20] Something as simple as a soft pad under the knees is of great value.

[21] The risk of moving during surgery must be discussed with the patient in great detail (see **Chaps.** 5 and 15).

Table 16.5 Troubleshooting: poor visualization through the BIOM

Problem	Solution
No image	The BIOM is not swung in place all the way The SDI knob is not turned all the way[a]
Visual field incomplete superiorly (inferiorly)	Microscope head not vertical (image no coaxial): cataract surgeon may have used the microscope last
Image blurry and cannot be fixed (see below)	Cornea/AC/lens/capsule too hazy The pupil is too small
Image gradually getting lost during surgery	Fogging on the front lens, usually because of condensation from the air in the OR or from the patient's breathing on the lens[b] Fogging on the reduction lens: if the BIOM was fixed to the microscope while it was still rather hot from the sterilization[c], the condensation will slowly darken the image. The BIOM must be swung out and the lens cleaned/dried with a sterile cloth
Image imperfect on one side of the visual field	The microscope's position was not adjusted to the eye's movement The X-Y joystick must be operated in harmony with the surgeons' hands as he rotates the eyeball. This lack of movement coordination is most conspicuous when the surgeon uses high magnification[d]
Image suddenly getting blurry during surgery	Front lens dipped into visco[e] Elevate the microscope, clean the lens, recoat the cornea
Image getting blurry during F-A-X	Shift in focus; in the phakic/pseudophakic eye, adjust the BIOM wheel upward, in the aphakic eye downward
Image not central	Adaptor plate/dovetail not pushed all the way One of the screws fixating the adaptor plate/dovetail is loose The screw's threads are worn out The front lens is not pushed all the way into its slot on the lens holder[f]
Blinding light reflex	See **Table** 16.2
Difficulty swinging the BIOM in or out	The mechanism is stuck Needs lubrication (silicone oil is an excellent fix; apply it over the swinging mechanism)
Difficulty going up with the focusing wheel[g]	The mechanism is stuck Needs lubrication (silicone oil is an excellent fix; apply it over the focusing mechanism). If sterile silicone oil is unavailable, the nurse should, gently and slightly, pull on the shaft of the BIOM lens holder[h]

[a]Not an issue if it is an automated function.
[b]Check whether the drape has not peeled off from the patient's skin around the nose. If yes, reseal it, drape over it, or "stuff" gauze underneath the drape opening.
[c]Steam autoclave.
[d]This is why the surgeon is advised to (1) work under the lowest magnification possible and (2) have the (dominant) foot on the X-Y joystick throughout the entire operation. The foot is only temporarily taken off the joystick when other functions of the microscope pedal are to be activated.
[e]The most common error in clinical practice.
[f]This is also dangerous: the lens can drop out of the holder when it is swung out.
[g]Downward it almost never happens.
[h]The direction is backward (opposite of [away from] the location of the front lens).

- Can breathe without difficulty.[22]
- Will not become claustrophobic under the draping.
- Will not get cold due to the cool air temperature in the OR (see below, **Sect. 16.10**).[23]

One arm of the patient must remain easily accessible throughout the surgery, ideally so that the surgeon must not stop his activities as the anesthesiologist works on the arm.

Pearl
The patient's face must be parallel with the floor. It is common to see patients on the operating table with their forehead higher than their chin (this is why the head part of the operating table needs to be adjustable; see **Sect. 16.2.1**. and **Fig. 16.5**). The parallel position may be uncomfortable to some people, but it allows surgeon access to the entire vitreous cavity and keeps the macula in the image center. If a patient finds this head position intolerable, he and the surgeon must work out a mutually acceptable compromise.

A uniquely important issue is that the correct eye of the patient gets prepared for surgery.

- The nurse who prepares the patient outside the OR must mark the eye with a sticker or ink on the forehead.

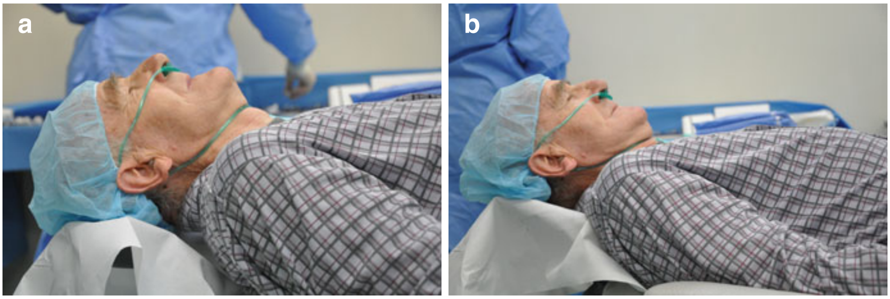

Fig. 16.5 **The position of the patient's head**. (**a**) Ideally, it is parallel to the floor (i.e., horizontal). This allows working on the macula and in most retinal areas without having to rotate the eyeball. The only area that may present accessibility issues is the superior periphery (hence the caveat against using heavy silicone oil (see **Sect. 13.3**)). (**b**) The most common error is for the patient's chin to be lower than his forehead: in this position, even the macular area is inaccessible unless the surgeon rotates the eye and maintains this artificial position even during ILM peeling. The superior quadrants are impossible to reach

[22] Oxygen is supplied.

[23] Heated blankets are available.

- The circulator who accepts the patient in the OR cross-checks and confirms this.
  – She also confirms that the eye is correctly indicated on the operating list.
- The person administering the local anesthesia cross-checks the mark and has it verbally confirmed by the patient.[24]
- The nurse at the operating table checks the mark on the patient's forehead.
  – If the surgery is under local anesthesia, the patient must verbally confirm that the correct eye has been prepped.
- The surgeon must have the final confirmation by the nurse and the wake patient.

The surgeon must remind the patient[25] of what also has been discussed before. This should cover all intraoperative issues (see **Sect. 15.2**) as well as postoperative positioning, the loss of vision if air/gas tamponade is used etc.

16.7 The Surgeon

There are numerous items on this checklist. With time, they should become (a) routine for surgeon and OR personnel.

16.7.1 The Posture (Ergonomics)[26]

One of the most common errors the beginner surgeon commits is trying to adjust his own position/posture to the microscope, operating table, and chair. You must do the exact opposite.

Pearl
You should sit comfortably in your chair, adjusting it (height, armrest) first. Next, adapt the height of the microscope to your position as you are sitting comfortably (neck position, lower back; see below). Finally, adjust the operating table to the microscope's height – but remember, patients have different head sizes and orbital architectures. The height of the operating table must be readjusted to accommodate these individual variations, not your posture.

The initial settings are to be done before scrubbing in.

- Adjust the chair's height to your comfort.
  – Your legs should reach the floor without having to stretch or knee-bending: your thighs should be fairly parallel to the ground when your feet are rested on the pedals, which should already have been placed under the operating table (see **Sect. 16.3**).

[24] "Which eye will you have surgery on?" is a better way of asking than "is it your right eye that is going to have surgery?".

[25] If the operation is performed under local anesthesia.

[26] Do not blindly follow the recommendations outlined here but think about these issues and find the best posture for yourself.

- Adjust the arm support's height to the length of your upper arm.
  – A roughly 90° angle between your upper and lower arms is the least stressful position.

With the chair set, roll the microscope in place, and adjust its height.

- When looking into the eyepieces, your back should be fairly straight without having to stretch.
  – Too high a microscope will result in extra strain on your back muscles.
- Your neck should be as vertical as possible.
  – Bending the neck is very likely to lead to aching, even short term; longer term even disc hernia threatens.[27] The microscope's eyepiece should be angled (tilting; see **Sect. 12.2**) so that your neck need not be stretched nor bent more than a few degrees.
- Adjust the pupillary distance.
- Adjust the focus separately for each eye (remember to take the video camera into account; see **Sect. 12.4**).
  – Do this under high magnification and by looking at a small object that is immobile.[28]

The subsequent settings should be done after scrubbing in.

- Have the patient comfortably lying on the operating table, in his "final" position (see **Sect. 16.6**).
- If the operating table is equipped with a "U"-shaped wrist support, its height must be adjusted to the individual patient's physical features.
- Swing in the microscope and adjust the table height to the specific microscope height you already determined.
- The pedals must be at an angle that is comfortable for the surgeon.[29]
  – Their distance from the surgeon must be "not too far and not too close," maintaining the lower leg's ~90° angle to the floor as well as allowing easy access/comfortable manipulation.
- No cables should be caught underneath the pedal.

To ensure that the surgeon maintains comfortable position/posture during vitrectomy is not simply a matter of convenience. It helps him preserve his musculoskeletal health and allows him to concentrate on the surgical tasks rather than on his aching body. For the same purpose, if the surgeon is able to do some stretching in-between operations, this is of great value.

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[27] Do not dismiss this warning easily. It is a very dangerous condition that can require *emergency* surgery, which is risky and has a long recovery time even if successful.

[28] This can also be done later, when the patient is already on the table and the speculum is in situ. Find a blood vessel in the conjunctiva and use that one as a target for both eyes, without changing any setting on the microscope other than the eyepiece (diopters) itself.

[29] I prefer if their distal end is turned outward at a ~15° angle (see **Fig. 16.3**).

Pearl
Maintaining poor posture for extended periods is like smoking: when it occurs, it usually causes no or only temporary complaint. The microtraumas add up, though, but by that time the damage is irreversibly done.

The height of the microscope has been focused to the eye's external surface. During PPV the microscope must be readjusted in two scenarios so that the retinal image is in focus: when the BIOM is swung in and when switching to a contact lens. The refocusing requires only a few centimeters in vertical adjustment,[30] but the surgeon still needs to reevaluate whether these height differences justify readjustment of the operating table and chair.[31]

There are three additional factors to consider when determining the need for the readjustment.

- The duration of the intraocular procedure.[32]
- The need to alternate between procedures in the AC vs in the posterior segment.
- Whether frequent switching between the contact lens and the BIOM will be needed.

16.7.2 At the Start of Vitrectomy

- Hold the light pipe in the nondominant and the probe in the dominant hand (see **Fig. 16.6**).
- With the dominant foot, zoom out fully and readjust the focus if necessary.
- Place the dominant foot's heel on the support bar (see **Fig. 12.3**) and have the toes over the X-Y joystick. This position is to be maintained throughout surgery, unless the focus or zoom buttons need to be used.
  – During PPV, the surgical field is often changed as you move the microscope to view different areas in the vitreous cavity. To avoid losing the image, simultaneously rotate the eye with *both* intravitreal instruments as you adjust the microscope's position with the X-Y joystick (see **Sect. 25.2.8**).

Pearl
Remember: the higher the magnification, the smaller the visual field and the greater the need to adjust the X-Y joystick to compensate for eye rotation. If the BIOM is used: the closer you are to the eye, the smaller an eye movement is enough to cause loss of the image.

[30] The height and the direction are determined by the type of microscope.

[31] With experience, the initial adjustment process, described above, takes into account the need for these upcoming readjustments.

[32] Obviously, the longer the surgery, the higher the need to readjust.

Fig. 16.6 **At the start of the vitrectomy.** The probe is in the surgeon's dominant right hand. Both wrists are supported by the "U" of the operating table (draped over, thus not visible here). The vitrectomy machine is to the right of the surgeon; therefore, the cable of the light pipe, held in the surgeon's left hand, is looped under his wrist (this keeps the rather rigid cable from curling into the field of view and reduces the risk that it touches a non-sterile surface). At the onset, the surgeon places the light pipe first and the probe second to reduce the chance that the tubings get entangled (the light pipe remains in the left hand during most if not all the operation; the instrument in the right hand may be replaced several times. If the tools are switched, the probe will be taken first). The light pipe is held by three fingers (thumb, index, middle), and in addition to the support under the wrist, the hand's position is further secured by resting three fingers (middle, ring, little) on the patient's forehead (the same is true for the right hand, not visible here). The BIOM is not swung in place yet; the nurse's table is seen on the left

16.7.3 Staring into the Microscope

Performing PPV requires unrelenting, maximal concentration from the surgeon (see **Sect.** 3.7). When someone is so concentrated on nonstop visualization of the actions of his hand movements, the normal blinking frequency (15–17/min while resting) can drop to 0–1/min. The ocular surface dries fast, exacerbated by the dry air in the OR. The surgeon should force himself to blink often.

16.8 Music in the OR

Most patients prefer it,[33] but some surgeons find it distracting. Decide for yourself whether you like to hear the noise of the various machines in the OR instead.

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[33] Just think about yourself being in the dentist's chair. You keep staring at the ceiling for extended periods, with nothing to occupy your mind. A patient may well spend even more time on your operating table, also with nothing to do – but also nothing to look at. The music helps in putting him at ease. Try to select a type of music that has no "rough edges" (baroque, smooth jazz, easy listening ─ not hard rock) and do not make it loud.

16.9 The Brightness in the OR

Some surgeons prefer working in total darkness, and in principle it indeed helps being completely adapted. However, the nurse's table needs to be illuminated so that she can find the instruments you ask for. You must work out a compromise between these two antagonistic needs.

16.10 The Quality of the Air in the OR

The air has two qualities that must be kept in mind to increase comfort for patient and personnel.

- The *humidity* in the OR is low: the air is about as dry as it is in an airplane.[34]
  - This issue is more important for the surgeon than for the patient.[35]
  - Reduced humidity can easily lead to dehydration.
  - The air cannot be humidified, and air conditioning is often used, making the air even drier.

> **Pearl**
> The surgeon should make it a habit to drink after each operation, even if not feeling thirsty. Going to the bathroom often is preferred to developing headaches or kidney stones.

- The *temperature* in the OR should be set around 18 °C (64 °F).[36]
  - Feeling cold is more important for the patient than for the surgeon; the latter wears two layers of clothing and produces extra heat due to his activities[37] and to his own anxiety.

16.11 The Nurse's Table[38]

There are two locations for the nurse to store the sterile instruments and materials that are (likely) to be used during PPV (see **Fig. 16.7**).[39] The most commonly used tools should be readily available on the mobile table; the less frequently required ones are kept on a fixed table/shelf nearby.

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[34] If air conditioning is not used, humidity in most homes is 35–60%, depending on the outside environment. In the OR, the air is usually less than 20% humid.

[35] Who spends less time there than the surgeon.

[36] While this temperature may be ideal for the surgeon, who prefers a colder environment due to his activity than those around him, the patient may feel extremely cold (see above, **Sect. 16.6**).

[37] I remember operating in ORs without air conditioning. On hot summer days, the circulator had to, every few minutes, wipe sweat off my forehead. Dripping sweat is a potential source of endophthalmitis.

[38] See also **Chap. 6**.

[39] Equipment, instruments, spare parts etc., which are very infrequently used, may be stored in cabinets along the wall, even outside the OR. The key is for the circulator to always be available;

Fig. 16.7 **The nurse's table**. (**a**) The minimalistic option. Only the most frequently used tools and materials are kept on a mobile table in front on the nurse. The accessories of the VR machine are found on the machine's own pullout tray on the right of the picture. (**b**) The maximalist option. Virtually any instrument and material that may become necessary are in front of the nurse, some on the "lower floor," and underneath a drape. (**c**) The reserve table, where less commonly used tools/materials are kept. One factor determining whether the minimalistic or maximalist option is chosen is the distance between the nurse's chair and this reserve table

Pearl
Clutter on the nurse's table is highly undesirable. Even if the nurse places all instruments onto the table in some kind of logical arrangement, "in the heat of the battle" this order will not be kept, and from then on, it will take time for the tools to be located. Each delay increases the surgeon's frustration, which in turn increases the risk of iatrogenic complications.

Ideally, the nurse finds the right compromise between having too many vs too few instruments on her table.[40] If the surgeon is dissatisfied with that compromise, he should voice his feelings (see **Sect. 16.13**) and the two have to work out a solution.

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both she and the nurse must know where that piece of equipment is stored and what its packaging looks like to shorten the time locating it (see above, **Sect. 16.1**).

[40] Different nurses, of course, define that compromise differently.

Q&A

Q *Should the surgeon take tools off the nurse's table himself or always ask for them?*

A It occasionally speeds up surgery if the surgeon simply takes the instrument himself. However, some nurses hate this; in addition, there is an inherent danger. The surgeon may take a syringe with the wrong fluid or wrong concentration or a sharp tool when the nurse also wants to handle it – and somebody gets stuck. In general, it is thus preferable for the surgeon to ask for the instruments from the nurse and wait patiently until it is placed in his hand.

16.12 The Blueprint of the OR

How the entire OR is arranged is an important part of the surgical setup. Just as all other issues related to PPV require a conscious decision, this arrangement should also be carefully considered, not simply accepted as a given fact – just because "it's always been like this."[41] The arrangement has many implications, including how the surgeon handles the tools connected to the vitrectomy machine (light pipe, probe). The following components must find their (permanent) location.

- Microscope.
  - If ceiling-mounted, it determines how far the operating table can be placed from it.[42]
  - If floor-mounted, the surgeon has a lot more leeway, but the arrangement should be such that the microscope does not require movement between surgeries. The length of the two mobile arms of the microscope determines how far the microscope can be from the operating table, but the two arms should never form a straight line. They should be at an angle to allow, should it become necessary, manual intraoperative adjustment of the microscope's head.
- Operating table: sufficient space must be left, preferably on both sides, for other equipment to be placed and for the OR personal to get to the patient.
- Vitrectomy and other machines.
  - The nurse and the circulator must have easy access to them (for re-/programming, draining the collected fluid etc.).
  - The surgeon must be able to see the display intraoperatively.[43]
- The nurse and her table.
  - The nurse should be seated behind her table, not forced to stand. She should be close enough to the surgeon for the instrument handover not to require stretching from either of them.

[41] Of course, other surgeons are likely to work with the same nurses in the same OR, which may require a discussion to find a solution everybody can live with.

[42] Before the microscope is fixed to the ceiling, its location must be very carefully evaluated.

[43] Having the display behind the surgeon is suboptimal.

  - The table should be close enough for the surgeon to be able to reach out for instruments.
  - Ideally, the nurse is also able to view the surgery through the microscope.
- Anesthesia machine: None of the tubes must be stretched in order to reach to the patient.
- Infusion-bottle holder[44]: Should be fixed to the operating table, not stand on the floor.
- Monitor: It should be wall-mounted and be positioned so that the surgeon (and the nurse) can easily view it.[45]

One possible blueprint of the OR is shown on **Fig. 16.8**. As mentioned before, the arrangement has implications, among others, for the use of tools connected to the vitrectomy machine. If, for instance, the cable of the light pipe[46] is too close to the surgeon, it can easily get into contact with a non-sterile object or snake into view – it needs to be secured (see **Fig. 16.6**).

16.13 The Captain in the OR

Especially if paired with an experienced nurse, the inexperienced young fellow tends to accept whatever the nurse is suggesting, even when he knows he should "stand up for his rights" (see **Chap. 6**). Avoiding a conflict this way brings early benefits but can be detrimental long term: it will be much more difficult to make the OR personnel change their habits and behavior later. Optimally, the surgeon knows what he wants and firmly but politely conveys to the OR personnel that he has a reason for what he is asking and that he expects everybody to oblige.[47]

Q&A

Q *Who should have the final word if there is conflict in the OR?*

A The surgeon. He is the captain of the ship, and he will be held accountable for anything, and everything, that goes wrong during the operation. With that responsibility, certain rights also come.

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[44] May carry the BSS bottle as well as that used by the anesthesiologist but, preferably, the two are on separate poles. If they hang from the same pole, both the anesthesiology and VR personnel must be keenly aware which is which.

[45] This is crucial for video recording; see **Sect. 12.4**.

[46] A rather rigid structure.

[47] I remember performing live surgery at a foreign institution. The pedals were placed opposite to my preference (see **Sect. 16.3**). The chief nurse was a strong-willed individual, who had been bossing everybody, including the local VR surgeon, around. When I asked her to switch the pedals around, she refused, telling me in an icy voice that "this is how it's always been in this OR." I replied, in a calm but firm voice, that I understand, and as long as it is somebody else operating, it is his business. But now it will be *me* operating; therefore, the pedals have to be placed the way I prefer it. She obliged and never argued again. (To note, once the local surgeon started operating, her bossing attitude returned.) In that OR, the nurse was the captain.

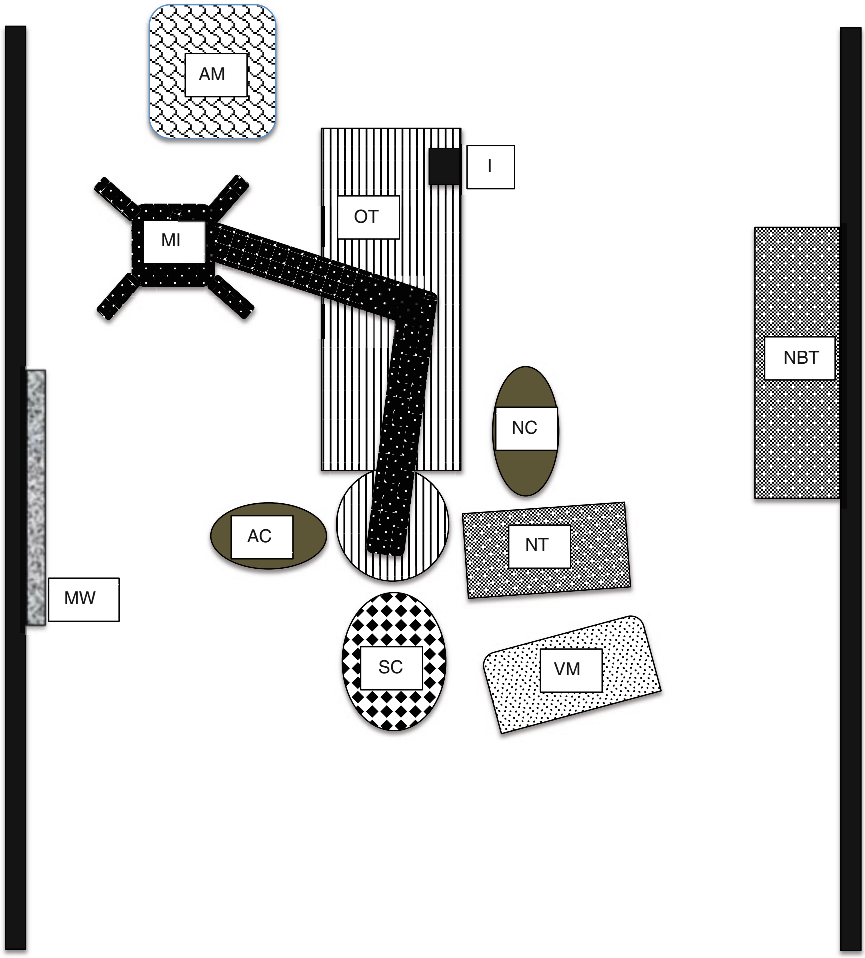

Fig. 16.8 **Schematic representation of one possible OR blueprint**. The surgeon is right-handed; the microscope is floor-mounted. Both the assistant and the nurse are able to view the operation through the microscope. Note that the microscope's two arms form an angle. See the text for further details. *AM* anesthesiology machine, *I* infusion stand, *OT* operating table, *MI* operating microscope, *NBT* nurse's backup table, *NC* nurse's chair, *AC* assistant's chair, *MW* monitor on wall, *NT* nurse's table, *SC* surgeon's chair, *VM* vitrectomy machine

It requires delicate political balancing from the surgeon to not alienate the nurse yet insist on his own ideas if he is convinced that his is the better option. Conversely, a surgeon who rejects any idea just because it is coming from "only a nurse" is a fool. He not only deprives himself of a useful advice (and prevents any that may have come in the future) but also alienates someone who should be his best friend (see **Chap. 6**).

16.14 The Fundamental Technical Rules of Performing Intravitreal Surgery

The surgeon is now ready to start the operation. Without providing more details, which are either unnecessary because the rule speaks for itself, or are provided in various chapters in this book, a brief summary of the most basic technical rules is provided in **Table 16.6**.

Table 16.6 A brief summary of the most fundamental technical rules in VR surgery

Rule	Comment
When inserting instruments into the vitreous cavity, always aim toward its center	An inexperienced surgeon may aim too anteriorly (lens injury) or at too shallow an angle (retinal damage)
When inserting instruments into the vitreous cavity, do not assume that they have indeed penetrated fully through the pars plana – visually confirm that they have (see **Sect. 21.6**)	Not having gone all the way into the vitreous cavity with the trocar/cannula is rare, but if it does occur, it leads to a waste of time as a minimum (see **Sects. 21.6.1** and **21.6.2**), but serious complications[a] can also be caused
When inserting instruments into the vitreous cavity, never go "all the way" but stop in the midvitreous cavity	It is not that difficult to go too deep and injure the retina, especially if there is bullous detachment
Never insert a probe into the vitreous if the probe has not been tested	Very rarely, the guillotine is stuck – aspiration without cutting causes VR traction
Once you have instruments inside the vitreous cavity, never look up from the microscope – make it a habit to pull out both instruments if you do have to look outside of the microscope[b]	It is very difficult to truly pay attention to two different things. If the surgeon pays attention to his surroundings, he cannot fully concentrate on the position of his intravitreal instruments
During most of surgery, it is best to visualize the working instrument but not to be able to see the light pipe	Do not go too close to the retina with the light pipe
Never do anything with an instrument that you cannot properly see; if you are uncertain of the position of the tool, pull it out and reinsert it	Occasionally even the most experienced surgeon loses sight of the working instrument. The angle of the shaft as viewed from the outside is of little help: the tools have no conspicuous external markings; therefore, knowing how deep they are pushed inside is impossible
Never adjust your chair's[c] position while instruments are inside the eye	If the chair (or your position) must be adjusted, it is preferable to simply withdraw the tools and reinsert them once the adjustment has been made
Never lose your concentration during the operation, no matter how "boring" a certain maneuver[d] may be	See **Sect. 3.7**

[a]E.g., tearing or even detaching the retina.
[b]This strict rule may be loosened with time as the surgeon's experience grows, but if he does look up, he needs to keep the instruments absolutely secured. His hands/fingers must remain in a fixed position and not make even the slightest move. Remember, even if the tip of the tool is kept truly in the center of the vitreous cavity, it is still only some 10 mm from the retina.
[c]Unless it is electrically controlled, and even then only after some precautions (see above).
[d]Such as delivering 1,200 laser spots after the truly difficult part of the surgery has been successfully completed.

Q&A

Q *Does the VR surgeon have to go through all the steps listed in this chapter every time he operates?*

A Some always (e.g., adjusting his posture or the head of the operating table), others only if something has been changed (e.g., the previously set brightness or temperature of the OR was altered). The important thing is to carefully consider all the items listed and make conscious decisions about them as the actual situation requires.

Part IV

VR Surgery: General Strategies and Tactics

Introduction

This part deals with general strategies and tactics in VR surgery. The operation is typically performed via the “standard” method (full-function vitrectomy machine, operating microscope, BIOM), but there are alternatives: the slit lamp, the endoscope, even a portable machine, the IBO, and 3D viewing. Each approach has its own advantages and disadvantages. Other chapters in this part discuss issues related to the general preparation of the patient, the placement of the sclerotomies/cannulas, the illumination system, the relevant anatomical and physiological attributes of VR surgery, and, finally, clinical guidelines. These latter chapters go through the most commonly employed maneuvers such as vitreous removal from the anterior and posterior segments, scleral indentation, lasering, working with pre- and subretinal membranes, the use of tamponades and dyes, and the handling of the lens as well as intraoperative complications.

Vitrectomy Performed via the "Standard" Method and Its Alternatives[1]

17

17.1 The "Standard" Approach: Microscope[2] and BIOM

This is how the vast majority of surgeons perform the vast majority of their vitrectomies:

- Three ports (sclerotomies) are used.[3]
  - A fourth, or even fifth, one may be used for additional ("chandelier") lightning.
- The two, superior "working sclerotomies" are for the light pipe (typically in the surgeon's nondominant hand) and for a working instrument[4] (typically in the dominant hand).
  - The tools are switched between the hands if required by the actual situation.[5]
- A third sclerotomy is created, usually inferotemporally,[6] for the infusion cannula.
- Intraocular access is provided transconjunctivally,[7] via cannulas that are introduced at the beginning and removed at the end of surgery (see **Chap. 21**).
- The surgeon views the entire surgery by looking into the eyepiece of the microscope.
  - Almost all of the procedure in the posterior segment is done using the BIOM or a planoconcave contact lens.[8]

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[1] The selection of the type of vitrectomy method is one of the decisions that belong to the second level of strategic planning (see **Sect. 3.1**).

[2] The microscope is typically in the coaxial position.

[3] There are variations on the number of ports used; for instance, the infusion, even in a phakic eye, may be placed in the AC, and thus only two, superior, sclerotomies are made.

[4] Probe, scissors, forceps, pics etc.

[5] For example, peripheral vitrectomy in the phakic eye.

[6] Occasionally the infusion cannula is switched into a superior position and the inferotemporal port is used for a working instrument (see **Sect. 21.6.3**).

[7] The previous "standard" was a 20 g vitrectomy with a separate conjunctival opening and dissection, followed by the preparation of sclerotomies with an MVR blade; no cannula (other than the infusion cannula) is placed inside the sclerotomy incisions (see **Sects. 4.4** and **21.9**).

[8] Except when working just behind the lens (see **Sect. 27.5.3**.) or in the periphery using indentation (see **Sect. 28.3**).

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17.2 The Slit-Lamp Approach

The microscope can be equipped with a slit illuminator, bringing the benefits, and some of the disadvantages, of the optical slit. The slit light makes the microscope act like a biomicroscope.

- Two ports are needed: one for the infusion and one for the working instrument; there is a single working instrument inside the eye.
  - If the situation requires it, a third port can be added for a second working instrument.
- The illumination angle is ~6°.
- The surgeon views the entire surgery by looking into the eyepiece of the microscope.
  - Most of the procedure is viewed through a three-mirror lens.
  - Fine perimacular manipulations are viewed using a planoconcave contact lens.
  - A “hybrid” approach is also possible, combining a wide-angle-viewing corneal contact lens with the slit lamp: it provides for a larger field.[9]

The advantages and disadvantages of the slit lamp/microscope are listed in **Table** 17.1.

Table 17.1 The advantages and disadvantages of the slit lamp/microscope

Advantages	Disadvantages
Illumination as an optic cut allows visualizing details that would remain invisible or barely visible with traditional lighting, for example: Glass IOFB in the cornea Posterior capsule/anterior hyaloid face Fine details of the structure of the vitreous and the VR interface Cellophane maculopathy	The field of view is very small compared to wide-angle viewing. The surgeon has excellent resolution at the actual worksite (which is illuminated), but no feedback about what is happening elsewhere. For example, the far end of a subretinal membrane can tear the retina as it is being pulled, but the surgeon’s visual field is limited to the area immediately surrounding the retinotomy[a]
Bimanual surgery is readily available if a third sclerotomy is prepared	The light reflex from the corneal contact lens is bothersome
If only one working instrument is inside the eye, the surgeon’s nondominant hand is free to do other tasks: Scleral indentation Adjusting the contact lens’ position Stabilizing the working instrument[b] (see **Fig.** 2.1)	If only a single working instrument is inside the eye,[c] it is much more difficult to stabilize the globe; this is especially a risk if the patient is under local anesthesia and the akinesia is not absolutely perfect
Reduced risk of phototoxicity	

[a]Akin to a person with advanced glaucomatous damage or retinitis pigmentosa. At the bus stop he can discern the number of the arriving bus, but the recognition that a bus is arriving is partly deduced from nonvisual sources (noise, memory, fellow would-be-passengers’ change in behavior etc.)
[b]With the nondominant hand’s fingers.
[c]A fulcrum is present at the sclerotomy site.

[9]Although it is still not as large as with the standard approach.

17.3 The Endoscope Approach (EAV)

With all alternative approaches, the image is captured outside the patient's eye, irrespective of whether the illumination is internal or external.[10] The endoscope's image capture is inside the vitreous cavity; the illumination is transmitted via the same endoscope probe, acting as a light pipe.

Typically, the endoscope probe is held in the surgeon's nondominant hand, freeing the dominant hand for handling the traditional tools of PPV. Endoscopy for VR surgery may be employed as a purely diagnostic tool,[11] as a therapeutic method,[12] or as supplementary weapon.[13]

One of the major differences between all other approaches and endoscopy concerns the use of scleral indentation. In many conditions it is crucially important to visualize the periphery and remove the vitreous, membranes, fibrin etc. With alternate approaches this can be achieved only if scleral indentation is employed (see **Chap. 28**). Endoscopy eliminates the need for indentation since the surgeon places "his own eyeballs" into the eye and can view otherwise invisible areas without distorting the anatomy.

EAV has many benefits and a few tangible downsides (see **Table 17.2**).

Pearl

Endoscopy also proves one of the dogmas in VR surgery wrong: it *is* possible for a surgeon lacking binocular vision to perform it. Those who have never had binocular vision will be able to learn vitrectomy without difficulty; those who used to have but lost it will need to relearn much of it and reenter the field only gradually – but they should not be prevented to do so solely based on having monocular vision.

17.4 Portable Systems

There are smaller,[14] portable devices[15] that can be used in the office.[16] These are intended not for full PPV but limited purposes such as sample-taking, removing vitreous blood, core PPV etc.

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[10] See **Sects. 17.1** and **17.2**, respectively.

[11] For example, evaluating the condition of the ciliary processes.

[12] To perform most or all of the operation via endoscopic viewing (EAV).

[13] Performing PPV via the traditional (or slit lamp) approach and utilizing the endoscope for certain, limited functions such as checking the vitreous base.

[14] Otherwise, the trend in the industry is to manufacture large, heavy (exceeding 50 kg), difficult-to-transport vitrectomy machines.

[15] May even be battery-operated.

[16] Where the legal system permits this. In many countries, even intraocular injections must be given in the OR, not in the office.

Table 17.2 The advantages and disadvantages of endoscopy

Advantages	Disadvantages
Both the illumination and the image capture are inside the eye; the quality of the view is excellent irrespective of any media opacity or pupil size[a]	A rather steep learning curve,[b] which is due to the following inherent characteristics: The VR image is viewed on a monitor, not through the microscope 2D, not 3D, imaging[c] The endoscope probe itself remains invisible on the monitor The orientation is difficult since "up" and "down" are not fixed[d] True bimanual surgery is impossible since one hand of the surgeon is dedicated to holding the endoscopy probe the entire time[e]
The resolution of the image is very high[f]	The view may be blocked if the endoscopy probe is submerged in blood; it needs to be removed and cleaned
The visual field and magnification can be easily changed by the surgeon via positioning the endoscope tip closer to[g], or further away from[h], the target area	Risk of phototoxicity when working in close proximity to the retina
Any and all areas of the vitreous cavity (vitreous base, ciliary body, posterior iris surface etc.) are accessible for both diagnostic and therapeutic purposes and without the need for scleral indentation[i]	The resolution of the smaller-gauge (i.e., 23) endoscopy probe may not be sufficient to allow fine work[j]
The illumination is coaxial; there is no shadowing	The probe[k] itself is invisible; there is a risk of lens damage if the surgeon tries to "reach over" to the other side in a phakic eye
The placement location (and introduction) of the infusion cannula and of the working sclerotomy can be properly selected and visually controlled once the endoscopy probe has been inserted into the eye	There is an inaccessible zone behind the tip of the endoscopy probe Expense of the equipment[l]

[a]Obviously, leftover opacities anterior to the vitreous cavity will represent a problem in the postoperative period; this is something the surgeon must keep in mind as he is planning his surgical strategy.
[b]How steep, of course, depends on the individual surgeon. Paradoxically, those with less experience using the standard approach may have less difficulty switching than those who have been operating via the microscope/BIOM approach for long.
[c]The surgeon will develop pseudostereopsis with time.
[d]The field of view is not changed by adjusting the position of the microscope (as with the standard or slit-lamp approaches) and rotating the eye but by repositioning the endoscope.
[e]The laser channel can be incorporated into the endoscopy probe (single sclerotomy needed for endocyclophotocoagulation or even panretinal laser treatment).
[f]Equipment-dependent, but technology is advancing fast.
[g]Smaller field, higher zoom.
[h]Enlarged field, lower zoom.
[i]Which distorts the anatomy: it can hide the presence of VR traction by approximating its endpoints (see **Chap. 28**).
[j]Less important at the vitreous base than in the posterior pole.
[k]Again, it also acts as the light pipe.
[l]The cost is expected to decrease as the EAV grows in popularity.

The procedure may require one or two[17] 23 g ports; viewing is either through a separate port (endoscope; see **Sect. 17.3**) or via the IBO. The former option reduces the benefits of the procedure (minimal infrastructure and cost); the latter option makes the intervention technically difficult since the image is upside-down.

17.5 3D Viewing

This is a recently developed option in VR surgery. The surgeon, instead of looking into the microscope, watches the surgical field, wearing 3D glasses, as projected onto a large monitor; the image is captured by a 3D camera mounted on the microscope.

The system[18] has certain advantages (such as allowing improved surgeon posture during PPV, permitting the fellow and all observers to see exactly the same image as the surgeon does, and decreased need for illumination power) and disadvantages (such as lower image resolution and the need of getting used to a completely new viewing option).

Pearl

The majority of PPVs will continue in the near future to be done using the traditional approach; however, the alternatives offer options that have distinct advantages for certain cases. As technology changes, the indication list of these currently rather limited approaches will undoubtedly grow. In an ideal world, the VR surgeon would have access to, and expertise with, all of the options listed above and select the most appropriate method in the particular case.

[17] Intrector and Retrector, respectively (Insight Instruments, Inc., Stuart, FL).

[18] TrueVision 3D Surgical, Santa Barbara, CA, USA.

18 Disinfection, Draping, and Perioperative Medications

18.1 Disinfection and Draping

Proper disinfection is a crucial element in endophthalmitis prophylaxis in eyes undergoing PPV.

- Prior to the operation, the eye and its vicinity should be carefully inspected. Surgery should not proceed if there is discharge or the suspicion of a surface infection.
- The skin must thoroughly be cleansed with 10% povidone iodine,[1] which must not be wiped off for at least 1 min. The area to be disinfected should be large (see **Fig. 18.1**).

Fig. 18.1 Preparing the patient for VR surgery. This patient is undergoing surgery in general anesthesia: the nostrils are tamponaded. The side for operation is marked and the skin disinfected with 10% povidone iodine in a large area

[1] An antiseptic (bactericide) solution, which has safely been used even in persons who are presumed to have "iodine allergy".

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- The ocular surface must be irrigated with 5% povidone iodine, again left for at least 1 min, and then irrigated with saline/BSS to completely remove the disinfectant solution.

  The drape may be placed by the nurse or the surgeon.

Pearl
Typically it is the nurse who drapes the patient. However, in case of an open globe injury, the surgeon should do the draping. Pressure on the globe must be avoided to prevent tissue prolapse or cause an ECH – risks the surgeon appreciates the most.

- The skin must be completely dry before the adhesive part of the drape is applied.[2]
- The drape must adhere to the skin "watertight."
  - Even if a small opening is present,[3] the air can escape as the patient is exhaling. This introduces a potential risk factor for infection from the untreated skin and may cause condensation on the BIOM front lens (see **Table 16.5**).
  - The opening also allows discharge from the nose to seep into the operative field; in general anesthesia, the nose should be tamponaded to prevent this (see **Fig. 15.1**). The nasal packings can also be soaked in 10% povidone iodine for added effect.
  - Occasionally, the drape releases from the skin during the operation. The risk is not "only" endophthalmitis but also that the intravitreal instruments may stick to it. The surgeon does not necessarily notice this in the dark as he is

Fig. 18.2 The typical error in placing the adhesive drape. There is an opening (no sticking) on the nasal side inferiorly. This is easiest to avoid if the drape is pressed against the side of the nose first, only then onto the rest of the skin

[2] The adhesive does not work on wet surfaces.

[3] Which is usually on the nasal side, due to the surface incongruence caused by the nose (**Fig. 18.2**).

focused on the retinal work. He simply feels resistance to the movement of his instruments (especially as he tries to penetrate deeper into the eye). Without realizing that there is resistance, he subconsciously applies greater penetration force. Once this overcomes the adhesion of the instrument to the drape, they suddenly separate, and the inertia carries the surgeon's instrument forward, possibly hitting the retina.

- The eyelashes must be tucked underneath the adhesive drape.
  - The lashes cannot be cleaned with the Betadine swipe as thoroughly as the skin.

The opening of the drape should be done by the surgeon; the risk of injuring the eyeball with the scissors is very small, but not zero. The scissors should be blunt, and once the initial "incision" has been made,[4] the blades must be turned so that they can be advanced with the tips pointing slightly upward. Often no cutting is needed, only the pushing forward of the blades.

Pearl
If the drape is not opened properly, the transparent overhanging plastic can cover the top of the cannulas as the eyeball is rotated during the operation. The surgeon may not actually notice this, sensing only that he is unable to insert his instrument into the cannula. When the microscope light is turned on to find out why this is, he will have rotated the eyeball so that the drape does not cover the cannula anymore. The drape must be cut flush with the lid margin.

18.2 The Monocular Patient

The monocular patient who wears a removable prosthetic eye requires special attention. In addition to preparing the eye undergoing surgery, precautions are in order for the prosthetic side:

- The prosthesis must be removed at least 1 day prior to the operation.
- The conjunctival sack must be disinfected.
- On the operating table, the prosthetic side must be treated as if this were the one undergoing the operation.
  - 10% povidone iodine on the periocular skin and in the conjunctival sac; this may be left behind, no need for irrigation.
- Ideally, the prosthetic side is draped over with a separate adhesive sheet.

[4] When the tip of the scissors point downward, possibly facing the eyeball.

Q&A

Q *Should antibiotic drops be used pre- or postoperatively?*

A Antibiotics require extended use to be effective. A few drops, whether applied preoperatively, postoperatively, or both, will not be able to live up to their antibacterial capabilities. Worse, the brevity of their application increases the risk of bacterial resistance. If antibiotic drops are used, they should be used for at least 5 days. I do not use them.

18.3 At the Conclusion of the Operation

- It is not routine to inject prophylactic antibiotics intravitreally.[5]
- Subconjunctival antibiotics are used by some surgeons; the rationale for this practice is highly questionable (see the Q&A above).
- Subconjunctival steroids[6] are, however, very useful in limiting the postoperative inflammation.
- IOP-lowering drops or acetazolamide tablet(s) may help to prevent pressure spikes, especially if gas or silicone oil has been implanted.
- At the conclusion of the operation, a few drops of 5% povidone iodine may be installed and need not be irrigated out of the conjunctival sack/eye surface.
- Oral/systemic pain medications are not used on a routine basis, only if the need arises.

[5] There is no protocol in VR surgery akin to the cataract surgeons' intracameral injection of cefuroxime at the end of surgery.

[6] For example, 4 mg dexamethasone.

The Speculum and Its Placement

19

The function of the speculum is to keep the lids securely apart during the operation *and* to prevent the eyelashes from contaminating the operative field (see **Sect. 18.1**).

19.1 General Considerations

- As opposed to cataract surgeons,[1] VR surgeons strive for opening the lids as wide as possible to provide unobstructed access to the front surface of the eye.
  - The lids' normal (default) position works against the intended purpose of the speculum.[2]

> **Pearl**
> The selection of the proper type of speculum does not seem to be an important issue until the surgeon is forced to struggle with it intraoperatively.

– If the lids are not widely separated, the visco may get wiped off the corneal surface as the surgeon rotates the eye.
– Conversely, if the patient's orbital fissure is very small, forcing the speculum wide open will have the opposite effect: The placement of the cannulas, and finding them during the operation,[3] will be more difficult (see **Figs. 19.1** and **21.7**).
– The speculum is able to prevent being closed by the squeezing patient.[4]

[1] Who typically spread the lids only loosely to avoid exerting pressure on the globe.
[2] This may be exacerbated by the wake patient squeezing.
[3] Especially of the superonasal cannula, which will tend to slide under the lid (see **Fig. 19.1**).
[4] This holds true for the duration of the entire operation.

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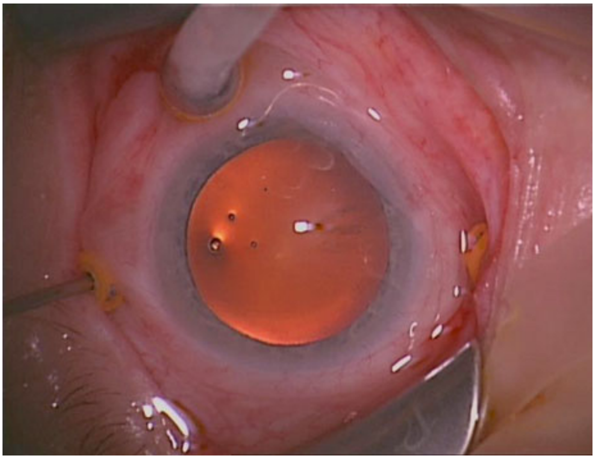

Fig. 19.1 **Narrow palpebral fissure, widely opened speculum**. It may be impossible to find the superonasal cannula when the surgeon wants to insert an instrument through it in the dark: a double-blind effort, according to the gallows type of humor. The cannula keeps sliding under the upper lid

– Wire-type speculums with no locking mechanism[5] should be used only if the patient is under general anesthesia when squeezing of the lids does not occur. They work as a spring, whose action is easily overpowered by the orbicularis muscle.

- The speculum should have no conspicuously outcropping parts (see **Fig.** 19.2).[6] This avoids getting sutures entangled by the speculum.[7]
- The speculum should not have long areas of contact[8] ("solid blades") with the lids (see **Fig.** 19.3). This avoids the danger of an intraocular instrument such as the probe, forceps, or scissors slipping on them and causing the intraocular tip to unexpectedly "jump" (especially during scleral indentation; see **Sect.** 28.2).
  – Conversely, these speculums are able to keep the eyelashes securely out of the field.

[5] For example, the Barraquer Wire or the Kratz Wire.

[6] For example, Guyton Park, Liebermann, or Kratz Wing.

[7] Most microscopes have a relatively small field of view even at their lowest magnification. Either the microscope must be manually moved to identify what has caught the suture or the nurse may help – but she may not realize that as she is pulling on the thread of the suture to free it up, she is also pulling it out from the wound.

[8] For example, Sauer or Feaster.

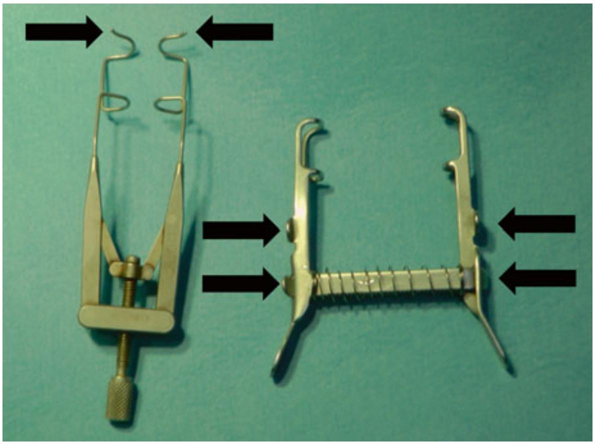

Fig. 19.2 **The self-tightening lid speculum**. Speculums with outcroppings (*arrows*) whose only function is to snare sutures. See the text for more details

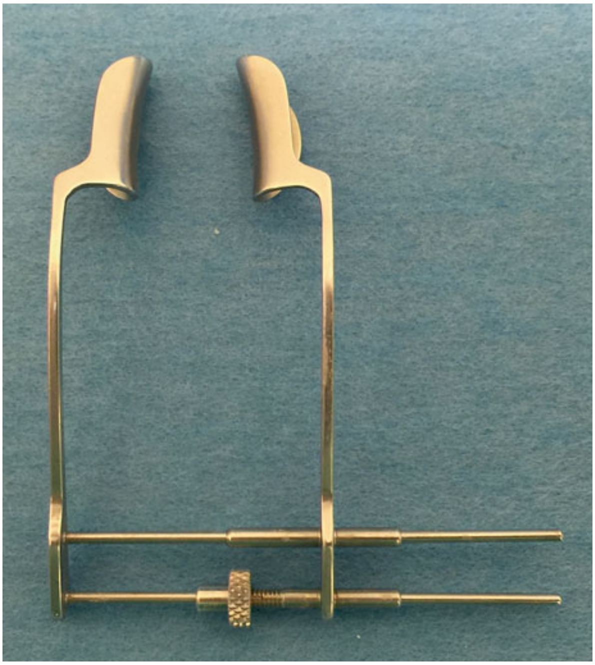

Fig. 19.3 **A speculum with a long blade**. The length of the blade presents a risk during scleral depression (see the text for more details)

19.2 Speculum Placement

- Upon insertion, make sure the blades do not slide between the plastic sheet and the lid.
  - Once this happened, the eyelashes will peek out, and from then on it is very difficult if not impossible to keep them away from the operative field.
- Be careful not to dislodge the already-placed first blade while inserting the second blade.
- Open the speculum wide, but do it slowly. Even well-anesthetized patients can feel pain if the lids are spread too far and too fast.
  - It is best to open the speculum to the maximum the lids allow and then loosen it a little.
- When securing the speculum width with a screw,[9] make sure it is tight enough – but do not overtighten because you will have to struggle loosening it at the conclusion of the operation.
  - Ideal is a self-tightening speculum that prevents the patient from squeezing the lid fissure smaller and has no unnecessary outcroppings (see **Fig. 19.4**).[10]

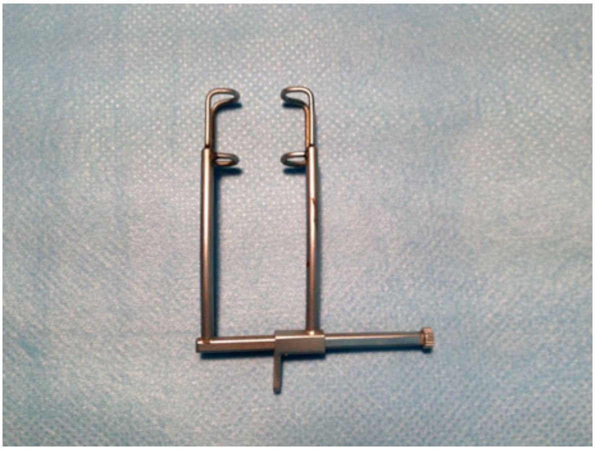

Fig. 19.4 The ideal self-tightening lid speculum. Not requiring a threaded tightening mechanism, this speculum reduces complexity and has no unnecessary outcroppings; it also has a wire type of "blade" that is sufficiently firm without being in the way. This is the speculum I favor

[9] For example, Cook or Clark.

[10] Geuder (Heidelberg, Germany) model G-16050.

Holding and Operating Hand Instruments

20

As mentioned before (see **Sect. 2.1**), the fellow should carefully observe the way the surgeon's hands and fingers manipulate the instruments he uses. What happens outside the eye explains some of what is happening inside, how external movements relate to internal consequences.

20.1 Holding an Intraocular Instrument[1]

- Holding a device with two fingers is far from ideal under any circumstances.[2] Intraocular tools (see **Fig. 39.2**) but especially intravitreal instruments need to be secured with three fingers (see **Fig. 20.1a, b**) to prevent any unintentional movement.[3]
- Using a forceps (see **Fig. 20.1c** and **Sect. 13.2.1.3**) to perform tasks requiring miniscule movements[4] with a very small margin of error requires the greatest possible stability.

> **Pearl**
> There is a reason why chairs have (at least) three legs: they offer stability. Everybody would laugh at a chair with two legs. The same principle applies to holding intraocular tools.

[1] Most of what is discussed here is true for non-intraocular tools as well, but the margin of error is smallest when fine movements on the retinal surface are required.

[2] Next time your hair is cut, notice that the barber holds the scissors with three, even four, fingers.

[3] Support for the hand (wrist) is also essential (see **Sect. 16.2.1**).

[4] As a reminder, the ILM is 2 μ thick (see **Sect. 5.11**).

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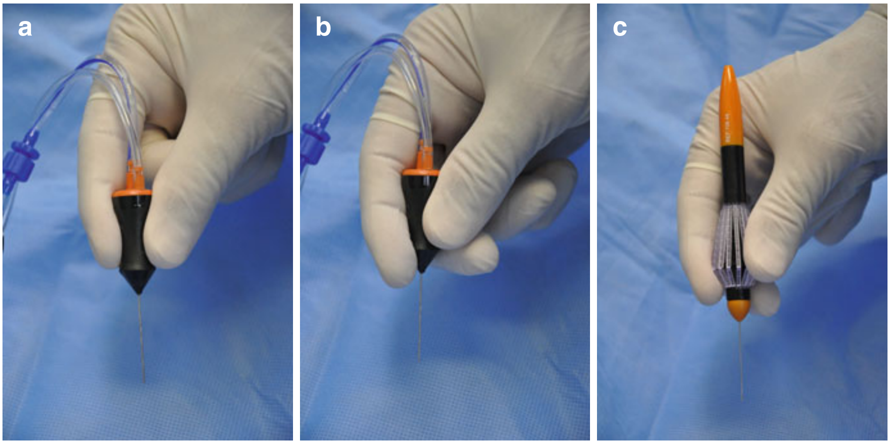

Fig. 20.1 **Holding the probe**. (**a**) Supporting the probe with only the index finger and the thumb makes it rather unstable, which is risky if fine maneuvers, such as working in the proximity of the retina, are required. (**b**) By adding the middle finger, the position and movement of the probe are precisely controlled by the surgeon. (**c**) If a forceps is used, it is even more critical to provide adequate support. Since in this case the surgeon not only holds the tool but must actually squeeze it to enable its function, the use of the supporting middle finger is mandatory

One of the most common mistakes a beginner surgeon makes is to squeeze the tool even when the instrument is simply held, not actively used, or if the tool is a non-squeezable one (e.g., light pipe).[5] This is a reflex, probably associated with the high concentration VR surgery demands. However, such squeezing not only offers no benefit, it is potentially detrimental since it increases the magnitude of tremor.

Pearl
The fellow must continually make a conscious effort to not squeeze the instruments unless squeezing is called for and even then to keep the force of squeezing to the minimum (see **Sect. 4.1**).

20.2 Operating an Intraocular Instrument[6]

The intravitreally inserted tools are used to execute actions inside the eye but also to rotate the eyeball.[7] Whenever an instrument is inserted into the vitreous cavity, there is potential for seesaw action with the fulcrum being at the sclera (see below).

[5] Call it "sympathetic squeezia."

[6] More on this topic is provided in **Chaps. 13** and **32**.

[7] One of the disadvantages of having a single tool inside the eye during the slit-lamp approach (see **Sect. 17.2**) is the limited ability to maneuver the eyeball.

- To rotate the eyeball the instruments in the two superior sclerotomies must move in harmony (see **Sect.** 25.2.8). As an example, if you want to turn the right eye toward 9 o'clock, you cannot tilt it by using your right hand only. *Both* tools must move to the right, *equidistant* and in exactly the *same direction*, and do so *simultaneously*.
  - During rotation, there is no seesaw action: the external and internal parts of the tools move in the same direction (see **Fig.** 20.2).
- The seesaw comes into play when the surgeon needs to access a different area in the vitreous cavity without having to rotate the eye. As an example:
  - While the posterior pole is in view, the field of action is to switch from the peripapillary area to one just temporal to the macula. The intraocular tools must be rotated (not the eyeball: the fulcrum remains stationary) so that their external and internal parts move in opposite directions (see **Fig.** 20.3).

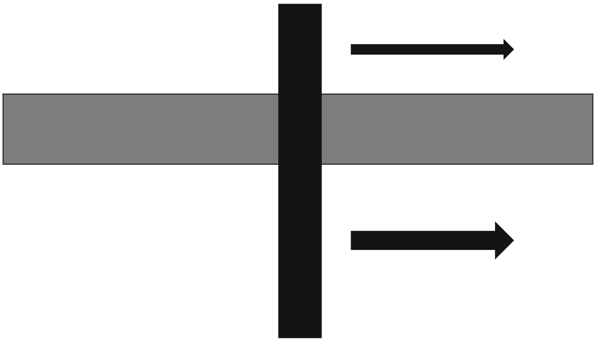

Fig. 20.2 Rotating the eyeball. The external (*thick arrow*) and internal (*thin arrow*) parts of the intraocularly inserted tool move in the same direction; there is no seesaw action

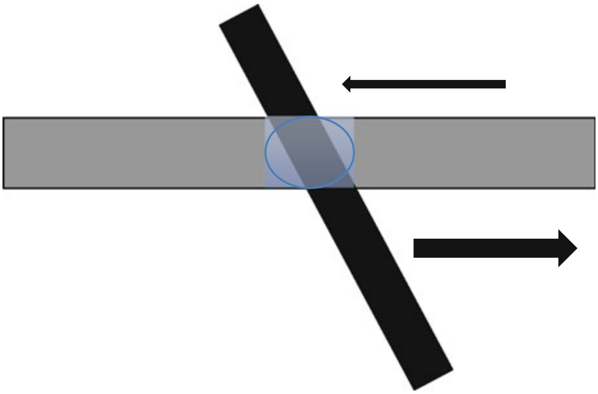

Fig. 20.3 Switching the field of action inside the vitreous cavity. The external (*thick arrow*) and internal (*thin arrow*) parts of the intraocularly inserted tool move in the opposite directions; there is seesaw action with the fulcrum (*blue circle*) being at the scleral insertion point

- To operate a forceps that needs to execute fine maneuvers, it must be held securely (see above) and break down the apparently single action into several independent movements[8]:
  - Moving over the target tissue.
  - Partially closing the jaws to reduce the distance they must travel before they are closed on the target tissue.
  - Lowering the jaws to the plane of the target tissue.
  - Pressing down into the target tissue.
  - Closing the jaws while remaining in the same plane.[9]
  - Elevating the jaws, with the grabbed material securely held onto, slightly above the tissue plane to patiently wait until the tissue rips.
  - Moving the grabbed, now torn tissue along a preplanned path.

20.3 Injecting into the Vitreous Cavity During Surgery

Regardless of the material being injected, the use of the palm, rather than the index finger, to push on the plunger reduces the risk of retinal injury (see **Sect.** 34.3.2 and **Fig.** 34.5**b**).

[8] In this case grabbing the ILM that has not been incised before (blunt opening, see **Sect.** 32.1.2.2).

[9] The inexperienced surgeon tends to lift the forceps before or as the jaws are closing; consequently there is no purchase of the membrane. This, of course, is less of an error than closing it while the jaws are pushed down.

21 Sclerotomies and the Cannulas

21.1 Transconjunctival vs Conjunctiva-Opening Surgery

The traditional option, 20 g PPV with two or three conjunctival incisions, is fast disappearing.[1] The trend is understandable since MIVS has many advantages and only a few disadvantages (see **Table 21.1**). Still, it must be emphasized that the main benefit of MIVS is not a reduced-sized sclerotomy.[2]

As mentioned in the *Preface*, all surgery-related issues discussed in this book are based on the 23 g approach.

21.2 Location of the Sclerotomies

The placement of the sclerotomies has huge implications for the techniques[3] and prognosis of the surgery. A number of issues must be considered.

21.2.1 Distance from the Limbus

My routine for decades has been to place the sclerotomies 3.5 mm from the limbus, even if the eye is phakic. I have not encountered any difficulty or complication anteriorly (lens injury) or posteriorly (retinal injury). There are also exceptions to the routine:

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[1] A few words are included at the end of this chapter on 20 g PPV since it is not completely out yet. It must also be mentioned that transconjunctival surgery is possible with 20 g instrumentation.

[2] The 20 g incision is 53% larger than a 23 g one, but it is a difference of only 0.35 mm. I therefore dislike the term "small-gauge surgery" to characterize the 23-25-27 g options. Since sutures are occasionally needed in MIVS as well, I do not prefer the term "sutureless surgery" either. I accept the term MIVS, but interpret it as "transconjunctival vitrectomy."

[3] Especially in the phakic eye.

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Table 21.1 23 g transconjunctival (MIVS) vs 20 g conjunctiva-opening PPV*

Variable[a]	*23 g*	20 g
Patient comfort/perisurgical trauma	*Greatly reduced trauma, consequently much greater comfort, for the patient.[b] It is also much less common to have subconjunctival bleeding (cosmesis)*	
Duration of surgery/speed of vitreous removal[c]	*The preparation for and conclusion of ("previtrectomy" and "postvitrectomy" phases) the actual surgery are shorter*	The removal of the vitreous itself is faster; the pre- and post-phases last longer
Sclerotomy site in case of a late reoperation	*Irrelevant; the site of the former sclerotomy is unlikely to be found*	Avoid the previous site/s if possible
Need to suture the sclerotomy/conjunctiva	*If the wound architecture is correct (see* ***Sect. 21.3****), suturing of the sclerotomy is only rarely needed. Exceptions include:* *Reoperations (if the same location as before is used)* *Thin sclera (high myopia, scleritis, autoimmune diseases* etc.*)* *Long surgery* *Silicone oil implantation*	Suturing is always necessary (unless some special technique is used to make the wound self-sealing), which can cause discomfort, astigmatism, and conjunctival scarring
Vitreous incarceration into the sclerotomy[d]/vitrectomy at the sclerotomy site	*This is virtually unavoidable (see* ***Fig. 21.1****) due to the presence of the cannula, unless the following measures are taken*: *In a pseudophakic eye, it is possible to clean the area underneath the sclerotomies by indenting the eyewall with the cannula itself.* *In a phakic eye, the only option is to remove the cannula, reintroduce the probe and perform "blind" PPV underneath the incision. The downside of this procedure is its increased chance for the wound to require suturing*	The wound is always cleaned of any prolapsed vitreous; the probe must actually be pushed inside the incision to prevent any internal incarceration (which would not be apparent on the scleral surface)
Tools with long blades	*Any and every intraocular part of the tool must adhere to the limit of 0.65 mm in diameter. The solution if an oversized, long-blade instrument is needed is to remove the cannula or create a 20 g sclerotomy for that instrument*	Any tool of any size and shape can be used in 20 g surgery, as long as its diameter does not exceed 0.9 mm: the instrument may have parts that exceed this dimension,[f] although this requires special techniques of tool insertion
Changing the wound size	*This is impossible. Tools of smaller size (g) can be used, but leakage through the cannula is inevitable. If a smaller cannula is inserted as replacement, the wound must be suture-constricted first*	The wound can be temporally enlarged and then suture-constricted as required

Difficulty with silicone oil of high viscosity	*Significant or minimal, depending on the equipment*	Minimal or none
Instrument bending[g]	*Significant or minimal, depending on the equipment. The tendency to bend is roughly and inversely proportional with size*	Minimal or none
Instrument fragility	*Much increased. It is crucial for the nurse to understand this, especially when working with forceps in the darkness of the OR (see* ***Chap. 6****); those who sterilize the instruments must also be warned about the tools' fragility*	Significant
Intraoperative difficulties	There are no major differences between 20 g and *MIVS*,[h] although *certain maneuvers such as lensectomy may be more difficult with 23 g; phacofragmentation is currently not available with gauges <23*	
Intraoperative complications	No hard-proven difference	
Complications due to instrument re/entries	*The problem does not exist since all instruments are introduced through the cannula. There is no difference in instrument introduction whether the tool has a sharp or blunt tip*	The wound may be damaged and an iatrogenic retinal break created, as the tools repeatedly penetrate the vitreous base. It is much more difficult and thus traumatic to push blunt tools through the sclera[i]
Postoperative complications	It appears that now, with the early MIVS-related issues having been worked out, *the risk is smaller with 23 g surgery*	
Cost	*Higher in 23 g surgery*	

[*]Some of the variables are the primary concerns of the surgeon, but all concern the patient, whether directly or indirectly.
[a]Obviously, not all represent the same significance.
[b]The smaller the gauge, the less discomfort the patient has. This, however, must be weighed against the increased technical difficulties the surgeon has with various maneuvers if smaller gauge instrumentation is used.
[c]There are other, more important factors influencing the speed of surgery; see **Sect. 12.1**.
[d]Apparently, what was described early in the vitrectomy era as "vitreous wick syndrome" is not such a dangerous condition as long as the incarcerated vitreous only tamponades the sclerotomy (a beneficial effect) but does not cause traction on the peripheral retina (a potentially deleterious effect).
[e]No such instrument is currently available. Manufacturing retractable tools of memory material is apparently not feasible.
[f]E.g., a subretinal forceps with long blades.
[g]Much of it is relatively easy for the surgeon to overcome.
[h]The bending of the instruments and the cleaning of the inside of the sclerotomies in the phakic eye have already been discussed above.
[i]The MVR blades come in 20 and 19 g varieties; the incision created with a 20 g blade is often too short to allow the introduction of a blunt tool such as a non-conical light pipe.

- Children. **Table 21.2**. shows the age-related recommendations.
- Highly myopic eye. I place my sclerotomies at 4 mm if the axial length exceeds 26 mm.

The scleral wound should be perpendicular to the limbus (see below, **Sect. 21.3**); the distance is measured from the limbus to the proximal endpoint of the wound.

> **Pearl**
> Transillumination helps the surgeon identify the lighter pars plana from the darker ora serrata. Endoscopy via direct visual control allows the surgeon to locate the most optimal site of the (remaining 2) sclerotomies (see **Sect. 17.3**).

Table 21.2 Limbus-to-sclerotomy distance of the pars plana incision in children

Age	Distance from the limbus, mm
≤6 months	1.5
6–12 months	2.0
1–2 years	2.5
2–6 years	3.0
≥6 years	3.5

21.2.2 Location in Clock Hours

The placement of the cannulas has huge implications (see **Figs. 21.1** and **21.2a, b, c, d**) for the ease of performing the surgery as well as the prognosis, especially in the

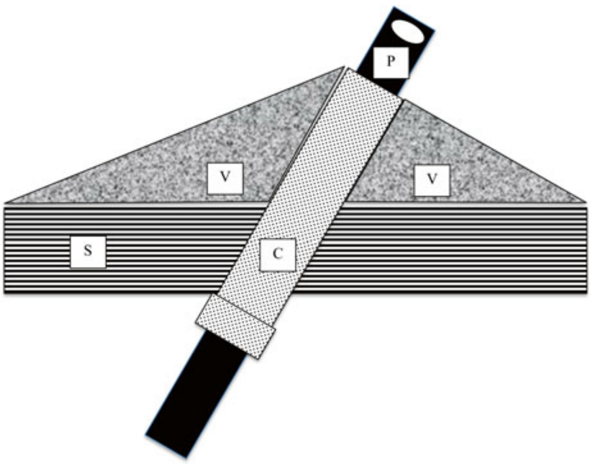

Fig. 21.1 **Schematic representation of the difficulty of vitrectomy underneath the sclerotomy in MIVS**. If inserted into the eye through a cannula (*C*) that sits in the sclera (*S*), the probe (*P*) cannot reach the vitreous (*V*) in the immediate vicinity surrounding the cannula. By changing the angle of the cannula, it is possible to remove a little more vitreous, but the only way to complete the vitrectomy is to reach the area from the opposite side of the eye or remove the cannula and reinsert the probe (neither option is shown here)

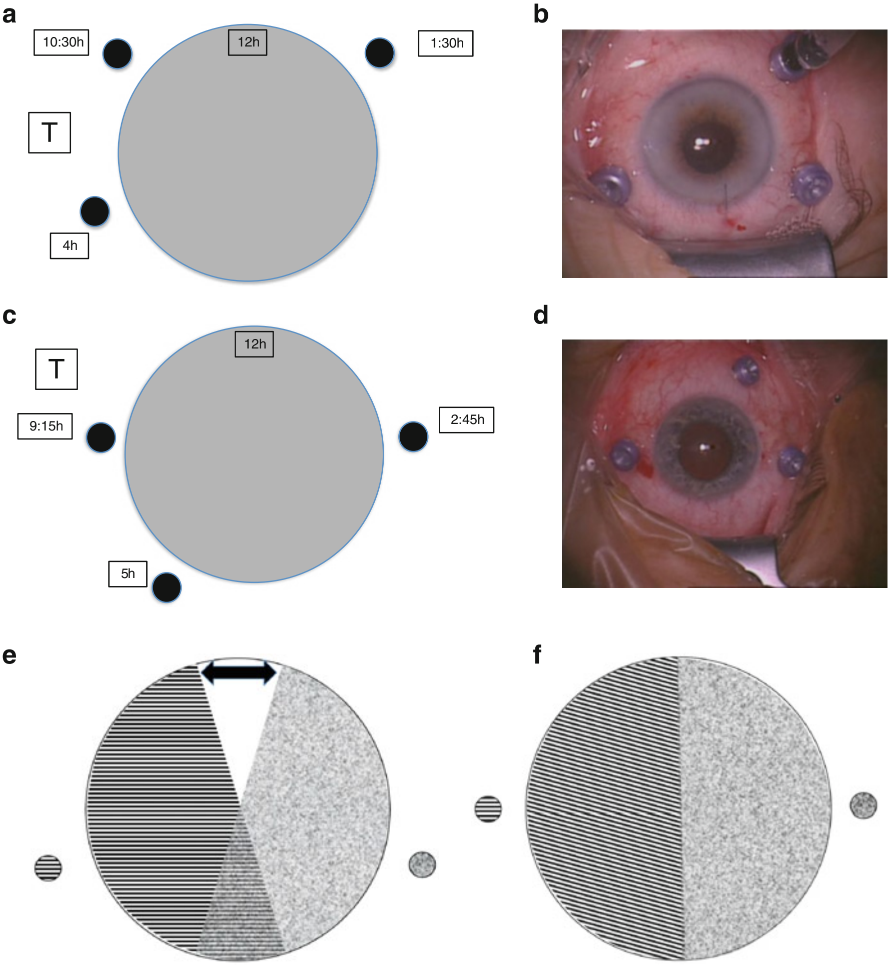

Fig. 21.2 The placement of the sclerotomies. (**a**) A common error is to place the working sclerotomies too close to each other (they are too superior; see the text for more details). *T* Temporal. (**b**) A clinical example, surgeon's view. (**c**) Schematic representation of the implications of correct cannula placement: the working sclerotomies are just superior to the 3–9 o'clock line. Note that the infusion cannula has been moved closer to the 6 o'clock position. (**d**) A clinical example, surgeon's view. (**e**) Schematic representation of the limitations caused by too-superior cannula placement. The shaded areas represent access to the vitreous base from the respective sclerotomy. The arrow shows the area that remains inaccessible in a phakic eye. (**f**) Correctly placed cannulas. The shaded areas represent access to the vitreous base from the respective sclerotomy. Even in a phakic eye, there is no area in the vitreous cavity that remains inaccessible to the probe

phakic eye. One of the most common errors a careful observer of VR surgeries[4] notices is that the superior (working) sclerotomies are too close to each other. The typical advice is to place them "150° to 160° apart" (in reality they are even closer

[4] Just look at the videotapes being shown at scientific meetings.

to each other). There are several disadvantages – and not a single advantage – with this arrangement:[5]

- It prevents the surgeon from performing peripheral vitrectomy in the phakic eye inferiorly (see **Figs. 21.2e, f**).[6]
  - This is often the real reason why surgeons feel the need to place an SB on the eye with RD if the retinal break is inferior (see **Sect. 54.5.2.2**).
- It makes it more difficult[7] to access and work in the periphery superiorly.
- Holding the hands closer together is less comfortable than keeping them further apart (as in the latter scenario with sclerotomies placed more inferiorly).
  - During a long surgery, less comfort can easily translate into less precision.

Placing the working sclerotomies very close to, but not right over,[8] the 3 and 9 o'clock locations alleviates all these problems, without introducing any drawback. If the surgeon switches hands, he can access any location the vitreous cavity and do so comfortably.

The traditional site of the infusion cannula is at 4 o'clock. I place mine more toward 5 o'clock[9] to make sure that there is enough room between the valves of the two temporal cannulas.

21.2.3 In Case of a Reoperation

This is a relatively common problem.

Q&A

Q *If an eye requires re-PPV, should the same site be used for the sclerotomies?*

A If the reoperation is performed early (within days/few weeks), the wound has not yet healed. If the original wound can easily be identified, it is preferable to reuse them. If the reoperation is performed at least several weeks after the previous surgery, any location is suitable.

In MIVS, it may be very difficult to identify the exact location of the previous sclerotomy without opening the conjunctiva – which would defeat one of the purposes

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[5] The most common reason for the erroneous site selection is simply that the surgeon does not consciously plan it (see 2.1.1).

[6] Between 5 and 7 o'clock.

[7] Not impossible, though.

[8] This is very important to avoid damaging the long ciliary nerves and arteries.

[9] In the left eye; in the right eye this is obviously mirrored.

of the transconjunctival approach. One advantage of always using identical clock hours during the primary PPV is to have a good idea where the sclerotomies should be found.

21.2.4 In Case of Scleral Thinning

If the sclera, for whatever reason (see **Table** 21.1 and **Chap.** 59), is visibly thin in the planned sclerotomy area, the site needs to be changed. An individual decision must be made to identify the most suitable and least inconvenient location. Scleroplasty (see **Fig.** 21.3) may be necessary even if the planned sclerotomy sites are outside the area of scleral thinning: the pressure needed to penetrate the sclera, inadvertent mechanical trauma during surgery, or the elevated IOP may cause a rupture with disastrous consequences.

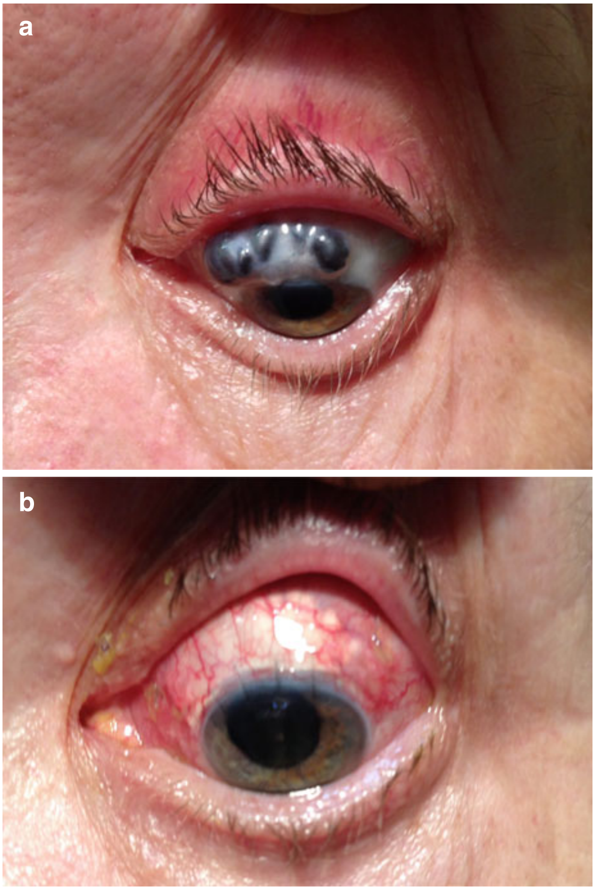

Fig. 21.3 **Scleral thinning**. (**a**) This patient had severe autoimmune disease and extreme scleral thinning with extensive choroidal prolapse. Before vitrectomy for a VH could be performed, scleroplasty was necessary. (**b**) Once the scleral graft has been secured, VR surgery became possible; the sclerotomies were placed outside the area of scleroplasty

21.3 Inserting the Cannula

The placement of the cannulas also determines the ease with which the surgeon can enter and reenter the vitreous cavity during surgery.[10] The trocar used to deliver the cannula is sharp and is almost always[11] easily able to insert the cannula. The globe, however, must be immobile to avoid iatrogenic damage to the lens or even the retina. The best tool for securing the globe is the pressure plate (see **Fig. 21.4**), also allowing the surgeon to:

- Move the conjunctiva away from the spot where the trocar will penetrate the sclera[12].
- Identify the required distance of the sclerotomy from the limbus.

Pearl
If the pressure plate is unavailable, I use my other hand's index finger to stabilize the globe upon trocar entry. Avoiding the use of tooth forceps prevents the tearing of the conjunctiva and/or causing conjunctival bleeding (see **Fig. 39.2** and also **Sect. 21.5**).

- The trocar is not a round but a slit-like tool; the slit must be held parallel with the course of the collagen fibers in the sclera[13] (see **Fig. 21.5a**).

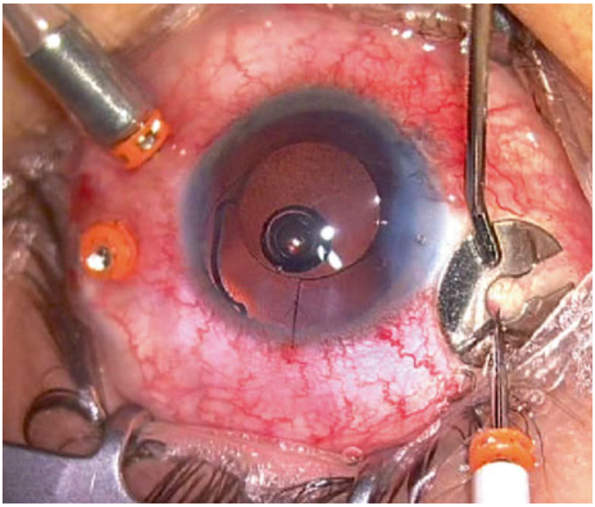

Fig. 21.4 Fixating the globe with the pressure plate. See the text for details

[10] It is exceptional that PPV can be performed with a "single in" and "single out."

[11] Except if there is extensive scarring on the inside of the sclera.

[12] Supposedly if the conjunctival opening is not right on top of the scleral opening, the risk of endophthalmitis is reduced.

[13] The fibers crisscross each other, but run fairly perpendicular to the limbus in its vicinity.

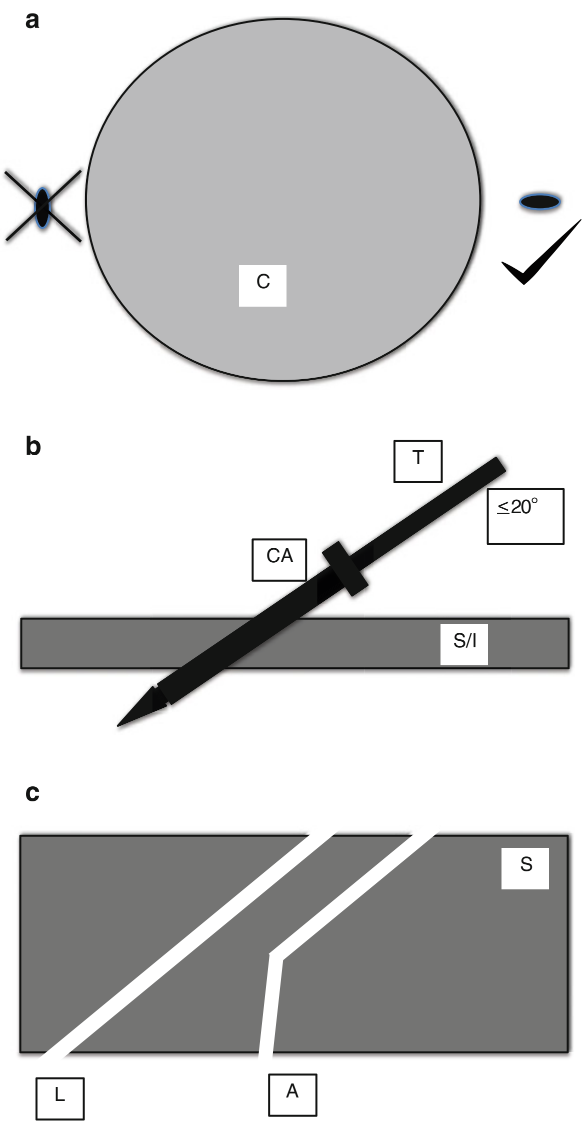

Fig. 21.5 Schematic representation of trocar entry into the sclera. (**a**) The slit of the trocar blade should be held perpendicular to (*right side*), not parallel with (*left side*), the limbus. *C* cornea. (**b**) The angle of the trocar and cannula (*T*/*CA*) to the plane of the sclera (i.e., iris, *S/I*) should be no more than 20°. (**c**) Most incisions end up being linear (*L*), even if they were planned to be angled (*A*)

- The trocar should be held at an angle (to the iris plane) not exceeding 20° (see **Fig. 21.5b**).
  - Trying to change the course of the entry vector midway into the act is a rational but rather futile effort. While an angled incision indeed has a higher chance of proper closure than a linear (straight) one (see **Fig. 21.5c**), the surgeon does not know how deep he has already penetrated the sclera and thus when to change course.
- An angle that is too shallow (<15°) is dangerous because it increases the risk of the tip of the cannula ends up in the suprachoroidal space (see below).

21.4 The Order of Cannula Placement

The globe must be pressurized the entire time; hence the general rule that *the first one in, and the last one out, is the infusion.* If the cannulas are not valved, the order of placement should be the following:

- At the onset of the surgery, the superior cannulas are not placed, and the *light pipe and the probe obviously are not inserted*, until the infusion line is connected and opened.
- At the conclusion of the surgery, the infusion line/cannula complex is not removed until the superior *cannulas have been removed and the wounds* are confirmed not to be leaking.

If the cannulas are valved, the three can be placed in any order[14], but the light pipe and the probe are not inserted until the infusion line is connected and opened (except when a sample for culturing is taken in [presumed] endophthalmitis). The conclusion of the PPV is identical to that described above.

- If the IOP is very low and the trocar for the infusion cannula is difficult to insert, inject BSS through the pars plana, connect, and open the infusion line before placing the superior cannulas.
- If combined surgery is performed (see **Chap. 38**), place the cannula for the infusion first. Connection of the line may be delayed until PPV commences so that it is not in the way. The two superior cannulas can be placed prior to the cataract surgery or after the infusion line has been opened.
- If AC manipulations are necessary, place the infusion cannula first but in most cases do not open it to avoid making the AC shallow. An AC maintainer or visco injection may also be needed.
- If the inserted infusion cannula cannot be visualized (see below),[15] connect the line but do not open it. If pressurization is needed, use an AC maintainer until the media have been cleared.

Once the infusion line is in place, tape it to the drape (see **Fig. 21.6**), especially if the eye is phakic. The tape should be close to the eye and leave enough slack so that during eye rotation the cannula is not pulled out: the risk is higher if the loop of the infusion line is too short. The cannula must point toward the midvitreous cavity so that it cannot, even during scleral indentation, puncture the lens capsule.[16]

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[14] Typically, I place the infusion cannula first but do not connect the line and then the superotemporal one because I do not have to exchange the hand holding the pressure plate; finally comes the superonasal cannula (see below, **Sect. 21.5**, the exception to this order).

[15] Significant hyphema, white cataract, severe vitreous hemorrhage etc.

[16] This is also important when silicone oil is implanted under air: you do not want the oil to coat the posterior lens capsule, but to drip straight down toward the posterior retina.

Fig. 21.6 Taping the infusion line to the drape. See the text for more details

21.5 If the Palpebral Opening Is Small

If the palpebral opening is narrow,[17] placing the cannulas can be technically difficult. When the superonasal cannula is about to be inserted, the eye cannot be rotated because the already-placed superotemporal cannula hits the eyelid, blocking the eyeball's movement. There are three possible remedies.

- Press down on the superotemporal cannula so that it slides under the lid.[18]
- Change the order of cannula placement: insert the superonasal one before the superotemporal one.
- Use the "double-trocar" insertion technique (see **Fig. 21.7**).

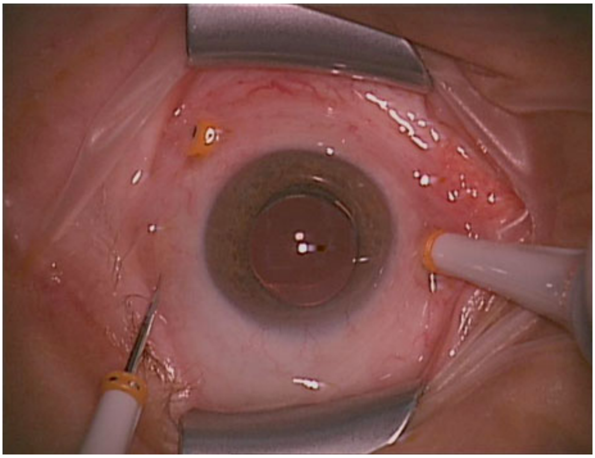

Fig. 21.7 The "double-trocar" insertion technique. Once the infusion cannula has been placed but before the infusion line is connected, the superonasal cannula is inserted, but the trocar is not withdrawn. The surgeon turns the eye nasally and uses the trocar itself to stabilize the globe as he inserts the superotemporal cannula

[17] May be compounded by the reduction of the orbital fat so that the eye is deep-seated; this is rather common in elderly patients.

[18] Later you will have to "fish it out."

Pearl

A narrow palpebral opening often causes an intraoperative problem too. As the eye is rotated, the lower lid can crimp the infusion line. You do not see this in the dark; only note that during vitreous removal, the eye collapses (you suspect the infusion bottle is empty). This may not be preventable since the eye must be rotated; simply stop and wait until the IOP normalizes.

21.6 Checking the (Infusion) Cannula

The consequences of suprachoroidal (occasionally even subretinal) infusion can range from the inconvenient to the extremely serious.

Q&A

Q *Can the VR surgeon actually kill his patient during surgery?*

A Yes. If F-A-X is performed and the infusion cannula is in the suprachoroidal space, the air can enter the bloodstream by tearing the choroid from the vortex vein ampullae. The air embolus will stop the heart.

21.6.1 Cannula Under the Choroid/Retina: Prevention

Even if it is "only" BSS that infuses the suprachoroidal space, it can rapidly lead to a choroidal detachment. To prevent this complication, the surgeon should do the following:

- Before the infusion is opened, the tip of the cannula must be checked.
  - A brief peek does not suffice. The choroid and ciliary epithelium may be depigmented[19]; the quick peek will not allow the surgeon to detect that something is covering the tip of the cannula.
- Even an initially properly placed infusion cannula may be but pulled out intraoperatively. It is easy to detect if the line is completely out but more difficult if only partially so.
  - Periodically check the position of the infusion cannula's external position (i.e., is it pushed into the cannula all the way?) during surgery, but especially during scleral indentation and before switching to air.

[19] Or appear to be so, due to tissue stretching.

- The position of the working-sclerotomy cannulas should also be checked. These do not represent the same danger, but iatrogenic damage can still be caused if they are partially out.

21.6.2 Cannula Under the Choroid/Retina: Management

If during the initial cannula insertion the tip of the cannula cannot be advanced all the way through the tissue, there are several options.

- Push a needle through the cannula itself; this will create a small opening in the choroid, which may slide back.
- If this does not work,[20] introduce another cannula, insert a needle[21] through that one, indent the sclera by pushing the first *cannula in, and slice open the tissue around* it so that you have a clear view of the tip. Once you created an opening, push the infusion cannula through it and then open the infusion and only then let the cannula, slowly, back into its normal position.

21.6.3 Infusion Going Under the Choroid/Retina: Management

If fluid did get under the choroid, the following usually restores the normal anatomy:

- Close the infusion immediately.
- Pull out the infusion line.
- Put the infusion line through another cannula – and check its position before opening it.
- Drain the suprachoroidal fluid through the infusion cannula.
  - If no fluid is coming or not all fluid has drained, pull out the cannula and enlarge the sclerotomy. Once the fluid has been drained, suture this sclerotomy and reinsert the infusion cannula at a different location.

Q&A

Q *Is it possible to drain suprachoroidal fluid internally?*

A In principle, yes; in reality, it is very difficult. The choroid shrinks when diathermized (see **Sect. 59.2**). If the pressure in the suprachoroidal space is high and the fluid not viscous (BSS, not blood), a simple needle/blade puncture may work.

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[20] It may not since the choroid is elastic, and the opening may immediately close.

[21] Bleeding is extremely rare from this. Do not use diathermy because it may shrink the tissue.

21.7 The Cannulas in Use

Ideally, the cannulas provide effortless and complication-free access to the vitreous cavity, remain in place until the end of surgery, and leave behind a self-sealing incision upon removal. Some of these are outside the surgeon's control, but he can help by observing the following:

- Since the cannula is placed at an oblique angle into the sclera:
  - The surgeon must insert all his instruments, and each time, at the same oblique angle to make the entry effortless and avoid stretching the sclera.[22]
  - The surgeon must withdraw all his instruments, and each time, at the same oblique angle to avoid pulling out the cannulas with the instrument.[23]
- With the infusion line, it is crucial that it does not point toward the macula or disc, especially during F-A-X. Especially if the air pressure is high, direct injury may result.

> **Pearl**
> A cannula that repeatedly gets pulled out during surgery is a signal that the sclerotomy will have to be sutured at the end.

Intraoperatively it may become unexpectedly difficult to reinsert a tool through the cannula. There are several potential reasons:

- The cannula is halfway out, which is invisible in the dark (see **Fig. 21.8**).
- The tool itself has some material (such as thread) stuck to it.
- The nurse handed over an instrument that is of larger gauge.
- A material the surgeon wanted to remove through the cannula got stuck (see **Fig. 21.9**).

21.8 The Removal of the Cannulas

The cannula is grasped with forceps (in the surgeon's dominant hand), while the upper lip of the wound is pressed down with an instrument (e.g., larger anatomical forceps) or the index finger of the surgeon's nondominant hand (my preference).

[22] Which would increase the leakage potential once the cannulas have been removed.

[23] There are other causes of inadvertently pulling out the cannula. Thin sclera; material stuck to the external surface of the instrument or the internal surface of the cannula (see below); a curved-tipped memory tool (such as laser probe) was not withdrawn into the shaft prior to tool removal; an outward bent hooked needle of the same gauge (see **Sect. 13.2.3.1**).

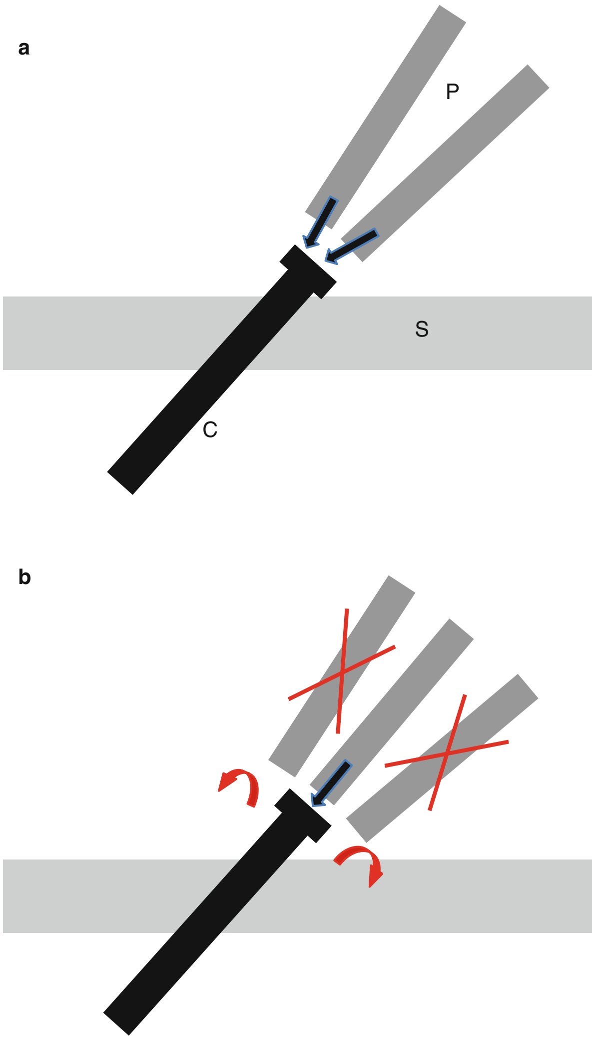

Fig. 21.8 Schematic illustration of the difficulty entering the eye through a half-out cannula. (**a**) If the cannula (*C*) is fully pushed in, the angle at which the probe (*P*) approaches the cannula is irrelevant as long as the angle remains within a reasonable range: the probe will easily slide in (*black arrows*) since the cannula will tilt once the instrument is inserted into it (it realigns itself with the tool). (**b**) If the cannula is partially pulled out, however, the probe can be inserted only if held exactly coaxial with the cannula. If approached at an angle different from the coaxial (0°), the cannula will keep tipping over (*red arrows*) until the coaxial direction is found or the cannula is pushed fully in. (I do this with my finger.) (The sketch is simplified, obviously even in the two unsuccessful attempts the surgeon would place the instruments over the cannula.)

Pressing down and gently massaging the site for a few seconds brings the wound lips together, preventing leakage and resulting in a normal IOP.

If the wound is not watertight, the conjunctiva becomes chemotic or air is seen bubbling under it (“emphysema”).

21.8.1 Hypotony: The Causes

In principle, the sclerotomy, being oblique and at a shallow angle, should be self-sealing: its lower (posterior) scleral lip (“flap”) is pressed against the upper lip by

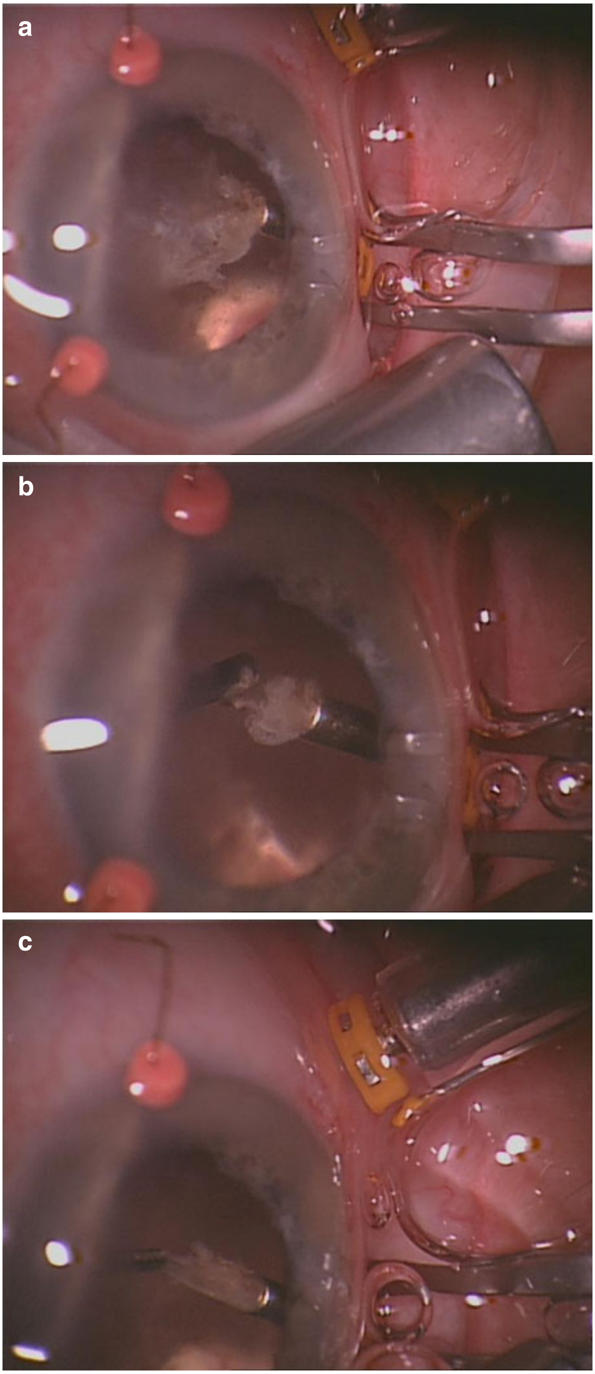

Fig. 21.9 **Scar tamponading the cannula**. (**a**) A large and hard piece of proliferative tissue is seen at the tip of the cannula. My intention was to remove the scar in one piece. (The probe is not the proper tool to chew it up: the tissue is hard and may not allow the probe biting into it, or does not have an attackable edge to feed into the port. Finally, even if the scar can be fed into the port, the scar may blunt the guillotine blade. The latter is dangerous because of the potential for traction if there is still vitreous left to be removed.) (**b**) I handed the forceps to the nurse, assuming that the scar was removed. I wanted to continue with the vitrectomy, but was unable to reinsert the probe into the cannula. The cause was the membrane, which was stuck in the tube; I used the probe from the other side to reduce the size of the scar. (**c**) The remaining stump is grabbed; it is now sufficiently stretched so I could remove it through the other cannula

the IOP, helped by a plug of gel vitreous, possibly air/gas. In reality, leakage can be expected in the following cases:

- Extremely efficient peripheral vitrectomy: there is no vitreous plug underneath.
- Very high IOP at the conclusion of surgery, which wants to normalize and is thus pressing fluid/gas outward. This can be caused by:
  - The high infusion pressure set on the vitrectomy machine.
  - External pressure on the eye by the surgeon's fingers or instruments.
- Thin sclera (high myopia, post-scleritis conditions, trauma etc.): the sclera does not have the structural strength to self-close.[24]
- Sclerotomy placed in the area of previous vitrectomy wounds or scleral scars of other causes.
- Silicone oil tamponade: as the cannula is withdrawn, the IOP forces oil droplets into the scleral channel, delaying the spontaneous closure.
- Long surgery where significant stretching of the sclera has occurred (see **Sect. 21.7** above).
- A sclerotomy that did not follow the course of the collagen fibers (i.e., is parallel with the limbus; see above, **Sect. 21.3**) increases the chance of insufficient wound closure.

If vitreous is incarcerated in the wound, it prevents leakage but increases the risk of endophthalmitis (see below, **Sect. 21.8.2**).

21.8.2 Hypotony: The Consequences

Low postoperative IOP can lead to:

- Hypotonic maculopathy.
- Intraocular bleeding (choroidal, retinal etc.).
- Miosis.
- Increased inflammation.
- Corneal edema and the folding of Descemet's membrane.

Contrary to popular belief (myth), endophthalmitis is not caused by hypotony.[25] Endophthalmitis, however, is a risk if vitreous is incarcerated into the wound and links the outside and inside worlds.

21.8.3 Hypotony: Prevention

- Proper wound architecture (see **Sect. 21.3**). If need be, use a suture (see **Sects. 14.6** and **63.5**).

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[24] The normal sclera does contain some elastic tissue to assist in its capacity to self-close.

[25] This would assume a negative IOP, sucking material into the vitreous cavity.

- Aim for an IOP of ~30 mmHg at the conclusion of surgery.[26]
- F-A-X: an air-filled eye is less prone to insufficient wound closure.
  – Conversely, the ciliary body may take longer to reach full aqueous production than it takes the air to absorb.
- Proper cannula withdrawal and wound “massaging.”
- If the hypotony is realized intraoperatively, suture the leaking wound and refill the eye with BSS or air/gas.
  – A single-loop suture is sufficient in most cases, even for 20 g wounds.
  – If silicone oil has been implanted, a special suturing technique is required (see **Fig. 14.3**).

21.8.4 Hypotony: Postoperative Management

- Inject air/gas/BSS with a 27 g needle through the pars plana.
- If the eye is filled with silicone oil, the fill is less than 100% (this is more of the problem, less the hypotony itself [see **Sect. 35.4.2**]) Only a reoperation suffices.

21.9 20 g PPV[27]

Only a few selected comments[28] are made here.

- Open the conjunctiva and Tenon’s capsule as a single layer.
- Make two separate openings, a larger one (~2 to 5 o’clock in the *left* eye) temporally and a shorter one (9–10 o’clock) nasally.
  – Grab and lift the conjunctiva with a toothed forceps and make a ~2 mm radial cut 1 mm from the limbus. If one such incision is sufficient per site, there is no need to do two. This will help when you suture it at the end of the surgery.
  – Do the incision in the most superior edge of the intended dissection area.
- Insert blunt scissors into the opening, keep it parallel to the surface, and bluntly dissect the subconjunctival space in an area larger than the incisions.
- Consider whether the bleeding vessels need to be cauterized.[29]
- Make the three sclerotomies with a 19 g MVR blade.
  – Technically, the 20 g blade should also work; however, it makes it very difficult to insert a blunt instrument, and also it increases the risk of iatrogenic choroidal detachment by forceful penetration efforts (see **Fig. 21.10**).

[26] Too high an IOP is just as problematic as a too low one (see **Sect. 21.8.1**).

[27] No transscleral cannulas are used.

[28] Based on my personal preferences.

[29] I had used to do extensive diathermy but then stopped unless a well-identifiable vessel caused a major bleeding or the patient had an increased tendency to bleed (see **Sect. 40.1**). The small hemorrhages soon stop spontaneously.

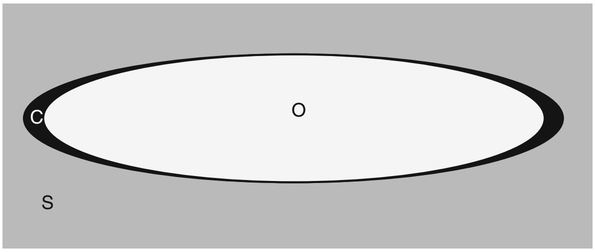

Fig. 21.10 **Schematic representation, seen from the surgeon's perspective, of incising the eyewall with an MVR blade**. The sclera is inelastic; the choroid is not. Even though it was the same-sized blade that penetrated both, the choroid's wound is shorter than the one in the sclera. This is not a problem unless the instrument is a blunt one with non-slanted tip (some light pipes are configured exactly like that (question to industry: why?; see the text for details)). The longer the incision (such as one to remove a larger IOFB), the greater the discrepancy between the length of the two de facto openings. In these cases, Vannas scissors needs to be used to cut the choroid at both ends to prevent loss of the IOFB at the incision or detaching the choroid if blunt instruments such as a non-slanted light pipe is forcefully pushed into the wound. *C* Choroid, *O* opening in the sclera and choroid: the actual sclerotomy, *S* sclera

  - The incision should be perpendicular to the limbus, to follow the course of the scleral collagen bundles (see above, **Sect. 21.3**).
  - If the eye has already been vitrectomized, only the sclerotomy for the infusion cannula is prepared, the two superior ones follow once the infusion cannula is in place and the infusion is open.
- The infusion cannula may be self-retaining or require a suture[30] to be held in place.
  - The suture may be preplaced, i.e., before the incision is made with the MVR blade. Especially if silicone oil is likely to be used, it makes sense to use a preplaced X suture (the suture is identical to that seen on **Fig. 14.3**), which in this case will be used to close the incision at the conclusion of the surgery.
- The infusion cannula should be normal sized (4 mm) unless it is difficult to visualize it or there is a bullous RD; in these cases, use a 6 mm cannula.

> **Pearl**
> The risk of iatrogenic lens damage greatly increases with a long infusion cannula.

- If there is a need to have a larger than 20 g incision,[31] a current one can be enlarged (the choroid must be separately enlarged; see **Fig. 21.10**) and then resized or a separate incision be prepared.[32] I prefer the latter option.

[30] 6-0 or 7-0 vicryl.

[31] e.g., to remove a larger IOFB.

[32] The original one is plugged until the fourth sclerotomy is sutured.

- Suturing of the 20 g sclerotomy requires a single, usually 7-0, vicryl suture, but it must be in the very center of the incision.
  - A sclerotomy, which was enlarged or is the last one to be closed and silicone oil has been used, should be closed with the X suture (see above).
- If silicone oil has been used, first irrigate the subconjunctival space thoroughly so that no oil is retained (see **Sect. 35.4**).
- Suture the conjunctiva with the same vicryl; try to stay further back from the limbus so that the suture stumps do not to irritate the cornea.
  - Do not make the knot too large.
  - Cut the suture so that the stumps are ~2 mm. This seems to cause less irritation than either shorter or longer ones.

Illumination

22

22.1 The Light Pipe

Typically held in the surgeon's nondominant hand, this light source is a very versatile one. The surgeon can influence the amount of light reaching the retina by changing the setting on the vitrectomy machine but also by changing the distance between the light pipe and the target area.[1] The distance also influences the field of illumination. The surgeon can also change the angle of the light emission,[2] enhancing the visibility of certain structures while "hiding" others. When using the BIOM, a wide-angle light pipe should be used.

The light pipe can be employed in three basic ways.

- *Direct illumination*: the light is shone directly on the area where the surgeon is working.
- *Indirect*[3] *illumination*: the light is shone behind or in front of the actual work area.
- *Transillumination*: the surgeon performs the scleral indentation with the light pipe itself.[4]

[1] The intensity of the illumination is proportional to the inverse square of the distance from the light source.

[2] A fine epiretinal membrane may be invisible under direct light but very visible with indirect light (see below); this can mimic the effect of the slit illumination.

[3] Also called retroillumination.

[4] This may be helpful in identifying a retinal break.

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During the operation the surgeon's attention is focused on the actions executed by his dominant hand; moving and monitoring the position of the light pipe are rather automated.

- The less experienced the surgeon, the closer he tends to hold the light pipe to the retina, dramatically increasing the risk of phototoxicity.[5]
  - It is *not* intuitive to keep the light pipe pulled back, close to the cannula. The light should be held as far away from the retina as consistent with still-adequate illumination. The surgeon must consciously monitor the light pipe's position and hold it at a safe distance.

Q&A

Q *How can the surgeon ensure that he is keeping the light pipe far from the retina?*

A By constantly reminding himself to do it – and by asking his nurse to do the same.

  - The power of the light on the vitrectomy machine should also be kept at the minimum level necessary to allow proper illumination; do not set the machine so that it is always on full power.

Pearl

Especially with older video cameras, there may a conflict between the needs of the surgeon (who can usually get by with less light) and the camera (which needs more light for a decent recording). Whatever the compromise, the safety of the patient is the decisive factor.

- During much of vitreous removal the surgeon works under partial retroillumination: the light is directed slightly anterior or posterior to the actual plane of the probe's tip. Some of the light he utilizes is reflected back from the eyewall (retina, choroid, even sclera), not the vitreous itself.
  - When vitrectomy is done in the periphery on the side where the light pipe is inserted, directly illuminating the vitreous is great to visualize it – but completely hides the retina underneath it. Safety demands that the surgeon alternates between direct and indirect illumination in this scenario.
- Direct illumination is used for vitreous removal some of the time and for retinal work most of the time (addressing membranes, performing laser etc.).
  - When the retina is directly illuminated, the working distance must be increased (see above).

[5] At a brightness of 8 lm, increasing the distance the light pipe is held from the retina from 4 to 8 mm multiplies (3–4×) the time needed to cause phototoxicity.

- During fine macular work the light should not be shone directly onto the macula itself. This is mostly because of the risk of phototoxicity, but also because the reflected light may be bothersome. I try to direct the light, holding it as far from the retina as possible, toward the perimacular area.
  - Even if the surgeon must illuminate the macular area directly, he must avoid shining the light onto the same area for more than a few seconds at a time.
- Under air, visibility worsens (see **Sect. 31.2**), even if the BIOM front lens is adjusted (see **Table 16.5**).
  - Fine details become impossible to discern; what was very obvious before is now invisible.
  - There is significant light reflection from the interface between air bubble and BSS/retina. It takes some time for the surgeon to find the most acceptable angle and distance of illumination,[6] and even that may be suboptimal.
- Although most of the time the light pipe is held in the surgeon's nondominant hand, under certain circumstances it has be switched over to the dominant hand. This switch may be mandated by the task (e.g., laser cerclage, 360° vitrectomy

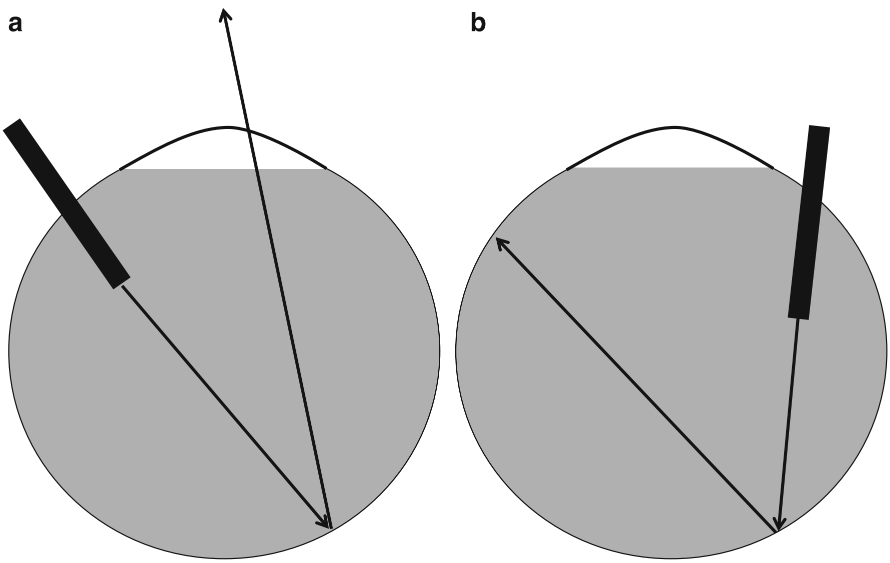

Fig. 22.1 Light reflected in the air-filled eye. (**a**) If the light is shone across the eye, the angle of the reflected light is such that it blinds the surgeon. (**b**) If the light pipe is moved onto the same side of the eye where the illuminated area is, the reflected light does not directly reach the surgeon's eye. This vastly improves his visibility

[6] Sometimes having to switch hands: the glare is worse, for instance, if the light is shone from the nasal side toward the temporal retina (see **Fig. 22.1**).

at the vitreous base in a phakic eye) or because it offers better visualization of certain structures (e.g., determining the size of an EMP, working under air on the opposite side of the light pipe; see above).[7]

22.2 Chandelier Systems[8]

The light is emitted from a device fixed at the sclerotomy. The options are the following:

- Incorporating the light into the infusion cannula.
- Stand-alone (independent; the much more commonly used version). It comes in a wide variety (single or dual fiber, twin, torpedo etc.).

Each of these devices is a stationary one, but they all allow some manipulation since the nurse can grab the extraocular portion (cable, tubing) and change the main direction of the illumination.

Regardless of type, these systems allow bimanual surgery. Use of a chandelier means that the light is much further away from the retina than it would be with the light pipe system, thereby greatly reducing the risk of phototoxicity – but at the cost of other potential disadvantages.

- Shadows cast by both working instruments.
- Light reflex (scatter, glare), which is more difficult to avoid than with a light pipe.
  - Using multiple light sources may compensate for these shortcomings, but, obviously, this requires using multiple sclerotomies, however small they are.
- The light fixture may be too far from the posterior retina to provide ideal illumination for fine work.

22.3 Light Built into the Handheld Instruments

The advantage of this option is that there is always light where the surgeon works – but the light may be too close to the retina for safety and comfort. Glare is another issue, as is shadowing. For these reasons, this option is rarely used nowadays.

[7] Which, naturally, means that the surgeon may be forced to use his nondominant hand for certain maneuvers; hence the need for at least some dexterity with this hand as well.

[8] May also be used in combination with each other and/or the light pipe.

23 The Checklist Before the First Cut with the Probe

Table 23.1 provides a brief summary of the items the surgeon should check before the onset of the actual operation. As mentioned before, this list does not mean that before each surgery every item on it must be check-marked such as a pilot would do before flying the airplane. Much of the preparation becomes routine with time; however, the checklist is necessary initially to establish that routine.

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Table 23.1 The previtrectomy checklist

Item	Comment	More details in
Surgical plan	If the case is of average difficulty, the plan can be finalized just prior to the operation. If it is expected to be more complex and difficult, the plan is best formulated the day before	**Sect. 3.1**
Arrangement of the OR	All major equipment, including the operating table, are in their desired position	**Chap. 16**
All cables and tubings are properly and securely connected; those linking the vitrectomy machine to the tools used by the surgeon are also fixed to the nurse's table so that they will not get in the surgeon's view	This includes the cables of the microscope and vitrectomy pedals (they are not caught underneath the pedals themselves or the wheels of the surgeon's chair)[a]	**Chap. 16**
The patient is properly prepared (anesthesia, medications etc.) and the correct eye marked for surgery	It is impossible to be too cautious about this	**Chap. 16**
Programming of the vitrectomy machine	If necessary, changed from the standard according to the expected actual situation	**Chap. 12, Sect. 16.3**
Checking that all necessary equipment, tools, and material are available and functioning	Including all from the microscope to the intravitreal forceps. Especially crucial for the surgeon is that he tests the vitrectomy probe (in addition to the testing [priming] done by the vitrectomy machine). A stuck guillotine blade can cause serious damage (aspiration without cutting), and discovering it inside in the vitreous cavity means it is too late The laser filter must be attached to the microscope but switched off/out until needed[b]	**Chap. 16**
Proper comfort for the patient	Comfortably lying while maintaining a head position that is ideal for the surgeon's access to all of the vitreous cavity	**Sect. 16.6**
Adjusting the microscope and the surgeon's chair according to the actual patient	Posture for the surgeon (height of the chair, distance from the operating table etc.). The chair's wheels are to be locked so that the chair cannot move as the surgeon's feet move	**Sect. 16.7**
Initializing the BIOM[c]	To ensure that the focus will need no readjusting unless F-A-X is required	**Sect. 16.5**
Final adjustment of the view through the microscope	The BIOM lens at a distance of ~2 mm from the visco-coated corneal surface and at a low zoom	**Table 16.3**

[a]This is why wireless pedals are so useful.
[b]Otherwise the colors inside the vitreous cavity are not realistic – neither for the surgeon nor for the video camera.
[c]Obviously, this requires the light pipe to be inserted into the vitreous cavity.

Using the Vitrectomy Probe

24

24.1 Removal of the Vitreous

The basic movements the surgeon makes with the probe are the following:

- Forward/backward (push deeper or withdraw along the same axis): closer to the posterior pole or to the sclerotomy.
- Around, 360° in the vitreous cavity, with the pivot point being at the sclerotomy site (see **Fig. 20.3**).
- Rotation, 360° around the axis of the probe's shaft.
- A combination of the 3. This is by far the most common occurrence.

While the positioning of the probe is done in a "semiconscious" way by the surgeon,[1] there are some caveats to remember, which help to reduce the risk of iatrogenic damage ththe probe may otherwise cause:

- The probe is not simply a port; its shaft must also be taken into account when maneuvering in the vitreous cavity. By concentrating only on the port (since this is the active ["useful"] part of the probe) the surgeon can easily forget that the shaft is also there, increasing the risk of "lens touch" during anterior PPV (see **Sect. 25.2.3.1**).

[1] That is, the surgeon focuses on the goal he wants to achieve with the probe, rather than on the placement of the probe so as to achieve that goal.

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- The angle between the probe and the retina changes according to where the probe is.[2]
  - The shaft is truly perpendicular to the retinal surface in certain areas on the opposite side of the disc,[3] although scleral indentation can also create the 90° angle (see below and **Sect. 28.2**). In the posterior pole the angle closely approximates being perpendicular. At all other locations, the angle is an acute one.
  - The shaft is parallel with the retina in the vicinity of the scleral insertion.
- The relation of the port's plane[4] to the retina varies with the shaft's angle, which in turn determines how vitreous or membranes are separated from the retina.
  - If the shaft is held at or close to a right angle with the retina,[5] the port cannot be turned so that it directly faces the retina.[6] If the probe is moved along (parallel to) the concave retinal surface, it is able to separate/cut/remove proliferative membranes safely (see below).[7]
  - Even in the posterior pole, however, this ideal situation is true in only a small area. The angle outside this relatively small circle starts to change, more rapidly on the side where the probe is (i.e., a nasally inserted probe maintains the close-to-right angle in a larger area temporally than nasally).
  - The smaller the shaft's is angle to the retina, the higher the risk that the rotation of the port toward the retina can result in iatrogenic injury: the probe can "bite" into the retina even if the vacuum/flow is very low and the duty cycle high. The implication when working in the periphery is an increased risk in the vicinity of probe insertion compared to that on the opposite side (see **Fig. 24.1**) – hence the suggestion to switch hands in the pseudophakic eye to complete the vitreous removal at the base.
- The surgeon must select the cut rate according to the demands of the actual situation.
  - A high cut rate increases the safety of vitreous removal when working close to the retina. However, with most vitrectomy machines it also reduces the speed of vitreous removal by keeping the port closed (no flow) a significant part of the time.
  - The increase in the cut rate also reduces the completeness of the removal of vitreous that is adherent to the retinal surface such as at the vitreous base.[8]

---

[2] The angle also depends, to a lesser degree, on the size and contour of the eye (see below).

[3] That is, on the nasal side if the probe is used through the temporal sclerotomy.

[4] Understood as a sheet laid over the port, across and perpendicular to the shaft.

[5] Such as in the posterior pole.

[6] The exception is a staphyloma in a highly myopic eye (see **Chap. 56**).

[7] Assuming the proper parameters have been set on the vitrectomy machine (see **Table 12.2**).

[8] Think about an object that is lifted with a rope: if you cut the rope, the object cannot be lifted. If the vitreous that is engaged by the probe via suction is instantly cut by the guillotine, at least some of the gel is left behind.

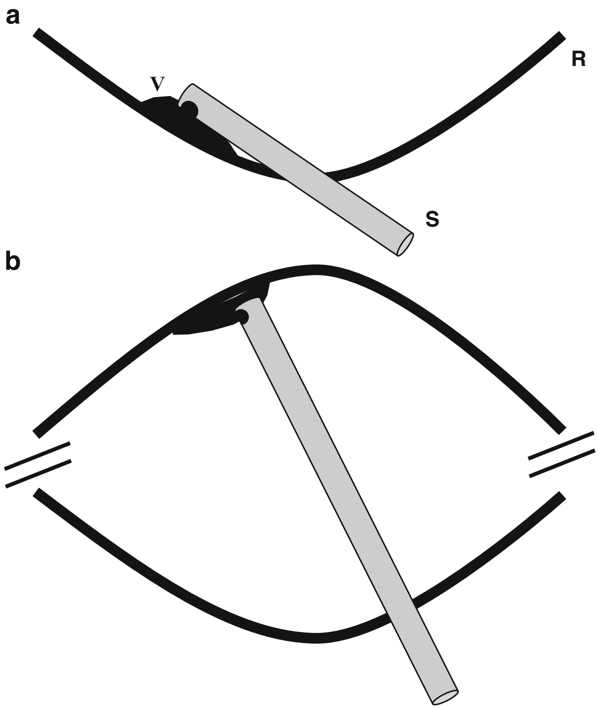

Fig. 24.1 **The angle of the probe's shaft and the risk of retinal injury.** (**a**) When the shaft (*S*) is held (close to) parallel to the retina (*R*), such as the case in the vicinity of the probe's insertion site, the port can be turned so that it faces the retina, increasing the risk of biting into it, rather than simply removing the vitreous (*V*) from the surface. (**b**) On the opposite side of the eyeball, the angle of the shaft is (close to) perpendicular to the retina. The port's plane makes it impossible to directly injure the retina (although injury is obviously possible if the retina is dragged into the port by the adherent vitreous). (This, however, completely changes if the sclera is indented; see **Fig. 28.1**.) In the posterior pole (not shown here) the angle is close enough to the perpendicular to mimic this scenario, allowing retina-parallel membranes to be cut by the probe if certain conditions are also met (see the text for more details)

The details of vitreous removal are given in **Chap. 27**.

Q&A

Q *What are the ideal parameters on the vitrectomy machine for fast yet safe vitreous removal?*

A This is impossible to determine unless the specific situation is known. There are many variables that need to be known: the distance of the probe's port from the retina; the position of the retina (attached or detached); the characteristics of the vitreous gel; the strength of adherence between vitreous and retina; the pump in the vitrectomy machine; the aspiration/flow rate; the duty cycle; the size, shape, and location of the port etc. (see **Sect. 12.1**). The surgeon must carefully experiment with his own machine and tailor his settings accordingly.

- Inexperienced surgeons often move the probe around constantly. This not only makes the operation longer but also potentially less safe.[9]
  - In most eyes and conditions the vitreous will "flow" toward the port from around the imaginary sphere surrounding the tip of the probe.[10] This can be called the "vitreous-to-port" technique. In such cases it is irrelevant whether the port is actually turned toward or faces away from the vitreous and whether the port is immersed in the vitreous or be held at some distance from it.
- In some eyes and conditions[11] the central vitreous gel has a stronger resistance/structure and will not allow being drawn into the port unless the probe is actually sunk into it; in such eyes the vitreous-removal time is dramatically longer since the surgeon must literally "go after" the vitreous. This can be called the "port-to-vitreous" technique.

The technique of vitreous removal is discussed in **Chap. 27**.

24.2 Removal of Proliferative Membranes

In 23 but especially in 25 and 27 g vitrectomy, the probe can also be used to cut and remove epiretinal proliferative tissues.[12] Low aspiration/flow and the highest possible cut rate should be used, and the shaft be held so that the port can be moved parallel to the retinal surface.

Pearl
In 20 g surgery different tools (scissors, forceps, spatula) and techniques ([visco-] delamination, segmentation) were used to cut, separate, and/or remove proliferative membranes. In small-gauge PPV, the probe can largely substitute for all these while also making the procedure faster, but the surgeon does sacrifice control to a certain extent. Scissors use provides the ultimate control, especially if a bimanual technique is utilized – but this requires greater dexterity and takes more time. Finally, remember that use of the probe does not reduce the risk of bleeding.

More details about dealing with proliferative tissues are provided in **Chaps. 32**, **52**, and **53**.

[9] Unless very high cut rates are used.

[10] This is true for the central vitreous gel but not for the still-attached cortex.

[11] Such as VMTS and PDR.

[12] As long as there is at least some space between the two tissues; this space is necessary even if the port is very close to the probe's tip (see **Sect. 12.1.2.2**). An EMP whose entire extent is adherent to the surface of the retina is thus impossible to remove with the probe.

24.3 Removal of the Retina

The probe may not be the safest tool to do retinotomy,[13] but it is the instrument of choice to do retinectomy (see **Chap. 33**).

24.4 Removal of the Lens

This is discussed under **Sect. 38.2**.

[13] If the flow (vacuum) is low and the port is turned away from the remaining retina, the probe *can* be used to do the retinotomy in the periphery, prior to the retinectomy. However, doing it without diathermizing the retina is playing Russian roulette: a major bleeding is always a threat (see **Sect. 33.1**).

Maintaining Good Visualization 25

The VR surgeon is exposed to various types of feedback.

- *Tactile* feedback is occasionally felt during intravitreal work, such as from a strong subretinal strand, but this has an insignificant role in tactical decision-making.[1] Pushing an instrument against the sclera (see **Sect. 33.3**) is also instantly felt by the surgeon.
- *Audible* feedback can be heard when the laser power is too high and the tissue "pops." Such a strong laser delivery is to be avoided because it can cause retinal bleeding or a rupture in Bruch's membrane, with the risk of secondary neovascularization.
- *Olfactory* feedback is possible if a very significant bleeding occurs on the ocular surface.

> **Pearl**
> All of the VR surgeon's tactical, and some of his strategic, decisions are based on visual feedback: appreciating the default situation and detecting the tissue reaction to his actions.

This all means that virtually the only type of feedback the VR surgeon[2] has of the consequences of his actions is visual.

---

[1] The decision regarding the location where the membrane/strand is to be grabbed or what direction to be pulled is still made based on the visual feedback from the site and behavior of the membrane.

[2] Unlike, for instance, a general or trauma surgeon.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_25

Maintaining the clearest view possible throughout the entire operation is thus crucially important for the VR surgeon. There are many elements to this puzzle, most of which is discussed below; this helps the surgeon find and fight the cause of suboptimal image clarity.[3]

25.1 External Factors[4]

25.1.1 The Microscope

Make sure that:

- You have adequate but not-more-than-minimally-necessary brightness.
- All optical surfaces are clean.
  - There is no fogging: condensation on the eyepiece because the surgeon is sweating[5] or the mask allows the exhaled air to be streamed onto it. For this reason, I wear the mask only over my mouth, not over my nose; another option is to tape it to the bridge of the nose.
- Adjust the focus to the needs of the video camera; then readjust the eyepieces so that each of your eyes has maximal sharpness (see **Sect. 12.4**).

25.1.1.1 The BIOM[6]

Make sure that:

- All optical surfaces have been cleaned.
- Both BIOM lenses have cooled off after sterilization (see **Table 16.5**).[7]
- All parts have been properly assembled and fixed onto the microscope.
- The focus has been set.
- The knob for the SDI, if it is to be set manually, is turned all the way.

25.1.2 The Contact Lens

Make sure that:

- The surface is not scratched.
- If the lens is reusable, it is completely transparent.[8]

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[3] With most items on this list, the solution to the problem is obvious; where it is not, a solution is proposed.

[4] In addition to all that is listed here, be sure that the patient's head is properly positioned (see **Fig. 16.5a**).

[5] Perspiration can occur even when the OR temperature is low (see **Sect. 16.10**). This, incidentally, enhances the condensation risk.

[6] See more in **Sect. 16.5**.

[7] This problem can be eliminated by the disposable BIOM.

[8] Repeated sterilization can cause irreversible reduction in light transmission.

- The lens is properly centered on the cornea. If the lens slides, the image may get distorted and the visual field reduced.
  - If the area to observe is slightly off-center, move the contact lens in the opposite direction of the area desired to be viewed.[9]

25.1.3 The Corneal Surface

Make sure that:

- The corneal epithelium is not edematous.
  - If it is, placing a piece of cotton saturated with 40% glucose is sometimes able to reduce the edema. This may also help with stromal edema.
  - If the edema persists, the epithelium may have to be scraped (see **Table 45.3**).
- In the presence of edema, all intraocular instruments look "foggy", with ill-defined borders.
- The visco is evenly distributed[10] and covers the entire surface.
- There are no air bubbles, however small, on the visco surface.

Q&A

Q *What is the correct technique of scraping the corneal epithelium*?

A Use the hockey knife, which is ideally angled and has just enough sharpness. Start from the corneal epicenter and move in a centrifugal direction first. Once you have a small denuded area, move toward it from all directions – avoid returning to areas that already have been scraped. Do not wet the cornea until you are done – it is easier to see the denuded area if it is dry. Do not scrape more than you need to, and avoid the corneal margin (close to the limbus). Do not leave loose epithelium behind.

Pearl

Air bubbles in the visual axis can cause major interference. The more anterior the bubble, the more it interferes with visualization: the same size of air bubble is more bothersome if it is on the surface of the visco than behind the lens capsule.

The cornea rapidly dries: this is why we blink every ~5 s and why it is highly advisable to use visco during vitrectomy. Requiring the nurse to "squirt" the cornea ever so often is cumbersome, may cause fluid droplets to splash back and smear the BIOM front lens, and increases the risk of corneal edema, which in turn may require scraping.

---

[9] Move the lens toward 6 o'clock if what you want to increase the field of view toward 12 o'clock.

[10] A surface-coating visco is preferable; if a cohesive visco (e.g., Healon) is used, a drop of BSS on its surface helps smoothen it.

25.1.4 The Corneal Stroma

The following abnormalities can lead to decreased light transmission.

- Stromal edema due to a posteriorly still open wound.
  - Corneal wounds of the injured eye should be closed with full-thickness sutures (see **Sect. 63.4**).
- Elevated IOP.
  - The high pressure can lead to not only epithelial but also stromal edema. If the edema is not long standing and the IOP is normalized, the cornea may "dry out" rather fast.
  - Corneal bloodstaining.[11] In the presence of significant hyphema and elevated IOP, the blood actually penetrates the cornea proper. If VR surgery becomes necessary, the only options are TKP-PPV (see **Sect. 63.10**) or EAV (see **Sect. 17.3**).
- Low IOP may cause folds in Descemet's membrane. Inflating the AC with visco can be helpful, but this requires the presence of the crystalline or artificial lens with intact zonules.

Q&A

Q *In eyes with severe hyphema, at what IOP should the blood be evacuated to prevent corneal bloodstaining*?

A There is no magic number regarding the IOP value as the risk also depends on the duration of the pressure elevation as well as on the "tolerance" of the individual patient's endothelium. My general suggestion is to remove the blood from the AC if, even on maximal topical/systemic antiglaucomatous therapy, the IOP exceeds 30 mmHg for 3 days. Err on the side of being too "aggressive."

25.2 Internal Factors

25.2.1 AC

Several materials can interfere with light transmission:

- Blood (see above and **Chap. 47**).
- Pus or fibrin (see **Chap. 45**).

[11] Imbibition is a much more accurate term: the intracameral blood actually penetrates the stroma, not just stains the endothelial surface. The blood can take several months to spontaneously clear and prevent proper visualization of all posterior structures.

- Visco: whether being left over from cataract surgery or used to keep silicone oil from prolapsing into the AC (see **Fig. 14.5**), it can interfere with visualization if it is uneven or contains air bubbles.

25.2.2 Pupil

The BIOM represents a huge advantage over the contact lens by allowing adequate visualization of the retina even if the pupil is small. Still, a wide pupil has tangible benefits for the surgeon. There are several methods to achieve pupil dilation on the operating table if the preoperative medication has been ineffective or the drugs used during general anesthesia caused secondary miosis.

25.2.2.1 Mechanical Forces Preventing Pupil Dilation

- A fine retropupillary membrane or fibrin may be the culprit. In such cases, gentle pulling on the iris margin with forceps (see **Fig. 48.1c, d**) or blunt dissection with a spatula may help. The surgeon must carefully observe how the tissues behave to avoid tearing the iris or rupturing the anterior lens capsule if posterior synechia is present, and switch to a sharp instrument if there is a risk.
  - A retroiridal fibrinous membrane is dangerous to forcefully pull on since the surgeon has no visual feedback about the consequences of his action until it may be too late.
- If fresh posterior synechia are present (see **Sect. 39.4**), usually a blunt spatula is utilized to break it. However, especially after trauma, it may be preferable to use scissors and cut the tissue responsible, sometimes preceded by endodiathermy[12] to prevent bleeding.[13] Limited amounts of visco can be injected to create space for the scissors between the iris and the capsule or control the bleeding.

Pearl

Never inject visco under the iris in order to try to break posterior synechia or separate a fibrinous membrane from the iris back surface: by doing so, you simply give up control over events (see **Sect. 3.2**). The visco will go wherever the resistance to its flow is the weakest, tearing some tissue (where *it* wants to, not where *you* would prefer it to) or disappear posteriorly.

25.2.2.2 Intracameral Adrenalin or Visco

If it is not synechia or a membrane (see above) that prevents iris dilation, intracameral adrenalin[14] usually works. Repeated injections of the drug, however, do not

[12] The blood vessels may be present on either surface of the scar or inside it, hidden from view.

[13] As a general rule, the more chronic (old) the synechia, the greater the need to use sharp, rather than blunt instruments.

[14] In a concentration of 0.01%.

help: the effect is typically one time. In older patients adrenalin occasionally *constricts*, rather than dilates, the pupil.

Visco may dilate the pupil and keep it so, but may also interfere with visualization (see above, **Sect. 25.2.1**).

25.2.2.3 Iris Retractors[15]

These are very potent weapons to widen the pupil and keep it wide throughout the case, and they can be used even in the phakic eye. A few caveats are worth mentioning.

- The angle at which you created the paracentesis with the needle[16] is crucially important. The retractor is too delicate to allow substantial modification to its trajectory once you pushed it past the intracorneal channel you just prepared.
  - When you create the channel, keep in mind the parallaxis phenomenon. Viewing from above, the instrument inside the AC gives the false impression that the tool is at a shallower angle (closer to the cornea) that it really is. Compensate for this when deciding the angle of penetration.
- Do not use toothed forceps to grab the retractors.
- Upon insertion, hold the retractor close to its hook (the working end) to avoid bending it. Never grab the hook itself.
- Keep the disc on the retractor close to the proximal (nonworking) tip of the retractor, never at the distal end: not all retractor types allow reinsertion of the shaft into the disc if it has been accidentally pulled off.
- Save time by creating all[17] paracenteses first, then place all retractors on the conjunctiva, and finally insert them.[18]
- Once the retractor is at the iris margin, you can slide the little hook laterally in either direction, with the paracentesis as the fulcrum point, before actually pulling the iris with the hook.[19]
  - If it is difficult to catch the iris margin, use the neighboring paracentesis channel and insert a second retractor, lift the iris, hook the iris there with the first retractor, and then slide it to place. Otherwise do not lift the iris until all (4) retractors are in place.
  - Weak posterior synechiae can be broken by the retractor, but a strong one or a retroiridal fibrinous membrane may prove too strong for the hook (see above), which straightens rather than lifts the iris margin.

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[15] See **Sect. 39.1** about the rules of paracentesis.

[16] If for retractor use, I prefer making the paracentesis with a 25 or 27 g needle instead of a blade.

[17] It is not always necessary to insert all 4 (or 5, since certain manufacturers supply 5 in the box) retractors. Plan the number and location in advance and use the fewest possible.

[18] Collect them in the same way upon removal; then hand back all of them together to the nurse, rather than doing it one by one.

[19] In other words, it is not necessary to hook the iris at the exact location where the retractor first caught it.

- The goal is not to have a perfectly shaped opening (e.g., a square) but one that gives adequate access to the posterior segment.
- Upon removal, unhook the retractors before pulling them out. Never grab the retractor between the hook and the disc but distal to the disc to avoid pulling the disc off.

25.2.2.4 Iris Ring

There are several ring designs.[20] They all provide for a stable iris, but the degree of dilation depends on the design.[21] The rings are also somewhat cumbersome to insert and remove.

25.2.2.5 Iridotomy

If *all* else fails and the surgeon must have a wide pupil, he can cut the iris with scissors.

- A few longer cuts can be made at the most appropriate locations.[22]
  - As described above, visco can used to create space for the blade of the scissors.
  - Use 20 g scissors with long blades.
  - As needed, the iridotomies can be sutured later (see **Sect. 48.2.2**).
- Several "mini" cuts can be made at the pupillary margin.
- This can be achieved with smaller-gauge scissors.
  - If the sphincter is cut, the pupil may remain wide open. If such an iris needs to be sutured, the iris purse string (cerclage) suture may be the best option (see **Sect. 48.2.3**).

25.2.3 Lens

25.2.3.1 Cataract

The most common cause of preexisting visual interference, cataract can be minimal enough so as not to require removal. Alternatively, it can be removed in a prior procedure or during PPV if, despite prior expectations, it proves to be too much of a hindrance (see **Chap. 38**).

25.2.3.2 "Feathering"

This type of temporary, intraoperative lens opacity is a rather unique one, occurring intraoperatively in some patients,[23] especially if the operation is long. It is bothersome but rarely so much as to seriously interfere with surgical success.

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[20] Malyugin ring (Microsurgical Technology, Redmond, WA, USA); Morcher Pupil Dilatator (Morcher GmbH, Stuttgart, Germany); Beehler Pupil Dilator (Moria SA, Antony, France).

[21] It is not adjustable such as with the retractors.

[22] Where the adhesion of the iris is strongest to the lens.

[23] Usually in older people.

25.2.3.3 "Gas Cataract"

It is a condition very similar to feathering, but is seen postoperatively, in the presence of intravitreal gas. It rarely persists but may justify lens removal if early reoperation is needed.

25.2.3.4 "Lens Touch"

An inexperienced surgeon[24] is especially at risk of bumping the probe or the light pipe into the lens. This leaves an imprint in the posterior cortex, visible as a linear opacity, whose size is determined by the area of contact.[25]

- The opacity is restricted to an area small enough so as not to seriously interfere with visualization.
- If the lens touch is really just that,[26] it rarely turns into cataract and can therefore be left alone. The opacity usually disappears in a few days.
  - Unfortunately, some surgeons also call a true bite into the lens capsule a lens touch. The difference is that in this case cataract is inevitable. Since the protective vitreous "cushion" is missing, the lens can swell rather fast, especially in children (see **Table 41.2**). The cataract is accompanied by a fast and significant IOP elevation.
  - If a lens bite occurs, it is best to remove the cataract during the same setting.

25.2.4 IOL

There are several ways the capsule/s and the IOL can interfere with visualization.

25.2.4.1 Phimosis of the Anterior Capsule

Constriction, and subsequent opacification, of the anterior capsule is rather common with certain types of IOLs.[27] In the presence of these conditions, the visual field may be too small for the VR surgeon to view the periphery.

- Through a temporal paracentesis, use scissors[28] to make several radial cuts in the capsule, and then the vitrectomy probe to remove the capsule in-between the cuts.
  - It may be necessary to make two paracenteses if scissors are used and the capsule needs to be cut 360°.

---

[24] Although it occasionally happens even to experienced surgeons.

[25] Obviously, the width is determined by the gauge of the instrument. The linear opacity on one end points toward the sclerotomy where the instrument was inserted.

[26] The posterior capsule is not broken.

[27] Such as hydrophilic acrylic, biconvex lenses. This is why the capsulorhexis should be at least 4 mm in diameter.

[28] The capsule is usually too strong and rigid and offers no edge, for the probe to directly bite into.

– If the capsule is too strong for the probe to bite into, the surgeon can try a bimanual method: holding the capsule with forceps and complete the cutting with scissors.[29]

Pearl
If you are using nondisposable scissors, consider the damage the strong tissue (capsule, membrane) will do to the blades. The scissors are very expensive and so is the sharpening of a blunted blade.

A phimotic anterior capsule can also twist an IOL and cause a true subluxation, which is an additional element in the loss of proper visualization (see below).

25.2.4.2 Deposit on the Anterior IOL Surface

Cells, dried blood from an old hemorrhage, fibrin etc., can collect on the IOL surface and prevent adequate visualization of fine posterior-segment structures. There are several ways to deal with this.

- AC irrigation with the jetstream directed toward the IOL surface.
- Vacuuming: the probe's port is turned downward, and at high vacuum/flow the material covering the IOL is aspirated without activating the cutting.
- "Window cleaning" (see **Fig. 25.1**).
  - Make a 20 g paracentesis temporally.
  - Take a 23 g crocodile forceps and a very small piece of cotton[30] from a cotton-tip applicator.

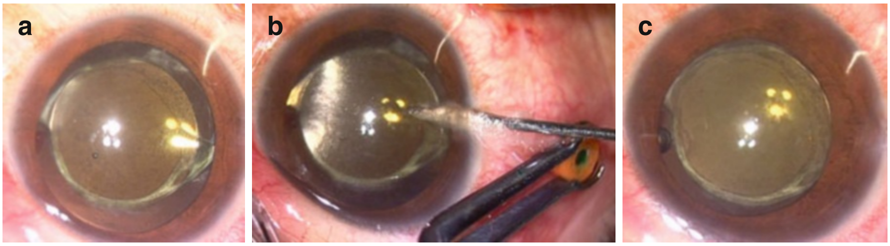

Fig. 25.1 **"Window cleaning" of the IOL surface.** (**a**) The anterior surface of the implant has numerous deposits, severely interfering with visualization of the posterior segment. (**b**) A 23 g serrated forceps, with a small piece of cotton in its jaws, is inserted into the AC through a 20 g paracentesis. A cannula forceps is used to atraumatically secure the eyeball during insertion. (**c**) The anterior IOL surface has been cleaned and the debris irrigated

[29] Alternatively, consider using a larger gauge and try to reduce the cut rate to a few hundred cpm.

[30] Only enough to wrap the jaws; otherwise, it will be difficult or traumatic to push the forceps into the AC.

– Wrap the jaws of the forceps with the cotton while it is still *dry*.[31]
– Dip the forceps into BSS so that the cotton is completely wet and gently push the cotton-wrapped forceps into the AC.
– Insert a long, curved, blunt spatula into the vitreous cavity from the nasal sclerotomy.[32] The spatula will serve as a counterforce and support the IOL during the AC manipulations.
– Gently wipe all deposits off the IOL surface. Do not push downward with the forceps too hard,[33] and try to coordinate your movements: push up the IOL with spatula exactly where the forceps pushes it down and with the same force.

25.2.4.3 Problems with the IOL Itself

- After a too-high-power YAG capsulectomy, there may be small impurities in the optic itself. Depending on their extent, they can cause minor or very severe visual interference.
  – Occasionally the only option is to remove IOL.
- Multifocal IOL. It may prevent having a sharp image of the macula.
  – These lenses are quite expensive, and unless the patient is also bothered by it,[34] the surgeon must try to work around the problem and complete his VR task even if visibility is suboptimal.
- The edge of the IOL may be visible if the pupil is really wide or if the IOL is subluxated.
  – If the IOL is in normal position, the surgeon must live with the problem and work in the periphery by alternatively viewing the retina through or outside the optic of the IOL. Because of the parallaxis, the image of the retinal area just viewed may suddenly disappear or an intravitreal tool's shaft apparently split, its straight course broken; this is a problem mostly encountered during panretinal laser treatment (see **Sect. 30.3.2**).
  – If the IOL is subluxated, the surgeon may try to reposition it.[35]

If combined surgery is performed, the surgeon may consider delaying the IOL implantation until all retinal work is finished so as to avoid some of the issues detailed above.

25.2.4.4 Fluid Condensation

After F-A-X fluid condensation (fogging) may occur on the back surface of the IOL in the area of capsulectomy (see **Chap. 31** and **Fig. 25.2**).[36]

[31] Once the cotton is wet, it becomes impossible to use it for wrapping.

[32] The anterior vitrectomy should have been completed beforehand.

[33] To avoid tearing the zonules or dislocating the IOL.

[34] I was asked to remove such lenses on a number of occasions.

[35] If the subluxation gave a lot of complaints to the patient, removing the IOL and replacing it with another one should be discussed preoperatively, during counseling (see **Sect. 5.2**).

[36] PFCL in an air-filled eye causes the same problem (see **Sect. 14.4**).

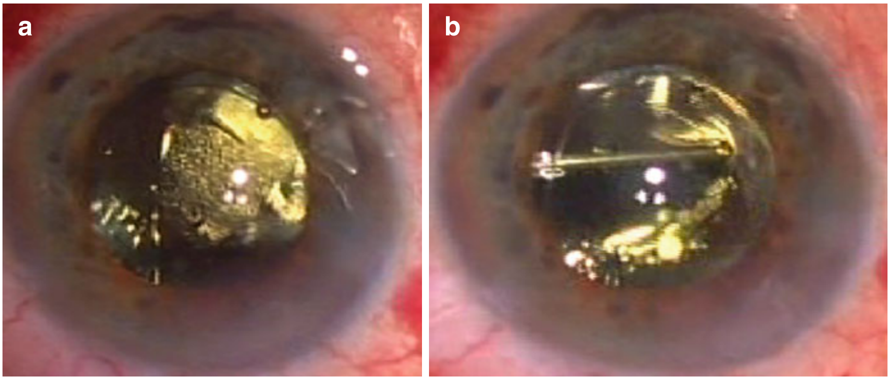

Fig. 25.2 **Condensation on the IOL in the area of the posterior capsulectomy.** (**a**) The already-poor image of the retina in the air-filled eye is further deteriorated by fluid condensation in the area of the posterior capsulectomy. (**b**) A tiny film of dispersive viscoelastic is spread over the IOL back surface. The use of too much or cohesive type of visco must be avoided as it would also cause distortion of the view (making the visco film too thick or uneven)

25.2.5 The Posterior Capsule

It is advisable to always do a capsulectomy in the pseudophakic eye to avoid intra-operative interference (for the surgeon) and postoperative interference (for the patient, see **Sect.** 4.5). Rarely, however, such a capsulectomy may bring undesirable consequences.

- Fogging during F-A-X, see above.
- If silicone oil needs to be implanted and the eye has a silicone IOL implant,[37] the oil will stick to the lens.
  – I use a forceps wrapped in cotton (see **Fig.** 25.1) and push the oil away from the center, toward the edge of the IOL where it is less visible; removal of the oil is virtually impossible.

25.2.6 The Vitreous Cavity

Dealing with materials such as blood and pus are obvious indications for PPV and are discussed in various chapters in **Part V**. The only issue mentioned here is *Schlieren*: draining thick (old) subretinal fluid internally temporarily interferes with visualization until the viscous fluid is cleared from the vitreous cavity.

> **Pearl**
> The subretinal fluid can be so viscous that passive aspiration with the fluid needle is ineffective. Active aspiration is needed, preferably with the probe because even the cutting may have to be activated (see **Sect.** 31.1.2).

[37] Shockingly, some cataract surgeons still use silicone IOLs because they are less expensive.

25.2.7 Epiretinal (Subhyaloidal) Materials

In addition to blocking the view of the underlying tissues, the settling on the retinal surface of blood or pus can be harmful, requiring its removal. If the posterior hyaloid is still attached, simply creating a PVD may be enough to lift the material off. If a PVD has already occurred, the technique is different.

25.2.7.1 Blood

If the blood is *liquefied*, the flute needle is the most natural choice for evacuation since its port is facing forward.[38]

- Keep the port over the pool of blood, lift your finger, and patiently wait for the blood to drain.
- If there is no drainage, you are probably too far away: carefully dip the tip into the blood itself.

Pearl
If the liquid blood does not evacuate even when the flute needle's port is sunk into it, either the needle or the silicone tubing is blocked, or vitreous remains over the blood (no PVD).

- You can also try to "back-flush" the blood away from the retinal surface.

If the blood is *clotted*, it can be very adherent to the retina.[39] It is best lifted using the probe, but keep in mind that a fragile retina may tear and/or the bleeding may recur. The clot is then cut with the probe, which temporarily mimics the appearance of a fresh bleeding.

25.2.7.2 Pus

In most cases, the pus is adherent to the retina. A vicious circle may be created: the surgeon does not remove the pus because he is afraid that he may injure the retina (see **Chap. 45**). However, the pus itself damages the retina, increasing the need for pus removal. It is true, though, that pus removal from a retina injured by the infection requires extra caution.[40]

- Use the probe only if it is held over the pus; never sink it into the purulent material.
  - The chance of success with this technique is rather low.

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[38] However, the probe can also be used. Typically it is sufficient to aspirate *over* the pool of blood. If the drainage is poor, immerse it *in* the blood, but be careful not to push the probe too deep into the blood so as to avoid injuring the yet-invisible retina.

[39] Commonly seen in diabetics.

[40] The technical difficulty is exacerbated by the presence of the cortical vitreous. The first step is thus the creation of a PVD.

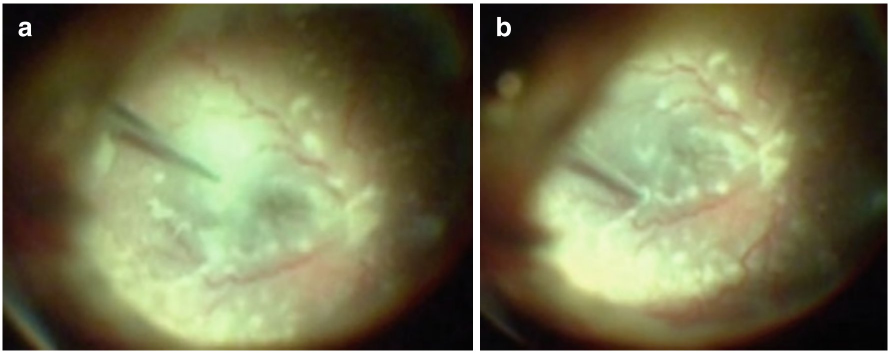

Fig. 25.3 **Evacuation of pus from the macular surface.** (**a**) The flute needle is placed just on top of the pus accumulation, then carefully sunk into it. (**b**) When the drainage is completed, the damage to the retina by the infection is even more obvious. The image seen here easily explains why pus must not be left on the macular surface

- Place the flute needle first *over* (**Fig.** 25.3), then, if this first attempt did not bring drainage, carefully *into*, the purulent material.
  - The material is not simply fluid; therefore very cautious mechanical "nudging" may also be necessary. The soft tip is a good option to do this with, but it will not allow drainage: its internal diameter is too small and the material too sticky.
  - Be patient; often the drainage process needs to be suspended and then taken up again later during the operation.

25.2.8 The Surgeon's Actions

The eye is rotated by the surgeon during much of vitrectomy. The inexperienced surgeon may not coordinate the movement of his two hands properly, which can result in corneal wrinkling, which in turn reduces the sharpness of the image (see **Sect.** 20.2). The microscope must precisely and simultaneously follow the eyeball (see **Sect.** 16.7.2).

- Make sure you coordinate the movement of your hands when rotating the eyeball.
  - The most common error is to move the eye in one direction with that hand (e.g., to the right with the right hand) and not properly follow it with the other (left) hand.
- Highly myopic eyes have a higher tendency for corneal wrinkling.
  - Occasionally the eye is too long for the probe to reach the posterior pole (see **Chap.** 42); in such cases, it is unavoidable for the eyewall to be pushed in, which may interfere with the image quality. The interference is more conspicuous if a contact lens, rather than the BIOM, is used.

25.2.9 "Chromovitrectomy"

Finally, the issue of the surgeon's visual aids must be mentioned. Their use is often referred to as chromovitrectomy; these materials help the surgeon delineate tissues that otherwise would be impossible or difficult to visualize. These are discussed in **Chap. 34**.

Anatomy and Physiology: What the VR Surgeon Must Know

26

26.1 Internal Ocular Anatomy and Physiology[1]

The vitreous, bordered anteriorly by the lens, the zonular apparatus, and the ciliary body and posteriorly by the retina and optic disc, constitutes the largest volume[2] (~4 ml) of the eye.

26.1.1 Vitreous Macroanatomy

- The *vitreous base*[3] is a several mm thick, three-dimensional ring, extending up to 2 mm anteriorly and up to 3 mm posteriorly from the ora serrata.
  - The collagen fibers of the vitreous are interconnected with those of the retina here, making the separation of the two tissues impossible.
- *Weigert's ligament* is a disc, 8–9 mm in diameter, connecting the gel to the posterior lens capsule. Only in the epicenter is a small space left between the two tissues (Berger's space).
- *Weiss ring* is a condensation of the vitreous gel's collagen fibers at the margin of the optic disc. If it detaches, it becomes visible in the vitreous cavity as mobile, truly ringlike structure (see **Fig. 27.3**).
- The outermost part of the gel is called *vitreous cortex*, consisting of densely packed collagen fibers. The anterior part (anterior hyaloid membrane/face) is located anterior to the vitreous base; the part posterior to it is called the posterior

[1] Only the minimally necessary information is provided here; more details are found in textbooks on VR surgery, ocular anatomy, and physiology.

[2] The total volume of the eye is 6.5 ml.

[3] The clinical implications of conditions shown in *italics* here are discussed in **Table 26.1**.

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cortical vitreous. The anterior cortex is 2 μ thick; the posterior is 100 μ. There is no cortex over the optic disc.

- The anterior hyaloid face adheres to but is not interconnected with the posterior lens capsule.
- The posterior hyaloid face is also adherent to (typically not interconnected with) the posterior retina, but is glued to it by an extracellular matrix.
- The posterior adherence is stronger than elsewhere at the margin of the macula or the parafoveal area, along the major blood vessels, in areas of certain retinal degenerations,[4] and especially at the margin of the optic disc (Weiss ring; see above).
- Both the anterior (to the lens) and posterior (to the retina) adherences weaken with age, but pathologic connections may develop posteriorly at the sites of chorioretinal scars, which can be caused by various diseases, injuries, or even overly strong laser spots.

• The *premacular bursa*[5] is an optically empty, fluid-only space measuring 7 mm in width and 0.6 mm axially, which also connects to the area of Martegiani[6] in front of the optic disc. The superior extension of the premacular bursa fuses with Cloquet's canal and courses through the vitreous, terminating behind the lens.[7]

26.1.2 Vitreous Biochemistry and Its Anatomical and Functional Implications

The vitreous is composed of ~98% water; the rest is made up of collagen fibers (mostly, but not exclusively, type II), hyaluronan, and many other molecules such as chondroitin sulfate, as well as a relatively small number cells (hyalocytes and fibroblasts, see **Table 26.1**).

The "normal" vitreous is entirely in a gel state: there is no free water content. For the gel to remain so and fill the vitreous cavity completely, both the collagen fibers and the hyaluronan are essential. Without the former the vitreous becomes a viscous fluid; without the latter, it shrinks.

With time the vitreous gel starts to break down; as early as at 4 years of age, the process of *syneresis*[8] begins. The normal collagen-hyaluronan relationship breaks down and free fluid (aqueous) appears in these lacunae. In a person 18 years old, up to a fifth of the vitreous is liquid.[9]

Aggregated collagen fragments are "swimming" in the lacuna fluid, casting a mobile shadow on the retina, and giving rise to what many people describe as "flying flies."[10]

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[4] Such as lattice.

[5] Also known as posterior precortical vitreous pocket.

[6] Also called cisterna preoptica.

[7] Berger's space; also known as patellar fossa or the space of Erggelet.

[8] Also called liquefaction; see **Fig. 26.1**, **Chap. 27** and **Fig. 54.2d**.

[9] See **Fig. 54.1** about the significance of changes in the structure of the vitreous.

[10] Commonly referred to in textbooks as mouches volantes.

Table 26.1 Selected anatomical and functional features of the eyeball and their clinical implications*

Feature	Clinical implication
AC depth	Primarily determined by the corneal contour but maintained by the aqueous, it quickly reforms if the corneal wound is not gaped. This is one of the reasons why a prolapsed iris should be pulled, not pushed, back into the AC
Extraocular muscles insertion into the sclera	This is the line posterior to which the surgeon must be extremely careful not to penetrate the sclera with a needle[a]. The difficulty of the suture placement is due to thinness of the sclera and to the curvatures of the sclera and the needle mirroring, not mimicking, each other
ILM	This is the only part of the retina that is inelastic, which explains the high success rate of ILM peeling in eyes with a posterior RD in a highly myopic eye. The ILM also provides a scaffold on which cells can proliferate – hence the sparing of the ILM-denuded area if reproliferation occurs in PVR and the lack of EMP recurrence after ILM peeling
IPM	The glue between the neuroretina and the RPE does not reform intraoperatively. If, during PPV, the retina is reattached by F-A-X but then the BSS is reinjected, the retina will redetach again in the area of the previous detachment
Long posterior ciliary nerve	To prevent damaging the nerve and thus cause iatrogenic mydriasis, fewer and lighter spots during laser cerclage should be delivered in the horizontal meridians
Macula	Traction on the macula by an anomalous PVD gives host to numerous conditions ranging from VMTS to edema
Optic disc	Over 100 million nerve fibers are packed into a very small area[b]; this is where the surgeon can do the most damage if he is not careful. An obvious example is diathermy for a bleeding vessel in PDR: sufficient distance must be kept from the disc and the power of the diathermy lowered to the minimum
Pars plana	The external anatomical landmarks are important to remember since this is the only safe area through which the vitreous cavity can be accessed
Pars plicata	It is crucial to be cleansed of vitreous, fibrin, membranes, capsular remnants etc. in eyes with severe trauma or proliferation (PVR, PDR)
Posterior pole	The most valuable part of the retina. The surgeon may need to sacrifice the more peripheral retina[c] for it in diseases such as (recurring) PVR
Premacular bursa	A structure that is not directly visible to the surgeon intraoperatively. Preoperatively, it may be demonstrated by OCT
PVD	A very often misused term, referring to the separation of the posterior hyaloid face from the retina. In truth, the preoperative diagnosis is unreliable (see vitreoschisis below). Even intraoperatively, and even with the use of TA, what appears as a PVD may still be vitreoschisis if the inner surface of the posterior wall of the schisis cavity is too smooth for the crystals to stick to it. The preoperative diagnosis of "no PVD" is therefore always correct, while that of "PVD" may not be
Retinal tear	An adherent vitreous is pulling on the retina with every move of the patient's eyeball or head. A tug of war develops between this traction force vs the combined resistance of the RPE pump, the IPM, and the retina itself. It is the outcome of this struggle that determines whether a retinal tear results. Once a retinal break is formed, the risk of RD significantly increases unless the retinal area under traction is completely torn (operculum)

(continued)

Table 26.1 (continued)

Feature	Clinical implication
Syneresis	The breaking down of the molecular structure of the vitreous gel, resulting in the presence of gel/fluid admixture in the vitreous cavity, is typically the first step in the development of an RD
Vitreoschisis	Not removing the posterior wall of the schisis cavity can lead to several postoperative complications ranging from EMP to RD
Vitreous base	Its significance lies in the fact that the vitreous here is inseparable from the peripheral retina. Even in a normal eye, the line of no-separation moves posteriorly as the person ages. Even in younger age, in certain pathologies such as RD, the surgeon often finds VR adhesion in a much wider area than the vitreous base itself That the vitreous cannot be separated from the retina at the vitreous base explains why truly 100% vitreous removal is impossible; at the vitreous base even when the VR surgeon refers to his action as "vitrectomy," in reality he does "vitreotomy": shaving the vitreous as much as possible, but still leaving a thin vitreous "skirt" behind[d]
Vitreous cortex (posterior)	This structure is typically invisible to the surgeon intraoperatively, unless the vitreous is stained (ICG) or marked (TA). Preoperatively, it may or may not be demonstrated by ultrasonography or OCT
Weigert's ligament	The adhesion between the posterior capsule and anterior hyaloid face weakens with age. This explains why ICCE in a young person has disastrous consequences: the prolapsing anterior gel exerts traction on the vitreous base and thus on the peripheral retina
Weiss ring	It is commonly assumed, even by experienced VR surgeons, that the presence of a Weiss ring corresponds to a PVD. In truth, the Weiss ring means only that the vitreous separated at the disc; the cortical vitreous may still be adherent to the retina elsewhere

*Listed in alphabetical order. See the text and the appropriate chapters for more details.
[a]If the eye undergoes scleral buckling, for instance.
[b]10 mm^2.
[c]Like a pawn for the king in chess.
[d]Think of a completely bald person vs one whose head is closely shaven.

A more important consequence of the presence of the gel/fluid mixture in the vitreous cavity involves the vitreoretinal interface.

- Posteriorly, the vitreous may separate from the retina completely (*PVD*), may retain some of its connections (anomalous PVD, which gives rise to VR traction and can present clinically as VMTS, macular edema, macular hole etc.), or *vitreoschisis* may also develop.

Pearl
Vitreoschisis is an entity that is often, erroneously, diagnosed as a PVD (see **Fig.** 26.2 and **Table** 7.1). Vitreoschisis may play a role in EMP or RD development.

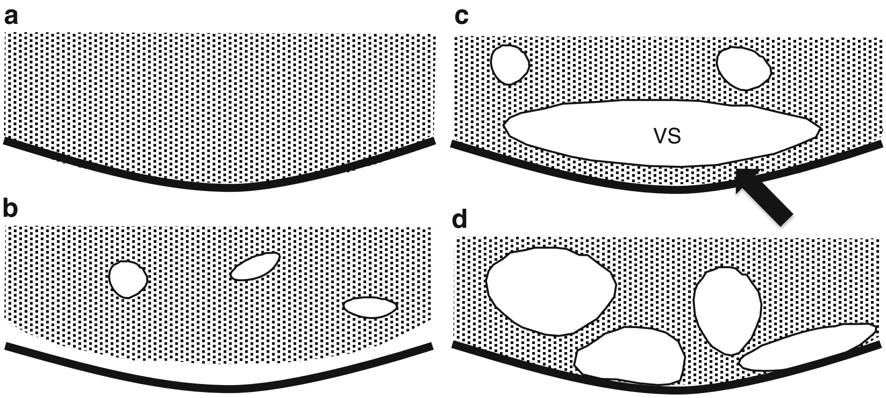

Fig. 26.1 The vitreoretinal interface, the condition of the gel, and its clinical implications. (**a**) The normal (ideal) condition: the vitreous is 100% gel and is in uniform contact with the posterior retina. The gel is completely transparent (no or negligible light scatter), and there is no traction on the retina. (**b**) A complete PVD with a few small lacunae. Since there is no VR contact, the risk of traction in this area is zero. (**c**) Vitreoschisis (VS) with a few small lacunae. The vitreoschisis is a special type of lacuna: it is large and very close to the retina, but still an "island," surrounded on all sides by vitreous. The posterior wall of the schisis cavity (*arrow*) may or may not be visible on clinical examination or OCT; if invisible, the erroneous diagnosis of PVD is often made since the anterior wall of the cavity is mistaken for the posterior hyaloid face. (**d**) Advanced stage of syneresis. A large volume of the gel is substituted by fluid pockets, allowing the gel to be highly mobile. At all sites of VR adhesion, there is a risk of traction. Within the lacunae, floaters may be present (not shown here). The thick black line represents the retina, the dotted area the vitreous, and the white areas the syneretic fluid pockets (lacunae)

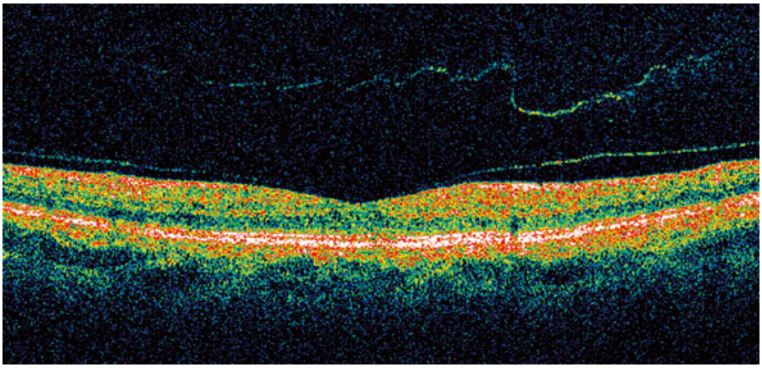

Fig. 26.2 Vitreoschisis on OCT. The vitreoschisis cavity is clearly seen in front of the macula. It is rare that the posterior wall is delineated at all, much less this obviously. The wall is partially adherent to the retina and remains static even upon eye/head movement. Conversely, the anterior (inner) wall is highly mobile with eye/head movement and gives the impression on clinical examination of a true PVD

- Anteriorly, *retinal tear*s may form at the posterior border of VR separation.[11]

Pearl
The vitreous has no per se function in the fully developed eye. This explains why its removal has no adverse effect, except the increased risk of cataract formation, which is due to the higher oxygenation in the cavity. Nevertheless, detachment of the retina progresses faster in eyes devoid of the mechanical support of the gel.

26.1.3 Retinal Histology and Macroanatomy

The retina is the "film of vision": it captures the incoming light, translates it into electric signals, and sends these toward the visual cortex. The retina has ten layers, except in the periphery and at the fovea; the outermost layer is the RPE, to which nine layers of the neuroretina[12] attach. The inner half of the retina gets its nourishment from the retinal blood vasculature; the outer half is supplied by the choroidal vasculature. The latter fact explains the deleterious effects of RD.

- Thickness: The retina is thinnest in the periphery (~0.1 mm) and gets progressively thicker posteriorly, reaching 0.23 mm in the peripheral part of the macula.
- *RPE*: Extending from the optic disc to the ora serrata,[13] this monolayer of some 120 million cells have a crucial role in maintaining retinal attachment (see **Sect. 26.3**). In the posterior pole the cells are narrow and tall, becoming thinner toward the periphery.
- *ILM*: Consisting mostly of the basal lamina of the Müller cells, this membrane of type IV collagen gives the retina a smooth inner surface and a shiny light reflex in younger individuals. It is 0.5 μ thick in the periphery and ~1.5 μ centrally.[14] It is missing over the optic disc and occasionally over the major blood vessels.[15] This is the sole inelastic layer of the neuroretina, and its rigidity plays a role in several pathological conditions, serving as a rational for ILM removal.
  - The ILM is transparent, remaining invisible during the operation – unless the surgeon holds the light pipe at a certain angle.[16] The ILM is so thin

[11] The classical description of RD development (see **Chap. 54**).

[12] Also referred to as sensory retina. In a strict interpretation of the condition, RD is not a true detachment but an intraretinal separation (between the RPE and the neuroretina).

[13] Where it becomes contiguous with the pigmented ciliary epithelium and then the anterior layer of the iris epithelium.

[14] The human hair is 20–180 (average: 70) μ thick.

[15] As seen during ILM peeling: the border of the ILM removal typically follows the major vessels.

[16] This is where using a slit lamp for surgical viewing has a clear advantage.

that even OCT machines with the highest axial resolution[17] are unable to delineate it.

For the VR surgeon, the important macroanatomical landmarks are the following:

- Ora serrata ("ora"). This is the endpoint of the retina with its ten layers; peripheral to the ora serrata, the retina becomes contiguous with the nonpigmented epithelium of the pars plana ciliaris. The ora is straddled by the vitreous base.
- *Pars plana*.[18] It is the posterior section of the ciliary body, a ring ~4 mm wide in adults.
- *Pars plicata*.[19] This part of the ciliary body, a 2 mm wide ring whose anterior border is at 1 mm posterior to the limbus, contains 60–70 ciliary processes.
- *Macula*.[20] A horizontally oval area of 2.0 × 0.9 mm, whose center is located 3.4 mm temporal and 0.8 mm inferior from the margin at the midline of the optic disc. The macula is responsible for ~20° of the visual field.
- Fovea. The central depression inside the macula, with a diameter of 1.8 mm. The light reflex seen here is explained by its slanted architecture.[21]
  - The fovea is inside the avascular zone, which is 0.5 mm in diameter.[22]
  - Its epicenter is called the foveola, with a diameter of 0.35 mm. It has no cells except the outer segment of red and green cones.
  - The fovea is surrounded by a 0.5 mm wide ring that is called the parafoveal area.
  - The parafoveal ring is surrounded by another, 1.5 mm wide ring called perifoveal area.
- *Optic disc*. An oval area measuring 1.76 mm horizontally and 1.92 mm vertically; this is the entry point of the arterial system for the eye and the exit point for the veins and neurons. It is located nasally from the macula, 2.3 mm to the optical axis.
- *Posterior pole*. An area typically meant to be bordered by the vascular arcades.

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[17] ~8 μ at the time of this writing.

[18] Technically, it is not part of the retina, but is discussed here because this is the intended entry site for intravitreal surgery and injections.

[19] Also called corona ciliaris.

[20] The proper name is macula lutea. The name comes from its somewhat yellowish color due to the high carotenoid pigment (xanthophyll), which is missing in the fovea. In clinical practice, "macula" is often used when "fovea" would be the correct term.

[21] Clivus (slope).

[22] The avascular zone is the forbidden area for laser treatment. This is especially true at the fovea, where even minor iatrogenic injury can inflict maximal damage.

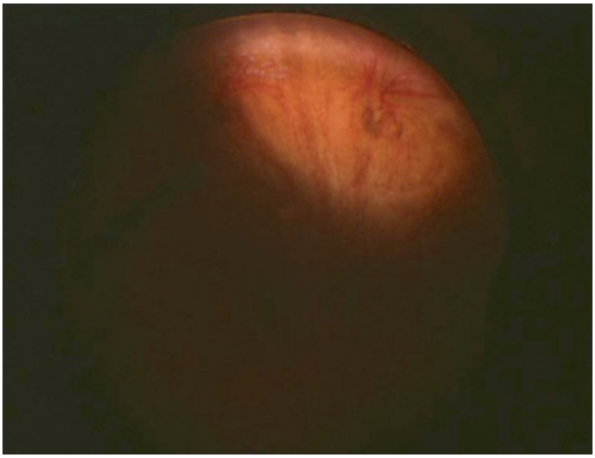

Fig. 26.3 **The equator.** In this eye the presence of the vortex vein and the lighter color of the retina peripheral to the equator are clearly visible. The laser cerclage is being completed so that the posterior border of the treatment ring is central to the equator (see more in **Sect. 30.3.3**)

- Equator.[23] This is an important, although ill-defined, landmark.[24] The vortex veins and occasionally the different coloration of the fundus help identify it (see below and **Fig. 26.3**).
- Maculopapillary bundle. The area between the fovea and the optic disc, containing the most crucial nerve fibers, those responsible for central vision.
- Peripheral retina. A ring of ~15 mm width, extending from the equator to the ora serrata.
- The *long posterior ciliary nerves*,[25] along with the long ciliary arteries at the 3 and 9 o'clock meridians, run intrascleral before reaching the suprachoroidal space roughly at the equator.

26.1.4 Anterior Segment Dimensions

- The *AC depth* is 3.15 mm.
- The diameter of the lens is 10 mm. It is 4 mm thick at age 20, increasing to 4.7 mm by age 60.
  - The thickness of the lens capsule is 4–24 μ, thinnest in the center.

26.2 External Anatomy for the VR Surgeon

The external anterio-posterior diameter of the eye is ~24 mm; the internal is 22 mm. The sclera is thickest at the insertion of the optic disc (1.2 mm) and thinnest (0.3 mm) at the insertion of the extraocular muscles; it is 0.5 mm at the equator and 0.8 mm at the limbus.

[23] That is, the largest circumference of the globe in the frontal plane.

[24] Crucially important for the surgeon when a PVD is created (see **Sect. 27.5.1**).

[25] Named "long uveal nerves" in a new terminology. These are not retinal structures, but their location justifies discussing them here.

The distance between the limbus and the ora serrata varies by quadrant: 6.5 mm temporally, 6.1 mm superiorly, 5.7 mm nasally, and 6.2 mm inferiorly. The distances are larger in myopic and shorter in hyperopic eyes. The distance between the limbus and the equator is ~13 mm.

The *extraocular muscles insert into the sclera* at the following distances from the limbus: medial rectus, 5.5 mm; inferior, 6.6 mm; lateral, 6.9 mm; and superior, 7.5 mm.

Pearl

The insertion of the extraocular muscles is slightly anterior to the ora serrata, but this is a close enough approximation for clinical purposes.

The seven vortex veins (fewer temporally than nasally) penetrate the sclera 3–6 mm posterior to the equator internally and 14–25 mm from the limbus externally.

The corneal diameter is 12 mm horizontally and 11 mm vertically; its thickness varies from 0.55 mm centrally to 0.7 mm in the periphery.

26.3 Physiology: What Keeps the Retina Attached?

In primate experiments it appears that a force as minimal as 0.25 mmHg is sufficient to detach the retina. In the human, clinical experience[26] tells you the opposite: an attached retina is difficult to separate from the RPE. This leads to the obvious question: What are the forces that prevent RD development under normal circumstances?

26.3.1 The RPE Pump

The RPE is the main factor in maintaining retinal attachment by constantly removing fluid from the subretinal space[27] toward the choriocapillaris; it is often referred to as a suction force.

- In eyes with high myopia and a posterior staphyloma, reduced pumping by the RPE is assumed to play a role in the development of the central RD (see **Chap. 56**).
- Drugs that interfere with the RPE's active transport reduce retinal adhesiveness.
- Retinas detach postmortem when the pump stops working.

[26] Intentionally detaching the retina in eyes undergoing full-rotation macular translocation is not easy.

[27] Thus virtual.

26.3.2 The IPM

The interphotoreceptor matrix acts as a glue, which helps the neuroretina stick to the RPE.

- Enzymes, given experimentally into the vitreous or directly into the IPM, degrade the IPM's proteoglycans and result in significant weakening of the retinal adhesion.
- The IPM requires time to regain its adhesive power. Clinical experience teaches the VR surgeon that once broken, the glue will not regain its efficacy for a few days postoperatively.[28]
- In diabetic eyes, intraoperative RD occasionally occurs when the surgeon works close to the retinal periphery and the vacuum/flow is not reduced.[29] No retinal break is present and the RD spontaneously resolves within a few hours or even intraoperatively, but the RD recurs when the surgeon returns to the same area later during the case.[30]

26.3.3 Presence of the Vitreous Gel

The vitreous body is an indirect supportive force: it mechanically prevents retinal separation as long as it maintains its true gel consistency and fills the vitreous cavity completely.

After cataract extraction, the gel will not be able to fill the extra space vacated by the lens, even if an IOL has been implanted; there is room for vitreous movement. This is the underlying cause of pseudophakic RDs.

26.3.4 IOP

Possibly contributing by "pushing" the retina back toward its foundation, the RPE

[28] It will certainly not work again during surgery, i.e., it is not a "superglue."

[29] If PPV is done using the same parameters in non-diabetic eyes, this phenomenon is almost never seen.

[30] Reduced pumping by the RPE may also contribute.

The Basics of Vitreous Removal

27

27.1 The Rationale for PPV

In a few indications, the surgeon's only *goal* is to remove the vitreous, but in most cases, PPV is a *means* to accomplish a variety of additional goals such as releasing VR traction.

> **Pearl**
> The original term "vitrectomy" does not truly characterize the field today when most cases also involve retinal work. "Vitreoretinal surgery" is therefore a more proper term, but even this cannot fully encompass the technique's full spectrum.

Table 27.1 lists a variety of conditions in which PPV is one of the treatment choices if not the most effective or only treatment option. In the absence of the vitreous gel, the disease would:

- Not occur at all.
- Have a smaller risk of occurring.
- Have a more benign course.
- Would resolve faster.
- Have a slower progression.
- Stop progressing.
- Would not recur or have a lower risk of recurrence.

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Table 27.1 Selected indications for PPV*

Indication[a]	Comment
AMD, dry	To address the VR traction and improve the oxygenation
AMD, wet	Removal of the subretinal membrane or retinal translocation is very rarely done today, but remains an option in a few, carefully selected cases
Anterior segment reconstruction	There are many conditions in which the anatomy of the anterior segment cannot or should not be restored without the use of the probe
BRVO	PPV improves retinal oxygenation and is able to deal with the macular edema; it also allows the opening of the capsule strangulating the vein at the arteriovenous crossing
Capsulectomy	The probe allows controlled opening of the capsule without leaving large floater/s behind; it also allows anterior vitrectomy, which is especially important in young children
Cellophane maculopathy	Removal of the ILM is the only curative option
Choroidal melanoma	PPV offers, in selected cases, long-term systemic prognosis that is not inferior to other treatment modalities while preserving vision without the risk of causing vision-destructive radiation retinopathy
Coats' disease	Complete vitrectomy with removal of preretinal membranes (and possibly draining the subretinal fluid) is an option in later stages or refractory cases
CRVO	PPV improves retinal oxygenation and is able to deal with the macular edema; it also allows cannulating the major vessel for clog-opening drug infusion
EMP	Removal of the scar (and for most surgeons of the ILM) is the only option that addresses the pathology itself, not simply its consequences[b]
Endophthalmitis	Not leaving pus (purulent vitreous) behind is the key to achieve the best possible prognosis
Floaters/synchysis	If the patient is bothered by the mobile shadows the opacities cast on the retina, PPV has excellent prognosis at minimal risk[c]
Glaucoma, ghost cell	Without clearing the reservoir[d], there is an almost infinite (re) supply of degenerated red blood cells
Glaucoma, malignant	Removal of the vitreous creates space for the normal aqueous drainage pathway and prevents the aqueous from pushing the vitreous forward
Hyphema (clotted)	It is rarely possible to remove the clot with forceps or simple aspiration; conversely, clot removal with the probe is possible even in phakic eyes, and the size of the clot is irrelevant
IOL, luxated	Total or subtotal PPV must precede manipulations of the IOL, whether removal or repositioning is performed
IOL, subluxated	Depending on the actual situation, capsulectomy, anterior vitrectomy[e], or true PPV may be necessary
Iris-claw lens[f] implantation	As a minimum, judicious anterior vitrectomy is necessary
Iris-IOL prosthesis implantation	As a minimum, judicious anterior vitrectomy is necessary
Lens luxated into AC	As a minimum, vitreous removal from the AC and judicious anterior vitrectomy are necessary

(continued)

Table 27.1 (continued)

Indication[a]	Comment
Lens luxated into vitreous/ dropped nucleus	Total or subtotal PPV must be performed before the lens is removed via phacofragmentation or lensectomy[g]
Lens subluxated	As a minimum, judicious anterior vitrectomy is necessary
Lensectomy	The probe is used to remove the entire lens[h]
Macular edema	Regardless of the etiology, the posterior hyaloid face must be detached and the ILM[i] should also be removed
Macular hole	At least minimal vitrectomy is needed and the ILM is also removed[j]
PDR	Complete vitrectomy is needed with removal of pre- and subretinal membranes
Phacomatoses	Typically, PPV is employed to treat a secondary RD
Prophylactic (e.g., high myopia)	To reduce the risk of RD, complete vitrectomy is performed, combined with lens removal (and possibly that of the lens capsules), and accompanied by judicious laser cerclage
Pupilloplasty	Anterior vitrectomy is to be considered in the aphakic and occasionally the pseudophakic eye
PVR	Complete vitrectomy is needed with removal of the pre- and subretinal membranes
RD	Complete vitrectomy is recommended, possibly also ILM removal
RD, central (high myopia), whether or not accompanied by a macular hole	As-complete-as-possible vitrectomy is necessary with peeling of the ILM in as large an area as possible
RD, hemorrhagic	Complete vitrectomy with removal of the subretinal blood if it is, or threatening to become, submacular (see below); tPA may also have to be used
RD, tractional	Complete vitrectomy is needed with removal of pre- and subretinal membranes
Retinoschisis	Technically the vitrectomy can be very challenging and should thus be delayed until the macula is threatened; if PPV is necessary, it should be as complete as possible
ROP	Vitrectomy is performed in the later stages and should be as complete as possible; the lens may be spared
RPE transplantation	A complete vitrectomy is part of this complex procedure
Silicone oil removal/ exchange	The retina should always be very thoroughly examined to determine whether manipulations such as membrane peeling and/or retinectomy are needed; unless the oil was implanted for nontraditional uses such as a macular hole, there is always some risk of postoperative RD development
Submacular hemorrhage	Complete vitrectomy with removal of the subretinal blood is necessary; it is crucial to do it early (see above)
Suprachoroidal blood	If acute removal of the blood is needed[k] and the blood is still clotted, the probe is the only weapon the surgeon has to shave down the clot
Toxocariasis	To remove the epiretinal scar; if a "collar button"[l] proliferation is present, the submacular part is usually left behind
Trauma, contusion	Crucial to perform total vitrectomy
Trauma, open globe	Crucial to perform total vitrectomy

(continued)

Table 27.1 (continued)

Indication[a]	Comment
Uveitis	Total or subtotal vitrectomy is recommended, also ILM peeling if macular pathology such as edema is already present or expected
VH	Less than subtotal vitrectomy is not recommended
Vitreous prolapse into the AC	Complete removal of the vitreous from the AC, including from the surface of the iris, or at least severing its connections to the posterior vitreous
VMTS	Subtotal or total vitrectomy to eliminate the traction not only centrally but also in the periphery and ILM peeling are recommended

[*]Defined here as "vitrectomy instrumentation is used," not strictly as "vitreous removal from the vitreous cavity".
[a]In alphabetical order. Many of these conditions are discussed in various chapters in **Parts IV** or V.
[b]Macular edema, for which some ophthalmologists employ intravitreal medications that obviously do not address the root cause.
[c]Counseling is especially crucial with these indications: the ophthalmologist should not deny the patient the possibility of PPV just because he can see the fundus well or the patient (occasionally) has full visual acuity.
[d]Which is the vitreous cavity.
[e]Remember, in this book, "anterior vitrectomy" means removal of the vitreous from the frontal part of the vitreous cavity, not a vitrectomy that is performed through an anterior approach.
[f]Artisan (Ophtec BV, Groningen, The Netherlands).
[g]Occasionally loop delivery if the lens is so hard.
[h]If the lens is soft, there is no need for utilizing ultrasound.
[i]I always peel the ILM in eyes undergoing surgery for macular edema.
[j]I always peel the ILM in eyes undergoing surgery for a macular hole.
[k]E.g., because of a kissing choroidal detachment.
[l]The proliferation is both subretinal (in front of or under the RPE) and epiretinal; there is, obviously, a break in the neuroretina. "Hourglass" proliferation may be a more descriptive term.

The absence of the vitreous gel in the vitreous cavity has further implications.

- The oxygen tension in the posterior segment significantly increases once no gel is present. This is especially beneficial for patients with vein occlusion, diabetes, or poor circulation for other reasons – but makes cataract development a *side effect*, not a complication.[1]
- The clearance of substances from the vitreous cavity increases after PPV. This is advantageous in vitreous (re)bleeding but disadvantageous if intravitreal medications are used.

[1]Contrary to widespread belief, this is also true for patients under 50 years of age. In younger patients, the cataract is indeed more delayed, but still presents earlier than it otherwise would.

27.2 How Much Vitreous to Remove?

Just as important as the question of *how* to remove the vitreous is *how much* to remove. The range stretches from "nonvitrectomizing" to "complete" PPV[2] (see **Fig.** 27.1 and **Table** 27.2).

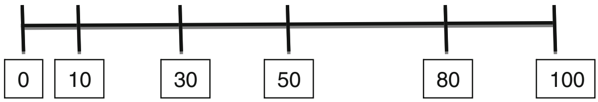

Fig. 27.1 **Schematic representation of classifying the extent of vitreous removal**. This is a personal, somewhat arbitrary, and not objectively measurable/verifiable attempt at distinction. The numbers represent percentages: 0%, nonvitrectomizing; 10%, minimal; 30%, core; 50%, semitotal; 80%, subtotal; 100%, total or complete (see **Table** 27.2 for more details)

Table 27.2 Classifying the amount of vitreous to be removed

Amount of vitreous removed	Comment[a]
0% (nonvitrectomizing)	The surgeon does not remove any vitreous Indications include EMP or, seldom, an IOFB that is rather far from the eyewall and did not cause any retinal damage
10% (minimal)	Only a premacular PVD is created and this vitreous is removed Indications include an EMP or a macular hole
30% (core)	A PVD is created and a decent posterior vitrectomy is carried out Indications include an EMP or a macular hole, rarely macular edema
50% (semitotal)	The posterior half of the vitreous is removed[b] Indications include numerous conditions from macular diseases to floaters
80% (subtotal)	All vitreous except in the anterior part of the vitreous cavity is removed. Often described (including in this book) as leaving a "vitreous skirt"[c] at the vitreous base, it is in reality a disc[d] Indications include virtually all conditions listed in **Table** 27.1 except RD and the presence of proliferative membranes
100% (total or complete)	In truth, this is impossible; some vitreous is always left behind. The goal is to shave the gel to end up with the thinnest possible "sausage" and to remove the anterior vitreous face as well Indications include RD and the presence of proliferative membranes

[a]The indications shown here represent an incomplete list.
[b]The opposite of what has been suggested, highly controversially, in the Endophthalmitis Vitrectomy Study.
[c]A more appropriate term would be "a sausage of vitreous".
[d]The anterior vitreous face is also retained.

[2]As one of my teachers, a pioneering giant in the field, Relja Zivojnovic, so eloquently described: "Vitrectomy is done when the vitreous is gone."

It is impossible to give blanket advice regarding the amount of vitreous that needs to be removed. It is influenced by several factors such as the etiology (indication), the condition of the vitreous, the VR interface, and the vitrectomy equipment (see **Sect. 12.1**). Below are a few general considerations; more details are found in **Part V**.

- For most surgeons, the primary factor determining how much vitreous he intends to remove in a particular case is the etiology. However, certain aspects of the perivitreal anatomy must also be taken into account. Only a brief summary of what was detailed in **Chap. 26** is provided here.
  - Posterior to the equator, a healthy vitreous is mildly adherent to the retina, but separation is generally possible (see **Sect. 26.1.2**).[3] The preoperative diagnosis of PVD is always uncertain; often a vitreoschisis is found intraoperatively (see below and **Fig. 26.2**).

Q&A

Q *Is it always possible to achieve vitreoretinal separation in the posterior pole?*

A No. In young patients, even a limited “truly posterior” PVD may be too risky. In certain conditions such as high myopia, creating a PVD can also be very difficult. More peripherally, just the recognition of the presence of a still-attached cortical vitreous can be a challenge. In diseases such as RD, PDR, or VMTS, the 2 tissues may be inseparable anterior to the equator or even posterior to it (see below).

  - At and anterior to the equator, the adherence between the two tissues may be weak, strong, or impossible to break.
  - At the vitreous base,[4] any attempt to create a PVD leads to the formation of retinal tears.
  - In young patients, the vitreous cannot be separated from the lens capsule, even if surgical detachment of the anterior vitreous face would be required.[5] The capsulovitreal adhesion eventually disappears with age.[6]

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[3] In children pharmacological vitreolysis may play a crucial role since safe surgical PVD is often impossible. However, the drug is currently very expensive and has a limited success rate.

[4] Scleral indentation is necessary; the surgeon should follow a certain routine to make sure that he does a complete job (see **Sect. 28.5**).

[5] Such as RD, PDR, PVR.

[6] The only area where the strength of the VR adhesion does not weaken with age is the vitreous base.

– Abnormal VR adhesions may be present at any location; the surgeon must always proceed cautiously so as to avoid damaging the retina by too fast or aggressive attempts of separation.

Pearl
If there is a vitreous-related complication following vitrectomy, it comes from vitreous that has *not* been removed.

- I do not perform nonvitrectomizing vitrectomy: I always try to create a PVD. Leaving cortical vitreous on the macula often leads to subsequent complications such as EMP development.
- In most macular indications, no untoward consequences are to be expected even if only minimal or core vitrectomy is performed.
- When the vitreous is a healthy gel (e.g., no floaters or traction), it is tempting to leave much of it behind. However, postoperative structural changes such as liquefaction and *mouches volantes* typically occur.[7] The patient, noticing the mobile object/s casting bothersome shadow on the retina, may attribute their presence to a surgery that was suboptimal.

Pearl
The default plan for PPV therefore should be a complete vitrectomy. In most cases, however, this is not necessary, and a less-than-total vitrectomy will suffice – but the surgeon must make a conscious decision why *not* to remove all or most of the gel in the particular case.

- If traction[8] is present, as-complete-as-possible vitreous removal is called for to reduce the risk of retinal tears developing postoperatively. Conversely, traction-elimination itself risks causing iatrogenic retinal tears intraoperatively. In such cases, the surgeon needs to decide which is the risk that he considers greater: carrying on with the PVD (intraoperative complications[9] may arise) or abandoning it (postoperative complications[10] may arise).

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[7] Another consequence of a less-than-complete PPV is increased mobility of the remaining vitreous, which increases the risk of RD development (see **Sect. 54.5.2.2**).

[8] In RD, PDR, PVR, VMTS etc.

[9] Retinal breaks, RD.

[10] RD, PVR.

27.3 Recognizing the Presence of the Vitreous Gel

The surgeon's job is not made easier by the fact that the normal vitreous is basically invisible. Manipulating the angle of endoillumination is helpful to a certain extent (see **Sect. 22.2**), but it is best to use some type of "visual aid" to identify whether vitreous is present.

Q&A

Q *What if the surgeon finds that an eye contains very little vitreous?*

A If the vitreous removal is completed much more rapidly than usual, it typically means that most of it is still attached to the retina (hence the rationale for P-A PPV, see below). TA should be used, a PVD created, then the remaining vitreous can be removed.

27.3.1 Mechanical Aids

- With BSS infusing the vitreous cavity, the gel hydrates.
  - During surgery the vitreous becomes increasingly recognizable. This phenomenon is barely conspicuous over the posterior pole but makes completing the vitreous removal in the periphery easier once the other tasks (e.g., EMP removal) are finished.
- Even if the vitreous itself is not visible, a mobile shadow from the edge of the gel[11] as the probe "bites" into it may appear as a snaking dark line dancing on the retinal surface below.
- In eyes with poor circulation or a very structured gel, pushing the probe into the vitreous cushion causes the retina underneath to whiten.
- If the retina is detached, it is crucial to determine whether vitreous is still adherent to it.[12]
  - Aspiration, even if the probe is at some distance from the retina, results in the retina moving toward the probe if vitreous is engaged, and no movement if only BSS is present.
  - When the probe is moved toward the retina, it will push it away if vitreous is present. In the absence of the vitreous cushion, no retinal movement is seen.
- In almost all eyes with PDR, a vitreoschisis is present (not a PVD), mostly anterior to the equator. Its thin outer wall[13] is so adherent to the retina that aspirating it can detach a previously attached retina. This is obviously not a recommended method to show the presence of the vitreous (see **Sect. 52.2**).

[11] i.e., at the border of gel and BSS.

[12] The use of the probe is described here, but the surest way is to inject TA (see **Sect. 34.1**).

[13] The outer wall of the schisis cavity is vitreous but behaves like a true membrane.

27.3.2 Air (Pneumovitrectomy)

Air allows visualization of the remaining vitreous "skirt" at the base (see **Sect.** 14.1 and **Fig.** 27.2)[14] while also reducing the risk of biting into the retina as the air pushes it against the RPE.

- Perform an F-A-X.
  - For the purpose of pneumovitrectomy, the drainage of the fluid need not be complete.
- Adjust the BIOM front lens so that you have the best possible visibility (see **Table** 16.5).
- The vitreous is invisible until you push the probe into it. The change in the light reflex clearly shows that vitreous is present. How close to the retina you can shave the gel depends on the angle between the probe's shaft and the retina (see **Fig.** 24.1).

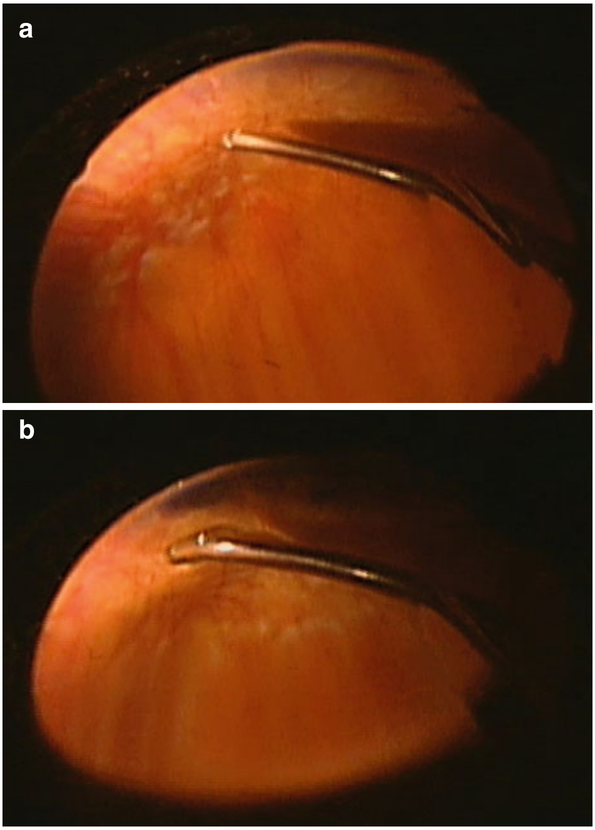

Fig. 27.2 Pneumovitrectomy. (**a**) The probe is close to the retina in the periphery; the eye is filled with air and the probe is kept in air. The view of both the probe's tip and the retina is rather clear and no unusual light reflex is seen. (**b**) The probe is being held in the same area, but its tip is now immersed in gel vitreous. A light reflex appears around the tip and the image of the probe's distal part is slightly distorted. Once the vitreous has been removed or the probe withdrawn into air, the image reverts back to that seen on (a)

[14] Air is also able to demonstrate the presence of vitreous behind the lens (see below, **Sect.** 27.5.3).

27.3.3 Stains and Markers

- Blood is a natural stain,[15] allowing the visualization of the gel after vitreous hemorrhage.
- Intravenously injected sodium fluorescein stains the vitreous after a few minutes and persists for a few hours.[16]
- ICG gives the vitreous a faint greenish discoloration (see **Fig. 34.1**).[17]
- The most effective weapon in the surgeon's armamentarium is TA (see **Sect. 34.1**), whether aiding in the creation of a PVD or allowing the visualization of vitreous elsewhere.

27.4 The Sequence of Vitreous Removal

There is no absolute rule; my default option is the P-A approach.

- A small amount of vitreous is removed from over the maculopapillary area.
- ~0.1 ml of TA is injected into this artificial lacuna (see **Fig. 34.2**).

Pearl
Do not inject more than this miniscule amount of TA. A thick coat of TA makes the PVD risky since the surgeon is unable to see the retina beneath and may push the probe into the retina or scratch it if he uses a sharp tool. The appearance of a retinal hemorrhage indicates that this has happened.

- If the vitreous cortex is still adherent to the posterior pole, a PVD is created (see below).
  – Remember that the proximal vitreous surface may be smooth, in which case the crystals do not adhere to it, giving the false impression that a PVD is present (see **Table 26.1**).
  – How far anterior the separation is carried depends on the indication and the conditions in the particular eye (see above).
- The central vitreous is removed.
- If indicated, the peripheral vitreous is removed/shaved using scleral indentation (see **Chap. 28**). TA may be used to identify the vitreous remaining on the retinal surface.

Pearl
When working in the periphery, use low magnification: since the BIOM front lens is close to the cornea, even a small movement of the eyeball will result in loss of the image.

[15] Obviously, intraoperative blood injection is not used in clinical practice.

[16] Fluorescein to stain the vitreous is not used in clinical practice.

[17] Since the dye does not penetrate into the vitreous, it is not used purposefully to stain the gel, except in the highly myopic eye with otherwise little contrast due to the loss of pigment (see **Sect. 56.2**).

- If indicated, the anterior hyaloid face is also removed; in the pseudophakic eye, a posterior capsule is also performed.

  There are important exceptions to the P-A approach.

- *Opaque vitreous*. If the retina is not visible due to blood, pus, synchysis etc., meticulous anteroposterior vitreous removal is recommended.
- Presence of severe *macular traction* in diseases such as VMTS, PDR, and PVR. The selected sequence is based on the particulars of the case and how well TA can show the traction forces.

Q&A

Q *What are the advantages of the P-A sequence of vitreous removal?*

A In principle, the further away the probe from the retina, the safer the vitrectomy and the faster it can be completed. In addition, it is easier to create a PVD when the posterior hyaloid face is still unbroken.

27.5 The Technique of Vitreous Removal[18]

27.5.1 PVD

As mentioned earlier, the presence of a Weiss ring (see **Fig. 27.3**) means nothing more than VR separation at the disc. TA still should be used to determine whether PVD must be created (see above). The separation should be started at the temporal side of the disc.

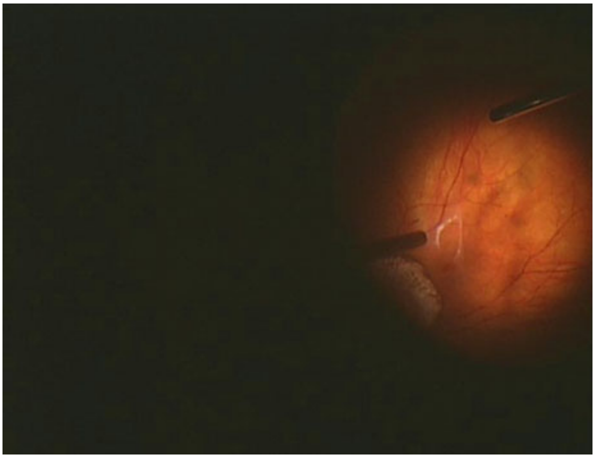

Fig. 27.3 **Weiss ring.** The vitreous has separated from the retina at the disc margin, allowing a ring of fibrous tissue to be seen in the vitreous cavity; the shadow of the ring is also visible on the retinal surface

[18] Vitrectomy at the base is described in **Chap. 28**; gel removal in the central area of the vitreous cavity requires no specific comments except what has been presented in **Chap. 24**.

Q&A

Q *Why not start the PVD on the nasal side of the disc where any iatrogenic damage to the nerve fibers has less serious consequences?*

A Because the PVD should be fairly symmetrically extended as it approaches the equator, and the retinal area temporal to the disc is larger.

If using aspiration only, do the following:

- Turn the probe sideways.
- Advance the probe just enough so that it barely touches the retinal surface.
- Start at the inferotemporal margin of the disc.
- Wait a few seconds for the port to engage the vitreous coating the retina. Use maximal aspiration but no cutting (see **Table 12.2** for the standard settings of the vitrectomy machine).
- Move the probe toward 12 o'clock along the disc edge on the temporal side until the vitreous is lifted from the retinal surface.[19]
- You may also use a barbed needle (see **Sect. 13.2.3.1**) to engage and then elevate the vitreous the same way. Unless too much TA is on the retinal surface, the depth of the needle's hook is clearly visible, and retinal damage can be avoided. Once the vitreous is lifted, switch to the probe.
- Extend the PVD carefully toward the periphery, but stop roughly at the equator to avoid the creation of retinal tears. In most eyes, the PVD may be carried a little more anteriorly (see **Chapters** in **Part V**); in some diseases,[20] it is highly advisable to do so.

27.5.2 Vitrectomy Anterior to the Equator

- If the vitreous separates from the retina easily and without tearing it, *and* you consider it important to carry the PVD more toward the periphery, carefully do so.
- If the separation is difficult *and* you consider it essential to continue toward the vitreous base with the PVD but the two tissues are inseparable and retina starts to tear, you have two options (see the dilemma above, **Sect. 27.2**).
  - Stop with the PVD and shave the gel in the periphery instead; shave it as close to the retina as possible.

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[19] This is actually a dangerous moment for the less experienced surgeon. Being content to see the PVD occurring, he may get carried away and extend the separation far too anteriorly – a common error until patients with postoperative RD accumulate and the cause of the RDs is identified.

[20] Such as RD, RDP, PVR, and retinoschisis. See **Part V** for more details.

  – If it is deemed essential to not leave any vitreous behind, choose retinotomy/retinectomy (see **Chap. 33**). The main indications for such a somewhat drastic measure are PVR, occasionally RD and PDR (see **Chaps. 52**, **53**, and **54**).

27.5.3 Vitrectomy Behind the Lens

In the pseudophakic eye, this is technically easy, and cutting into the iris is the only risk.[21]

If the eye is phakic, the lens is not completely clear, and the surgeon decides against simultaneously removing the cataract, the somewhat opacified posterior capsule may help in delineating the border between it and the anterior vitreous face. Nonetheless, even in these cases but especially if the lens is clear, it is safer to do the following:

- Swing out the BIOM and use the microscope's illumination at relatively high magnification.
- Inject a few small air bubbles behind the lens.
  – If there is no vitreous present, the air bubbles will migrate toward the equator of the lens.[22]
  – If vitreous is present, the air bubbles are trapped behind the lens and give a good approximation regarding the location of the posterior capsule.
- Reintroduce the probe, focus the view through the microscope slightly behind the air bubbles, and aspirate/cut while keeping the probe *behind the air bubbles* the entire time; once the vitreous is removed, the air bubbles move out of the visual axis.

Pearl
If the eye is aphakic, performing anterior vitrectomy has a high risk of biting into the iris since the gel is commonly very adherent to both iris surfaces. Turn the port *sideways* (never toward the iris) and increase the vacuum/flow only gradually.

[21] Remember to also make a posterior capsulectomy.

[22] A higher plane than the lens' posterior pole.

28 Scleral Indentation

In principle, it would be preferable not to employ scleral indentation since it distorts the anatomy and the surgeon is forced to perform his maneuvers in an artificially altered environment. In reality, the only way to avoid scleral indentation as the surgeon works in the periphery is to use the endoscope for viewing (EAV, see **Sect. 17.3**). In traditional PPV, however, scleral indentation is a necessity if the surgeon needs to access the anterior part of the vitreous cavity.

28.1 The Advantages of Scleral Indentation

- Normal structures, which would remain hidden from view otherwise, become accessible and their pathologies treatable. The structures include the peripheral retina, the vitreous base, and the ciliary body.
- A bullous or highly mobile retina, if indented, will have reduced mobility. The safety margin of PPV increases both on the "hilltop" and on the "slopes" (see below and **Fig. 28.1**).

28.2 The Mechanics of Vitrectomy with Scleral Indentation

The contour of the eyeball dramatically changes with scleral indentation. If the retina was attached, what had a concave profile before becomes a convex one; if the retina was detached, it is now reunited with its foundation.

The angle between the probe's shaft and the retina changes; consequently the port's plane relative to the retinal surface also changes. The person performing the

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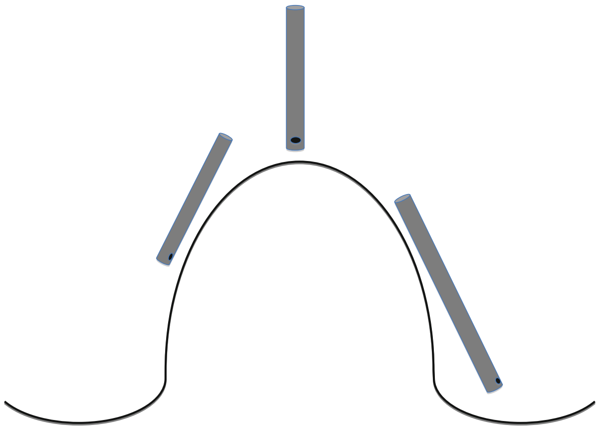

Fig. 28.1 **Cross-sectional view of performing vitrectomy during scleral indentation.** The internal elevation created by the indentation of the sclera is not cone-shaped. The effect is a radially oriented "mountain" or a circumferentially oriented "hill" with typically symmetric slopes on either side. The more peripheral the indentation, the less radial the direction of the ridge. If the retina was attached before, it will remain so during the indentation (shown here). If the retina was detached before and the detachment is not too high, the indentation results in a (temporary) retinal reattachment on the hilltop, but the RD persists on the slopes. Vitrectomy should be performed not only over the hilltop but also on the two slopes. The angle of the probe's shaft relative to the retina changes according to the location the indentation and the site of the sclerotomy (see the text for more details). The surgeon must decide, based on the visual feedback of his actions, whether to turn the port toward, parallel with, or away from the retina. He must also change the settings of the vitrectomy machine according to tissue behavior

indentation must understand its mechanics as well as the risks involved (see below and **Sect.** 24.1). Retinal injury can result in multiple scenarios.

- Lack of coordination between the external vs the internal movements[1] (see below).
- Unexpected changes in the characteristics of the indentation while the intraocular tissues are being manipulated are very dangerous.
  - A sudden increase in the height or location of the indentation.[2] A common cause of slippage is a lid speculum with a long blade (see **Fig.** 19.3). When the area of contact between speculum and lid is small, the depressor can be inserted on either side of it and there is no slippage. When moving the depressor along the long blade in the darkness, however, the nurse has no feedback that she reached the blade's edge until it is too late and the depressor suddenly "jumps."

[1] The depressor's and the intraocular tool's (probe, scissors etc.).

[2] Accidental slippage or a nurse who is not paying proper attention.

Pearl

Four variables should be taken into account to accurately describe the characteristics of the indentation: *height* (depression of the eyewall into the vitreous), *location* (according to clock hours in the frontal plane), *depth* (how far posterior from the ora serrata), and *angle* (this is the variable that changes the least; typically, the direction is radial).

- A surgeon too focused on the port of the probe. If the vitrectomy is done in a central location, the shaft may rub against the peripheral retina and cause an erosion (break) or bleeding.
- Incorrectly set PPV parameters. The aspiration/flow is too high, not adjusted to the peculiar demands of the periphery (see **Table** 12.2); a retinal break or detachment may result.
- A surgeon who does not take into consideration the implications of the change in the eyewall's contour (see below).
- Phakic eye. The lens is at risk if the surgeon does not switch hands at the midline (see **Fig.** 21.2**f**). Inferiorly, it is impossible to perform peripheral vitrectomy if the working sclerotomies are not properly placed (see **Sect.** 21.2.2).

In a pseudophakic/aphakic eye, the surgeon must decide whether to switch hands to complete the process. **Table** 28.1 shows the consequences if the probe remains in the same sclerotomy.

Table 28.1 The implications for the execution of peripheral vitrectomy according to the location of the scleral indentation*

Indentation location	Consequences
9 o'clock	The probe has access to the hilltop and both slopes
	The probe's port can be turned toward or away from the retinal surface as well as sideways; this is true both on the hilltop and on the two slopes
6 and 12 o'clock	The probe has access to the hilltop and the proximal slope; the area of the distal slope will become accessible as the indentation is relocated and what was distal before becomes proximal
	The port on the hilltop can be turned toward or away from the retinal surface as well as sideways; on the slope its only available position is sideways, but here it can be turned 360°
3 o'clock	The probe has access to the hilltop and both slopes
	The port's only position on the hilltop is sideways, but here it can be turned 360°; on the two slopes it can be turned toward or away from the retinal surface as well as sideways

*The indentation causes the formation of a "hilltop" and two "slopes" that are radially oriented (i.e., not very peripheral); if the indentation is more peripheral, the consequences change accordingly. In the example used here, the probe is inserted at the 9 o'clock location.

28.3 Internal vs External Illumination

External illumination (BIOM swung out, see **Fig. 28.2**) has certain advantages.

- The surgeon can choose whether to perform the indentation himself or by the nurse; in the latter case, bimanual surgery is possible, allowing the use of two working tools (see below).
- A larger area of the surgical field can be visualized.

The major disadvantage is that the resolution afforded by the microscope's light is inferior to that of the light pipe (see **Fig. 28.3**); the vitreous is more difficult to visualize.

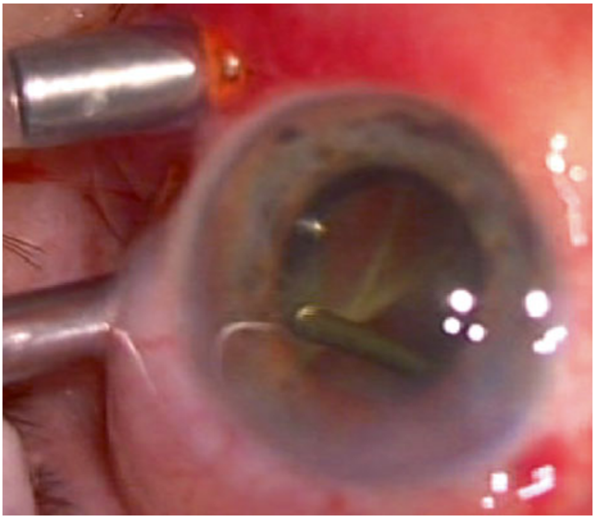

Fig. 28.2 **Self-indentation under external illumination**. See the text for more details

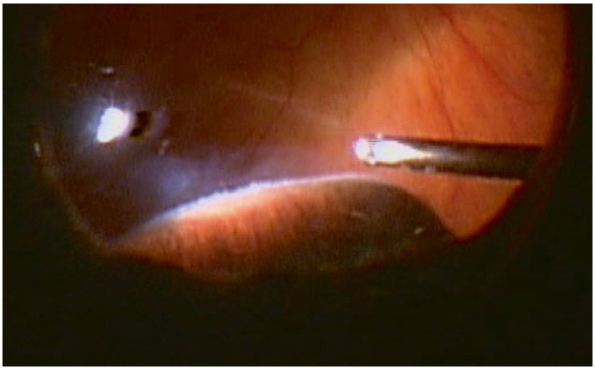

Fig. 28.3 **Indentation with internal illumination.** See the text for more details

28.4 Nurse vs Surgeon Indenting the Sclera[3]

Allowing the nurse to do the indentation has certain advantages.

- The image is superior if the light pipe is used, and the illumination angle can also be changed as needed (see **Sect. 22.1**).
- The surgeon is able to concentrate on the intravitreal part of the task.

Q&A

Q *Why is it so important that the nurse is well trained in performing scleral indentation?*

A Because disaster is not far away if she does not do a proper job. She must have constant visual feedback of her actions; not get distracted during the process; prevent the depressor from slipping; not allow sudden, unannounced changes in any of the characteristics of the indentation; and avoid pulling out the infusion cannula (see **Sect. 21.3**). She has to switch her hands as she is moving around the eye and maintain a steady hand even as she is forced to stand and lean forward.

Self-indentation also has certain advantages.

- Indentation and the intravitreal work are easily coordinated.[4] The surgeon can instantly change the height, location, depth, or angle of the indentation as the internal situation demands.
  - Making the process dynamic can provide the surgeon with extra information about the anatomy and pathology of the area.
- The risk to the retina resulting from slippage of the scleral depressor is reduced.
- No verbal instructions need to be given.
- The nurse is able to monitor the position of the infusion cannula during the entire process.

  Self-indentation is not possible if the eye is phakic.

28.5 External Illumination and Nurse Indentation

This hybrid option is chosen typically when bimanual surgery is needed on the ciliary body; obviously, the eye must be aphakic or pseudophakic.

[3] The question can also be phrased differently: bimanual vs monomanual surgery? or external vs internal illumination? see above.

[4] This is by no means automatic, though; it takes a lot of practice for the inexperienced fellow to be able to pay attention to the indentation itself, not simply to the actions executed by the working hand.

28.6 Instrumentation and Technique

- Use a speculum with a wire type of blade (see **Fig. 19.4**) and open it to the widest aperture possible.
- Decide whether to:
  - Indent yourself or have the nurse do it.
  - Use internal or external illumination (the latter allows bimanual surgery).
- The position of the infusion cannula must be constantly monitored.
- With depressors of a straight shaft[5], the more posterior (deeper) the depression, the more the angle of the shaft must be changed[6] so that it does cause too high an indentation anteriorly. Shafts that follow the contour of the globe[7] do not pose such a problem.
  - A hard plastic cover capping the light pipe (DORC [(Zuidland, the Netherlands)], offers improvement in visualization while also allowing proper indentation is another option.
- No matter who performs the indentation, switching of the hands will eventually be necessary. Caution is in order if the person's nondominant hand has weak dexterity.
- If the nurse is performing the indentation, she may be forced at some point to get up from her chair – and standing with a bent back increases fatigue and thus the risk of depressor slippage.[8]
  - This is especially important to remember in MIVS. Having the depressor over the conjunctiva, rather than naked sclera, as in 20 g surgery, increases the slippage risk.[9]

Pearl
It is very useful to always follow the same routine when 360° maneuvers such as scleral indentation are performed: this way you do not attempt to work in the same area twice or leave any area untouched. It is a matter of personal preference how you determine which routine to use. (I usually [see one exception below] start at 6 o'clock and proceed clockwise.)

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[5] Almost any tool, even a cotton-tip applicator, with a firm, cylindrical shaft will suffice.

[6] This is obviously limited by the configuration of the bony orbit but also by the size of the eyeball.

[7] e.g., SD-610 by Eyetech Ltd., Morton Grove, IL, USA.

[8] The problem is exacerbated if the nurse is sitting on the side opposite to the eye being operated on (i.e., the nurse is on the patient's right and the left eye is vitrectomized).

[9] The conjunctiva tends to slip over the sclera, less than the depressor slips on the conjunctiva.

- If the nurse does the indentation, you typically have the light pipe plus a working instrument inside. If the eye is phakic, take extra caution not to damage the lens with the light pipe.[10]
- By the time indentation is needed, most or all of the vitrectomy has usually been done: the eye is full of fluid, which is not compressible.
  - Start aspirating before the nurse actually indents, and rotate the eyeball in the opposite direction so that it is easier for her to insert and place the scleral depressor.[11]
  - Ask the nurse to increase the indentation slowly and then to stop before it is too high.
- If there is a partial RD, start the indentation in an area where the retina is attached and move to the RD area last; this helps reduce the risk of extending the detachment over a larger area.

Finally, it must be mentioned that some surgeons employ an encircling band to cause a (permanent) indentation, which in this case serves an intraoperative goal as well (see **Table 54.7**).

[10]You are less likely to cause lens trauma with the probe since you are monitoring it closely, but the light pipe is not under your continual observation.

[11]i.e., if the indentation will occur at 4 o'clock, rotate the eyeball toward the 10 o'clock direction.

Cryopexy

29

The endocryo probe used to be standard equipment in 20 g surgery; it was helpful in removing IOFBs or dislocated lens material/IOL. Unfortunately, this tool is not available in MIVS.

Q&A

Q *Is it permissible to use "blind" cryopexy?*

A Although some surgeons still use it over the wound in open globe injuries to "treat invisible or potential future retinal tears," blind cryopexy is *contraindicated*. It increases the inflammation, a precursor of PVR; the precise location of the treatment is pure guesswork, and the surgeon knows neither whether his treatment has any effect nor whether he is overtreating.

Transscleral cryopexy today is employed as an adhesion-inducing force in RD surgery as well as a destructive agent in pathologies such as Coats' disease, vascular tumors and telangiectasias of the retina, and intractable secondary glaucoma.[1]

29.1 Indication in RD

By causing an inflammatory reaction and the breakdown of the blood-ocular barrier with consequent scarring, cryopexy causes chorioretinal scarring around a retinal break. The confluent spots create a "wall," which seals the lesion. The scar involves all retinal layers,[2] a beneficial effect if destruction is the goal (see below, **Sect. 29.3**). The scar takes up to a week to develop.

[1] Most of what is discussed here relates to RD surgery.

[2] Unlike with laser, which typically involves only the external retinal layers (see **Chap. 30**).

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29.2 Surgical Technique

The freezing may be applied over the conjunctiva or directly over the sclera. Ideally, the surface is dried first.

- If you have a choice, select a cryoprobe that has a narrow and curved shaft.[3]
- Test the machine: observe whether an iceball forms over the tip of the probe and how many seconds it takes.
- Open the speculum to the widest possible and try to avoid touching the lids while freezing.[4]
- Have the nurse activate the machine by stepping on its pedal; you just give clear verbal instructions: "start" and "stop."
  - It is preferable that you concentrate on placing the cryoprobe and the freezing effect.
- Always have visual control over the intraocular effect.
  - It is best to perform the cryopexy under the microscope; otherwise, use the IBO.

Pearl
Never count on the time of cryoapplication to determine its efficacy, only on your visual feedback (see **Table 29.1**).

Table 29.1 The visual feedback options in cryopexy for a retinal break

Color in the area of treatment	Interpretation
White	The retina turns white as it freezes over The application of cryopexy must be stopped as soon as the whitish discoloration starts to appear: the thick iceball seen over a large area is not a sign of "sufficiently strong" treatment but a precursor to PVR
Dark grey	It is not only retina that is being treated but the entire area of the retinal break (e.g., retina plus the naked RPE). The retina adjacent to the break turns white but the naked RPE shows a contrasting dark color The only acceptable scenario for this color to appear is a break that is very small (i.e., the size of the break is at most a little larger than the area of contact with the cryoprobe)[a]
Pink	The color is that of an RPE that is being treated, but it is not naked The retina is detached over the area of treatment but the detachment is too high[b] for the freezing effect to involve it. The ultimate danger in this scenario is that the surgeon either waits until all the subretinal fluid freezes over so that the iceball finally reaches the retina[c] or that the retinal break upon retinal reattachment will settle over an area that has not been treated. This is the reason why in eyes with a very high RD it is advisable to drain the subretinal fluid prior to cryoapplication

[a]"Bull's eye" sign: a dark area is surrounded by a white ring, which represents the retinal effect.
[b]That is, bullous.
[c]And the white color appears; see above.

[3] Some older models have a freezing effect along the shaft, not only at their tip (see the comment about the scleral depressor under **Sect. 28.6**): the area affected by the freezing is larger than intended.

[4] Significant and potentially painful lid swelling develops postoperatively if the lid has been caught.

- Do not treat the retinal break itself; treat the retina around it (see **Fig. 29.1**).
- Avoid overfreezing; stop the application as soon as the retina starts to turn white.
- Even if the surface was dried prior to placing the cryoprobe, an iceball forms on the ocular surface. This iceball takes a few seconds to melt after the cryo-application is stopped. Do not try to lift the cryoprobe off the surface, especially the conjunctiva, before the melting is complete – you may tear the tissue.

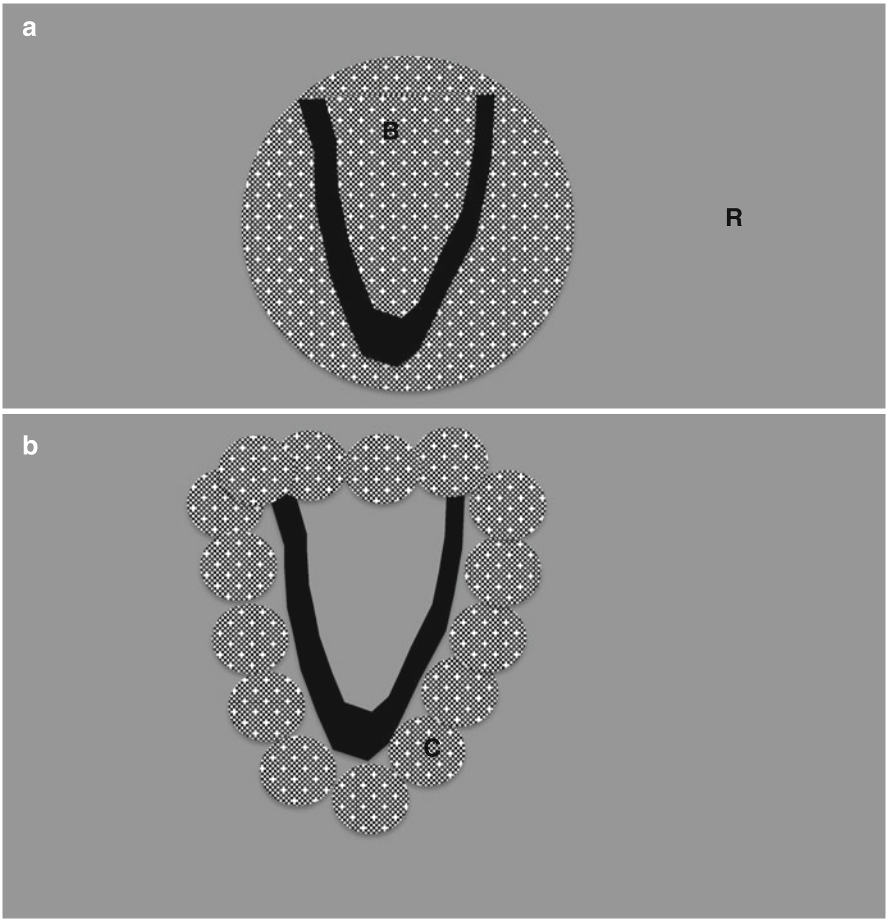

Fig. 29.1 **Cryopexy for a retinal break.** (**a**) The retinal break is illustrated by the thick black line. If the cryopexy is done incorrectly ("place the tip over the break"), the entire area freezes over, liberating RPE cells and further increasing the risk of PVR. The "single-spot" treatment is especially dangerous if the break is relatively large: to freeze the entire area takes a long time, and the effect will be greater in the center, where there is no "cover" over the RPE cells. Such a single-spot option is acceptable only if the retinal break is very small. (**b**) Done properly, the freezing involves only the area adjacent to the break, surrounding it with contiguous, light applications. *R* retina, *B* break, *C* cryo spot

It must be emphasized again that while cryopexy is an effective weapon in creating chorioretinal adhesion in eyes with RD, it has a higher complication rate[5] than laser. As much as possible, laser should be selected to treat around a retinal break (see **Sect. 54.4.2.2**).

29.3 Cryopexy as a Destructive Force

Although the technique's popularity is waning, the cryoprobe can be employed to destroy the ciliary body in eyes with intractable glaucoma and the peripheral retina in diabetic eyes with severe neovascularization or large areas of nonperfusion. In these indications "blind" cryopexy may be permissible: once the effect has been titrated in one location, the same duration of treatment can be applied in the rest of the area.[6]

- Ciliary body: continuous spots 1.5 mm from the limbus, ~30–50 s each. 180° (no more than 270°) treatment is recommended as the initial step.
  - Cryodestruction of the ciliary body risks leading to phthisis.
- Peripheral retina: continuous spots just posterior to the ora serrata (see **Sect. 26.2**), no more than ~30 s each. The entire area may be treated in one session.

Pearl

Even if the risk of postoperative PVR is higher with cryo- than with laser therapy, properly administered cryoapplication remains a useful weapon in the VR surgeon's armamentarium for diseases such as Coats', Eales', familial exudative vitreoretinopathy, and vascular tumors. The effect of cryoapplication must be monitored in these conditions as well (i.e., no blind cryopexy).

The inflammatory response may be severe after the destructive intervention, requiring judicious steroid treatment.

[5] That is, PVR risk.

[6] The duration indicated below is therefore only a rough estimate.

Endolaser

30

Laser, as photocoagulation in general, uses light to cause tissue coagulation as the energy from the light source is absorbed by the tissue and converted into thermal energy.[1] Laser's significant therapeutic benefit is thus delivered via a force that is destructive in nature.

Laser to the retina is typically applied at the slit lamp or via the IBO. Unlike endolaser, with these techniques the laser is delivered from outside the eye. Both involve at least some inconvenience to the patient,[2] and even if retrobulbar anesthesia is used, treatment close to the fovea poses some risk of misdelivery.

All other parameters (see **Table 30.1**) being equal, three factors determine the effectiveness of the laser therapy: the depth of penetration of the laser beam[3] and the type and amount of tissue pigment[4] that absorbs the laser energy. **Table 30.2** provides a list of selected conditions in which (endo)laser[5] therapy is applied.

Endolasers of different types[6] are available; the use of Argon green (514 nm) is described here.

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[1] Coagulation necrosis occurs with denaturation of the cellular proteins when the temperature exceeds 65° C.

[2] With IBO, scleral indentation is usually needed, which can be rather painful, even under anesthesia.

[3] YAG laser (1,064 nm) can penetrate the choroid and cause bleeding and vascular occlusion.

[4] Melanin in the retina.

[5] Most, although not all, of the conditions listed can also be treated by laser therapy delivered at the slit lamp or via the IBO. In principle, endolaser as a technique is preferable because it allows more precise and convenient delivery to the target – but, naturally, it also requires surgery.

[6] Argon, diode, double-frequency YAG, dye, krypton etc.

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Table 30.1 The parameters influencing the efficacy of the endolaser

Variable	Variable	Increasing effect	Decreasing effect
Laser parameter	Duration	Longer	Shorter
	Power	Higher	Lower
	Size	Smaller	Larger
Distance of probe from retina		Closer	Further away
Angle of probe relative to the retina[a]	Perpendicular	Maximum	N/A
	Parallel	N/A	N/A
	In-between perpendicular/parallel	Closer to 90°	Closer to 0°
Pigment content of the retina		More	Less
Fluid content of the retina (edema)		Less fluid	More fluid

[a]The spot is a perfect circle if the angle is at 90° and becomes increasingly oval as it approaches 0°.

Table 30.2 Selected indications for endolaser therapy

Indication[a]	Comment
Central serous chorioretinopathy	To close the vascular leakage as seen on fluorescein angiography
CNV	To destroy a (parafoveal) membrane[b]
Diabetic retinopathy[c]	Panretinal or focal treatment, depending on the severity of the disease; the goal is to destroy ischemic areas that produce vasoproliferative agents and to prevent bleeding and exudation
High IOP[d]	Endocyclophotocoagulation to destroy (some of) the ciliary processes
IRMA[e]	To close the vascular leakage
Macular edema in diabetes, vein occlusion etc.	To dry the macula – the mechanism how laser may work is not known
Prophylactic[f]	To prevent RD (endolaser cerclage)
PVR	To prevent redetachment (endolaser cerclage)
RD	To seal the break and to prevent redetachment (endolaser cerclage)
Retinal tear	To seal the break to prevent RD development
Retinal telangiectasias[g]	To reduce exudation and prevent progression
Retinal vascular tumors[h]	Destruction of the feeder vessel or the tumor itself
Retinoschisis	To prevent progression or mark the central border of the pathology
Retinotomy/retinectomy	To seal its edge to prevent redetachment
ROP	Retinal ablation to halt disease progress
Vessel, abnormal	A feeding vessel of a tumor or other pathology containing one or vessels in a proliferative membrane may be closed with high-intensity laser application. Argon green (512–534 nm) is the best option for this purpose because it is absorbed by blood. Nonetheless, diathermy or preoperative bevacizumab is typically preferred to laser in these cases

[a]In alphabetical order.
[b]This option should not be neglected even in the anti-VEGF era.
[c]And other vasoproliferative diseases such as Eales'.
[d]Unresponsive to other treatment modalities.
[e]Microaneurysms, perivascular leakage, telangiectasias.
[f]E.g., in an eye with high myopia.
[g]Coats' disease, idiopathic juxtafoveal telangiectasias, Leber's miliary aneurysms.
[h]Capillary hemangioma, cavernous hemangioma, racemose hemangiomatosis, vasoproliferative tumor.

30.1 The Consequences of Laser Treatment

- The retina becomes edematous after laser treatment. The surgeon notices that within a few seconds, the spot, which was white with sharp borders upon delivery, turns fuzzy-bordered, and its color turns a bit grayish.
- With time,[7] the spot turns into a scar. The RPE, the photoreceptors, and the retinal layers external to the inner nuclear layer are involved in the scar; there is some hyperplasia and hypertrophy of the remaining RPE. Glial cells also contribute to the development of the scar.
  - The visual consequence of the scar is a miniature, focal scotoma: the overlying nerve fibers are spared (see **Fig. 51.4**).
  - If too high laser power is used, all retinal layers, including the nerve fibers, are scarred over.[8]
  - The size of the scar increases by ~50% with time.

Q&A

Q *What may be the undesirable consequences of an "overpowering" (endo)laser spot?*

A Pain, even if the rest of the operation was painless; corresponding defect in the visual field; significant retinal bleeding; retinal break formation; break in Bruch's membrane with development of a neovascular scar; if a spot is close to the fovea, RPE migration into it with loss of the central vision; and the vitreous "burned" into the scar, making PVD creation impossible.

- After treatment, the oxygen consumption of the retina is reduced.
  - Oxygen is able to diffuse through the laser scars without being consumed by the photoreceptors, relieving the inner retinal hypoxia and raising its oxygen tension.
  - The retinal arteries constrict and the blood flow decreases. The hypoxia relief reduces VEGF production, and the neovascularization process stops or regresses.

30.2 The Setup

The initial step is to ensure that the laser filter is properly situated on the microscope. It should be mounted so that it provides protection for the surgeon, his assistant, the nurse, and the video camera. The first three are a matter of safety[9], the fourth of convenience. It is advisable for all in the OR to wear safety goggles when the endolaser is in use.

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[7] Roughly a month is needed for the chorioretinal adhesion to reach its maximum strength.

[8] I have seen many patients with almost black fundi, with the hyperpigmentation approaching or even reaching into the fovea.

[9] For the surgeon, to view endolaser delivery without the proper filter is unpleasant at best and blinding at worst.

The laser pedal should be in the middle (see **Fig. 16.3a**) and operated by the nondominant foot.

30.3 The Technique of Endolaser Treatment

Unlike cryopexy, laser is ineffective if applied over detached retina.[10] This is the reason why, for instance, in RD surgery laser is delivered after drainage of the subretinal fluid and under air.

Pearl

As a general principle, the parameters should be adjusted so that the effect is a discreet but visible whitening of the retina with no apparent major tissue disruption (strong whitening, bubble formation, significant bleeding, audible "pop").

30.3.1 General Considerations

To deliver a spot that causes mild retinal whitening, all three main parameters must be properly set.[11]

- My default parameters are the following:
  - Duration, 100 ms; spot size, 100 μ; energy, 150 mW.
  - Since the effect also depends on the pigmentation of the fundus,[12] major changes in the settings may become necessary. It is best to test the parameters at a peripheral location (see below).
- An additional parameter to set is the "repeat" mode (see below).
- Ideally the laser probe is curved so that the surgeon can always keep it perpendicular to the surface and be able to reach any retinal area without difficulty or risk in the phakic eye.
  - The straight probe has significant limitations regarding reach and safety.[13]

[10] This is true only to a certain extent. Even when the retina is detached, if an RPE reaction to the laser is visible and the retina is attached within hours, the chorioretinal scar still may form. Such treatment, however, is difficult and somewhat unreliable; it is far better to reattach the retina first.

[11] Remember: the power required to produce a visually visible spot decreases with increasing pulse duration and decreasing spot size (see **Table 30.1**).

[12] Lightly pigmented eyes (e.g., high myopes) require higher power or longer duration. The reason why laser treatment is not used in a staphyloma-spanning posterior RD (see **Chap. 56**) is the lack of melanin (hence the white fundus) and therefore uptake of the laser energy.

[13] It is more difficult to perform peripheral laser in the 6–12 o'clock meridian and impossible on the opposite periphery in the phakic eye.

  - The curved probe (may be retractable if made of memory material) can be held truly perpendicular to the retina at all locations – but the surgeon must remember to pull the laser probe into the shaft before exiting the cannula with it (see **Sect. 21.7**).
  - In a phakic eye it is possible with the curved probe to avoid damaging the lens, but extra caution is still needed: the surgeon tends to focus on delivering the laser spots, not on the actual position of the laser probe's shaft.
- The spots should not be confluent; as a general rule, the distance between spots should be roughly the same as the spot diameter.
  - When panretinal treatment is employed, this rule is difficult to keep (see below).
- The working distance[14] is typically ~1–2 mm – with some caveats.
  - When lasering under air (see **Sect. 31.2**), it may be difficult to clearly see the tip's distance from the retina, especially in the periphery. The laser probe must be advanced close to the retina,[15] and the surgeon should carefully observe the distance between the shaft's tip and the shadow it casts.
  - Different areas in the fundus have different degrees of pigmentation. If the laser power proves too strong (weak) at the "test site," it is more efficient to increase (decrease) the working distance than continually adjusting the power on the console.

Pearl
When working in "repeat" mode (see below), too short a working distance is dangerous: it is easy to bump into the retina as the probe is moved along.

- The initial "test" spot should always be delivered well outside the macula. If no effect on the retina is seen, examine the aiming beam (this may tell you whether the cable is broken) before you increase the power/duration or shorten the working distance.
- PFCL has a cooling effect and this makes recognition of the spots more difficult – overtreatment is a risk.
- Avoid lasering a hemorrhage[16] since the blood may absorb it and cause damage to the more superficial retinal layers.

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[14] The distance between the tip of the laser probe and the retina.

[15] Such close proximity may require a reduction in the laser power.

[16] The microaneurysm, which may be indistinguishable from a small bleeding in diabetes, is an obvious exception.

Pearl
It is somewhat controversial whether a posterior retinal break or retinotomy (i.e., in an area where the vitreous has been verifiably removed) requires laser treatment. *In principle*, the answer is no, since no traction is left behind; the laser spots also increase the size of the scotoma. *In practice*, laser may make sense because of any possible future traction. An individual decision is needed (I very rarely do laser for posterior retinal breaks; see also **Sect. 8.1**).

- Edema, whether caused by RD[17] or other conditions, reduces the efficacy of the treatment.

30.3.2 Panretinal Treatment

The technique presented here about the order of spot placement reflects my personal approach. Every surgeon must develop his own philosophy – what matters is that some kind of order be kept.

- I initially apply 2–3 rows in a circle around the macula so as to reduce the risk of inadvertently venturing too close to the fovea during the delivery of many hundreds of laser spots.[18]
- I follow with the full treatment on the opposite side of the retina, then switch hands to complete the laser application on the other half of the fundus.
- Usually I do the treatment centrally first and in the periphery second, due to the ease of maintaining visibility, especially in the pseudophakic eye (see below). It is advisable to use the dominant hand to complete the laser application at the posterior pole.

---

[17] The treatment is over a retina that has just been reattached.

[18] The risk is that the concentration drops once the exhausting part of the surgery has been completed (see **Sect. 3.7**).

- Switching hands at some point is unavoidable in order to complete the treatment.
  – When to switch hands has no strict rule: it need not be exactly at the 6 and 12 o'clock meridian. When the spots are becoming oval, a switch is in order.

Q&A

Q *May the surgeon complete the panretinal laser coagulation during the same operation, or should it be finished during a 2nd session at the slit lamp or via the IBO?*

A Even 1,500–2,000 spots, delivered during a single session (see **Fig. 30.1**), have not been associated with any detrimental effect – in fact the outcome may be better than with multiple sessions. The reason why multiple sessions are used at the slit lamp has more to do with patient comfort and convenience, which are not an issue with endolaser (Using micropulse laser at the slit lamp, it is now possible to complete the treatment in a single session.)

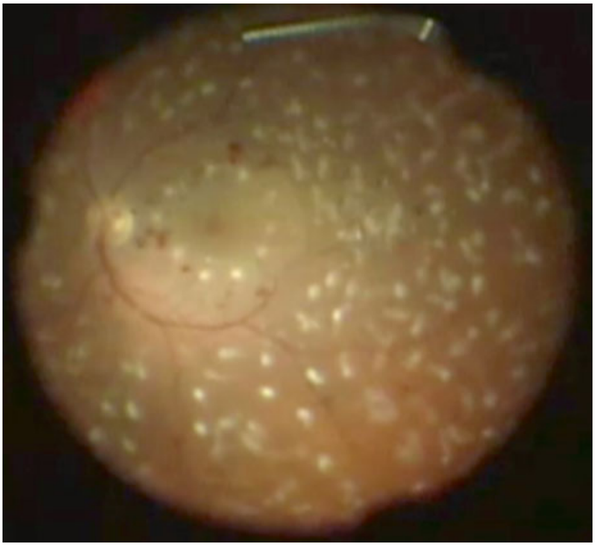

Fig. 30.1 **Panretinal endolaser**. The treatment of the posterior pole has just been completed; the spots are white and only slightly edematous. The curved (non-retractable) endoprobe is still visible inferiorly

- I always use the "repeat" mode of the laser equipment; no surgeon should be forced to step on the laser pedal 1,000 times. This is not only inconvenient but also risky: eventually you will have to readjust your posture and may accidentally deliver laser to an unintended location.

Pearl
The more experienced the surgeon, the shorter the repeat time can be.

- The edge of the IOL causes parallaxis (see **Sect. 25.2.4.3**). The surgeon, if the pupil is wide enough, will have to alternatively view the retinal periphery outside or through the optic.
  - If this is the case, it is best to finish a large area's laser treatment viewed either outside or through the optic and then move on to the other area. Switching the view back and forth in quick successions is tiresome.
- When lasering close to the macula, extra steps are necessary to avoid "hitting the bull's eye."[19]
  - Use the single, not the repeat, mode (one spot per one pedal pressing).
  - Make sure the spot is not too strong (see above).
  - Avoid lasering in the foveal avascular zone (see **Sect. 26.1.3**).
- If the laser is employed for macular edema, inject bevacizumab or TA a few days earlier so that the macula is rather dry at the time of surgery, and then try "laser maculopexy" (see **Fig. 30.2**).

Pearl
All ophthalmologists must keep in mind that with time the optic disc will turn pale after panretinal laser treatment. This is a normal phenomenon and must not be appreciated as a disease-related atrophy.

30.3.3 Endolaser Cerclage and Its Complications

A variant to panretinal treatment, this laser is aimed at preventing RD or redetachment.[20]

- Deliver a more compact treatment[21] than for panretinal lasering (see **Fig. 30.3**).
  - In an emmetropic eye, 900–1,200 spots are needed.

[19] The risk of delivering a laser spot in the foveola is smaller during endolaser than at the slit lamp or via the IBO since the eye's position is firmly controlled by the two intraocular instruments in the surgeon's hands. This is true, however, only if the surgeon does not lose concentration during the process (see above).

[20] Only the technique is presented here; the indications are listed in **Chap. 54**.

[21] I.e., the spots are closer to each other.

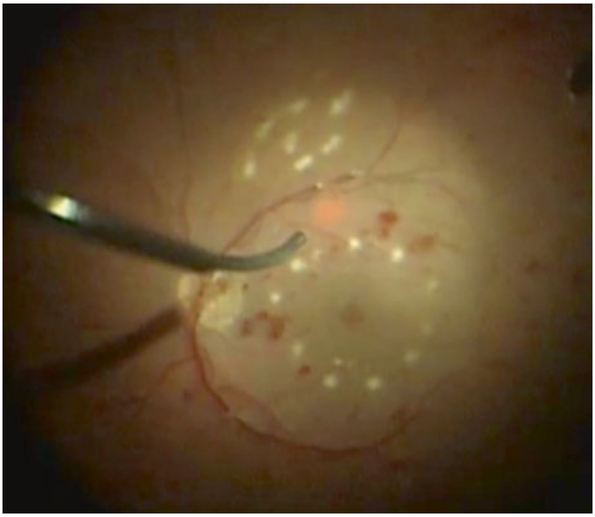

Fig. 30.2 **Laser maculopexy**. The macula has been dried with a prior intravitreal bevacizumab injection (see the text for details). A circular laser treatment is delivered close to the avascular zone to act as "nails" to reduce the risk of re-swelling of the retina

- The area to treat is from the ora serrata to slightly central to the equator (see **Fig. 30.3**).[22]

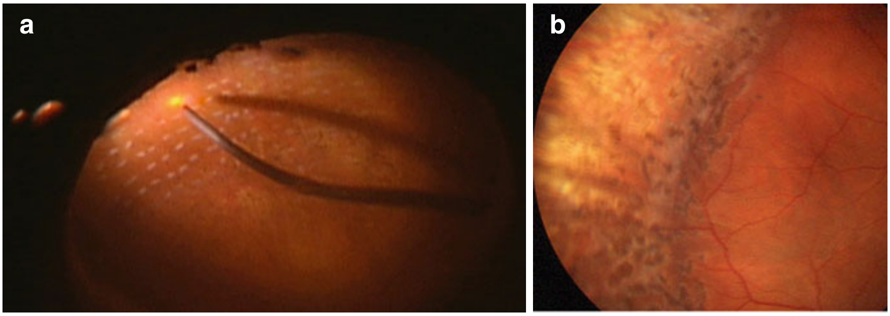

Fig. 30.3 **Endolaser cerclage**. (**a**) Endolaser cerclage is being performed. The posterior border of the area to be treated is posterior to the equator. (**b**) The healed spots form a confluent area of scars to counteract the effects of any remaining or new traction (or retinal break) in the anterior retina

- At the 3 and 9 o'clock positions, reduce the power/number of laser spots to avoid damaging the long ciliary nerves. A *dilated pupil* is one of the potential complications of endolaser cerclage.[23]
  - The other complication, just as with panretinal treatment, is *EMP*, occurring in 1–2% of the eyes. Prophylactic ILM peeling should be considered.

[22] The result is the creation of an "ora secunda" (a term coined by Robert Morris, MD).

[23] Fortunately this is extremely rare. If it does occur, pilocarpine 1–2% twice a day should be prescribed. After a few weeks, the pupil almost always regains its normal size; if not, the patient should continue using pilocarpine as needed. Pupilloplasty is another possibility (see **Sect. 48.2.3**).

Endolaser cerclage is best done using the wide-field front lens of the BIOM under air[24]; this allows visualizing the retina up to the ora serrata if the pupil is wide enough. An alternative option is scleral indentation.

Pearl
If the RD risk is similar in the fellow eye, prophylactic endolaser cerclage must be discussed with the patient (see **Sect. 42.1**). If done properly, such an intervention is *almost* a guaranty against future RD (see **Sect. 54.2.4.1**).

30.3.4 Endolaser as a Walling-Off (Barricading) Tool

- In eyes with *peripheral retinoschisis*, the purpose of the laser treatment is twofold:
  - By creating a barrier of adhesion, it prevents progression of the condition toward the macula.
  - By marking the border of the pathology, it allows the ophthalmologist to accurately monitor whether progression has occurred.[25]
- In eyes with *PVR* or *PDR* and partial RD whose progression is prevented by silicone oil, the laser barricade acts as an additional weapon in maintaining retinal attachment.

The laser spots should be tightly placed (see **Fig. 30.4**) or be "painted" by continuous application and extended all the way to the ora serrata on both ends to prevent the intraretinal fluid to "come around the laser wall." The treatment must be especially firm inferiorly, where, due to gravity, the risk is higher than in the superior part. 2–3 rows are needed to ensure maximum effect.

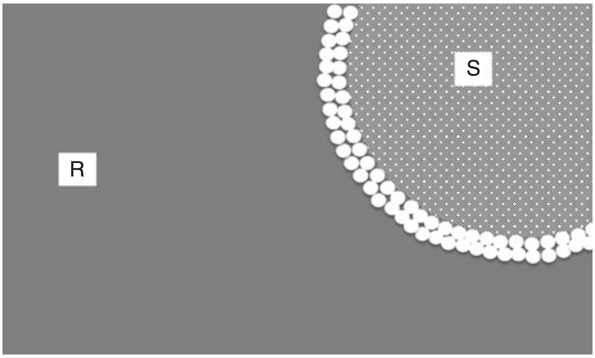

Fig. 30.4 Walling-off laser. The retinoschisis (*S*) is surrounded by two contiguous rows of laser applications (represented by *white circles*) to prevent progression of the condition into the attached retina (*R*). See the text for more details

[24] Acting as a lens, the air increases the visual field. This effect is especially useful in the aphakic eye if the AC is also filled with air.

[25] As detailed in **Sect. 57.1.2**, the ophthalmologist's goal is to *avoid* surgery in this condition. The laser application is therefore ideally done at the slit lamp, not intraoperatively.

30.3.5 Endolaser as a Welding Tool

- The *retinal break* is the most common indication and has the same goal as in the case of cryopexy (see **Fig. 29.1b**). The laser spots must surround the break in a contiguous fashion, by 2–3 rows.
- A *retinotomy* that is posterior so that all vitreous can safely be assumed to have been removed does not require laser treatment – but the surgeon may feel he will sleep better if he does it. If the retinotomy is in an area where it is not certain that the vitreous removal was complete (see **Fig. 63.9**), it is advisable to surround the lesion with laser.
- Following *retinectomy*,[26] a laser treatment similar to that shown on **Fig. 30.4** is recommended to prevent elevation of the remaining retinal edge.

30.4 Peripheral Laser and the Beginner VR Surgeon

Performing panretinal laser in the periphery, and especially laser cerclage, is perhaps the most frustrating part of VR surgery for the beginner. The procedure appears rather easy when *viewed* through the assistant's microscope or on a videotape but can be cruelly difficult when *performed*, for numerous reasons.

- Visibility is poor, especially if the laser is performed under air and in the pseudophakic eye, due to parallaxis, and if either of the capsules is hazy (see above). It is difficult to view the retina, the tip of the laser probe (i.e., the proper working distance; see above), and the delivered laser spot unless the power is too strong.
  - Condensation of the back surface of the IOL in the air-filled eye adds to the difficulty (see **Fig. 25.2**).
- Occasionally, even if visibility is acceptable, no visible laser spot appears after the application. One of the many possible causes[27] is that during the previous spot, the tip touched the retina and the surface is covered with tissue.
  - If the laser is performed under fluid, any small air bubble that is inside the vitreous cavity will adhere to the tip of the probe and prevent laser delivery.
- The most distal portion of the shaft should be held perpendicular to the retina (the plane of the tip itself is parallel to it). If a straight probe is used, the surgeon has no control over this, and the shape of the laser spots will become oval. If a *curved probe* is used, the procedure's technical complexity grows because the surgeon must adjust the position of the probe according to how the geometry of the treated area (in effect the angle between retina and the probe itself) changes.
  - If a retractable probe is used (see **Fig. 30.2**), one possibility is to increase or decrease the length of the shaft. This allows the surgeon to maintain the

[26] In diseases such as PDR or PVR.

[27] Others include damage to the fiber-optic cable, malfunctioning of the equipment, or intraocular causes such as lack of fundus pigmentation or increased tip distance from the retina.

correct angle between the shaft and the retina, but the adjustment is rather cumbersome and somewhat dangerous.[28]
  – A better option with the retractable probe (and with a probe whose curvature is fixed, see **Fig. 30.1**) is to twist the shaft around its main axis. In most areas, it is easy to have visual feedback of the position (angle) of the bend, but in the horizontal meridian, the surgeon sees the shaft as a straight line; it is impossible to determine whether concavity of the bend on the probe points upward or downward.
  – The further the probe is away from the horizontal meridian, the more sideways it will be held,[29] increasing the visibility of its curvature.
- The light pipe's position must also be monitored to avoid bumping it into the retina or the lens.
  – Even if the retina is not injured mechanically, phototoxicity remains a risk if the light pipe is held too close to the retina (see **Sect. 22.1**).
- In addition to the constant adjustment of actions of the two hands described above, the surgeon's two feet must also have closely coordinated movements (with each other and with the hands): the nondominant foot operates the laser pedal, the dominant foot the X/Y joystick (see **Fig. 30.5**).

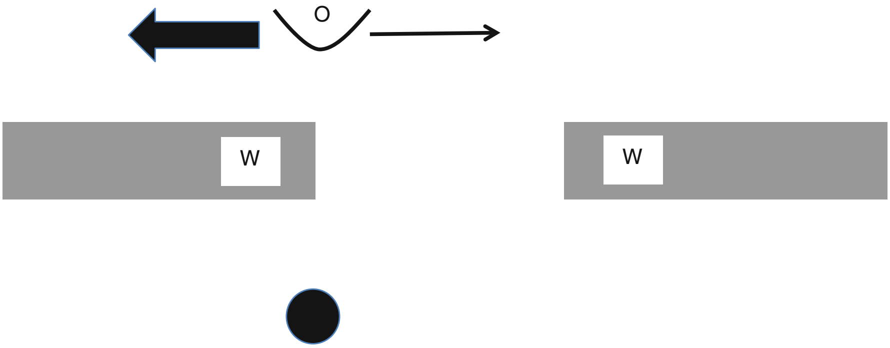

Fig. 30.5 Schematic representation of the adjustment of the image during endolaser cerclage. If an object (*black dot*), which is in another room and partially hidden behind the wall (*W*), is to be viewed through a doorway, the observer (*O*) simply moves so that the view is unobstructed (*thin arrow*). If the retinal periphery is to be viewed through the BIOM, sometimes the opposite is needed: moving as if further behind the wall (*thick arrow*)

[28] The retractable shaft may be pushed too far out, hitting the retina, or the entire probe is accidentally moved as the surgeon's index finger tries to locate the slider. In addition, the slider may initially resist the movement (similar to what is described under **Sect. 20.3**).

[29] The plane of the bend thus changes from the sagittal to the frontal.

- The process is lengthy; the surgeon's eyes become dry and his lower back starts to hurt (see **Chap. 16**).
- The patient's nose may be in the way.

Pearl
To avoid the frustration, do not start performing laser cerclage early in your VR career, and even then do it only gradually (smaller, more central areas but away from the macula first). Do not be discouraged by the early difficulties; all surgeons had to go through the same process.

30.5 Endocyclophotocoagulation

If the IOP is high and cannot be controlled medically, one of the many options is cyclodestruction. Proper scleral indentation by the surgeon (see **Sect. 28.4**) allows visualization of the ciliary processes, which can be individually shrunk by applying high-power laser treatment (see **Fig. 30.6**). The effect is both visible and occasionally audible (see **Chap. 25**).

Even though the success rate of the intervention is usually rather limited, do not treat more than 180° in the initial session: the effect on the individual process is irreversible.

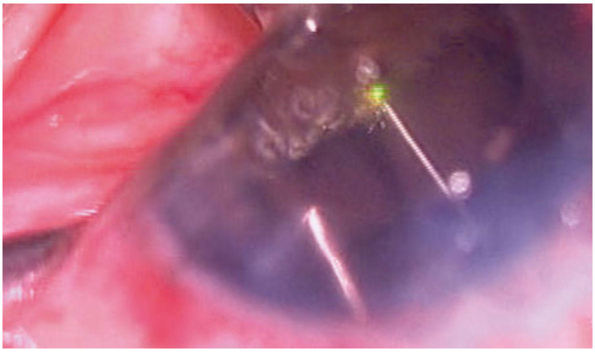

Fig. 30.6 **Endocyclophotocoagulation**. Scleral indentation brings the ciliary processes into view; laser is applied to destroy the selected processes. The infusion cannula is also visible inferiorly

30.6 Laser Cerclage at the Slit Lamp

It is possible, even if more difficult, to perform proper treatment at the slit lamp. Instead of the three-mirror contact lens, use a contact lens with a very large field[30] and try to achieve a similarly wide zone of treatment as described above (**Sect. 30.3.3**).

[30] Such as the Super Quad 160 lens (Volk, Mentor, OH, USA).

Working With and Under Air

31

Air in the vitreous cavity is the weapon of choice to achieve retinal reattachment (F-A-X); the air is then kept in the eye to perform the laser treatment. Laser cerclage, even if the retina is attached, is easier to carry out in the air-filled eye (see **Sect. 30.3.3**). Air can also be used a short-term tamponade (see **Sect. 35.1**) and for various other purposes (see below, **Sect. 31.3**).

31.1 The Technique of F-A-X

Regardless of all other circumstances, two caveats are important to keep in mind:

- Never use too high an air pressure.
  - The jetstream hitting the retina is one possible cause of a visual field defect.
- Do not allow the infusion cannula to point toward the disc or macula.

31.1.1 Attached Retina

This is a rather straightforward procedure.

- Keep the flute needle over the disc.[1] Do not touch the disc, and hold your hand firmly.
- Switch to air and aspirate the fluid as the air is coming in and pushes the BSS posteriorly.
- If absolutely all of the BSS needs to be evacuated,[2] patience is in order. It will take a couple of minutes for all the fluid to collect posteriorly.

[1] In highly myopic eyes, the staphyloma may be the deepest point of the eyeball.

[2] Such as if silicone oil is to be implanted (see **Sect. 35.4**).

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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Pearl
The intravitreal fluid adheres to the retina, however weakly: trickling down takes time. Think about your coffee mug after you drank all your coffee; within seconds, a small pool of coffee starts to become visible at the bottom of the mug.

31.1.2 Detached Retina (Retinal Reattachment via Draining Through a Retinal Break)[3]

This may be a rather frustrating maneuver for the inexperienced surgeon.

- Mark the central edge of all retinal breaks[4] so that they remain visible in an air-filled eye.
  - The retinal break, so conspicuous under fluid, is likely to "disappear" under air.
- Turn the eye so that the central-most retinal break is at the deepest possible point of the eye.
- Insert the flute needle. Position your hand firmly, holding securely the tip of the flute needle just *above* the break.
  - Lift your finger off the silicone chamber only when the flute needle's tip is in position.
  - Occasionally, the subretinal fluid will drain even without employing air.
- Switch to air. The air pushes the subretinal fluid posteriorly, toward the flute needle's opening.
  - Unless the RD is old, the fluid is not viscous: the fluid column readily enters the flute needle as long as the column is not interrupted.

Q&A
Q *How do you drain a subretinal fluid that is very viscous?*
A Too viscous a fluid will either not enter the flute needle at all or it will rapidly obstruct it. (Naturally, the smaller the gauge, the greater the chance that this occurs.) The surgeon either asks the nurse to repeatedly flush the silicone chamber and the needle itself, or, preferably, choose active suction. The latter may be possible with the flute needle (see **Fig. 36.2**) or the probe. The port may need to be "dipped" into the subretinal space to avoid catching the retina (see **Sect. 25.2.6**).

[3] Additional details and a summary are provided in **Table 35.3**.

[4] Except if they are in a cluster and at equidistance from the ora serrata; here a single mark is sufficient.

- A highly mobile retina can easily be caught in the port as the surgeon's finger is lifted off the flute needle's chamber.
  - Carefully push the tip of the needle into the subretinal space through the break. This maneuver risks injuring the choroid, but it greatly reduces the chance of retinal incarceration.
  - Alternatively, inject PFCL to keep the retina immobile. This, however, introduces its own issues if air is used: the PFCL evaporates, and tiny droplets collect on the IOL (see **Sect.** 31.2).
- With the air entering and the subretinal fluid escaping the eye, the surgeon has a good chance of achieving a complete drainage. The capillary effect assures that the fluid will keep streaming even if the retinal break is not at the deepest point of the eye, as long as the fluid column is not interrupted – which is the beginner's most difficult task to achieve.

Pearl

A F-A-X can also serve as an air-test. If no membranes are left on the retinal surface, no significant subretinal membrane is present, and the retina is not shortened, the retina will be attached but not stretched when the drainage is complete, and its surface will be smooth.

  - Initially, the air forms small bubbles as it enters the vitreous cavity (see **Fig.** 31.1), and it takes a few seconds, sometimes longer, for the bubbles to coalesce. Until this happens, the view is completely lost; if indeed the surgeon holds the flute needle absolutely steady, drainage continues.
  - Conversely, once the fluid column is broken, the air pushes the central edge of the retinal break onto the RPE, and the subretinal fluid is trapped centrally.
- In cases of residual *subretinal* fluid you have the following options.
  - Redetach the retina (acceptable though not ideal), and repeat the entire process.

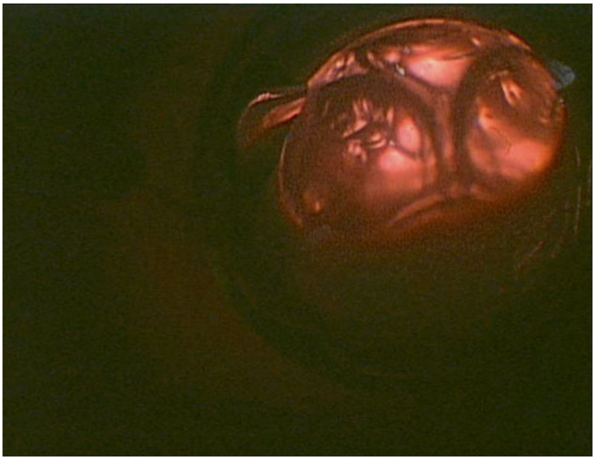

Fig. 31.1 Multiple air bubbles during F-A-X. It is rare that the incoming air immediately forms a single, large bubble. View of the posterior retina is lost until these small bubbles coalesce. See the text for more details

- Inject a small amount of PFCL and turn the eye so that you push the subretinal fluid toward the break, then try to complete the drainage.
- Make a small central retinotomy and drain through it. This is not advisable since it represents a risk factor for PVR.
- If only a small amount of subretinal fluid remains and silicone oil is not used, leave the fluid behind and the RPE will pump it out it within days.[5] If the RD was macula on, keep the fluid out of the submacular space (steamroller effect, see **Sect. 54.6.3.1**).
- Leaving a larger amount of subretinal fluid behind is unacceptable. If silicone oil is used as the intraocular tamponade, you cannot achieve a 100% fill. If gas is used and the border of the detachment is close to the fovea, a macular fold may be caused.[6]

- Drain all the subretinal fluid first, before collecting the BSS in front of the disc; otherwise the incoming air may push the remaining subretinal fluid into the submacular space.

Q&A

Q *Is it always possible to drain all the subretinal fluid?*

A No. If the surgeon does not use PFCL and the break is very peripheral, some fluid will be retained subretinally. A very viscous fluid may form a difficult-to-remove film on the retinal back surface. Especially after SB surgery, a small fluid pocket may be retained for months under the fovea (see **Fig. 54.11**).

- Whether all the *intravitreal* BSS needs to be collected depends on whether silicone oil or gas tamponade is to be used (see above).

31.2 Working in the Air-Filled Eye

Accept that visibility will be poorer under air than under any type of fluid.

- The BIOM's front lens in a phakic or pseudophakic patient must be adjusted higher (see **Table 16.5**).
- Retinal tears of small size tend to "disappear," unless marked by diathermy (see **Sect. 54.5.2.3**).
- Condensation may occur on the surface of the IOL in the area of the posterior capsulectomy.

[5] Unless the fluid is very viscous – try to remove such viscous fluid completely (see below).

[6] A real disaster if it is through the fovea. If a fold develops, the retina must be redetached to deal with it – easy if the fold is discovered intraoperatively. However, if the retina reattaches and the fold is noticed only weeks postoperatively, even a successful anatomic result (no small feat by itself) may not bring functional improvement.

Pearl
Fluid, whether BSS or PFCL, condensation on the back surface of the IOL can significantly worsen the view. The surgeon can wipe it off with a blunt tool or "smear" a *thin* layer of *dispersive* visco on the IOL (see **Fig.** 25.2).

- Even in phakic eyes, the air will occasionally enter the AC.
  - Either fill the AC with visco or readjust the BIOM front lens.

  Working in the air-filled eye also has tangible benefits.

- The visual field increases under air, allowing access to peripheral areas that were out of view before. This is especially beneficial when extensive lasering is necessary in the periphery.
- The air allows safe vitreous removal in the periphery (pneumovitrectomy, see **Fig.** 14.1 and **Sect.** 27.3.2).

31.3 The Utilization of an Air Bubble

Air can also be employed for the following purposes.

- Demonstrating the presence of vitreous behind the posterior capsule (see **Sect.** 27.5.3).
- Demonstrating the presence of vitreous in the AC: the normal, perfect-sphere shape of the bubble is distorted if vitreous gel is present (see **Sect.** 63.6).
- Preventing the iris from prolapsing into a (paracentesis) wound (see **Sect.** 39.1).
- Preventing silicone from prolapsing into the AC (see **Sect.** 35.4.4).

Working with Membranes 32

This chapter discusses the *technical* issues of dealing with different types of membranes inside the vitreous cavity.[1] Additional details[2] about these membranes are discussed either here or in various chapters in **Part V**.

32.1 ILM[3]

32.1.1 Instrumentation and Infrastructure

The most delicate surgical maneuver (see **Sect. 15.2**) performed on the human body is ILM removal.

- The microscope must have excellent resolution (see **Sect. 12.2**).
- The surgeon must sit comfortably with his wrist firmly supported (see **Sect. 16.2**). While ILM peeling can be performed without wrist support (only the surgeon's fingers resting on the patient's forehead), this is far from ideal.[4]
- All equipment and instruments must be in working condition[5] and the materials prepared in advance and readily available.
  - The forceps (see also **Sect. 13.2.1**) must be a dedicated ILM forceps to allow grabbing the ILM whose thickness is less than 2 μ.

[1] The "what" and "how" questions (see **Sect. 3.4**).

[2] The "when" and "why" questions (see **Sect. 3.4**).

[3] **Table 32.1** provides a summary of the indications for ILM peeling.

[4] "I'm able to peel the ILM without wrist support" – such boasting is irresponsible, rather than a tribute to the surgeon's exceptional dexterity.

[5] The ILM forceps is an extremely delicate tool; whether reusable or disposable, it should not be automatically assumed that its operating mechanism actually works or the jaws perfectly close.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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Pearl
Repeatedly grabbing *hard* membranes (in PVR or PDR) with the ILM forceps can cause enough "microtrauma" to the closing surfaces that they will not work on the ILM anymore.

  - If the membrane is infinite (no edge initially), it is the width of the jaws' tip that determines the area of contact between the forceps and tissue. Once an edge is present, the entire jaw surface can make contact with it.[6]
  - The greater the width of the ILM forceps, the more secure the grip and the less likely that it tears the ILM. However, increasing the width also interferes with the visual feedback the surgeon has over the depth of contact between forceps and ILM.
- The plano-concave contact lens should be scratch-free and fully transparent.
  - Using the smallest amount of visco, rather than lots of it, also helps, provided the amount is sufficient not to trap any air bubble under the lens. Still, the nurse should have at hand a tool such as a muscle hook to be able to gently nudge the contact lens if it slides and needs to be re-centered.
- Increase the zoom as much as possible – find a compromise between image size and sharpness.
- Although it is not mandatory to stain the ILM (see **Fig. 32.1**), it is highly recommended to do so since it has numerous advantages (see **Chap. 34**).

32.1.2 Opening the ILM

Unlike all other membranes inside the vitreous cavity, the ILM has no free edge to grab: it must be surgically opened before it can be removed. The ILM can be opened in two ways: sharp or blunt.[7]

32.1.2.1 Sharp Opening: Incision First

Sharp opening of the ILM involves the use of a barbed[8] needle (see **Sect. 13.2.3.1**).

- Place the tip of the hook over the retina at a convenient and safe location[9] (see **Fig. 32.2**) so that the tip barely touches the ILM surface. Avoid all visible blood vessels.

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[6] A thick proliferative membrane does have an edge; in this case the size of the initial grab is determined by the space between the membrane and retina. If the lower jaw of the forceps can be pushed far beneath the membrane, the entire surface of the jaws can be in contact with it.

[7] Another way of classifying the opening is to distinguish between a one-step (forceps) or two-step (open with one tool and peel using a second) procedure.

[8] Without the barb, the maneuver is less safe: the tool must be kept and moved while being held perpendicular to the retinal surface. The shaft is at an acute angle to the retinal surface but is moved parallel to it. The barb is needed to incise, hook, and lift the ILM.

[9] My preference is outside the foveal avascular zone close to, but inside of, the vascular arcade, superotemporal to the fovea in the right and superonasal in the left eye.

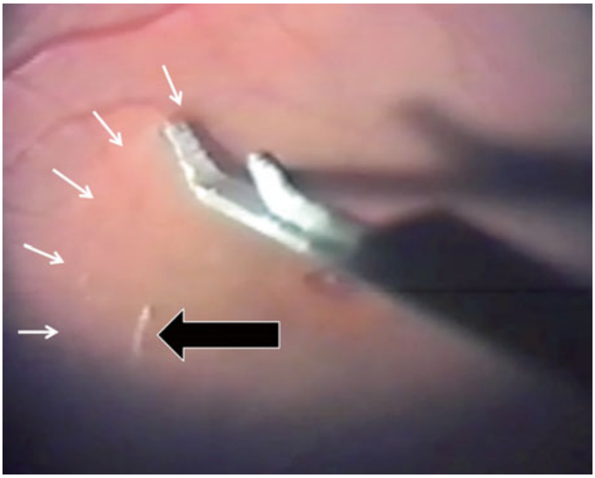

Fig. 32.1 Recognizing the unstained ILM. In this eye with macular hole, the unstained ILM has been incised with a barbed MVR blade. The lower blade of the forceps (Storz #E 1964 20 g; Bausch+Lomb, St. Louis, MO, USA) is pushed between the ILM and the nerve fibers and used as a spatula to separate them in a larger area. The two signs that give away that the lower jaw of the forceps is in the correct plane are the circumscribed light reflex (*black arrow*) and the faint semicircle of discoloration (*white arrows*)

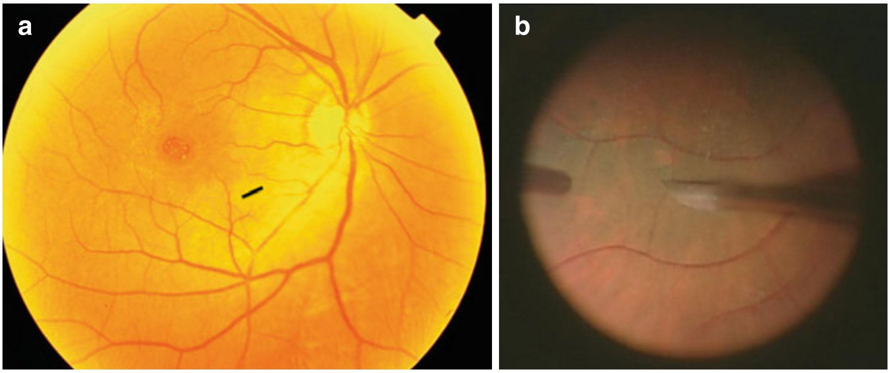

Fig. 32.2 The location of the initial ILM incision. (**a**) In this right eye with a macular hole, the surgeon places the barbed needle, held in his dominant right hand, in the superonasal area from the fovea. Ideally, the direction of the slice follows the course of the nerve fibers so that even if the incision is too deep, the damage will be limited. The incision avoids all visible vessels to reduce the risk of bleeding. (**b**) The ICG-stained ILM is opened with a barbed 23 g needle

- Once your hand is truly steady, gently push down with the barb.
- Slowly drag the barb, parallel to the retinal surface, a millimeter or so. The stained ILM will produce a visible flap, indicating that it has been incised. The opening should be at least as wide as the jaws of the forceps.
- Take a forceps and grab the flap and then peel the ILM (see below).

In principle, working with a sharp tool is the least traumatic way to open the ILM. The surgeon needs to control no more than a single maneuver at a time – the depth to which the tiny hook is sunk into the retina first and then moving the tool "in plane"[10] and even that over a little distance only.

Q&A

Q *Is it not a contradiction to say that a sharp tool is safer than a blunt one?*

A No – as long as the surgeon is able to control the depth to which he pushes the barb into the retina. With forceps, there are additional variables to control (see below). The third option, the scraper, is even more dangerous, precisely because the surgeon gives up control (see below).

32.1.2.2 Blunt Opening: No Incision

Blunt opening of the ILM is possible in two very different ways: via a primarily vertical movement (forceps) and a primarily horizontal one (scraper).

The ILM Forceps[11]

The advantage of this technique is that the same tool is used to tear and then peel the ILM. The disadvantages include the difficulty controlling the depth (so as to avoid tearing the nerve fibers, which run just beneath the 2 μ thick membrane) and the complexity of the maneuver.

- Place your forceps over ILM (see above the site-selection criteria).
  - All current forceps designs are such that the tip of the jaws is perpendicular to the axis of the jaws – none is slanted. Since the jaws face a concave surface, the initial contact point of the forceps should be rather posterior so that the tip is parallel with the retinal surface (see the concept under **Sect. 24.1**). Moving it too peripherally means that only the corner-edge of the tip of the jaws, a very tiny area, will be able to grab the ILM (see **Fig. 32.3**).
- Gently press down with the forceps. The depth should be just enough to create a depression so that when the jaws will be closed, a loop of ILM is caught but no nerve fibers (see **Fig. 32.4**).
- Close the jaws.

Pearl

The most common error the inexperienced surgeon commits is to combine all movements into a single motion, instead of separating it into its basic elements. (1) Have your wrist firmly supported *and* keep your little finger on the patient's forehead. (2) Position the forceps over the ILM in the selected area. (3) Close the forceps ~80% so that the ILM will easily fit into the jaws yet the distance your fingers will have to travel to close the jaws is shortened. (4) Push down with the forceps so that the ILM bulges as a loop in-between the jaws. (5) Close the jaws. (6) Lift the forceps. (7) Repeat *all* steps if there is no purchase.

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[10] That is, parallel with the surface.

[11] See also **Sect. 20.2**.

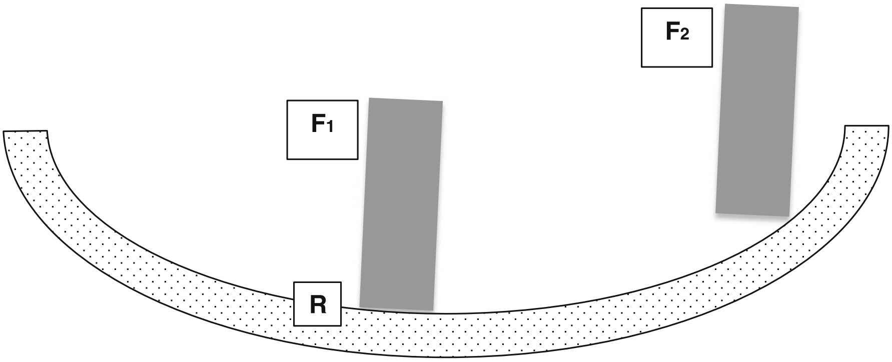

Fig. 32.3 **Schematic representation of the point of attack with the ILM forceps**. If the forceps is used rather centrally within the vascular arcade, the tip of the forceps is parallel with the retina (*R*), allowing the surgeon to grab the ILM with the entire width of the forceps (F_1). If he tries to grab it further away from the central area, only the edge of the tip will make contact (F_2), increasing the likelihood that the ILM will tear or that he pushes the forceps too deep

- Lift the ILM gently and hold it for a few seconds. The ILM is rigid and will rip.
- Start peeling it in a certain, predetermined direction and angle.[12] Even if the ILM tears subsequently – and it will – from now on, you will have an edge to grab, which is much easier (see below).

The Scraper

The diamond-coated instrument is repeatedly dragged over the ILM until the membrane breaks: the main vector component of the movement is parallel with the retina.

- However, the silicone flap of the scraper must also be pressed downward to allow engagement of the ILM. The surgeon has no visual control over how much downward pressure is exerted.
- Once the ILM has been opened, accidentally dragging the diamond crystals over the now-denuded nerve fibers instantly becomes possible, and tearing of the nerve fibers is almost inevitable. This is especially dangerous if the surgeon is not using an effective dye so that he knows exactly over which surface not to use the scraper.

Q&A

Q *Should the scraper be used to open the ILM?*

A No. A surgeon who uses the scraper for opening the ILM gives up control in favor of apparent ease. The risk of such a maneuver far exceeds its benefits.

[12] Characteristics such as direction and vectors are determined by the pathology (see various chapters in **Section 5**).

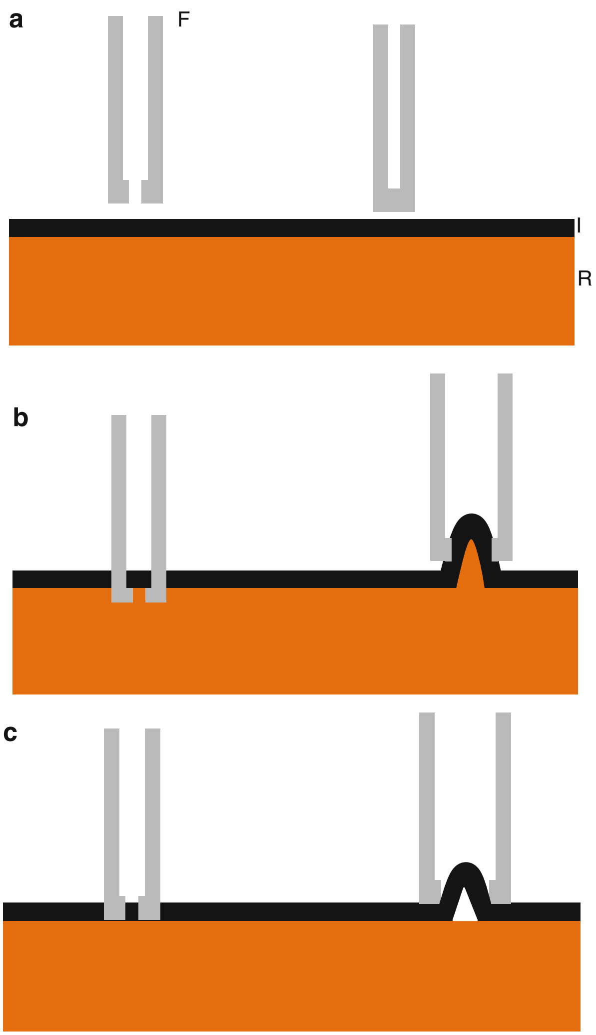

Fig. 32.4 Schematic representation of grabbing the intact (unincised) ILM with forceps. (**a**) *Left*: the forceps approaching the ILM. *Right*: the forceps closing too early; no ILM between the jaws. (**b**) *Left*: too deep a grasp will result in picking up deeper retinal layers as well as the ILM. *Right*: blown-up image showing nerve fibers, seen clinically as white "fluff," between the forceps jaws (shown for demonstration purposes with the forceps open). (**c**) *Left*: perfect grabbing of the ILM. *Right*: blown-up image showing that only the 2 ILM layers and no nerve fibers are caught by the forceps jaws (shown for demonstration purposes with the forceps open). *F* forceps, *I* ILM, *R* retina

32.1.3 Peeling the Membrane

Once the ILM has been opened, the surgeon's task becomes much easier, since now he has a clear edge to grab.[13] Although peeling can also be done with the probe (under constant aspiration, with the probe turned away from the retinal surface)

[13] Provided the ILM has been stained or at least marked with TA, otherwise the ILM remains barely if at all visible (see **Fig. 32.1**). Blind attempts to regrab an inconspicuous, delicate membrane overlying a fragile structure such as the nerve fibers make iatrogenic trauma difficult to avoid.

or the scraper[14] (flipping the ILM over, similar to how the barbed needle is used to complete the capsulorhexis), it is best performed using forceps.

- Grab the edge of the ILM.
  - The two areas where ILM grabbing should be avoided are the center of the fovea and the maculopapillary bundle, especially if close to the disc margin. If the ILM tears here, try to peel the ILM from elsewhere toward/into these areas.
- Pull it at an acute angle in a predetermined direction.
  - It is almost inevitable that the ILM will tear multiple times, not come off in a single piece.[15]
  - If repeated tearing occurs in a small area (several small pieces are torn off), change the direction of pulling (see **Fig. 32.5**).
  - Especially in eyes with thickened ILM or increased adhesion, the ILM may have to be regrabbed many times. This alone represents a higher risk of causing retinal damage, even if the forceps is in the hands of the most experienced and cautious surgeon (see **Fig. 32.4b**).

Pearl
The sight of white, fluffy material in the jaws of the forceps signals that the surgeon grabbed nerve fibers, not (only) the ILM.

- Never forget that, even if the risk is low, the retina may tear[16] if the ILM is very adherent and/or the retina is already damaged.
  - The appearance of small hemorrhages[17] if typical. They rarely occur as a result of direct forceps damage (i.e., they are not found at the point of grabbing); as the ILM is separated, the wall of a *small* vessel is broken. The bleeding usually spontaneously disappears in a day and without clinically detectable consequences.
  - Very rarely, the ILM is so adherent to the wall of a *major* vessel that the peeling will tear the vessel's wall and cause a significant bleeding. Most commonly, however, the ILM actually tears along the vessel: the border of the peeling will be congruent with the course of the vessel.

---

[14] An absolute contraindication ("taNO") in my opinion, and the inventor-genius Dr. Tano fully agreed with this statement. The risk of iatrogenic retinal damage is unacceptably high: those who boast that they are as safe with scraper use for ILM peeling as with needle use for capsulorhexis should remember that the risks are incomparable. It is not the nerve fibers that lie beneath the lens capsule.

[15] How often the ILM tears is partially up to the surgeon (do not proceed too fast; use a forceps with a large platform) but mostly up to nature. It depends on whether the ILM is healthy (e.g., in case of a macular hole – lower tendency to tear) or not (e.g., diabetic macular edema – high probability of tearing). The ILM comes off more readily in large pieces if retina has been detached.

[16] Or, in cystoid macular edema, an intraretinal cyst may get unroofed (see **Fig. 49.4**).

[17] In many thousands of ILM peeling cases, I had only one so major a hemorrhage. The bleeding stopped when the IOP was elevated, and the clot could easily be removed a few minutes later.

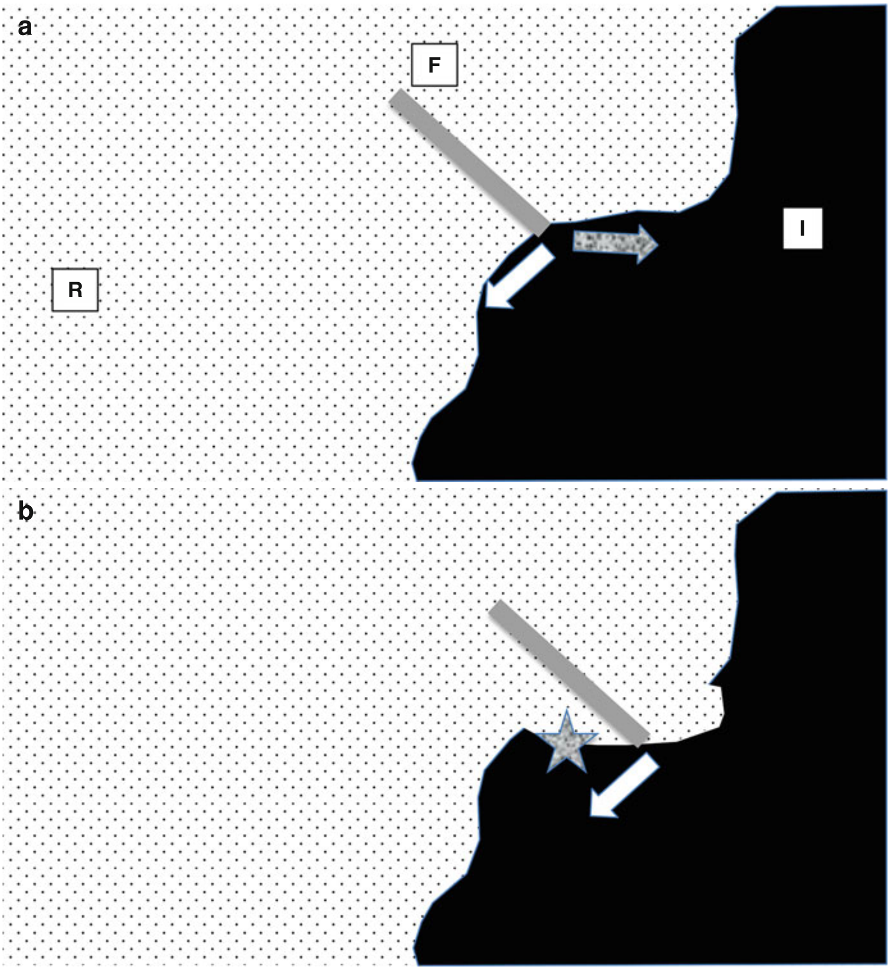

Fig. 32.5 **Schematic representation of reducing the risk of ILM tearing during peeling.** Surgeon's view. (**a**) If the ILM keeps tearing in the intended direction of pulling (*white arrow*), change the direction (*granite arrow*). (**b**) Once a larger ILM piece is removed in that area, return to the original site (shown by the *granite star*) and grab/pull the ILM as initially intended (*white arrow*) but with a slight modified peeling direction. *R* retina, ILM already removed, *I* are where the ILM is still present, *F* forceps

- Always proceed slowly and keep a close watch over the (advancing) border where the ILM separates from the retina.
  – Although it is practically impossible to visually appreciate the curvature of the eyewall, remember that you work over a concave tissue, not a flat surface. If you do not simultaneously watch the advancing tip of the forceps, you may bump it into the retina (see **Fig.** 32.6). The greater the distance between the

forceps' tips and the border of ILM separation, the higher the risk of bumping into the retina.[18]

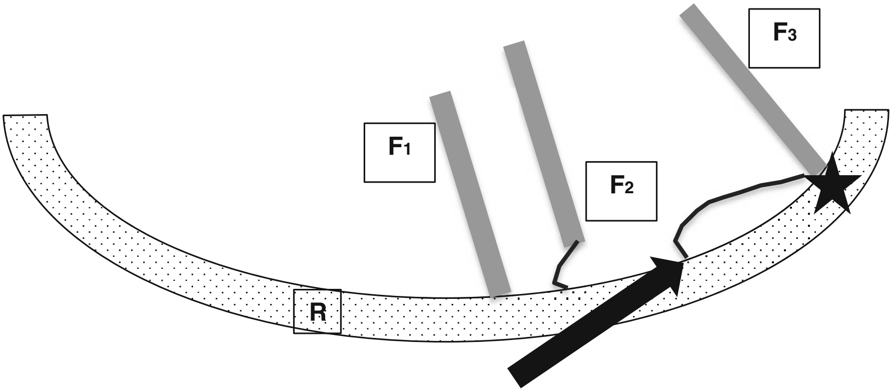

Fig. 32.6 **Schematic illustration of the risk of retinal "bumping" during ILM peeling.** The forceps (F_1) approaches the retina (*R*) and F_2 picks up the ILM (*black line*). If the surgeon monitors only the advancing separation between ILM and retina (*arrow*), but not the distance between the tip of the forceps (F_3) and the retina, the forceps will hit the arching retina at some point (*black star*). The danger is increased if the ILM held in the forceps is a long piece and if the forceps must be kept close to the retina (edema-damaged retina; see **Chap.** 49)

- The peeled area may rapidly turn white. This discoloration, probably caused by temporary edema, spontaneously disappears within hours and without clinically detectable consequences.
- The peeling technique greatly depends on whether the macula is healthy or unhealthy (see **Sect.** 49.2).
- Inevitably, small ILM fragments get stuck to the forceps jaws. Remove them (see **Fig.** 32.7) before you attempt to regrab the ILM: the fragments interfere with visualization, not allowing you to see how deep into the retina you push the forceps jaws. They also make the regrabbing more difficult.
  – The vitreous cavity will contain numerous ILM floaters by the end of the peeling; carefully collect all of them before the completion of the operation.

32.1.4 The Extent of ILM Peeling

How far to carry the ILM removal varies with the condition, but it is mostly the individual surgeon's decision; there is no proven recommendation about the size of the area. A few things need to be kept in mind.

[18] Think about the issue of offside in football. The linesman is supposed to simultaneously watch two locations. First, the position of the last man on defense as it relates to the position of the attacker A, who will receive the ball, and, second, attacker B, who may be far away and who will kick the ball to attacker A. The moment to determine whether attacker A is offside is when the ball is being kicked by attacker B. If the linesman is unable to simultaneously observe the situation at both locations, he will probably make the wrong call.

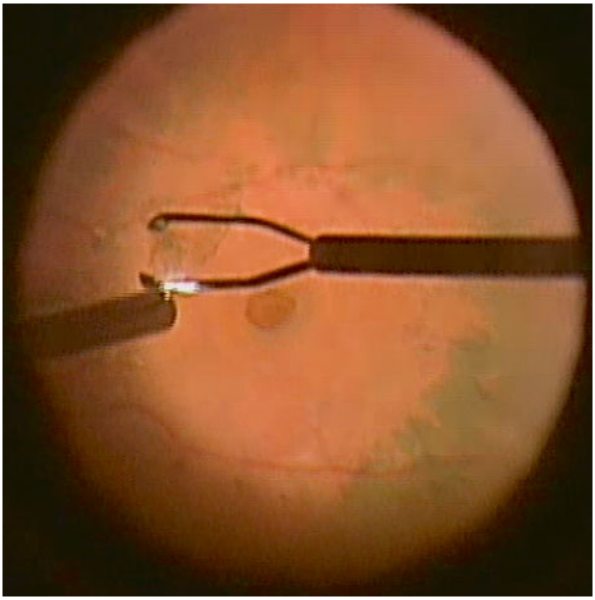

Fig. 32.7 **Getting rid of a small ILM fragment stuck to the forceps jaws.** In this picture the ILM is stuck to the jaw that is closer to the surgeon (the inferior one as viewed on the image). Twang that jaw with the light pipe *after* you brought the forceps to the light pipe – not the other way around so that you are away from the retina. Do not push the light pipe between the jaws but do the twang outside-in

- Except for a few eyes with high myopia, there is no ILM over the optic disc. Occasionally, a tiny hole is seen in the ILM over the foveola.
- The ILM may be missing over the major vessels: the tearing will occur exactly over them (see above). This is why ILM peeling is rarely extended beyond the arcades.
- Outside the major vessels, it becomes very difficult and eventually impossible to peel.
- In eyes with RD, especially if at high PVR risk, as large an area as possible should be peeled (see **Table 54.9**). Fortunately, in this scenario it is relatively easy to peel beyond the vascular arcades.

32.1.5 What If the ILM Cannot Be Peeled?

Although it is very rare that the ILM is impossible – or too risky – to remove, it may occur in the following cases:

- *There is no PVD*. With vitreous on the retinal surface, the ILM will tear, as it is too weak to withstand the weight of the gel (see **Table 32.1**).[19]
- Similarly, *thick EMP*s do not allow ILM removal (see below).
- *Highly adherent* ILM. This may be the case in very young children and some diabetics. It is a judgment call whether to continue or abandon – and if yes, at what point – the peeling.[20]

[19] In fact, the surgeon has difficulty even to grab the ILM through the vitreous cushion.

[20] I can recall 3 such eyes in my career.

Table 32.1 Indications[a] for ILM peeling

Indication	Comment
"Assuring the PVD has been done"	This is a rather nonsense of an argument. ILM removal is not the correct way to achieve PVD; in fact, the presence of the vitreous cushion on the retinal surface interferes with ILM removal: the ILM tears under the weight of the vitreous. Conversely, very fine proliferative membranes may be removed together (as one piece) with the ILM (see below) – but in these cases the ILM comes off with the epiretinal membrane, not vice versa
BRVO	Sheathotomy at the arteriovenous crossing, in addition to dealing with macular edema (see below)
Cellophane maculopathy	To remove the diseased surface and to prevent continual/recurring growth
EMP	To ensure that all of the proliferation is removed and eliminate the risk of recurrence
Hemorrhagic macular cyst in Terson syndrome	In the submembranous type, the blood-accumulation is under the ILM; once detached, the ILM never readheres
Macular edema[b]	To help dry out, and keep dry, the retina[c]
Macular hole	To increase the success rate by eliminating all traction forces
Optic pit	A somewhat controversial indication since ILM removal can also weaken the already damaged retina on one hand, but may, on the other hand, help if a macular hole is present
PDR	Removal of current, and prevention of subsequent, membranes growing on the macular surface, in addition to dealing with macular edema (see above)
Prophylactic	Against the future development of EMP or edema, which may threaten in many diseases as well as the result of the treatment itself
PVR	Complete removal of current, and prevention of subsequently developing, membranes on the macular surface
RD	To prevent EMP formation and treat the edema in long-standing cases
Staphyloma-spanning central RD	Removal of the rigid ILM allows the remaining, elastic neuroretina to conform to the eye's increased concave contour at the posterior pole
VMTS	To ensure that the traction is completely relieved

[a]In alphabetical order. See the appropriate chapters for more details.
[b]Of different etiologies.
[c]The mechanism how these goals are achieved is not clear, even if the clinical results are hard to dispute. Elimination of the traction, removal of the thickened ILM (barrier to oxygen transport from the vitreous), and a reactive, surface-perpendicular intraretinal gliosis, among other factors, have been cited.

- The *highly myopic* eye. The staining is usually faint, even with ICG, and the contrast is very weak, due to the depigmentation of the posterior pole. In addition, the retina is extremely thin,[21] further increasing the risk (see **Chap. 42**).
  - Although technically very difficult and associated with an increased chance of iatrogenic retinal damage, ILM removal in these eyes has extreme benefits; a careful consideration of risk vs benefit is needed.

[21] Down to one-third of the normal.

32.1.6 ILM Removal in Eyes with Detached Macula

The ILM is usually easier to remove from areas of detachment, but the detachment also presents unique challenges. The surgeon has two options to peel the ILM over a detached macula.[22]

32.1.6.1 Reattaching the Macula First

- Stain the ILM with ICG (see **Chap. 34**).[23]
- Inject enough PFCL to reattach the macula.[24]
- Peel the ILM. There are two major differences compared to peeling under BSS and over previously not detached retina.
  – The ILM tears easily, and the free edge instantly gets pressed against the retina by the weight of the PFCL, making the regrabbing technically more difficult.
  – The retina is mobile[25]: the forceps drags the retina along, however minimally.

32.1.6.2 Peeling When the Macula Is Still Detached

- Stain the ILM with ICG.
- Drain the subretinal fluid as much as possible to reduce the height of the detachment, but do not perform F-A-X.
- Begin the peeling just above the maculopapillary bundle at the disc margin (see **Fig. 32.8**).[26]
- The direction of the peeling is always away *from* the disc, where the retina is fixated.
  – Even though the ILM will separate in atypically large sheets, regrabbings are still necessary; it is easier to grab too deep if the retina is detached.[27]

32.2 EMP

Although some ophthalmologists try to "treat" the patients with anti-VEGF injections, this obviously addresses only one of the consequences of the membrane (ME), not the cause. What offers definite cure is PPV with removal of the EMP.

---

[22] RD, PVR, PDR, and staphyloma-spanning posterior detachment.

[23] It is a little more difficult to stain the detached retina as the dye tends to accumulate in the deeper points of the eye.

[24] Do not use air: visibility is too poor to peel, and the PFCL bubbles will condensate on the back surface of the lens (see **Sect. 31.2** and **Fig. 25.2**).

[25] Broken IPM (see **Sect. 26.3.2**).

[26] For example, at ~1 o'clock at the disc margin in the left eye.

[27] Whether the peeling is done over reattached or still detached retina, try to extend the centrifugally oriented peeling beyond the major vessels, especially inferiorly. In the latter case, it may become necessary to periodically drain more subretinal fluid to reduce retinal movement as the detachment's height may increase as the result of the peeling.

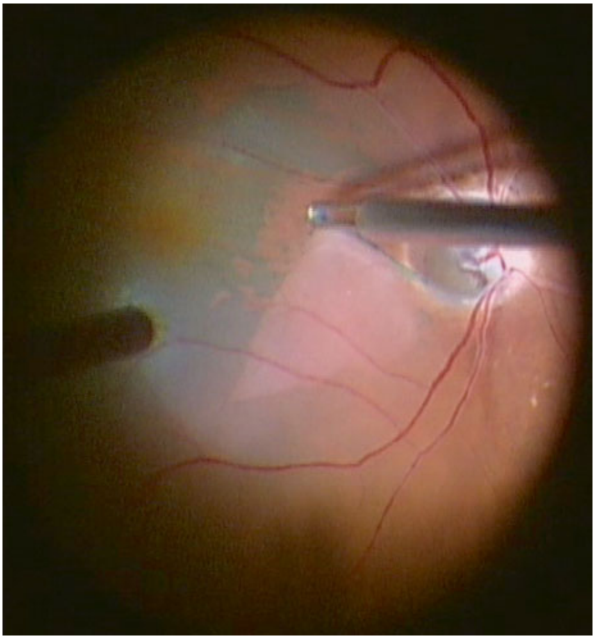

Fig. 32.8 Peeling the ILM over detached retina. The peeling is started much closer to the disc margin than is usual (see **Fig. 32.2a**). The peeling direction is always away from the disc to reduce the movement of the retina and to provide a counterforce against the vector of the peeling. The retina is lifted (tenting) as the forceps is dragging the ILM and the retina temporally: a white line is visible at the border of ILM separation. The same phenomenon is noticed if a strongly adherent ILM is peeled in an eye with severe macular edema (see **Fig. 49.3**)

Pearl
In the vast majority of eyes with EMP, a spontaneous PVD is present at the time of PPV.

32.2.1 The Clinical Characteristics of the EMP[28]

- The membrane may be any of the following "pairs" – or something in between.
  - Very thin or extremely thick.
  - Small or large, spreading outside the field accessible through the contact lens without moving the microscope.
  - Made up of a single or multiple layers.[29]
  - Surrounded by retina that has several or no folds.[30]
  - Located in the epicenter or parafoveally.

[28] Only those features are discussed here that are relevant to make technical (removal) decisions; the rest are detailed in **Chap. 50**.

[29] This is not known until the membrane is actually being peeled.

[30] Cellophane maculopathy is understood as a fine, clinically invisible (and surgically "ungrabbable") epiretinal membrane, which creates folds (wrinkling) in the ILM (see **Chap. 50**).

– During peeling, the membrane will prove to be very adherent to, or simply located on top of, the retina.[31]
– During peeling, the membrane will prove to be rigid or fluffy. The latter is much more difficult to peel because the membrane is elastic (composed mostly of cells). Occasionally it can give the surgeon the shivers since it resembles "peeling" of the nerve fibers (see above).

32.2.2 Removal Technique

32.2.2.1 Staining or Not?

Proper staining (see **Sect. 34.2**) helps identify the membrane and helps both in tactical decision-making and its execution.[32] My personal decision-making related to the timing of staining is shown in **Fig. 32.9a**; **b** is a clinical example of the staining being useful.

32.2.2.2 Instrumentation

As a first maneuver, the membrane can be separated from the retinal surface by any of these tools.

- *Forceps*. Used in most cases by most surgeons; unlike with ILM removal, various forceps designs are acceptable, especially if the membrane is not too thin.
- *Scraper*. It is very helpful to "pick up" a membrane whose border is inconspicuous.[33]
- *Barbed needle*. The hook is turned downward to pick up the membrane.[34]

32.2.2.3 Location of the Point of Attack

By the time the surgeon selects this location, he already must have decided whether to carry out the membrane peeling in a centripetal or centrifugal direction (see below).

Since I always try to progress in a centripetal fashion, I attack the membrane at its edge, far away from the fovea.

- *Forceps*: Select an area where the membrane is rather thick, grab, and gently lift it (see **Fig. 32.10**).

---

[31] The variables of most other "pairs" are usually visible and can be determined preoperatively; the strength of the adherence, however, is not known until the membrane is actually being peeled.

[32] I use "negative" staining: the ICG will stain the ILM, but not the overlying EMP, giving a relief-like image.

[33] The scraper is used by some surgeons to remove the entire membrane. While it is technically possible, there are inherent dangers. As mentioned above, the downward pressure is difficult to control, and areas of strong membrane-to-retina adhesion will remain hidden from view. The ILM or the full thickness of the retina may get torn.

[34] It can then be turned upward and lift/separate the membrane, occasionally even complete the procedure (see **Figs. 13.8e, f**).

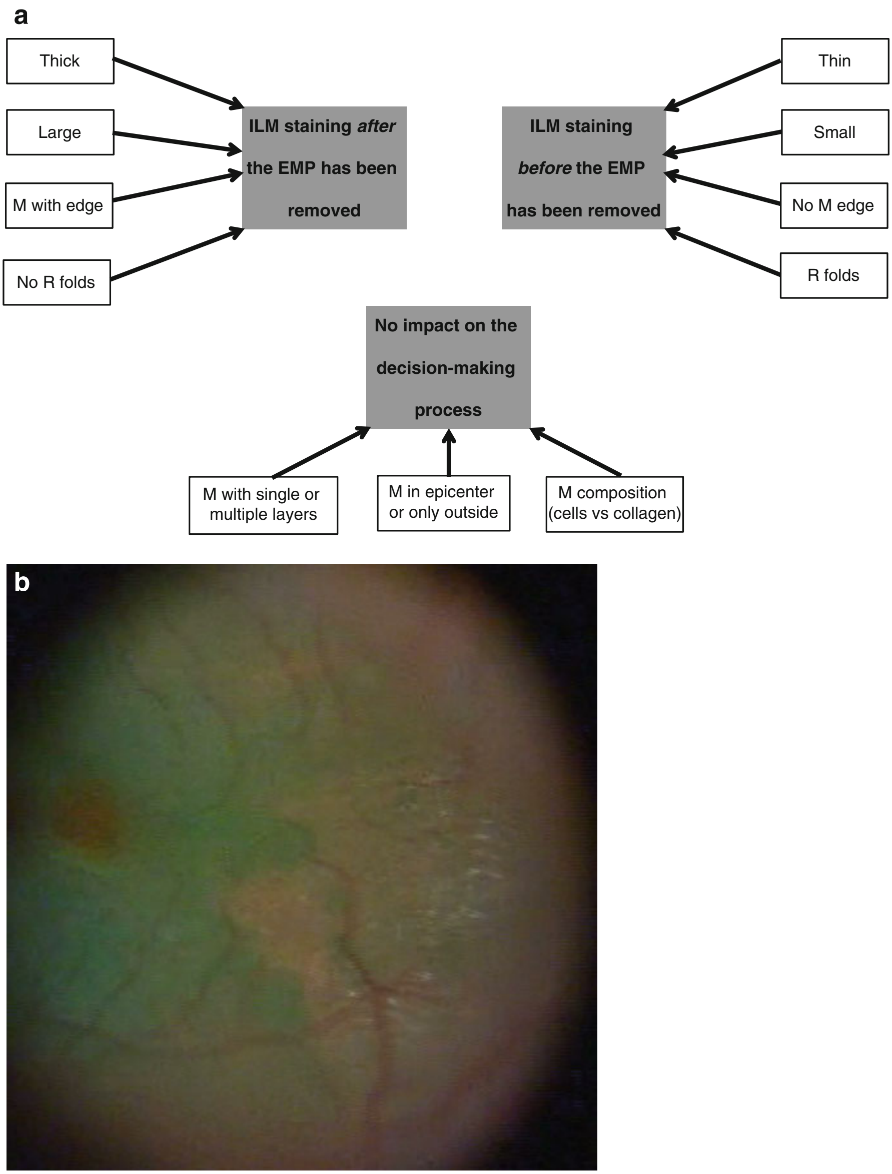

Fig. 32.9 Staining the ILM in macular pucker surgery. (**a**) Decision-making flowchart: staining before or after EMP removal. (**b**) "Negative" staining of the EMP. On the left of the image, the ILM has been stained with ICG; on the right, the EMP prevented the underlying ILM from turning green. Otherwise, only the light reflex gives away the presence of the EMP; the membrane itself is barely visible. *M* membrane, *R* retina

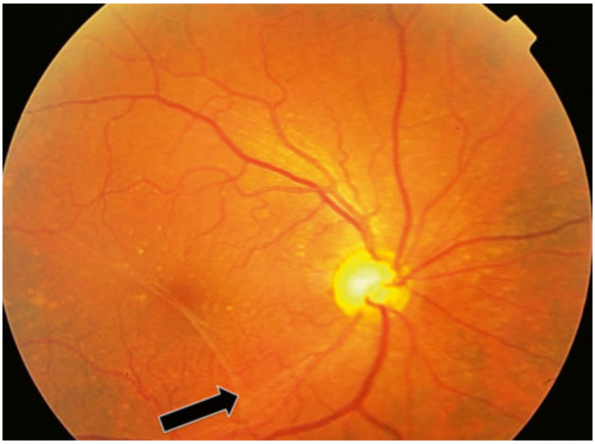

Fig. 32.10 **An EMP with an obvious edge.** Such an EMP requires no staining; the *arrow* marks the recommended initial point of attack if forceps is used for grabbing and peeling

- *Scraper*: Select the most convenient area; you can start even where the membrane is thin.
- *Barbed needle*: Select the most convenient area where the membrane is not too thin.

Q&A

Q *Is there any magical trick to make the peeling easier?*

A No, but the initial grab with the forceps has crucial importance. Membranes are often multilayered; if such a membrane is not grabbed in its full depth, the surgeon will struggle by having to peel several layers separately: a frustrating and unsafe maneuver.

32.2.2.4 The Major Risks When First Grabbing an EMP

- The greatest risk of the initial grab is to mix up the membrane's edge with a large retinal fold the membrane has caused (see **Fig. 32.11**): a very large retinal rip can result.
- It is almost equally dangerous to incorrectly tackle an area where multiple smaller retinal folds are present (see **Fig. 32.12**).

32.2.2.5 The Direction of Peeling: Centripetal vs Centrifugal

The goal is not simply to remove the membrane but to do so without damaging the underlying retina; this means undue traction on the fovea must be avoided.

- If the membrane shown in **Fig. 32.13** is grabbed centrally, where it is likely to be thicker than in the periphery, the direction of peeling[35] will have to be *centrifugal*. This will result in traction, which is uncontrollably spreading to ever-

[35] That is, separation between membrane and retina.

larger areas, and include the fovea as well. The line of advancing separation between membrane and retina is rather large, making it difficult if not impossible to simultaneously determine whether retinal damage is occurring. The membrane will surely be removed, but the surgeon sacrificed control for the sake of convenience.

- With *centripetal* peeling, the surgeon gradually separates the membrane at its edges, 360°, with the fovea being the last phase. The area of advancing separation between membrane and retina is very small – and the size of the separation line is entirely controlled by the surgeon – making it easy to notice if the adhesion is too strong. If it is, scissors or the probe must be used.

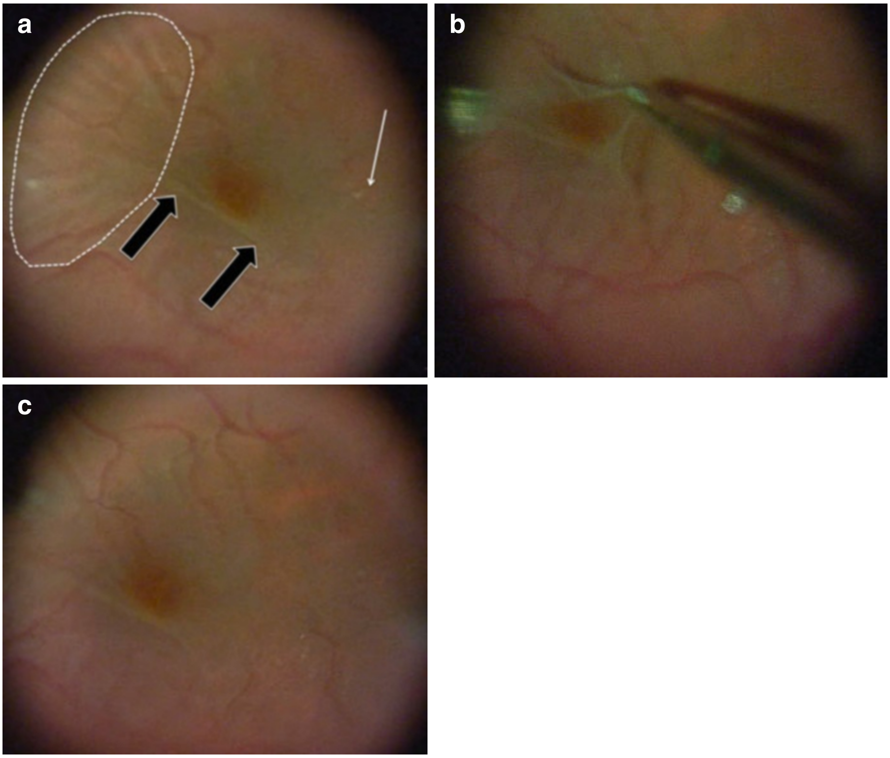

Fig. 32.11 Retinal fold masquerading as an EMP. (**a**) The dashed white line shows an area temporal to the macula, with several full-thickness retinal folds caused by the contracting EMP. The membrane itself, however, is barely visible; only a small light reflex gives it away (*white arrow*). What appears to be the thick edge of the EMP is in fact another superiorly located retinal fold (*thick black arrows*). (**b**) The fluffy EMP is being removed; the large superior fold is still visible. (**c**) With the EMP removed, the light reflex and most of the temporal folds have disappeared; the large superior fold is still rather conspicuous. Once the ILM is also peeled, this fold will rapidly smoothen out

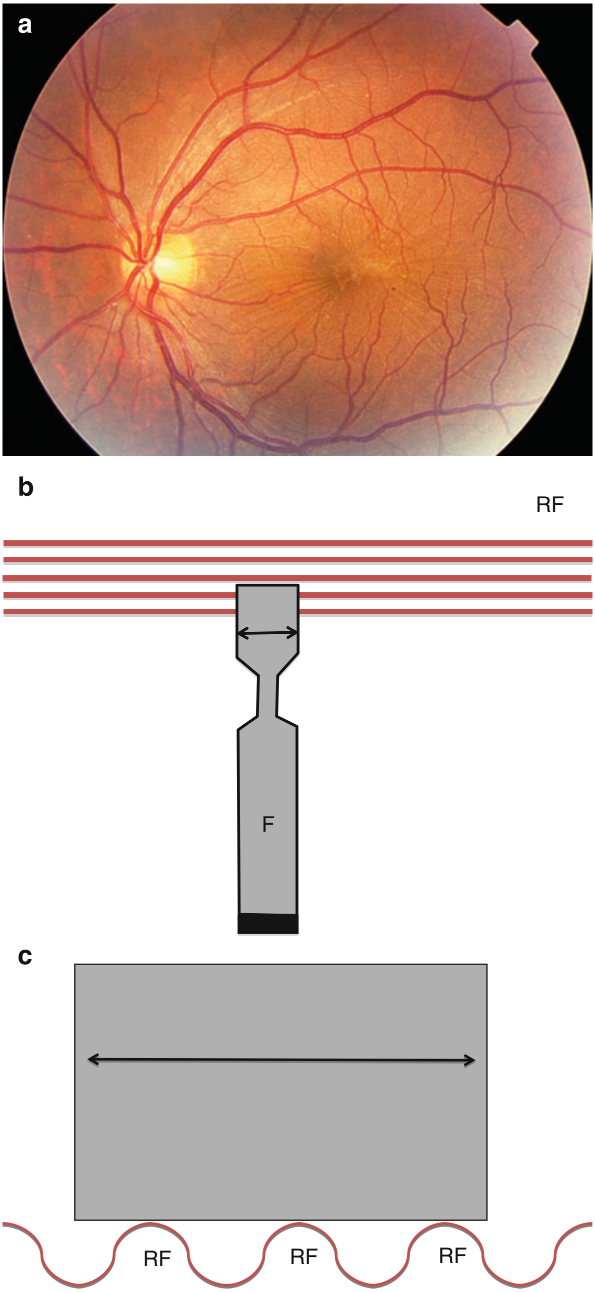

Fig. 32.12 **To remove an EMP from over retinal folds.** (If the ILM is wrinkled, the same rule applies.) (**a**) Virtually the entire macular area is wrinkled. (**b**) Schematic representation of the *incorrect* approach to grabbing tissue over a folded retina. The forceps jaws are held parallel with the folds, making it likely that numerous nerve fibers will also be picked up. Surgeon's view. (**c**) Schematic representation of the *correct* approach to grabbing tissue over a folded retina: the forceps jaws are held perpendicular to the folds' axis. Nerve fiber damage can still occur, but for this, the surgeon must push the forceps jaws unreasonably deep. Cross-sectional view at a much higher magnification than on the previous image. *RF* retinal folds, *F* forceps. The *double arrow* is in the direction of the width of the forceps jaws

32.2.2.6 The Speed of Peeling

This advice is very simple: be slow. It is not that uncommon for a membrane to easily separate from the retina initially and in most areas subsequently, only to show strong adherence in a small area later on. If the surgeon is too fast, he can easily cause an iatrogenic tear.

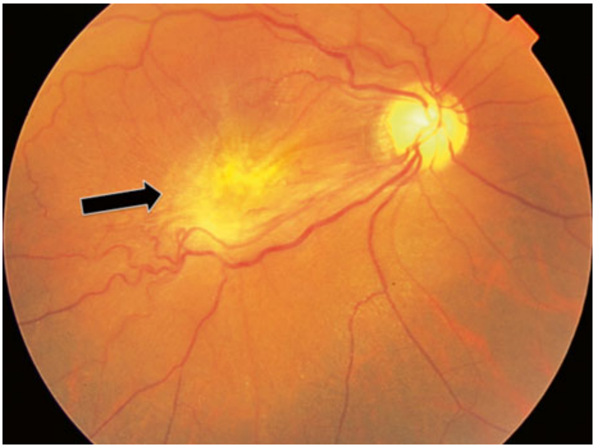

Fig. 32.13 **A very thick, dense EMP.** The underlying retina is invisible; there is foveal ectopia and the exact location of the foveola is up to guesswork. Such a membrane is best tackled with a barbed needle first. The needle allows separation of the membrane from the retina in a very small area and under constant viewing, without fear of the forceps jaws blocking it. The barbed needle also helps finding the correct plane of cleavage if the membrane is multilayered, which, in this case, is rather likely. The point of attack should again be at the periphery of the membrane, probably at the 9:30 o'clock from the presumed foveola location (*arrow*). Depending on the behavior of the membrane, a new point of attack may become necessary

If a point of strong adhesion is found, it may be preferable to cut the membrane, instead of forceful peeling.

32.2.2.7 The Extent of Peeling

Definitely remove the membrane from the entire macular area. If the ILM is also removed (see below), it is not necessary to separate the EMP further toward the periphery; if, however, the ILM will not be removed, try to peel the entire membrane to prevent its regrowth into the fovea.

32.2.2.8 ILM Peeling

The rationale for also removing the ILM is the up to 10% recurrence rate if the ILM is intentionally retained.[36] If the ILM has also been removed, the risk of EMP recurrence is eliminated.

I always remove the ILM in pucker surgery. If the EMP is thin and rather small, I try to remove the two membranes together, otherwise as a second maneuver. If ICG was used prior to EMP removal, it may have to be repeated once the EMP is off.

[36] Small fragments or even large pieces of the ILM are inadvertently peeled in almost all eyes as the EMP is too strongly adherent to the ILM in at least a few areas.

Q&A

Q *Which is technically easier, ILM or EMP removal?*

A Although such a question is difficult to answer, my general response is that the EMP removal is much more complex and requires a lot more decision-making *and* good dexterity. A young surgeon should, once he has gained sufficient experience with other aspects of VR surgery, try ILM peeling first and EMP removal only after he became comfortable with ILM peeling. Even then, an experienced surgeon should be sitting next to him when he tackles EMPs until he gained considerable experience with it.

32.2.2.9 Completion of Surgery

The surgical field after EMP removal may look like a battlefield: there are hemorrhages, folds, and circumscribed areas of retinal detachment. Some surgeons prefer to use an air or gas tamponade and ask the patient to be in facedown position to speed up the process of normalization of the appearance of the posterior pole.[37]

Removal of the ILM virtually assures that the retina will look normal the following day.

32.3 Proliferative Membranes[38]

32.3.1 PVR[39]

32.3.1.1 Recognition

The membranes are rarely vascularized and, unless immature, are clearly visible; they can also be stained (see **Chap. 34**); a PVD may also have occurred spontaneously, although it is usually only partial. Even if a membrane is not conspicuous, there are indirect signs that reveal them:

- Distorted course of retinal blood vessels, similar to what certain EMPs cause (see **Fig. 32.13**, the area just beneath the arrow).
- Star fold (see **Fig. 32.14**).
- Decreased mobility of the detached retina.

[37] The inside joke is that this is actually done so that the surgeon won't have to look at the ugly image he just created.

[38] See also various parts of **Chap. 13** for the use of intraocular instruments.

[39] An EMP is, strictly speaking, also a proliferative membrane; in clinical practice, however, it is not perceived as such because of its limited extent.

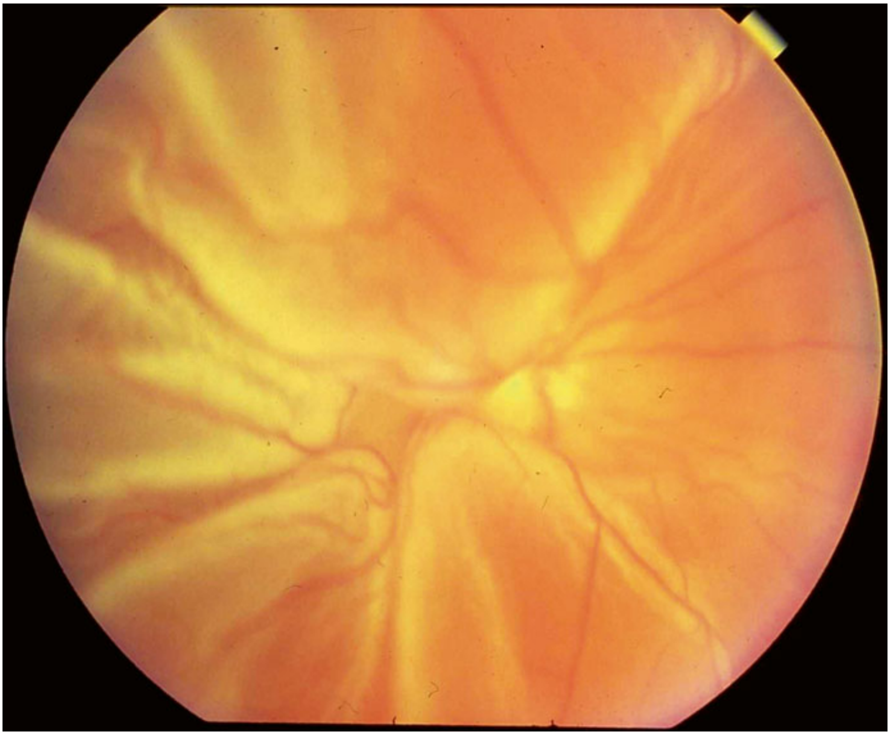

Fig. 32.14 **Retinal star fold in PVR.** The retina has radially oriented folds, pointing toward a center where the membrane is presumably the thickest

32.3.1.2 The Goals of Surgery

To achieve retinal reattachment and hopefully prevent redetachment, the following need to be done:

- The vitreous removal must be complete (see **Sect. 27.2**).
- All tractional membranes, whether subretinal[40] or preretinal, must be removed.
  - ILM removal should be considered.
- All breaks must be sealed.
- The retina must be mobile and not shortened (stretched) upon reattachment (air-test; see **Sect. 31.1.2**).

32.3.1.3 Instrumentation

- *Scraper* to pick up immature, difficult-or-impossible-to-visualize membranes.
- *Barbed needle* to search for and lift membranes.[41]
- *Spatula* to bluntly separate membrane from retina.

[40] Subretinal membranes that do not prevent retinal reattachment may be left behind (see below).

[41] While this is very safe, its use over detached, mobile retina is not easy (see **Sect. 53.2**).

- *Forceps* to grab and lift membranes.
- *Scissors* to lift membranes and/or cut[42] membranes.

Viscodelamination and the probe are not reasonable options in dealing with PVR membranes. Bimanual surgery, however, is very helpful (see **Sect. 24.2**).

32.3.1.4 Surgical Steps

- Remove the lens if the eye is phakic.[43]
- Check if PVD has occurred (see below); if not, create one and carry it as anteriorly as possible.

Q&A

Q *Is it acceptable if the creation of PVD causes retinal tears?*

A It is preferable not to cause iatrogenic breaks. However, in diseases where the primary cause is traction, this may be a price worthwhile to pay if the vitreous can thus be separated from the retina. If a PVD cannot be created, retinectomy may be the next best option. The worst is to leave traction behind when breaks are also present.

- Find and remove all membranes.[44]
  - This is much easier in the posterior pole than in the periphery.
  - The membrane and the retina may adhere to each other as two sheets glued together, showing the crucial role the nondetached cortical vitreous plays in the process. If the membranes/posterior cortical vitreous complex is impossible to separate from the retina, the choice is between a retinectomy (see **Sect. 33.1**) and a SB (see **Sect. 54.4**).
- Check whether the retinal surface is now smooth; if not, the blood vessels remain corkscrew-like. Continue trying to identify and remove membranes until the retina is smooth.
  - Remember that the cause may be a subretinal membrane.
- Using air or PFCL[45], reattach the retina and check if it is under tension (air-test; see **Sect. 31.1.2**).
  - If the retina does not readily reattach, remove the tamponade and continue searching for membranes or determine whether the retina is shortened and retinectomy is needed (see above).
- Repeat the F-A-X.

---

[42] Cutting (rather than removing) membranes is rarely done in anti-PVR surgery.

[43] Unless the patient is young, but even then sacrifice the lens if it prevents complete anterior vitrectomy.

[44] This is described in **Sect. 32.2**.

[45] See **Chap. 35** for more details about tamponades.

- If the retina is reattached and appears completely normal:
  - Perform laser treatment.
  - Fill the vitreous cavity with silicone oil.

32.3.1.5 Closed Funnel/Retinal Incarceration

It is crucial to remove all pre- and subretinal membranes if the surgeon wants to reattach a retina in an eye where the disc is invisible.[46]

- Remove the subretinal membranes first.
  - Membranes may be broken in 2; with the adhesion to the photoreceptors now only at a single site, the membrane will cease causing traction and can be left behind.[47]
- A crucial area is close to the disc, where a ring proliferation may be present; without breaking up and removing this ring, the retina will not reattach but in cross section resemble a bell curve.
  - Injecting PFCL over the choroid helps keeping the retina in a relatively stable position, allowing the surgeon to manipulate over the photoreceptors without the mobile funnel blocking the view every time a membrane is lifted.
- When no subretinal membranes are visible anymore, diathermize the anterior part of the funnel or the incarceration.
  - Not all surgeons use diathermy; however, because of the risk of bleeding and its consequences,[48] it is highly recommended.
  - The line of diathermy spots may be too anterior; the final location of the line will be determined only after both the vitreous and all proliferative membranes will have been removed from the inside the funnel. The goal is to leave a central retina that is devoid of the gel (complete PVD) and any membranes on either side.

> **Pearl**
> If it is not only a closed funnel, but the retina is also incarcerated into the eyewall, I leave a small area, maybe 2 clock hours, incarcerated until all manipulations inside the funnel are also complete – this makes the retina much less mobile, aiding the manipulations.

- PFCL will not be able to open the funnel and provide access to the inside; the only option is to use cohesive visco such as Healon (see **Sect. 13.3.2**).
  - Inject the Healon as posteriorly in the funnel as possible and very slowly. Its strength is sufficient to tear the retina if the membranes are very adherent.

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[46] The surgeon is looking at the back surface of the retina in a closed-funnel detachment. Obviously, what is called “subretinal membrane” here is initially *over* the retinal surface according to the surgeon’s view.

[47] The air-test will help determine whether this is the case (see above).

[48] Increased risk of postoperative PVR.

- Gradually remove the vitreous with the probe and all the membranes with forceps. The visco may have to be reinjected.
- When all the membranes are removed, cut the retina (see **Chap.** 33 for further details about retinotomy and retinectomy).
- Replace the visco with PFCL.
- If the retina is not completely flat or the retinal vessels remain distorted, look for more membranes on either surfaces of the retina.
- Perform laser treatment.
- Replace the PFCL with silicone oil.

32.3.1.6 ILM Removal

Removing the central ILM is the most important step in the prevention of new proliferation growing over the macula in case of PVR recurrence. As mentioned above (**Sect.** 32.1.4), always try to do the peeling in the largest possible area.

32.3.2 PDR[49]

Much of what has been described under **Sect.** 32.3.1 also applies for eyes with PDR. Only the significant differences are described below. **Table** 32.2 provides a direct comparison between the two conditions.

- Discuss with the patient what to do with the lens.[50]
  - PPV-related cataract often presents later in diabetic eyes than it would in other conditions.
- Spontaneous PVD virtually never occurs in eyes with PDR, but the thin, membrane-like layer of cortical vitreous is invisible; only the behavior of the tissues being manipulated gives away its presence.

Q&A

Q *How can the surgeon identify and remove this delicate membrane?*

A The visible membranes are part of the anterior wall of this giant vitreoschisis cavity. Make an incision in the anterior wall just peripheral to the thick neovascular membrane. Use a barbed needle to pick up the thin epiretinal vitreous cortex, which may be multilayered and so adherent that the retina may get detached if blunt separation is attempted. Try carefully to extend the membrane detachment all the way to the periphery. Stop when the separation becomes impossible, hopefully before breaks appear. Any vitreous left behind must be further reduced via pneumovitrectomy (see **Sect.** 27.3.2), but always consider retinectomy as an option (see **Sect.** 33.1).

---

[49] With or without an RD component. More details are provided in **Chap.** 52.

[50] Retain it if the patient is young, but the lens should be sacrificed if it prevents complete anterior vitrectomy.

Table 32.2 Comparing the eyes with PVR vs PDR

Variable[a]	PVR	PDR
Intraoperative hemorrhage, risk of	Very small	Significant, unless preoperative anti-VEGF injection is given
Laser	Focal + endolaser cerclage	Panretinal
Lens and IOL	Remove it, unless the patient is very young, or if you do remove it, remove the capsules as well Consider not implanting an IOL until the PVR process has stopped	Consider removal, based on the patient's age and the eye's condition IOL implantation is usually done in the same setting
Macular involvement	Common	Rare
Membrane removal	Must be complete	Segmentation is acceptable[b]
Membrane removal, order of	Up to the surgeon	Start centrally and progress in a centrifugal direction
Posterior location, predilection for	No	Yes
PVD	May be present posteriorly	Extremely rare to be present; usually a vitreoschisis is found
RD, combined	Rare initially, often as part of a recurrence	Rather common initially
RD with closed-funnel configuration	Rather common	Very rare*
Recurrence of the condition	Common	Less common, and it is usually PVR
Retina fragile	Rare	Very common
Retina highly elevated	Rather common	Very rare*
Retinal break, iatrogenic during surgery	Rare	Not uncommon
Strong adherence to retina	Yes	Yes
Subretinal component	Rare	Rare
Vascularization/bleeding	Very rare	Very common
Vitreoschisis/multilayered membrane	Rare	Very common
Vitreous attachment to membrane	Mostly in the periphery	Both posteriorly and in the periphery

[a]In alphabetical order.
[b]See the text for more details.
*Occurs mostly when PVR develops as a postoperative complication.

– A surgeon who does not look for, and remove, this membrane neglects it at his own[51] peril.
– Removal of the posterior wall (the "invisible" membrane) is much more difficult than that of the clearly visible membranes that form the anterior wall of the vitreoschisis cavity.

[51] More importantly, at his patient's.

- The membranes in the anterior wall need not be completely removed.
  - Complete removal is called *delamination*. This can be achieved using the tools and techniques described above but also by employing the probe at a high cut rate with a low aspiration/flow. Smaller-gauge probes and ones with a very distal port are especially excellent for this purpose. Viscoelastics may also be used, but they are less safe (see **Sect. 13.3.1**).
  - Parts of the membrane may be circumcised: connections to adjacent areas are severed 360°. Such *segmentation* is especially useful when there is a risk of tearing the retina at this location with forceful removal/separation attempts. The membrane stump is diathermized and left behind.
  - Bimanual surgery is especially beneficial in these eyes; typically, a forceps is held in the nondominant and the probe or scissors (spatula) in the dominant hand.
  - The stump is also left on the disc, at least 1 mm in length. This allows the stump to be safely diathermized and prevents both intra- and postoperative bleeding.
- Even if bevacizumab has been injected preoperatively (see **Sect. 52.2**), bleeding from newly formed or even normal-appearing vessels may occur. There are two related dilemmas for the surgeon: are you going to use diathermy? And if yes, when?

Q&A

Q *Should all bleedings be diathermized?*

A The rationale for using diathermy is that these bleedings are unlikely to spontaneously stop and especially to do so early, and the clot tends to adhere to the retina very strongly.

  - Diathermy may be used on "continual" basis: every time there is a hemorrhage, the probe/forceps/scissors/spatula is exchanged for the diathermy probe, and the source of the bleeding is cauterized. The advantage of this technique is that all bleeding sources are easily identified and taken care of; the downside is that it requires numerous instrument exchanges.
  - The alternative technique is to wait until all work is done and then cauterize the spots where bleeding still occurs. The advantage of this technique is that only a single instrument exchange is needed; the downside is that the blood rapidly coagulates in diabetes, and the clot may be difficult to remove. It may also adhere to the retina so strongly that it tears the retina upon being lifted.

Pearl

There may be vessels that do not bleed during surgery due to the elevated IOP intraoperatively; however, they will readily bleed postoperatively, causing disappointment both to the patient and surgeon. Try to provoke the bleeding during surgery by shutting off the infusion and aspirating some of the intravitreal fluid so that the IOP drops, and cauterize any hemorrhage that is observed. (In some machines the aspiration automatically restarts the infusion; in such cases use the flute needle to aspirate the fluid, not the probe.)

- It is best to start the membrane work in the center and gradually move toward the periphery.
- Unlike eyes with PVR, here the retina is not healthy; its tolerance (resistance) to traction during blunt membrane separation is much lower – in other words, the retina tears much more easily.
- If a retinal break is created, it becomes even more important to fully relieve all tractions.
- The macula is often spared by the thick membranes but is covered by thin ones[52] and is edematous. ILM removal is therefore highly recommended. Often it is only after the ILM peeling when the surgeon realizes the vastly different appearance of the central retina, how much material he had removed, and how difficult it would have been for the macula to recover without ILM peeling.
- As mentioned above, if the peripheral vitreous cannot be separated from the retina, retinectomy may be needed (see **Chapter 4.17**).
- Panretinal laser is always necessary.
- The benefits of silicone oil implantation include bleeding prevention, maintaining retinal attachment, and allowing visualization of the retina even in the immediate postoperative period.
  - Conversely, the retina may not tolerate the physical presence of the oil, especially if the retina is ischemic.
  - The recurrence of the proliferation is often a mixture of PDR and PVR. This is one of the most difficult challenges to the VR surgeon because of the technical complicity in trying to remove thick, strong, adherent membranes from a thin, fragile retina.

32.4 Subretinal Membranes/Strands

32.4.1 PVR and PDR

Not all subretinal membranes cause retinal detachment or prevent reattachment. Since a retinal break must exist to access them, the surgeon should not to be tempted to remove a subretinal membrane just because it is there (see **Sect. 8.1**). If the membrane does need to be removed, keep in mind the following.

- Complete the vitrectomy, paying special attention that a complete PVD has been created.
- Before dealing with the subretinal membranes, always make sure no epiretinal membrane is left behind. This is especially crucial if an access retinotomy needs to be created.

[52] Posterior cortical vitreous.

- Not everything that looks to be a subretinal strand is indeed one: retinal folds can give the same appearance. The folds, however, disappear if the retina is reattached or pushed, see below.
- Evaluate the number, location, and strength of the membranes. The latter is assessed by pushing on them with the probe's blunt tip and noting the retina's mobility over the strand; the air-test is also useful.
  - If multiple membranes at multiple locations (see **Fig. 32.15**) need to be removed, consider mixing the gauges: use a 20 g subretinal forceps with a long reach (see **Fig. 32.16**) so that the minimal number of retinotomies is needed to provide access all membranes.
  - If there are multiple membranes at multiple locations and you are using MIVS, you will need multiple retinotomies.

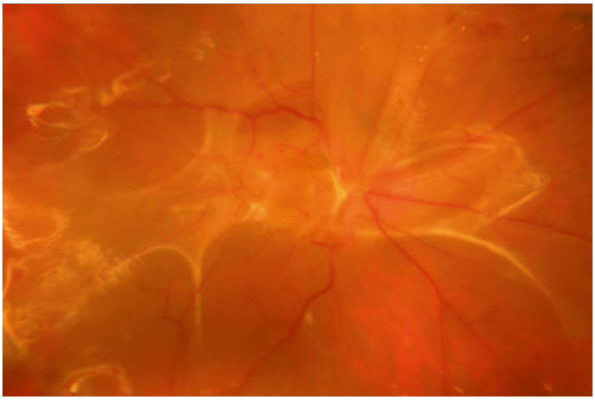

Fig. 32.15 Subretinal proliferation. Extensive subretinal proliferation following 360° retinectomy (see **Sect. 33.1**) for a total RD and retinal incarceration. Unless a 20 g subretinal forceps is used, it is impossible to remove all membranes through a single retinotomy

Pearl

Horizontal forceps is preferred to vertical ones because the jaws do not have to be inserted between the retina and membrane in order to grab the membrane.

- To perform the retinotomy, select a site that:
  - Is rather far from major vessels.
  - Provides access to the membrane so that the forceps can be held in your dominant hand.
  - Is right over the membrane.[53] This also overcomes the unexpected difficulty when the membrane is further away from the retinotomy and is difficult to grab: even though its exact location was very obvious before the forceps was inserted into the subretinal space, once the retina is somewhat lifted with the forceps, the membrane "disappears" (see below).

[53] The forceps blades are too short to reach the membrane otherwise. With 20 g surgery and use of the proper subretinal forceps such as the 1286.0 model from DORC (Zuidland, the Netherlands; see **Fig. 32.16**), the retinotomy need not be right over the membrane.

Fig. 32.16 **A 20 g subretinal forceps.** (**a**) Overview of the 20 g instrument. (**b**) Close-up of the blades

- Apply a diathermy spot at this location.
  - The diathermy eliminates the risk of hemorrhage and possibly helps create the postoperative chorioretinal adhesion.
- Grab the membrane and slightly pull it up. Never pull the membrane simply upward; this can put excessive traction on the retina.
  - Change the vector so that the membrane is stretched toward its endpoint in one direction (see **Fig. 32.17**).
  - Once the membrane is liberated in that direction, change the vector of pulling toward the opposite direction until the separation is complete there.
  - Never lose sight of what is happening at the membrane's far end[54] where it is separating from the retina. Occasionally the adhesion between them may be so strong that the membrane tears the retina and drags the retina underneath itself.
  - Occasionally, the membrane's strong adhesion is not to the retina but the choroid: as the surgeon pulls on the strand, it detaches the choroid. Simply stop the maneuver and cut the strand; the choroid will readhere (see **Sect. 54.5.2.2**).
  - If the adhesion between the retina and membrane is too strong and the membrane breaks at a location too far from the retinotomy for the forceps to regrab it through the same retinotomy, there is a high chance that this is still sufficient to eliminate the traction the membrane had caused. The air-test will determine whether this is indeed the case (see **Sect. 31.1.2**).

[54] This is one of the many reasons to view the entire process through the BIOM.

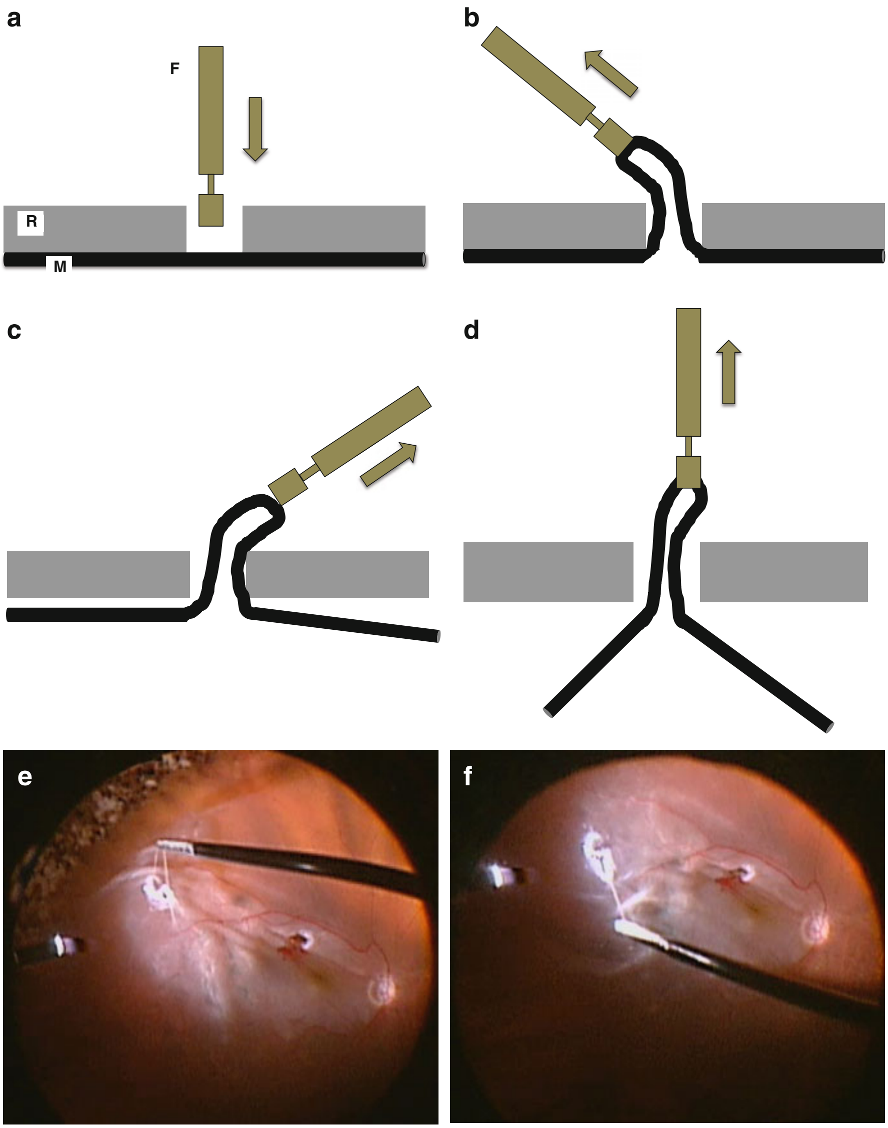

Fig. 32.17 Removal of a subretinal membrane. (The illustration is showing a retinotomy that is right above the membrane; as mentioned in the text, this location allows the use of any type of forceps.) (**a**–**d**) Schematic representation. (**a**) The forceps is approaching the membrane; the retinotomy has already been prepared. (**b**) The membrane is grabbed and pulled; the movement's vector is a combination of an upward and a retina-parallel movement, along the axis of the membrane in one direction. (**c**) Once the membrane is freed from the retina in the direction opposite of the previous pull, the direction of pulling is changed 180°. (**d**) Once the membrane is free in both directions, it is pulled up and removed. (**e**–**f**) Clinical examples. (**e**) The retinotomy has been created right over the subretinal membrane, which is grabbed by a serrated forceps and lifted. (**f**) The membrane is pulled in a close-to-retina-parallel direction on one side; it will be turned 180° and pulled in the other direction. This minimizes the traction on the retina and allows much more control than a simple pulling-up motion [i.e., as if continuing with the movement seen on (**e**); see the text for more details.] *F* forceps, *R* retina, *M* membrane

Q&A

Q *If the membrane is rather far from the retinotomy site, how easy is it to grab it?*

A It is not easy and not without risk. First, the visibility of the membrane dramatically drops once the retina is somewhat lifted by the forceps. What was "clearly there" before all of a sudden disappears (see above). Second, as the surgeon is struggling to find the membrane, he may injure the choroid accidentally and cause a major hemorrhage. Third, the retinotomy may get significantly enlarged.

- The membrane may be very long, requiring it to be pulled-regrabbed several times to entirely lift it into the vitreous cavity. Alternatively, the forceps can be spun as if it were a fork to eat spaghetti or a bimanual technique employed with two forceps.
- Once the membrane causing the RD is removed, a F-A-X is carried out, and the surgeon must decide whether to laser the central retinotomy (see **Sect. 30.3.1**).
- If there are numerous membranes in multiple locations, a retinectomy, rather than multiple retinotomies, may be the preferable option.
  - Make sure the inner retinal surface is free of membranes.
  - Do a retinectomy (see **Sect. 33.1**).
  - Flip the retina over, take a crocodile forceps, and try to grab all obvious membranes.

Pearl

What appeared so obvious to be a subretinal membrane when viewed in the retina's normal position becomes much less so once the retina is flipped. It may be necessary to turn the retina over and back several times to identify all membranes. Also, it is not that difficult to grab too deep and engage the retina proper; the more parallel with the retina the forceps is held, the smaller the risk of this complication. Some of what looked like focal strands before will turn out to be true membranes, covering a much larger area.

- Not all membranes need to be removed since some of them are not strong or elastic enough to cause an RD (see above, air-test).

32.4.2 CNV

Surgical removal of such membranes is still performed occasionally, even though this procedure is largely replaced by anti-VEGF injections today.

- The surgeon is in full control how he removes the membrane. He has, however, no control over whether he also removes a large part of the adjacent RPE or

causes a major bleeding (see **Table 40.1**). The risk of bleeding is reduced, but not eliminated, by repeated anti-VEGF therapy administered in the weeks prior to surgery.
  - The patient has to understand these and accept the risks.
  - OCT helps in determining whether the membrane is under or over the RPE; membranes that are underneath pose a much higher risk of ripping the RPE, which would result in a stable condition but a large central scotoma.

32.5 Membranes Over the Ciliary Body[55]

In eyes with anterior proliferative disease or after trauma with significant PVR risk, it is crucial to thoroughly clean the surface of the ciliary processes. Failure to do so, and do so early, is a huge risk factor for postoperative hypotony.

- Remove the lens and the capsules (see **Sect. 38.5**).
  - No IOL is to be implanted until the PVR risk is over.
  - IOL implantation is indicated only if the visual function justifies it. If there is visual potential, implant an iris-claw lens.
- Do self-indentation.[56]
- Use various instruments (probe, scissors, forceps, spatula etc. – but never a scraper) to lift vitreous, fibrin, blood, membranes etc., off the surface so that the ciliary processes are completely free.
  - Switch hands and repeat the maneuvers 360°.
- There are two major risks with the procedure:
  - Bleeding if the ciliary process is damaged by a sharp tool. The bleeding is profuse and difficult to stop. The diathermy must be applied “blindly,” inevitably damaging a rather large area (see **Table 40.1**).
  - Pulling off the ciliary body with a blunt tool. If the ciliary body detachment is longer than ~2 clock hours, it should be sutured back into place.

32.6 Cutting Epiretinal Membranes with Scissors[57]

Below are a few suggestions for the use of scissors, as opposed to forceps or the probe, to deal with epiretinal membranes.

- The most versatile type of scissors is the vertical one.

[55] This is an indication where the superiority of EAV is unquestionable.

[56] This is a rather time-consuming procedure where perfect coordination of the indentation and intraocular maneuvers is necessary; it is virtually impossible to achieve such coordination if someone else does the indentation. This is true even though self-indentation makes bimanual surgery impossible.

[57] See also **Sect. 13.2.1.4**.

- Ideally, the tip of the blade should show at the far end of the membrane before any cut is made. This reduces the risk that retina, which may be very adherent to the membrane, is also cut.
- Once the blade is inserted between the membrane and retina, it can be used as a spatula (see **Fig. 32.18**).

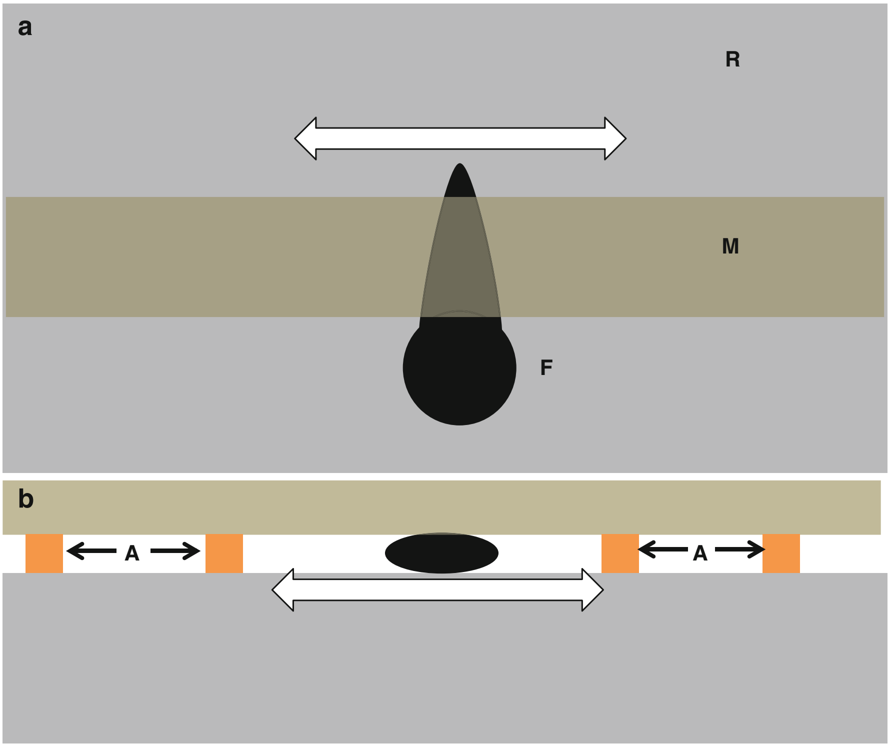

Fig. 32.18 Schematic representation of using the scissors as a spatula in separating an epiretinal membrane from the retina. (**a**) The forceps' lower blade is inserted underneath the membrane so that the tip of the blade is past the membrane's far edge. The membrane is not cut; instead, the surgeon moves the blade (*double arrow*) in a retina-parallel plane to sever the adhesions between the two tissues – although he is not able to actually see the adhesion points. Surgeon's view. (**b**) The adhesions serve as anchor points so that the two tissues remain locked together until the last of the adhesions is broken; for this reason, the surgeon should try to move the forceps in both directions alternatively, not "go all the way" in one direction first. Should he do that or cut the membrane, the maneuver becomes impossible to execute. Cross-sectional view. The concept is identical to that seen in **Fig. 13.10**; the advantage of using scissors, as opposed to a spatula, is that if the adhesion proves to be strong, cutting instantly becomes possible, without the need to exchange the tool. Alternatively to inserting the lower blade under the membrane, insert both blades with the scissors in closed position. *R* retina, *M* membrane, *F* forceps, *A* adhesion point

Pearl
If the membrane is cut, the "spatula" option for the forceps is no longer available since the anchors that are needed for spatula-action are removed.

- If the membrane is vascularized,[58] it will bleed when cut. Use diathermy to close the vessel(s) but keep in mind that it is often not possible to establish from which direction the blood vessel is fed; it is best to cauterize the adjacent area in both directions.
  - Remember that the diathermy causes shrinkage as well; it may become more difficult to insert the blade under the membrane.
- Never forget the carpenter's rule: measure twice before cutting once.
- Do not try to cut a subretinal membrane unless it is so adherent that it wants to turn the retina underneath itself when the membrane is pulled (see above).

[58] Except when it becomes a "ghost" vessel due to the anti-VEGF injection.

Retinectomy, Retinotomy, and Chorioretinectomy

33

33.1 Retinectomy

Retinectomy is a procedure where a part of the (detached) peripheral retina[1] is removed. The two major indications include retinal shortening or a retina with inseparable vitreous and/or membranes on its surface. A retinotomy should always precede the retinectomy, making the selection of the characteristics of the retinotomy the primary issue in surgical planning. There are two important questions to answer: location and length (see below).

The decision to perform a retinectomy should never be taken lightly; the "carpenter's rule" (see **Sect.** 32.6) is especially true for this procedure. Reproliferation on the remaining central retina, whether due to a retinectomy done improperly (see below) or just as a natural process, may cause the remaining retina to "roll up like a rug" – a condition very difficult to treat.

Q&A

Q *How do you determine the ideal location of the retinotomy?*

A There are two antagonistic principles. On the one hand, the further anterior the site, the smaller the loss of the peripheral visual field. On the other hand, the surface of the remaining retina (i.e., central to the retinotomy) must be clean of all material. Leaving vitreous or membranes on the retina increases the risk of reproliferation, which is even more difficult to treat than usual. The more central the retinotomy, the more likely that no vitreous or membrane is left on the remaining retinal surface.

[1] "Peripheral" here means a retina that is peripheral to the *retinotomy* (see below), not necessarily a retina anterior to the *equator*.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_33

Q&A

Q *How do you determine the necessary length of the retinotomy?*

A It can vary between a few clock hours to 360°. The golden rule is: "A little more won't hurt, a little less might." It will be at the edge of the retinectomy (where the circumferential line turns toward the periphery) where it may become stretched and start to redetach. If any traction is experienced during the air test (see **Sect. 31.1.2**) or PFCL implantation, extend the retinotomy further. A crucial issue is to decide between 350° and 360°. In the latter case the entire retina can be twisted around the optic disc as the anchor point, which poses technical difficulties but also offers advantages (see below).

- Create a PVD and remove all epiretinal membranes as far to the periphery as possible. With few exceptions, the retinotomy is done along a line that is more or less parallel with the ora serrata.
- Apply diathermy in an arching line, marking the site of the retinotomy, central to the line where vitreous/membrane vs retina separation was impossible: any vitreous or epiretinal proliferative tissue still present must remain anterior to this line. If the retinotomy is less than 360°, make sure that the edges reach the ora serrata.
  - Use high diathermy power so that all blood vessels, especially the larger ones, are closed.
  - If this is a reoperation and proliferative tissue is present anterior to the retinotomy line, blood vessels may feed the conglomerate from anteriorly; in such cases either be prepared to deal with the occasional hemorrhage or, preferably, create a more peripheral second diathermy line.
  - The diathermy tip of most probes are not Teflon-like: the burnt tissue will stick to it and the tip needs to be cleaned repeatedly. You can do it inside the eye with the light pipe (see **Sect. 32.1.3**), or hand it over to the nurse.
  - The small air bubbles created by the diathermy process will gather behind the lens (see **Sect. 27.5.3**).[2] These bubbles will interfere with visualization and thus need to be removed from time to time.
- Cut the retina in the middle of the diathermy line (not outside it so as to prevent bleeding).
  - Cutting it with scissors[3] is safe because it is fully under the surgeon's control, but time-consuming in MIVS.
  - Cutting it with the probe is much faster but more difficult to control. The risk is that the probe bites into the retina that has not been diathermized and will

[2] The cornea in the aphakic eye.

[3] Especially if smaller than 20 g.

bleed. To minimize this risk, use low aspiration/flow, and turn the probe toward the peripheral retina, not toward the central retina.

- Once the retinotomy is complete, use the probe to remove the entire peripheral retina.[4] Scleral indentation may be needed to accomplish this task.
  - The detached, nonfunctioning peripheral retina is a major producer of VEGF.
- Reattach the retina under air or PFCL (see **Fig.** 33.1 and **Table** 35.2).
  - 360° retinectomy allows examination of the back surface of the retina and removal of any membrane that may have grown on it, including the ring proliferation (see **Sect.** 32.3.1.5).
  - 360° retinectomy introduces the risk of inadvertent retinal translocation. Make sure that the retina is correctly positioned, i.e., the macula is where the macula should be (see **Fig.** 33.2). The scraper (see **Sect.** 13.2.3.2) is a great tool for "massaging" the retina in place.[5] Do the twisting in small increments.
- "Weld" the edge of the central retina to the choroid with 2–3 rows of laser (see **Sect.** 30.3.5).
- Implant silicone oil (see **Sect.** 35.4.4) (**Table** 33.1).

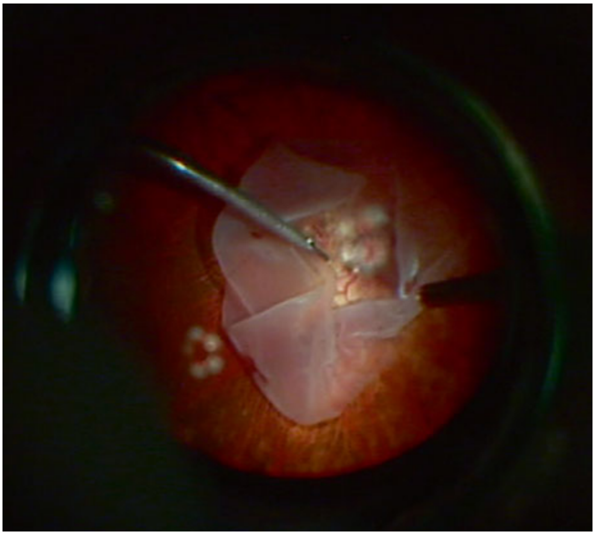

Fig. 33.1 **360° retinectomy,** intraoperative image. All sub- and preretinal membranes and the vitreous gel have been removed. The retina is being reattached with PFCL; small air bubbles are stuck to the heavy liquid's surface

[4] This is why the correct name of the procedure is retinectomy.

[5] Anatomically, the retina can adapt amazingly well to being twisted around the optic disc: I once saw a patient who underwent seven surgeries for PVR and had a retina that was reattached after 360° retinectomy, but it was turned 180°. Functionally, as little as 10° misalignment can cause severe visual disturbance.

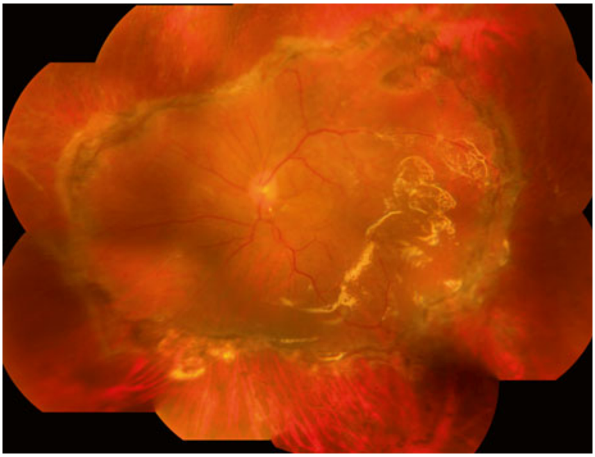

Fig. 33.2 **360° retinectomy,** postoperative image. The retina is attached under silicone oil; there is no PVR reaction. The line of retinotomy was very posterior – the patient presented with bare LP vision 3 months after a large rupture and total retinal incarceration

Table 33.1 Silicone oil implantation after 360° retinectomy if PFCL-fluid mixture ("fluid sandwich[a]) is in the vitreous cavity

Step	Comment
Place the flute needle just above the PFCL bubble and aspirate as much of the BSS as possible first as the silicone oil enters the eye through the infusion cannula[b]	The silicone oil-BSS meniscus is more difficult to visualize than the one between BSS and PFCL. It is therefore rather common that silicone oil will enter the flute needle, occluding it; it needs to be flushed[c]
When the BSS is visible no more, continue the aspiration by holding the flute needle above the disc and removing PFCL	Remember that as the PFCL bubble gets smaller, it takes on an increasingly round shape. This means that while a rather substantial bubble is still visible over the posterior pole, the edge of the retinectomy is not covered by the bubble anymore. There is BSS here, and the retinal edge will float off
Because of the elevation of the retinal edge, move the flute needle over the choroid next to the retinal edge inferiorly – rotate the eye so that this is now the deepest point – and continue aspirating	You are now aspirating BSS, and the meniscus is barely visible. A more reliable sign that all the BSS has been aspirated is to watch the movement of the retina: as soon as the BSS is gone, the retina will slide toward the flute needle[d]
After the PFCL bubble has been aspirated, continue aspirating the fluid still forming the film on the eyewall	Collection should take place both at the inferior retinal edge and in front of the disc, until no retinal movement or meniscus is seen

[a]This is why a 100% PFCL fill is preferred.
[b]Aspirating the PFCL first may cause retinal redetachment and is thus not recommended.
[c]The surgeon must monitor the optic disc, and if the vessels are pulsating, stop the injection. If the disc turns white, it is very likely that the oil has been aspirated into the flute needle.
[d]Hence the need to inject the silicone oil at low pressure – the BSS removal becomes equally slow, thus greatly reducing the risk of aspirating the retinal edge into the flute needle.

33.2 Retinotomy[6]

Retinotomy may be employed as the initial step in performing a retinectomy (see above), but stand-alone indications also exist.

- If the retina is shortened circumferentially, a radial cut can relieve the traction.

> **Pearl**
> The real strength of the traction force “tearing apart” a tissue is often not seen until the tissue is actually cut (see **Fig. 33.3**). When a tissue under traction or the tractional membrane itself is cut, the endpoints separate immediately and disproportionally.

- A small retinotomy is created if access to the subretinal space, to drain fluid or remove a membrane, is needed. The selection of the retinotomy site is described under **Sect. 32.4.1** and the technique under **Sect. 31.1.2**. Whether the retinotomy needs lasering is discussed under **Sect. 30.3.5**.

33.3 Chorioretinectomy[7]

The goal of this procedure is destroy the cells[8] that are primarily responsible for postoperative PVR development. Chorioretinectomy is also able to liberate incarcerated but still attached retina that has developed full-thickness folds (see **Fig. 33.4**). The procedure is ideally done before proliferation occurs.

- Remove all vitreous in the area. Make sure that a PVD has been created.
  - Anteriorly this may be impossible; remove the peripheral retina before applying the diathermy, especially if the procedure is done in the context of injury (see **Sect. 63.7**): it may be impossible to completely remove the vitreous in the vicinity of the planned chorioretinectomy.
- Reattach the retina so that you know precisely the final resting place of the retinal edge.
- Use the highest setting of the diathermy probe[9] to create a contiguous line of treatment spots.
  - The treatment may be applied over bare RPE adjacent to the retinal edge if a retinectomy has been performed or in the entire area of the retinal break (giant tear).
  - Involve the retina as well if there is a deep IOFB impact site (see **Fig. 63.9**) or the retina is incarcerated and thus covers the RPE.

---

[6] The procedure discussed here is a stand-alone one, not as a precursor to retinectomy.

[7] For want of a more accurate term, this word describes the intentional destruction of both the retina and choroid. It is not truly an “ectomy” since the tissue is burned, not removed.

[8] Fibroblasts and the RPE.

[9] See above (**Sect. 33.1**) the caveats about diathermy use.

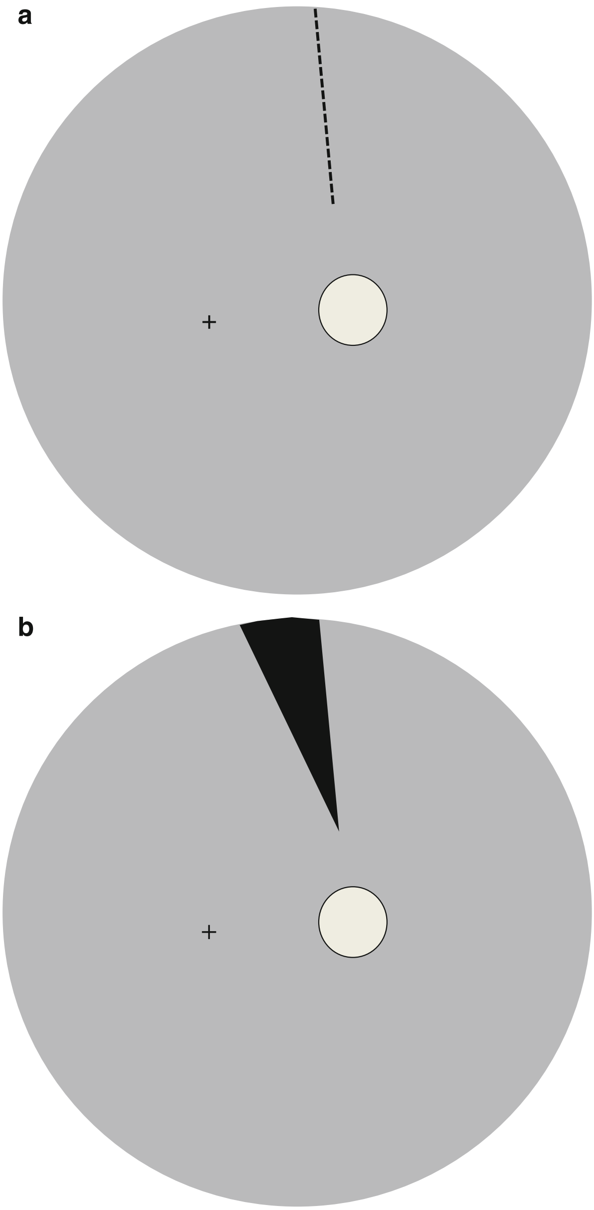

Fig. 33.3 Schematic representation of the power of the traction force acting upon the central retina. (**a**) The intended line of retinotomy is indicated by the dashed line. (**b**) The result is far from a simple line of separation between two retinal edges: showing how much traction has existed, a V-shaped area forms as the retinal edges retracted (the final result would suggest that a retinectomy has been performed)

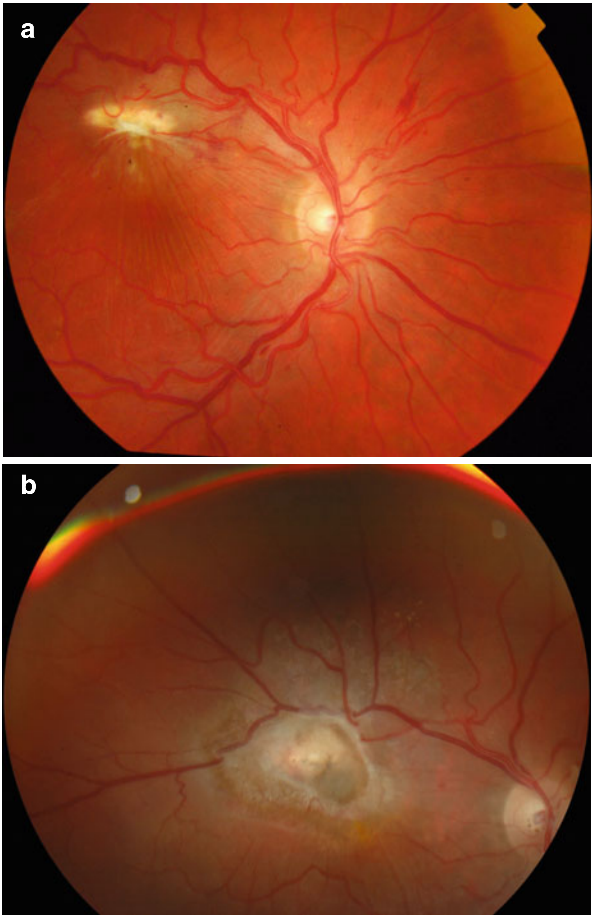

Fig. 33.4 **Late chorioretinectomy for full-thickness retinal folds**. (**a**) The scar that usually develops if the IOFB's impact involved the RPE and the choroid (possibly the sclera as well) also captures the retina, resulting in full-thickness folds. These folds cause disproportional visual disturbance, and chorioretinectomy is the only way to deal with them. Part of the scar is superficial, which is also removed during the reoperation, and the ILM is peeled to remove the surface that may have been seeded by proliferation-prone cells. The original, deep scar is not excised. (**b**) Following chorioretinectomy, the folds are gone, the surface is smooth, and the vision is normalized

- Vacuum the area with the probe or flute needle, but there is no need to remove any tissue with forceps. If a deep scar is already present in the treatment area, do not attempt to excise it.
- If the lesion is central and you do not expect traction to develop, laser is not mandatory. If the lesion is peripheral, weld the retinal edge with laser (see **Chap.** 30).
- Postoperatively only bare sclera should be visible along the retinal edge, but reactive pigmentation may occur centrally (see **Fig.** 33.5).

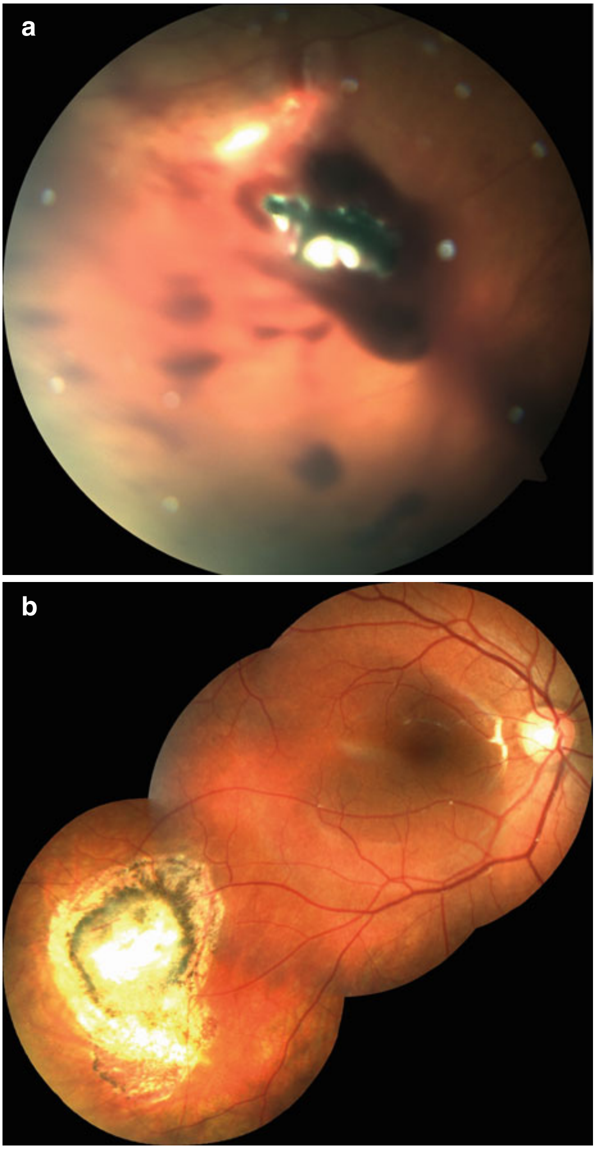

Fig. 33.5 Acute chorioretinectomy after severe trauma. (**a**) IOFB injury with a VH and a hard-to-see deep impact site. There is also retinal and choroidal hemorrhage; the IOFB lies in the pool of blood. (**b**) Following chorioretinectomy, the retina is attached, and the silicone oil has been removed. There is no PVR, no retinal fold formation, only scattered hyperpigmentation along the retinal edge. The central area of the treatment has a pure white color, indicating that this is bare sclera

Chromovitrectomy

34

It is a strange paradox that VR surgeons, whose goal is to restore vision, are often forced to work with tissues[1] that are very difficult or impossible to visualize. The use of dyes – or markers[2] – makes numerous tasks easier for the surgeon and safer for the patient (see also **Sect.** 27.3.3).

34.1 Posterior Vitreous Cortex

Autologous blood[3] and *ICG* are able to faintly stain the vitreous, but the former is not an easy material to prepare and use for this purpose, while the latter does not result in a consistent marking (see **Fig.** 34.1).

The material of choice is *TA*. Either use a preservative-free version[4] or filter it if you want to leave it behind; if used for diagnostic purposes only, there is no need for filtration.

- Following the creation of a small vitreous-free pocket in front of the posterior pole (see **Sect.** 27.4), inject a miniscule amount of TA over the posterior pole.
  - Aspirate all excess (free-floating, non-sticking) crystals.

> **Pearl**
> If the crystals adhere to the surface, this is evidence that there is PVD. If there is no crystal sticking, it is still possible that PVD has not occurred; the inner surface of the vitreous is simply too smooth for the crystal to adhere to it (false-negative result; see **Sect.** 27.4).

[1] Healthy vitreous, ILM, fine epiretinal membranes.

[2] TA does *not* stain the vitreous (or the ILM; see below); it only *marks* the tissue.

[3] Whether via spontaneous bleeding or surgeon-injected blood.

[4] Triesence (Alcon, Fort Worth, TX, USA).

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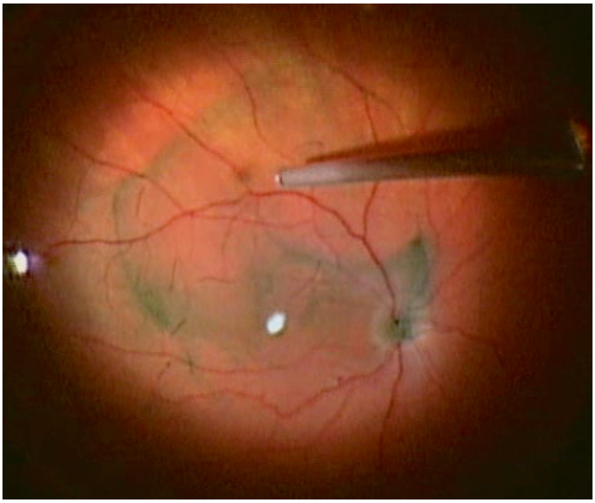

Fig. 34.1 ICG-staining of the posterior cortical vitreous. The green dye created a faint marking of the vitreous that is still present on the posterior retina. In eyes with poor contrast and lack of the normal pigmentation in the posterior pole this may be the only option to show the presence of the posterior cortical vitreous (see **Sect. 56.2**)

- If there is TA on the surface, detach the cortical vitreous (see **Sect. 27.5.1** and **Fig. 34.2**).

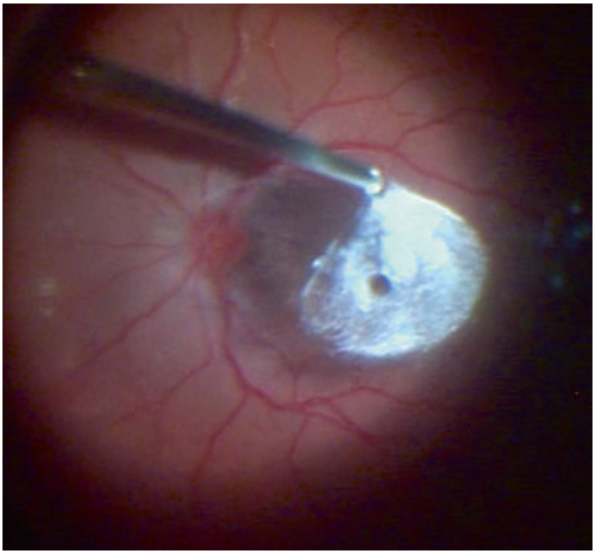

Fig. 34.2 TA marking the nondetached posterior hyaloid. The crystals clearly signal the presence of vitreous on the posterior retina. The PVD is created by aspiration using the (20 g) probe. A tiny hole in the middle shows that the posterior cortical vitreous was absent over the fovea

TA is also extremely useful in marking the vitreous that has prolapsed into the AC (see **Sect. 63.6**) as well as demonstrating the presence of vitreous adherent to the anterior retina. Even though it is not a "chromo-" weapon, air also makes vitreous in the periphery visible (see **Sect. 14.1**).

34.2 EMP

The membrane can be stained directly (using trypan blue[5]) or highlighted via "negative staining" against a stained background (see **Fig. 32.9b**). Trypan blue stains both the EMP[6] and the ILM, but the ILM stains much more weakly. A dye combination[7] is able to stain both membranes well.

Staining can be done under air or BSS; in the latter case, the surgeon can try to use a cold dye or a solution with a drop of 50% dextrose in it so that the dye readily sinks to the bottom of the eye. For more details about staining, see below.

34.3 ILM

Staining this otherwise invisible membrane makes its removal much easier and less traumatic. The best result is achieved using *ICG*, followed by *brilliant blue*.[8] The latter's heavier-than-water version is easier to use and has a staining capacity that is almost as good.

TA is also being used to mark the ILM. It settles as a dust on the surface and is thus able to delineate the border between retinal areas with and without ILM cover. The problem with TA use is that while it does show the extent of the ILM-peeled area ("horizontal signaling"), it can interfere with the surgeon's visual feedback about how deep his instrument is ("vertical signaling").

A well-stained ILM[9] may give a uniform greenish color, show nonstained islands (negative staining; see above), or enhance the visibility of ILM wrinkling: more dye accumulates in the "valleys" than on the ridges (see **Fig. 34.3**).

34.3.1 False-Positive Staining with ICG

If ICG is injected onto the retina after the ILM has been peeled, the nerve fibers will show a faint and not uniform staining – but staining nevertheless. Since the surgeon may be unaware that the ILM has been peeled,[10] it requires extra caution not to start "peeling."

---

[5] MembraneBlue (DORC, Zuidland, The Netherlands), which can also be used subretinally to identify retinal breaks.

[6] And other proliferative membranes on the retinal surface (see below, **Sect. 34.4**).

[7] MembraneBlue-Dual (brilliant blue G + trypan blue; DORC, Zuidland, The Netherlands).

[8] Brilliant Peel (Geuder GmbH, Heidelberg, Germany), ILM-Blue (DORC, Zuidland, The Netherlands).

[9] The use of ICG is described here.

[10] For example, the previous surgery was done elsewhere and the ILM peeling was not noted in the discharge summary. This, unfortunately, is not that rare.

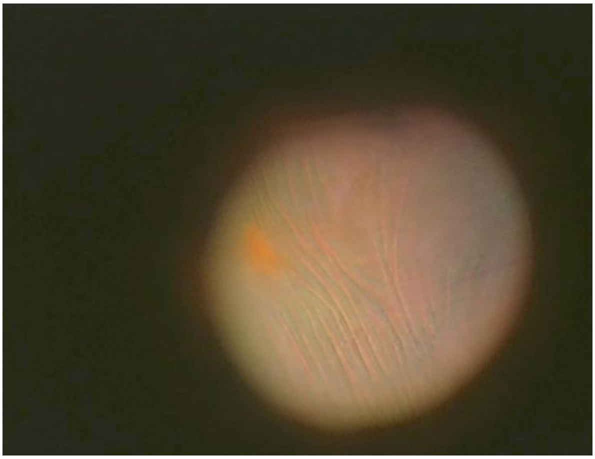

Fig. 34.3 ICG-staining of a wrinkled ILM. The microfolds in the ILM are not really conspicuous on external examination or even intraoperatively, but staining enhances them because of the increased contrast (see the text for more details)

34.3.2 Injection Technique for Staining the ILM

- Use a tuberculin syringe and a flute needle; make sure that there is no obstruction to the dye's flow.
- Introduce it into the vitreous cavity and close the infusion.
- Inject the dye over the posterior retina to cover the entire area where you intend to peel (see **Fig.** 34.4).
  - Rather than pushing the plunger with your finger, use your palm to do it (see **Fig.** 34.5).
  - Use minimal force; if there is no flow, do not push harder on the syringe but withdraw it and flush the needle while having it outside the eye.
  - Never aim the jet stream at the fovea.

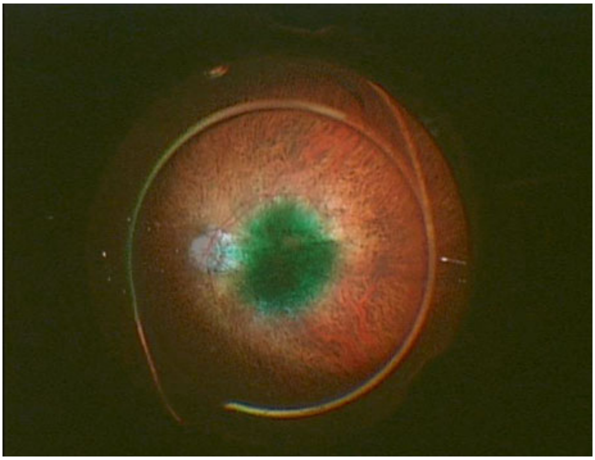

Fig. 34.4 ICG-pooling on the posterior retina. Simply closing the infusion before the actual injection allows the dye to settle on the macular area. This limits the amount of ICG needed and will not allow the dye to disperse throughout the vitreous cavity

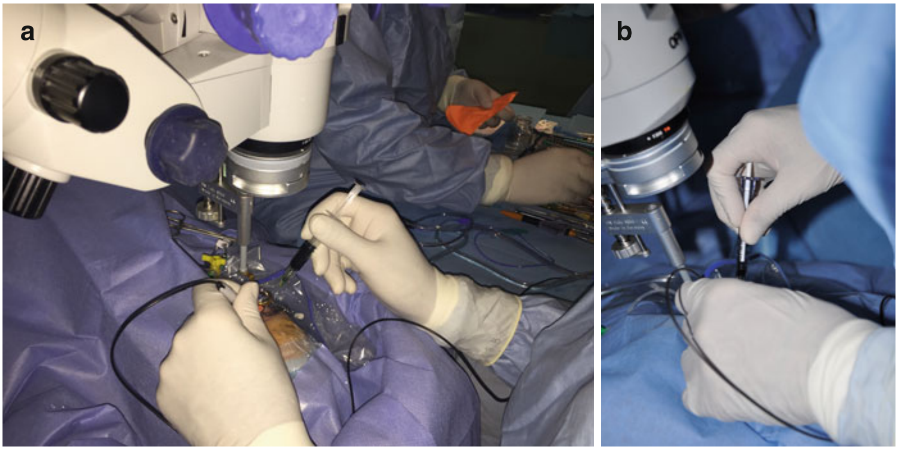

Fig. 34.5 **Injecting dye by minimizing the risk from the jet stream.** (**a**) Upon entry, the syringe is secured with three of the surgeon's fingers. This kind of support is necessary to guide the tip of the flute needle through the cannula. (**b**) Just before injection, the way the syringe is held should be changed. The goal is to give the surgeon maximum control over the power of the jet stream. (Occasionally the plunger has increased resistance against the push, which in turn forces the surgeon to increase the force used for injection. The index finger would need to be extended were it to be employed for the push, which reduces control. It is possible that as the resistance of the plunger is overcome, the jet stream is strong enough to create a retinal break and inject the dye subretinally.) The surgeon changes the way he holds the syringe and does the actual pushing of the plunger with the palm of the hand. He must carefully monitor through the microscope the position of the flute needle's tip while the hand's position is changed: the risk is pushing the needle into the retina as the surgeon's fingers "crawl up" the syringe

- Open the infusion after ~10 s and aspirate the dye with the probe.

Pearl

In eyes with a macular hole, several materials have been recommended to protect the RPE by blocking dye-access to it: TA, PFCL, visco, and autologous blood. None is efficient or easy to install *and* keep over the hole. The TA crystals may also be damaging to the RPE; the PFCL is either too small a bubble and rolls away or too large and then leaves a large area unstained; the visco tends to drift away as the needle is withdrawn; and the autologous blood is cumbersome to produce.

34.3.3 Toxicity[11]

To reduce the risk of RPE or retinal damage by the ICG, a number of steps should be taken[12]:

- Keep the light pipe even further away from the retina than otherwise while the dye is in the eye.
- Make sure the dye is iso-osmolaric.
  - Dissolve the 25 mg of ICG powder in 5% glucose, not in its original vehicle.[13]
- Minimize the time of dye contact with the retina.
- Avoid injecting directly into a macular hole and try to limit the time of dye contact with the RPE.
  - Aspirate the dye from the macular hole when you remove the ICG from the vitreous cavity.
  - Maximal drying of the surface at the end of F-A-X (see **Sect. 50.2.4**) is also helpful in preventing the dye from remaining in contact with the RPE.

If the indication for ILM peeling is not a macular hole, the risk of toxicity is dramatically lower.

34.4 Newly Formed (PVR) Membranes

Trypan blue is the dye that makes these membranes visible. The dye should be used with an intravitreal air bubble to protect the posterior capsule from being stained. Mixing the dye with 50% dextrose or using it at cold temperature are not good alternatives when large retinal areas need to be stained.

[11] It is not really an issue in eyes without a macular hole (i.e., no dye access to the subretinal space).

[12] Having followed what is outlined here, I have not seen a single case of toxicity in several thousands of eyes with ICG staining.

[13] Water.

Tamponades

35

As the VR surgeon removes gel from the vitreous cavity, he typically replenishes it with BSS. Gaseous materials or fluids, in addition to being used as intraoperative tools, may be employed as "tamponade," kept postoperatively for weeks or months or permanently.[1] During the operation, several exchanges between these materials may need to be performed.

35.1 Air

Air in the VR surgeon's hands has many uses (see **Sect. 14.1**), of which retinal reattachment (F-A-X, see **Sect. 31.1**) is the most important. Air, which does not expand after implantation,[2] is rarely used[3] as a postoperative tamponade since it disappears from the vitreous cavity within days.

> **Pearl**
> The air should never be injected at high pressure to avoid retinal damage by the jet stream, and it must be filtered first (Millipore 0.22 μ, EMD Millipore, Billerica, MA, USA).

[1] **Chapter 14** provides additional information about these materials.

[2] Unless the patient is at high altitude; see below.

[3] Some surgeons tried it in macular hole surgery, but the initial enthusiasm for air use has subsided.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
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35.2 Gases

35.2.1 General Considerations

Depending on the type and concentration of the gas, it may stay in the vitreous cavity for ~2 weeks (SF_6) or ~2 months (C_3F_8). As N_2 and O_2 diffuse into them, pure gases expand after their implantation, most rapidly within the first 8 h; SF_6 needs ~2 days to reach its maximum expansion, C_3F_8 needs ~4 days. For this reason, no more than 1 ml of pure gas should be injected into an emmetropic eye.

The potential for gas expansion during general anesthesia as the N_2O diffuses into the intravitreal gas[4] and the "collapse" of the intravitreal gas upon termination of the general anesthesia are important issues requiring proper adjustment from both the surgeon and the anesthesiologist (see **Sect. 14.2**).

The beneficial effects of the gas include their surface tension, buoyancy, space occupation, and the fact that proliferating cells do not penetrate it, nor will they attach to its surface.

35.2.2 Surgical Technique[5]

Typically, surgeons flush the air-filled eye with a premixed concentration of the gas. This method works but wastes a lot of gas. My technique is the following, regardless of the type of gas used:[6]

- Prepare two 2 ml syringes. Leave one empty for air withdrawal and fill the other with 2 ml of pure (undiluted) SF_6. *Loosely* attach a short 27 g needle to the empty syringe.
- Remove all cannulas.
- Through a superotemporal location, insert the needle attached to the empty syringe into the vitreous cavity. Aim toward the center of the eye and *constantly* monitor the needle,[7] keeping it in the same position throughout.
- Press the cone of the needle against the orbital bone or secure it firmly with your fingers, or both.[8]
- Withdraw ~1.5 ml of air[9] into the syringe. The nurse must announce the amount of air being removed at every 0.5 ml interval.
- Detach the syringe from the needle, and hand it to the nurse. Attach the gas-filled syringe to the needle's cone.

---

[4] Pure SF_6 will expand by ~250% as N_2O penetrates it.

[5] See **Fig. 35.1**.

[6] My default choice is 30% SF_6. This provides tamponade for a sufficiently long period (~10 days) for the laser spots to take effect.

[7] This means that you never look up from the microscope during the entire process.

[8] This is determined by the patient's facial anatomy.

[9] More if the IOP was high and less if the IOP was low at the beginning of air withdrawal; more in a myopic and less in a hyperopic eye.

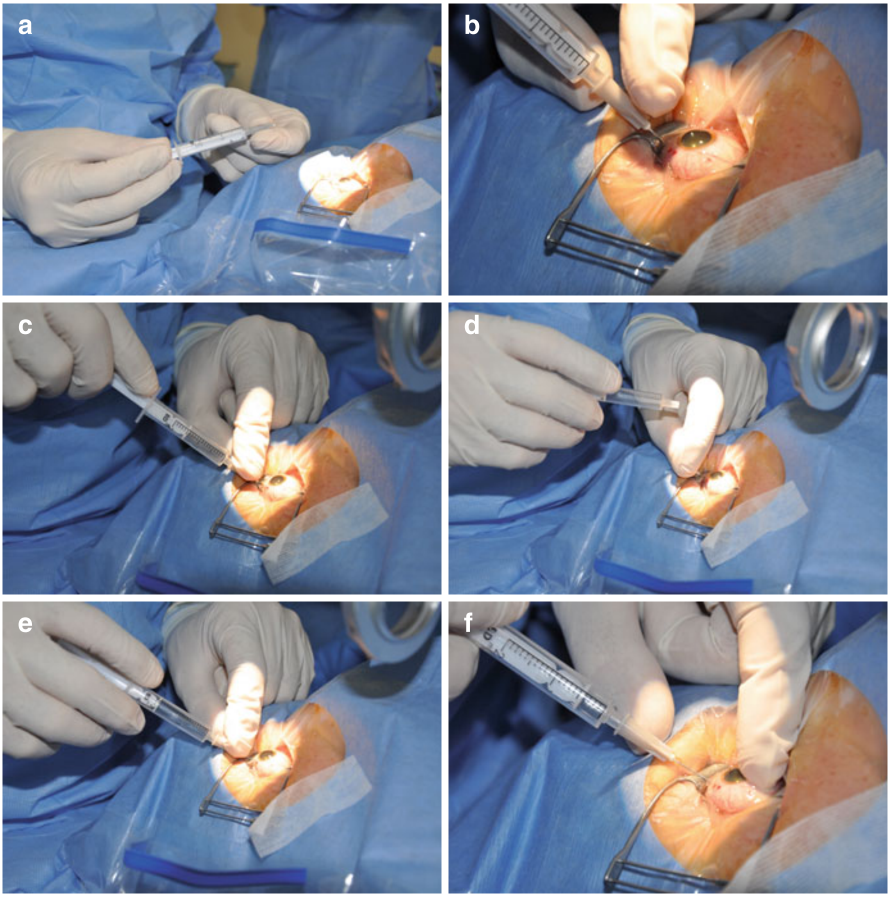

Fig. 35.1 **Mixing the gas for tamponade**. (**a**) The 27 g needle is loosely attached to the 2 ml syringe. The needle from this point on, until the completion of the entire mixing process, is held with the thumb and index finger of the surgeon's nondominant hand; once the needle is inserted into the vitreous cavity, no further adjustment to the syringe's position should be made. (**b**) The vitreous is entered with the needle, which is aimed toward the center of the cavity. From this point on, until the completion of the entire mixing process, the surgeon's gaze is fixed on the tip of the needle – he never looks up from the microscope. (**c**) 1.5 ml of air is withdrawn, monitored by the nurse who announces the progress at every 0.5 ml interval. (**d**) With the needle's cone securely fixed, the surgeon removes the air-filled needle and replaces it with a syringe that contains exactly 2 ml of gas. Such accuracy is needed to allow easy determination of the amount injected. (**e**) 1.5 ml of the gas is injected; the plunger is pushed with the surgeon's palm, not with his index finger, to increase his control over the injection. (**f**) With the non-dominant hand's thumb continuing to provide extra support to the syringe, a finger-tap assures that the IOP is in the normal range as the gas injection nears its completion. If the eye is soft, a small amount of extra gas is injected

- Inject ~1.5 ml of the gas as the nurse announces the progress. With your nonworking hand's index finger tap on the eye to make sure the IOP is in the normal range.

Pearl

If a gaseous tamponade is used, the patient must be warned, both pre- and postoperatively, that it *is* normal to initially "see dark" through the bubble, but it is *not* normal to have severe pain. If there is significant pain, he must seek help immediately. Vision will improve soon, even while the gas bubble is still in the eye, although the interface may remain bothersome, especially when the gas-aqueous interface is right in front of the macula.

35.2.3 Gas Injection into the Nonvitrectomized Eye

Most commonly used in eyes undergoing pneumatic retinopexy (see **Sect. 54.6**), the pure gas compresses the gel[10] and may induce PVD.

35.2.4 The Eye with Gaseous Tamponade

Even if the implanted gas is of a nonexpansile concentration, the gas (air) will expand if the atmospheric pressure drops. Patients with air/gas in their vitreous cavity should not fly or be exposed to an increase in elevation exceeding a few hundred meters.[11] The acute rise of the IOP, should these warnings be neglected, can lead to blindness.

Q&A

Q *What if a patient needs a gas tamponade but must travel by airplane, lives on a mountain, or has to travel through a mountain*?

A Silicone oil must be used, not gas – and this needs to determined preoperatively.

35.3 PFCL[12]

35.3.1 Indications to Use Heavier-Than-Water Liquids

- Flipping the inverted flap of a giant retinal tear.

[10] Hence the high (up to 30%) rate of secondary retinal tears: the traction is weakened at where the gas bubble is but may occur elsewhere.

[11] In other words, it is the *change* in altitude that matters, not the absolute height above sea level.

[12] It is almost never used as a true tamponade, but for didactic reasons it makes sense to discuss PFCL use here.

- Keeping a highly mobile detached retina (relatively) immobile in RD surgery.
  – Temporarily reattaching the macula to allow ILM peeling (see **Sect. 32.1.6**).
- Keeping an-already-opened funnel open in PVR surgery (see **Sect. 32.3.1.5**).
- Floating (lifting) dislocated lens particles or IOL or IOFBs toward the iris.
- Facilitating the removal of liquefied blood in eyes with suprachoroidal hemorrhage (see **Sect. 60.2**).
- Pushing residual subretinal fluid toward the retinotomy (see **Sect. 31.1.2**).
- Displacing submacular blood (see **Sect. 36.4**).

35.3.2 Surgical Technique

35.3.2.1 Implantation

- All tractions must be addressed *before* PFCL injection; otherwise, only small amounts to stabilize the retina may be used, and only if no posterior retinal break is present (see below).
- If possible, avoid injecting into an air-filled eye since the PFCL will rapidly start to evaporate and collect on the back surface of the IOL/posterior capsule (see **Sects. 14.4** and **31.2**). The evaporation is so fast that the PFCL disappears even from the bore of the needle[13] and explains the introduction of a small air bubble every time PFCL is injected; multiple injections result in multiple air bubbles (see **Fig. 33.1**).
- Never inject the PFCL too fast. The BSS must drain to avoid a circulation-stopping IOP elevation (see below).
- If the injection is not continuous, several large bubbles may form, but they will rapidly coalesce.
- If small amounts are injected and many small bubbles form,[14] shake the eye and they will coalesce. To prevent the fish-egging, keep the flute needle's tip inside the enlarging PFCL bubble.
- Never try to fill the vitreous cavity with PFCL if there is a posterior retinal break under traction.[15] The bubble will escape into the subretinal space instead of flattening the retina. It is the traction, not the presence of the break, why PFCL is contraindicated.[16]
- If the PFCL is injected in order to be exchanged for silicone oil, it is best to fill the vitreous cavity completely. This avoids creating a "fluid sandwich,"[17] in

[13] This is why it is only a waste of PFCL if the nurse tries the usual deaeration before she hands the PFCL-filled syringe over to the surgeon.

[14] Fish eggs.

[15] The same principle applies if BSS is reimplanted into an air-filled eye that had an RD and a posterior retinal break earlier during the operation.

[16] In other words, PFCL *can* be injected if the posterior break is not under traction. The only exception to this rule is a closed-funnel RD (see **Sect. 32.3.1.6**).

[17] BSS in-between silicone oil and PFCL.

which case the completion of the drainage is lengthier and technically more complex (see below, **Sect. 35.5**).
- When injecting into an eye that has a foreign object[18] in the vitreous cavity, avoid pouring the PFCL on top of, rather than around and underneath, the object.

35.3.2.2 Removal[19]

The PFCL bubble has very low resistance to flow and readily escapes the eye,[20] regardless of what replaces it. PFCL is also easy to discern, irrespective of what it is interfacing with. It is used almost exclusively as an intraoperative tool, although occasionally left behind[21] for a few weeks.

- The larger the bubble, the flatter its anterior contour; a smaller bubble will form a sphere.
  - During the initial phase of the removal the *apparent* spread (horizontal dimension) of the bubble is unchanged, only its height[22] seems to decrease.
- Obviously, the deepest point of the eye is where the bubble will be easiest to collect. However, the eye is often rotated during removal and the single large PFCL bubble may break up into smaller ones, which lose connection with each other; these must then be aspirated separately.
- Residual PFCL bubble in the vitreous cavity: not a per se indication for removal.
- Residual PFCL bubble subretinally: not a per se indication for removal.
  - If it is subfoveal, though, it should be removed as it may be toxic. A small retinotomy is sufficient, and the bubble will readily escape.
- Residual PFCL bubble in the AC: easy to recognize since in a patient sitting at the slit lamp the bubble will be inferior. A small inferotemporal paracentesis will result in spontaneous drainage (see below, **Sect. 35.6**).

35.4 Silicone Oil

Silicone oil is used as a temporary or permanent substitute. Its major drawback is that in the former case the patient must undergo a second operation to remove the oil. "Oil changes" are also needed if the longevity of the oil[23] is shorter than its required duration. The choice between silicone oil and gas tamponade in RD surgery is discussed under **Sect. 54.5.2.5**.

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[18] Which needs to be levitated; see above.

[19] See below for additional details about exchanges.

[20] This includes PFCL that is under the retina (see below, **Sect. 35.3.1.2**).

[21] "Double fill," with 1,000 cst silicone oil as the counterpart. The potential problem with such a mixture is that the two materials will not completely fill the vitreous cavity, leaving space between them and thus allowing the proliferation to develop in-between – i.e., centrally.

[22] The bubble height is indicated by the interface seen on the shaft of the flute needle.

[23] Emulsification, see below.

35.4.1 Selecting the Type of Silicone Oil to Implant

Silicone oil is available in "normal" viscosity (1,000–1,300 cst) and high viscosity (5,000 cst; see **Sect. 14.3.1**). The more viscous the oil, the less likely it is assumed to emulsify.[24] The normal oil provides better tamponade superiorly, the heavier-than-water version inferiorly.

- I use almost exclusively normal oil (lighter than water and low viscosity).
  - The only exception is eyes that require a permanent fill (see below), in which case I use 5,000 cst oil.
- I do not use heavy oil.
  - While heavy silicone oils can indeed prevent inferior proliferations, they increase the risk superiorly, where they are technically more difficult to access and deal with.

Q&A

Q *Long-acting gas or silicone oil*?

A For me this is a rather easy question to answer. If an eye requires long-term (months) tamponade, I prefer oil (see **Table 35.1**).

35.4.2 General Considerations

- A silicone oil fill is supposed to 100% (see below and **Sect. 14.3.2**).
  - A less-than-complete fill increases the risk of emulsification and the likelihood that the cells responsible for proliferation will aggregate inferiorly (hence the rationale to use heavy oil).
- Unless the oil is to be kept permanently (see below), the patient must understand that oil implantation involves at least one additional operation.
- The patient has to accept that the eye's refraction will be significantly changed by the oil's presence.
- If there is a risk of oil prolapse into the AC, the patient may have to position (facedown) in the first few days.[25]
- Decide, preferably in advance, the fate of the lens (see **Sect. 4.5**). Ideally, measure the axial length prior to surgery, when there is no silicone oil in the eye.[26]

[24] Emulsification is also dependent on other factors such as silicone oil purity, the completeness of the fill (100% fill representing the smallest possible risk), the patient's lifestyle etc.

[25] If the eye is aphakic and silicone oil prolapsed into the AC intraoperatively, the pupil must not be constricted as long as there is oil in front of it.

[26] Unless there is significant cataract, the axial length can be measured under oil with the LenStar (Haag-Streit AG, Koeniz, Switzerland).

Table 35.1 Comparison between long-acting gas and silicone oil

Variable	Long-acting gas	Silicone oil
Concurrent IOL implantation	May require visco in the AC; power calculation is for gas-free condition	May require visco in the AC; power calculation is for oil-free condition. Adjustment is needed if the oil is to be retained forever
Injection of medication into tamponade	No if the fill is 100%	Yes; the dose may have to be reduced
Need for positioning	Yes	No, except in certain circumstances and even then only initially (see the text for more details)
View of retina after the implantation	Poor, then improves	Excellent from day 1
Risk of IOP elevation	High initially then none	Normal initially then may increase (emulsification)
Duration of tamponade	Several weeks	Months to forever
Effect on PVR prophylaxis	No; if PVR develops, it usually but not necessarily starts inferiorly	Possibly; if PVR develops, it starts inferiorly
Possibility of sudden collapse of retina (closed funnel)	As long as gas is present: no	As long as silicone oil is present: no
Subretinal migration of tamponade	Very small risk, at the time of implantation (see **Fig.** 54.9b)	No until PVR develops; with ongoing PVR, the risk increases
Phthisis risk	Unchanged	Reduced if the fill is 100% (see the text for more details)
Issues with altitude (lower atmospheric pressure)	Yes; avoid as long as gas is in the eye	No
Another surgery needed to remove tamponade	No	Yes

35.4.3 Indications

35.4.3.1 Semipermanent Tamponade

- Prevention of rebleeding, mostly in eyes with PDR (see below and **Sect.** 52.2).
- Maintaining retinal (re)attachment.
- Prevention of PVR development in eyes at high risk.
- Prevention of the development of a closed funnel in RD/PVR/PDR.
- Prevention of reproliferation in PVR (including giant tear) and PDR.
- Macular hole.[27]

35.4.3.2 Permanent Tamponade

- Hypotony[28] or phthisis.
- Repeatedly recurring PVR, which leads to RD if the oil is removed.

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[27] For patients who cannot position and for failed holes (see **Sect.** 50.2.5). Some surgeons use silicone oil as their primary tamponade.

[28] Typically less than 4 mmHg.

– While the oil cannot be removed, an inferior RD can be left to persist[29] under the oil as long as the detachment does not involve/threaten the macula.
- Recurrent VH. Most often seen in diabetic patients; they may have a full panretinal laser treatment, no visible proliferation, and good systemic control of the diabetes and blood pressure, yet the intravitreal bleeding keeps recurring unless a silicone oil tamponade is present.

35.4.4 Implantation

- Consider removing the lens (see **Sect.** 4.5 and **Chap.** 38).
- If an IOL is present, perform a large posterior capsulectomy.
  – Posterior capsular opacification is inevitable.
- Hydrophobic IOLs (e.g., silicone) should be removed since the oil sticks to them.
- It is much faster and technically easier to implant the oil under air than BSS (see below, **Sect.** 35.5).
- To achieve a truly 100% fill, make sure you remove all the vitreous, suprachoroidal, and subretinal fluid/blood and do not overinflate the AC with visco.[30]
- The fastest way is to suture-close the infusion sclerotomy and inject the oil superonasally, directly through a short needle attached to the syringe, while draining the air through the superotemporal sclerotomy with the flute needle.
- The easiest way to implant is to attach the syringe containing the oil to the tubing of the infusion cannula at the stopcock; this way the tubing is short.
  – Use the vitrectomy machine's "viscous fluid injection" mode (or ask the nurse to do it[31]).
  – Do not apply too high an injection pressure – the tubing can disconnect at either end and the oil will be lost. You can gradually increase the pressure if all goes well.
  – While you are pressing the pedal and inject the oil, have the nurse monitor the syringe and the tubing to make sure that nothing gets disconnected.
- Simultaneously aspirate the PFCL (BSS) with the flute needle held in the dominant hand. Aspiration in these cases is from the bottom of the eye.
- If the eye is filled with air (the recommended option), aspirate it from the anterior part of the vitreous cavity, through the temporal sclerotomy.
  – There is no initial need to aspirate the air; it is compressible plus almost always leaks spontaneously through the cannula, even if it is valved. Use the time during this initial phase of oil implantation to suture the nasal sclerotomy (see below).

[29] That is, reoperation is not necessarily indicated.

[30] Visco may be needed in the AC to prevent silicone oil prolapse; see below.

[31] This obviates the need for the rather expensive disposables.

Pearl

Suturing the sclera is a rare chance for the VR surgeon to experience tactile feedback. Even if the needle is invisible underneath a swollen conjunctiva, the surgeon will feel the sclera's extra resistance against the needle's advancement. However, if the eye is soft, this feedback disappears, and the only way the surgeon can determine whether the needle indeed engaged the sclera is to try to lift the tip of the needle. If he caught only conjunctiva, the needle will easily lift it; if the sclera has also been penetrated, the needle's tip cannot be lifted.

  - As the air bubble is becoming truly small, you will notice that the image through the microscope[32] is darkening.
  - The size reduction of the air bubble is a saccadic motion;[33] fluids show a smooth, continual decrease.
  - The remaining small air bubble can spontaneously escape via the superotemporal cannula,[34] or if the valve prevents this, it can be removed with the flute needle. If the eye is phakic, do not use the flute needle:[35] remove the cannula and let the air out that way.
- Suture the superotemporal sclerotomy before you complete the oil injection.
- Inject silicone oil to achieve an IOP that is slightly higher than normal (~30 mmHg).
- Take a tooth forceps[36] in your *nondominant* hand and a cannula-forceps in your dominant hand. Grab and lift the sclera with the tooth forceps so that the scleral wound is immediately closed as you remove the cannula with the other forceps.
  - Exchange this forceps for the needle holder and put in the "X" suture (see **Fig. 14.3**).[37]
  - The suture may inadvertently be pulled through during tightening if the thread has been caught by the speculum (see **Sect. 19.1**) or a sticky drape.
  - Pulling the needle through the loop you just created helps to close the wound immediately.
- If, despite these precautions, the oil has leaked, check whether the IOP is still slightly high.
  - If the IOP is too low (too much oil lost), inject more by reinserting the cannula.
  - If the IOP is as desired, try to remove the subconjunctival oil. It is cosmetically unappealing, takes years to spontaneously disappear – if at all, since it often gets encapsulated. In the worst case, puncture these oil-containing cysts at the time of silicone oil removal (see **Fig. 35.2**).

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[32] Since the intraocular task had been completed before the air was injected, there is no need to observe the oil implantation inside the vitreous cavity through the BIOM.

[33] In other words, it is not proportional to the amount of oil being implanted.

[34] Rotate the eye so that the superotemporal area is the uppermost part of the globe.

[35] The risk of lens damage is rather high.

[36] The "colibri" forceps is the ideal tool for this: it has teeth that are sharp and large enough to grab sclera through the conjunctiva, but small enough to minimize the risk of tissue damage.

[37] This suture looks like an X underneath the sclera; the 2 threads are parallel on the surface.

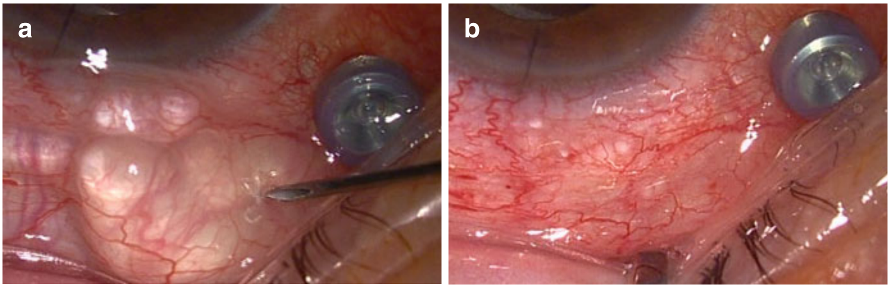

Fig. 35.2 **Subconjunctival silicone oil**. (**a**) A large amount of silicone oil has escaped subconjunctivally. Multiple bubbles are present, requiring the surgeon to make several punctures with a 23 g needle. A muscle hook is then used to push the oil toward the holes (not shown here). (**b**) The large cysts have been emptied, but the surgeon should not expect that he can drain *all* oil bubbles *completely* (nor encourage his patient that the procedure will fully restore the eye's native appearance.)

- If silicone oil enters the AC, it typically does so during implantation (see below for postoperative oil prolapse).
  - A small bubble is well tolerated and need not be removed. A bubble that is large enough to interfere with the patient's vision or with fundus examination may also damage the endothelium and should therefore be removed.
  - After all sclerotomies have been sutured, make a temporal paracentesis that is larger than the cannula you intend to use.
  - Place a blunt cannula, on a syringe containing cohesive[38] visco, into the AC and push the cannula to the far end of the AC (see **Figs. 35.3** and **14.5**). Do not use BSS since this may escape posteriorly, pushing even more oil forward; air occasionally also works.
  - Slowly inject the visco while pressing down the lower lip of the paracentesis to allow the oil to escape.
  - Do not try to remove the visco; it would restart the oil prolapse.
  - Constricting the pupil is not going to reduce the risk of oil prolapse; it just hides the oil from view.

If the eye is *aphakic*, a few special rules apply.

- Before the F-A-X, prepare a 6 o'clock (Ando) iridectomy[39] to prevent angle-closure glaucoma.[40]
  - Insert the probe with the port facing upward.
  - Make sure the port is at the desired location.[41] Aspirate before cutting into the tissue, and do not be surprised if a small bleeding occurs. Unless rubeosis is present there is no need to use the diathermy, which does not work well anyway: it causes tissue contraction (see **Table 40.1**).

[38] To avoid coating the AC structures; this reduces the severity and duration of IOP rise.

[39] The iridectomy is much more difficult to perform if air in the vitreous cavity is pushing the iris forward. Create the iridectomy before the F-A-X.

[40] It develops if the aqueous is misdirected posteriorly, behind the oil and thus pushing forward.

[41] Which is the periphery of the iris, away from the sphincter.

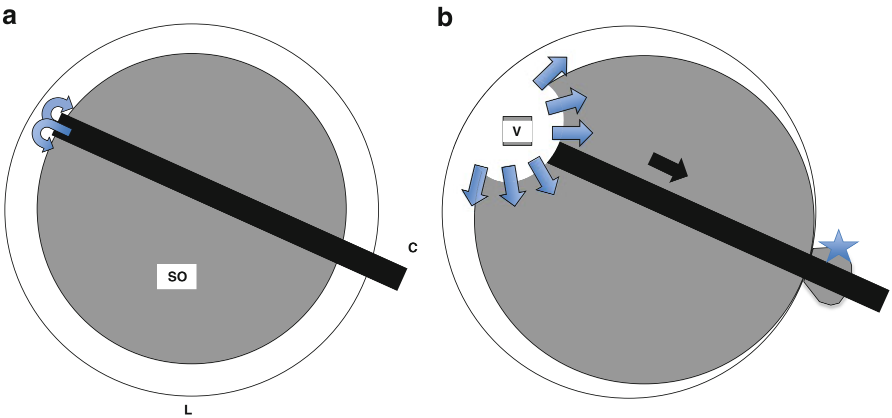

Fig. 35.3 **Pressing silicone oil out of the AC with visco**. (**a**) The cannula is advanced to the far end of the AC before visco is injected (*blue arrows*). (**b**) As the injection commences, the visco starts to push the bubble away from the AC periphery in either direction. The cannula is slowly withdrawn (*black arrow*), and with the visco continually entering the AC, the oil is exiting the AC (*star*). Make sure that the AC is split midway by the cannula: if it deviates to one side (let's say toward 1 o'clock on this image), oil will remain trapped on the other side (toward 7 o'clock here). *C* cannula, *SO* silicone oil bubble, *L* cornea, *V* viscoelastic

- Keep the flute needle just behind the iris as you aspirate the air. Stop injecting oil once it reaches the iris plane. The eye will be soft but more oil will be added shortly (see above).
- Leave an air bubble in the AC to prevent oil prolapse.

35.4.5 With Silicone Oil in the Eye

35.4.5.1 General Considerations

- Silicone oil will not conform to a SB; a ring of fluid will be able to accumulate at the bottom of the central slope if a circumferential buckle has been used.
- A retina that is detaching under silicone oil will first push the oil anteriorly (see **Fig. 35.4**). If this is for some reason impossible,[42] it will cause a tractional retinal tear and enter the subretinal space. The retinal break will have a characteristically oval shape (see **Figs. 14.4** and **35.5**).
- Very thin membranes often develop at the oil-retina interface. Usually they are detected only by the light reflected from their surface; their removal is not mandatory and is often risky.[43]

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[42] The AC is already full of oil in the aphakic eye or the oil cannot find a passage to the AC in the (pseudo)phakic eye.

[43] The clinical experience is that the retina is more fragile if it has been in contact with the oil for extended periods.

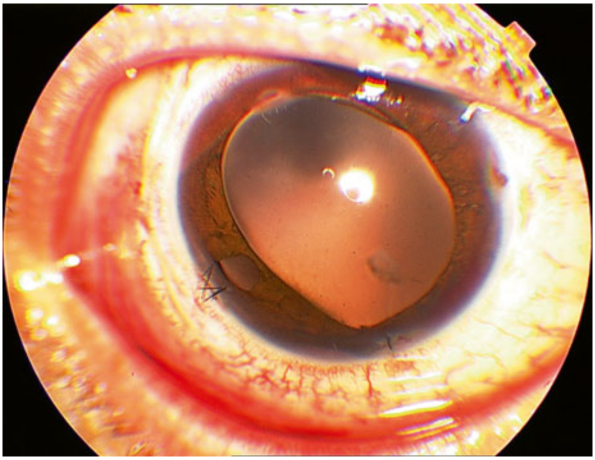

Fig. 35.4 Silicone oil being pushed anteriorly. Unless the eye had the same appearance at the end of surgery – a highly unlikely scenario – the surgeon who sees this image during follow-up should immediately suspect that the retina has detached and is now pushing the silicone oil into the AC. The (in this case not exactly) 6 o'clock iridectomy is patent. Were it closed, it would still not be the cause but the *consequence* of the oil prolapse: as the pupil is stretched wide open, the iris stroma can be compressed

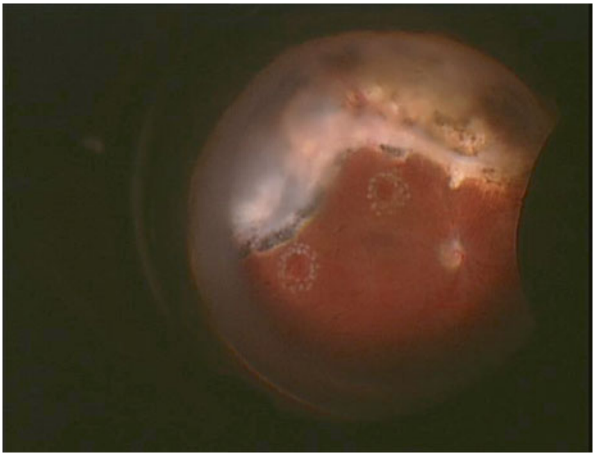

Fig. 35.5 Tractional retinal tears developing under silicone oil. The retina has remained reattached after the silicone oil has been removed. Two small, characteristically oval-shaped tractional tears have been found and surrounded by laser. The right-hand side of the image is blocked by the incoming air bubble

- If true proliferation occurs under normal oil, this will be inferiorly. The RD developing will progress slowly toward the posterior pole.
- Whether reoperation under silicone oil is necessary (see above) depends on many factors, mostly whether the macula is threatened. If reoperation is performed, remove the oil first, deal with the membranes, reattach the retina, and then reinject the silicone oil.

Q&A

Q *What are the benefits of removing the silicone oil first during a reoperation, rather than "operate under oil"?*

A First, the true anatomical situation is much more obvious to see, such as the location and strength of traction forces or retinal shortening. Second, TA and stains can be used to search for vitreous remnants and proliferative membranes. Third, if there is subretinal oil, its removal becomes possible. Fourth, if the oil must be reimplanted, its longevity is now increased (the "emulsification clock" starts anew).

35.4.5.2 Emulsification

It may occur a few weeks or several years after installation and has many undesirable consequences. The cause can be "natural aging" of the oil, poor quality (i.e., low purity), or a less than 100% fill (probably due to the oil being shaken during eye/head movements).

- Emulsified oil does not fulfill its intended function – that requires a large, single bubble.
- Visibility is reduced, both for the patient and ophthalmologist.

Pearl

Even if no emulsified oil is seen in the AC (see **Fig. 35.6**), bubbles may be present but hidden from view at the slit lamp. If the patient has decent vision, ask him whether his vision is worse when he is lying on his back and looks up at the ceiling – the oil bubbles collect in the visual axis in this position. For the same reason, a few previously undetected droplets always become evident as they gather behind the corneal apex when the patient is on the operating table.

- The IOP may rise to such levels that conservative treatment is not able to control it.[44]

The oil droplets can stick to any surface such as epiretinal membranes, the ciliary processes, or the back of the iris, but especially to vitreous that was left behind (see **Fig. 35.7**).

35.4.6 Removal

With a few exceptions regarding etiology[45] the patient must be told that there is a risk of retinal (re)detachment after oil removal.

[44] Since the oil removal is never complete (see below), the glaucoma may persist for many months.

[45] Such as macular hole or VH.

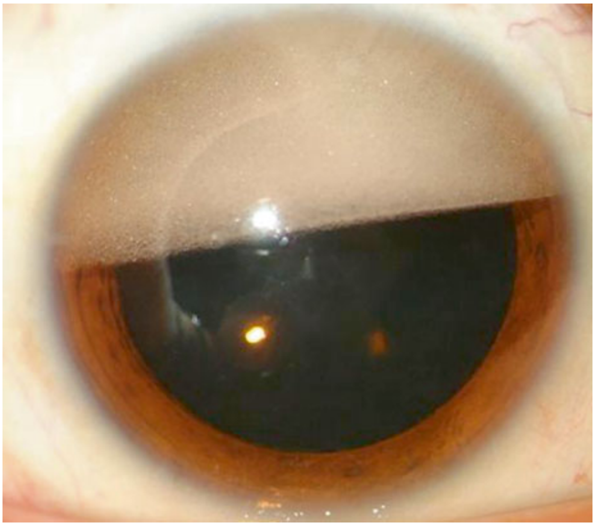

Fig. 35.6 Emulsified silicone oil in the AC. Some 40% of the AC is filled with emulsified silicone oil. Such a large amount is easy to recognize, but if only a small amount of bubbles is present, this may remain hidden at the slit lamp (see the text for more details)

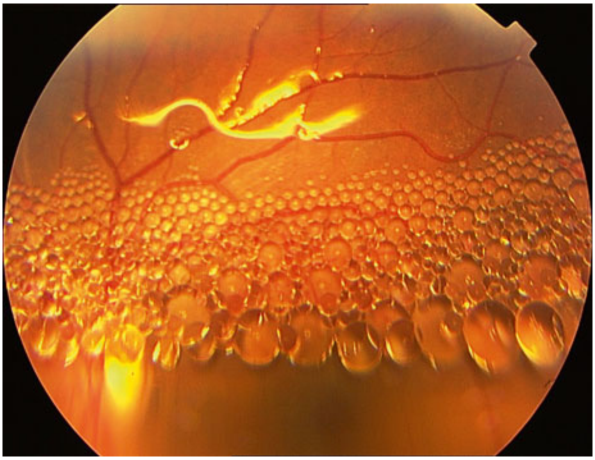

Fig. 35.7 Emulsified silicone oil stuck to the retinal surface. In this eye there are emulsified oil bubbles within the still-present large silicone oil bubble. Upon removal, the surgeon should at least try to remove the small bubbles that are adherent to the retina, but first he must check whether the previous surgeon performed an incomplete PVD. Vitreous remnants have a high affinity for "capturing" emulsified oil bubbles

Q&A

Q *Why is RD after silicone oil removal common with some surgeons but rare with others*?

A One of the possible answers is the completeness of the vitrectomy. Silicone oil is *not* supposed to be implanted in an eye with less than total PPV. Contraction of the residual vitreous or true reproliferation is common after the oil is no longer in the eye. The surgeon should never rely on silicone oil as a *substitute* for proper vitrectomy, but consider the oil as an *additional* weapon. If the surgeon says: "well, I will struggle removing the peripheral vitreous but, just in case, I'll use oil anyway," he may end up *not* doing a complete job. This happens subconsciously, akin to asking a person to meticulously clean the room. If he is told that another person will also be asked to clean the room *after* him, he is much less likely to do a meticulous job.

35.4.6.1 Timing

As a general rule, it depends on the etiology, the condition of the eye, and whether emulsification has occurred.[46] My personal guiding principles are the following:

- If the silicone oil is used in macular hole surgery, removal is at ~1 month.
- In eyes with RD as the original indication, the removal is at ~4 months if the PVR risk is average and at ~6 months if the PVR risk is high, such as in severe trauma (see **Sect. 63.12**).
- In eyes with recurrent VH as the original indication, the patient has to decide.

35.4.6.2 Surgical Technique

- If there is little or no oil in the AC, start the oil removal posteriorly (see below). If the posterior maneuvers cannot be visualized because so much emulsified oil is in the AC, clear the *AC* first.
  - Make a paracentesis larger than the diameter of the cannula you want to use.
  - Use BSS to flush the droplets out; unlike a large bubble, these droplets will readily exit the eye. There may be a constant resupply of droplets from the vitreous cavity and posterior chamber so that the irrigation may have to be repeated several times before the oil removal can be completed posteriorly.
  - Irrigate the AC one more time after the posterior oil has been extracted.

  Removal of the silicone oil from the *vitreous cavity* requires several steps:

Pearl

Place all 3 cannulas before connecting the infusion line to prevent the oil entering the silicone tubing as you insert the superior cannulas. Even with the improved IOP regulation of today's vitrectomy machines it takes some time to push the oil from the tubing back into the eye.

- BSS entering the eye through the infusion cannula will replace the oil.
  - Make sure that the position of the infusion cannula is such that the BSS is directed *behind* the oil bubble, not anterior to it.

[46] And on the individual surgeon's philosophy. I err on the side of keeping the oil longer.

- Use active aspiration to speed up the process.[47] Some companies supply a short metal cannula that is pushed *through* the cannula,[48] others a silicone tube that is placed *over* the cannula. In the latter case a non-valved cannula must be used.
  – A flute needle with active aspiration (or the probe) can also be used for oil removal. To avoid the clogging of the small-gauge probe by the silicone oil, occasionally operate the cutting function of the probe. Conversely, avoid cutting if the probe has to be pushed into the subretinal space.
- The removal of the oil is through the superotemporal sclerotomy.
- Regardless of the instrumentation or surgical technique, no oil removal will be truly complete as the bubbles adhere to all intraocular structures (see above and 25.2.5).
- Occasionally the oil bubble disconnects from the cannula during extraction. Try to aspirate the large bubble with the probe (see **Fig. 35.8**) or grab the cannula, rotate the eye so that this is uppermost point of the globe, and let the oil escape (see **Fig. 35.9**).

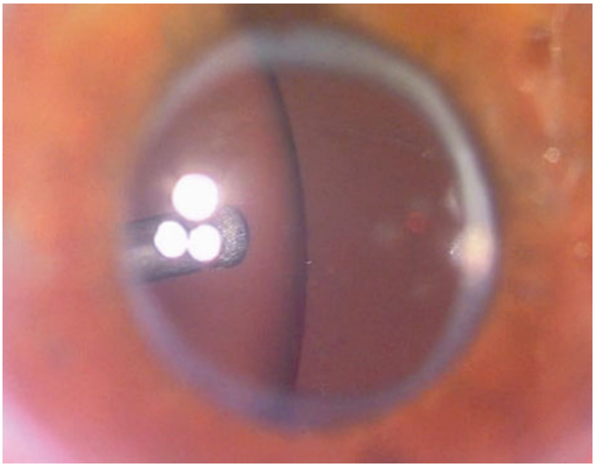

Fig. 35.8 Aspiration with the probe of a large residual silicone oil bubble. A large bubble of silicone oil has escaped during removal and is now free-floating in the vitreous cavity. One option to remove such a bubble is to aspirate it with the probe. As the bubble decreases in size, the eye must be rotated so that the tip of the probe is at the highest point of the vitreous cavity; otherwise, the oil can escape again. During aspiration it may be impossible to have visual feedback that the bubble is getting smaller; the surgeon may have to turn the probe sideways and close to the bubble's edge to be sure that the oil is flowing. The change in the shape of the bubble is a telling sign: a small funnel forms if there is oil drainage (another example showing the need to insert the tool from the *temporal* side if the manipulations are to be performed in the anterior part of the vitreous cavity.)

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[47] Passive removal is also an option. With a gaped *20 g* sclerotomy (the conjunctiva must obviously be opened first), the oil will readily exit the eye, but the surgical field will be messy. Copious irrigation of the ocular surface is needed to avoid trapping silicone oil subconjunctivally.

[48] This reduces the diameter of the channel through which the oil must flow.

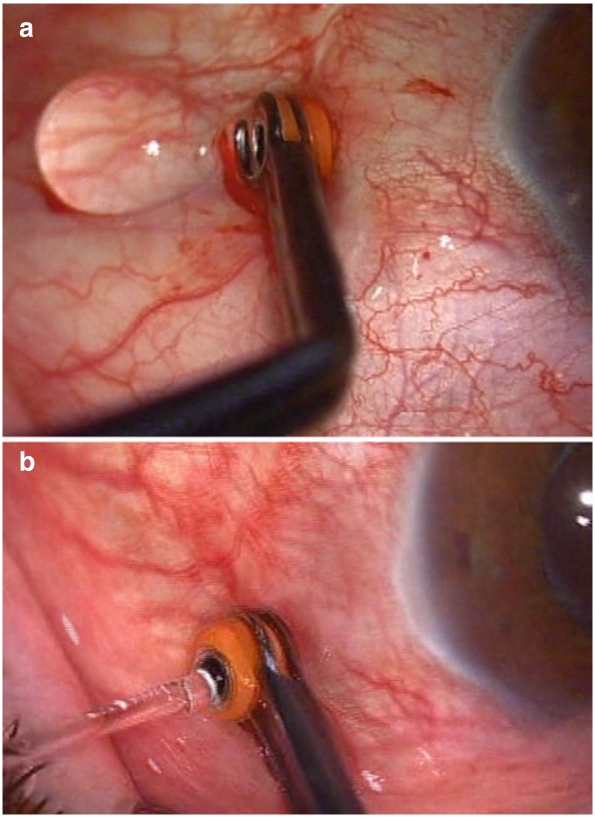

Fig. 35.9 **Passive silicone oil outflow through a non-valved cannula**. (**a**) The cannula is grabbed with a special forceps, and the eye is rotated so that the cannula's (invisible) tip is at the highest point of the vitreous cavity. If this is successful, silicone oil droplets are seen exiting through the (obviously non-valved) cannula. (**b**) Once all the silicone oil has drained, the image instantly changes: the BSS is more akin to a jet stream

- In MIVS a smaller oil bubble will also be trapped around each of the superior cannulas; these bubbles become visible only when you push instruments through the cannulas (see **Fig. 35.10**).
  - You can readily aspirate with the probe the bubble that is stuck to the light pipe. The oil bubble that is adherent to the probe must first be transferred to the light pipe and then removed. The maneuver is similar to how you sharpen a knife, just keep the safe distance from the retina.
  - Droplets that are stuck to the retina[49] are difficult to remove. You can try to passively aspirate them with the flute needle,[50] but do not expect to be able to do a complete job.

[49] Again, make sure that vitreous is not left on the retinal surface.

[50] Which will often need to be flushed.

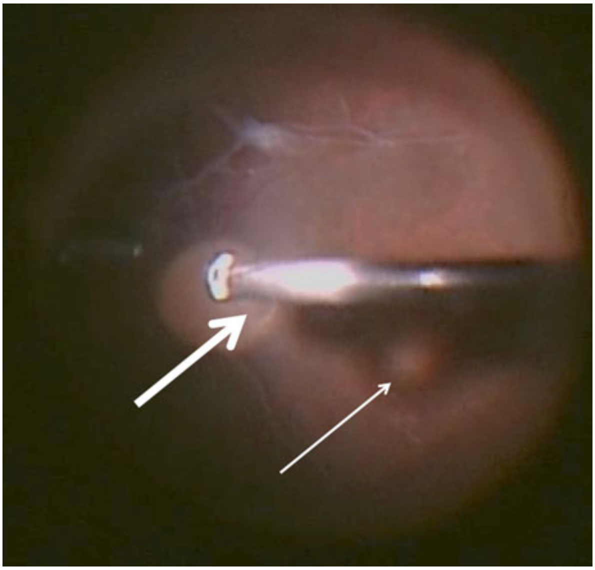

Fig. 35.10 Silicone oil droplet on the probe. The *thick arrow* points at the small oil droplet that is stuck to the probe; the *thin arrow* shows the shadow it casts on the retinal surface. The oil will be removed by first transferring it to the light pipe and then aspirated with the probe. This maneuver may have to be repeated several times in MIVS; in cannula-free 20 g surgery such an issue does not exist

Pearl

If heavy oil has been used, you will likely be forced to use the flute needle and collect droplets from the retinal surface. Because this oil is not viscous, it usually exits the eye without active aspiration (which would be potentially risky since the port faces the retina). However, the droplets may also be so adherent that their removal is extremely difficult.

– Subretinally trapped oil is best removed with active suction via the probe. As the bubble gets smaller, the remnant will eventually “break through” and then be aspirated from the vitreous cavity.

- Gently shake the eye and, if possible, the iris separately to release at least some of the oil bubbles that are stuck to it. Gently aspirate over the posterior capsule and the IOL surface as well.
- Once all of the visible oil bubbles have been removed, perform a F-A-X. Use the probe (not the flute needle)[51] to aspirate the fluid.
  – Keep the probe on top of the BSS surface and do not use full aspiration. You will see the oil floating on the surface of the water, just as in an industrial oil spill; skim the surface. Keep the port facing the center (i.e., visual axis) so that you can see the floating oil gushing into the port.
  – When the meniscus is very close to the disc, replace the probe with the flute needle and collect any remaining BSS/oil. You will see tiny oil droplets rushing toward the needle port. Since you basically have to touch the surface, make sure you adjust the BIOM front lens first.

[51] It speeds up the process and prevents blockage.

  - The F-A-X can be repeated but remember that even then the oil removal will never be 100%.
- The patient must be warned that small, circulating dark circles may be seen for months postoperatively; these represent tiny oil droplets, which cannot be removed (without another surgery, and even then only to a certain degree), but they are harmless.
- Despite your best efforts, oil droplets may be present under the conjunctiva. These can bother the patient enough to warrant removal (see **Fig. 35.2**).

35.5 Exchanges

Table 35.2 provides the rational and the technical details for most the commonly used exchanges, including the issue of the "fluid sandwich." Only those that concern eyes with RD are discussed below.

- Air will push the subretinal fluid posteriorly; PFCL will push the subretinal fluid anteriorly.
  - In principle, air is preferred if the break is central and PFCL if the break is in the periphery.
  - In practice, air can effectively be used in almost all cases (see **Table 35.3**) – but it may be a technical challenge for the beginner surgeon (see **Sect. 31.1.2**).
- If the RD is old, the fluid is likely to be very viscous.[52]
- In an eye with macula-on detachment there is substantial risk of any remaining subretinal fluid getting pushed under the macula postoperatively. "Steamrolling" is called for,[53] in which the gas bubble is brought over the macular area from *attached* retina.

35.6 If the Eye Is Aphakic

Even today, the VR surgeon occasionally encounters an eye with no lens or IOL; this has a few special implications when tamponades are used.

- *Air*: if it fills the AC, the BIOM front lens must be adjusted. If F-A-X is planned and then silicone oil implanted, make sure to aspirate the BSS that is often trapped in the angle.[54]
  - The presence of BSS is easily recognized because the air bubble does not completely fill the AC.[55]

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[52] Active aspiration in the subretinal space with the probe may be necessary, which increases the risk of catching the retina or injuring the choroid.

[53] This must be explained to the patient in great detail. The maneuver is detailed under **Sect. 54.6.3.1**.

[54] Also, remember to do an inferior iridectomy (see above, **Sect. 35.4.4**).

[55] That is, the diameter of the air bubble is much smaller than the diameter of the cornea.

- *PFCL*: intraoperatively it will not enter the AC, but if a bubble is inadvertently left behind, postoperatively the bubble will intermittently appear in the AC. It is always inferior if the patient is sitting. If the surgeon wants to remove this bubble, there are 2 options.
  - Seat the well-anesthetized patient at the slit lamp. A nurse should hold the patient's head against the bar to make sure he is not moving away. This is dangerous because the surgeon cannot adjust his progressively worsening image himself; therefore he will ask the patient to press against the bar – and since the blade or needle is already held in position to enter the eye, an inadvertent perforation may occur. The paracentesis should be inferotemporal and small.
  - If the procedure is not legally allowed to be done outside the OR and the eye is aphakic, constrict the pupil before the patient lies down on the operating table. Adjust the table so that the patient's forehead is higher than his chin (see the example on **Fig. 16.5b**, as opposed to on **a**). The removal is through a needle paracentesis on the temporal side, and the patient's head must be turned toward the temporal side so that the paracentesis is at the deepest point of the AC.

Table 35.2 Exchanges in the vitreous cavity*

Exchange			
From	To	Technique[a]	Comment
Fluid[b]	Air (F-A-X)	See **Sect. 31.1** for details	
Fluid	PFCL	The infusion is closed, the PFCL is injected with the flute needle[c] (see the text for injection technique and below for the "fluid sandwich")	Make sure the IOP does not rise – periodically drain the BSS through the same cannula/sclerotomy[d] In case of an RD, the filling should stop only when the PFCL is anterior to the anterior edge of the break (see also **Sect. 14.4**) If silicone oil is to be used, a 100% fill is recommended to avoid having a "fluid sandwich" in the eye
Fluid	Silicone oil	The fluid is drained with a flute needle, collected at the bottom of the eye	The meniscus is not easy to see, and it takes a very long time for all the fluid to accumulate at the bottom of the eye; switching to air first and then an air-silicone oil exchange is preferred (see below)
Fluid	Heavy silicone oil	The fluid is drained with a flute needle, progressively bringing it up from the bottom of the eye to anteriorly	Oil may remain stuck to the retinal surface centrally
Air	Gas	See **Sect. 35.2.2** for details	

(continued)

Table 35.2 (continued)

Exchange			
From	To	Technique[a]	Comment
Air	PFCL	The PFCL is injected with the flute needle	Cave: the PFCL will evaporate and condensate on the posterior capsule/IOL (see **Sect.** 31.2)[e]
Air	Silicone oil	See **Sect.** 35.4.4 for details	A dark "smoke" often forms in the anterior vitreous, severely interfering with visibility of the fundus – hence the need to perform all laser treatment under air, not under oil
PFCL	Silicone oil	As silicone oil is pumped in, remove the PFCL from the bottom of the eye with the flute needle	The meniscus is readily visible
PFCL-fluid ("fluid sandwich")	Silicone oil	As the silicone oil enters the eye, keep the flute needle in the BSS, just above the PFCL, and try to aspirate as much as you can, before dipping the tip of the flute needle into the PFCL bubble, which is then collected at the bottom of the eye. Once the PFCL has been removed, the procedure becomes a fluid-silicone oil exchange (see above)	As mentioned above, it is best to avoid this fluid sandwich because it makes the exchange slower and more complicated:[f] fill the vitreous cavity first with PFCL fully, and install the oil only afterward If you do have a fluid sandwich and a 360° retinectomy has been performed, special steps need to be taken (see **Table** 33.1)

[*]The retina is attached, unless otherwise indicated.
[a]The substitute enters the eye through the infusion cannula unless otherwise indicated.
[b]BSS.
[c]On a syringe; the injection is done by the surgeon, not the machine.
[d]A double-barrel needle or a non-valved cannula may also be used.
[e]In principle, "coating" the PFCL bubble with BSS may eliminate this problem; in practice, this is difficult to achieve.
[f]The benefit of the fluid sandwich is financial: a smaller amount of PFCL is needed.

- *Silicone oil*: see above **Sect.** 35.4.4.

Table 35.3 Internal drainage of subretinal fluid*

Step	Comment
Turn the eye so that the most central retinal break[a] is at the deepest possible point of the eye. Position your hand firmly so that the tip of the flute needle is securely held and is just above the break; keep the flute needle's chamber closed	Occasionally, the subretinal fluid will drain even without the need for air. In most eyes, however, it is the air that will push the subretinal fluid toward the flute needle
Turn on the air and lift your finger off the chamber opening only when the flute needle's tip is firmly in position	The drainage should commence. If the retina is very mobile, the flute needle may catch the retina. In such cases release the retina (backflush) and then carefully[b] push the tip into the subretinal space through the break[c]
Keep your flute needle in a steady position, even when the view is initially blocked[d]	The capillary effect[e] assures that the fluid will keep streaming even if the retinal break is not at the deepest point of the eye, as long as the fluid column remains uninterrupted[f] Once the fluid column is broken, the air collapses the edge of the retinal break onto the RPE, and the subretinal fluid is trapped centrally[g]
Complete the aspiration of the subretinal fluid before draining the intravitreal BSS that is still present in front of the disc	Otherwise it is easier for the incoming air to push the remaining subretinal fluid into the submacular space
Drain the BSS in front of the retina by holding the flute needle in front of the disc	If silicone oil is to be used, wait patiently[h] for the thin film of fluid that has been coating the retinal surface to accumulate at the disc[i] If gas tamponade is planned, it is not critical to drain every last droplet of BSS

*See also **Sect. 31.1.2**.

[a]The break should have been marked by diathermy to allow easy identification under air (see **Sect. 54.5.2.3**).

[b]To avoid touching the choroid and causing a hemorrhage.

[c]The alternative is using PFCL to keep the retina immobile, just remember the possibility and consequences of PFCL evaporation.

[d]The air forms fish eggs before the bubbles coalesce – this may take an uncomfortably long period.

[e]"The ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, gravity."

[f]Hence the need to not move the tip of the needle while draining.

[g]In such cases there are 3 options (see also **Sect. 31.1.2**). Redetach the retina and repeat the procedure (acceptable though not ideal); create and drain through a central retinotomy (don't); or, if the fluid is minimal, silicone oil use is not planned, and the fluid can be kept out of the submacular space (steamrolling, see **Sect. 54.6.3.1**), leave it behind and the RPE will remove it within days.

[h]It takes several minutes to complete this step.

[i]This is how a 100% fill can be achieved.

Submacular Hemorrhage

36

The blood, whether of AMD,[1] trauma, or other etiology, causes severe damage to the photoreceptors[2] and does it very early; the thicker[3] the blood, the more the damage. Several options are available, including *observation* – justified if the blood is long standing, the hemorrhage is thin and small, or the visual acuity had been very poor prior to the bleeding.

36.1 The Nonsurgical Approach: Intravitreal Gas and tPA

The goal is to push the liquefied blood from under the fovea.

- Inject up to 100 μg tPA into the vitreous cavity.
- Inject up to 0.3 ml of pure perfluoropropane (C_3F_8) gas into the vitreous cavity.
- Position the patient[4] for 3 days.

36.2 Removal of the Clot In Toto

Technically, the blood clot is not as difficult to remove as it may appear, nor does it require as large a retinotomy as the clot's dimensions would suggest. It is usually possible to remove the elastic clot in one piece and through a rather small retinotomy.

[1] Anti-VEGF therapy must also be employed, irrespective of how the bleeding is treated.

[2] Eventually the blood may turn into a scar.

[3] "Thick" is usually defined as over 500 μ.

[4] Facedown is the typical recommendation, but it makes more sense to ask the patient to be *erect* so that the blood settles inferiorly.

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- Complete the vitrectomy (especially, create a PVD).
- Use diathermy to create a small retinotomy at a convenient location.[5]
  - The retinotomy should be far away from the major vessels in the area.
  - The retinotomy should be placed right above the clot in MIVS.[6]
  - If the clot proves to be too large, the retinotomy will stretch somewhat.
- Use a small, blunt, angled,[7] cannula or a soft-tipped flute needle to inject a little BSS over, and if possible under, the clot to separate it from the neuroretina above and the RPE beneath.[8]
  - The injection should be very slow and at low pressure.
  - It is difficult for the surgeon to precisely control both the position of the cannula's tip and the attributes of the injection. It is best to use a tool (see below, **Sect. 36.4**) that allows the nurse to inject the fluid while the surgeon monitors the tip of the cannula.
- Grab the clot with forceps and slowly retrieve it. Pausing during retrieval may help the retina to slide backward, separating from the clot.
- Gently irrigate the subretinal space with BSS.
- Perform a F-A-X and exchange the air for gas (see **Fig. 35.1**).

The main problem with this approach is that large areas of the RPE may be inadvertently removed, making the prognosis unpredictable. The patient must understand in advance this risk and that its occurrence is not due to surgeon error (counseling; see **Chap. 5**).

Pearl
The patient must always be told in advance that the functional outcome after removal (or displacement) of submacular bleeding is questionable, but that in most cases it still may be the best hope for improvement.

A very large clot requires a large peripheral retinotomy for removal; this typically occurs in trauma (see **Fig. 36.1**), although occasionally AMD is the etiology.

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5 Typically, superotemporal to the macula.

6 May be at the edge of the clot in 20 g PPV if a subretinal forceps (see **Sect. 32.4.1**) is available.

7 A tip bent at ~30°. Not angling the cannula means the jet stream hits the RPE or the clot, rather than creating a cleavage above or underneath the clot. The soft-tipped cannula is obviously unable to produce such an angle, but having a cannula in the sclera in MIVS limits the surgeon's choices regarding instrumentation: the cannula must be smaller than the g used and the angled distal tip must be very short.

8 Sub-RPE clots should not be removed, only displaced; OCT helps distinguishing between the two.

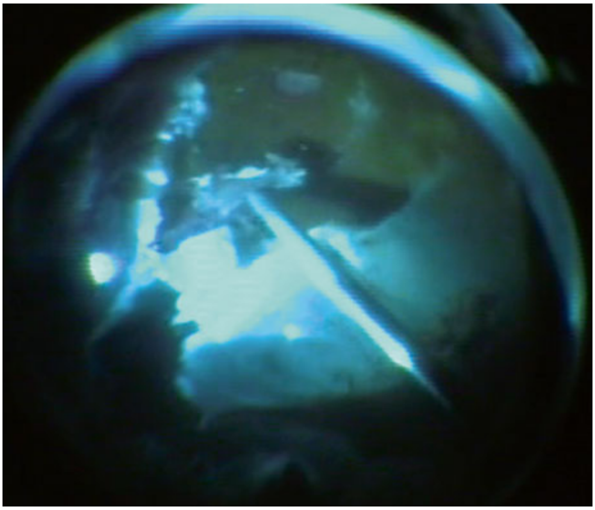

Fig. 36.1 **Removal of a large clot through a large peripheral retinotomy.** In this severely traumatized eye, the huge clot (the blood did not liquefy in 20 days) is removed after a 90° peripheral retinotomy was created. The retina is folded back, and the 20 g vitrectomy probe is used to aspirate the clot, lift it into the vitreous cavity, and then cut and remove it

36.3 Submacular Irrigation[9]

- Complete the vitrectomy (especially, create a PVD).
- Use diathermy to create a small retinotomy at a convenient location (see above).
- Use a bent cannula (see above) or a special flute needle (see **Fig. 36.2**) with injection capability, to gently inject BSS under the macula.
  - Use of the *cannula* means the blood is flushed into the vitreous cavity; you need to remove the cannula and evacuate the intravitreal blood, then repeat the process a few times.
  - Use of the *special flute needle* means that the nurse must inject the BSS to irrigate the subretinal space, which requires skills, attention, and dedication (see **Chap. 6**). The process will have to be repeated a few times.

If there is residual blood under the fovea, PFCL may be injected to try to push the blood out of the epicenter toward the retinotomy, similar to the technique employed during the removal of subretinal fluid in RD surgery (see **Sect. 31.1.2**).

[9] The same technique applies for subretinal fluid of other types.

Fig. 36.2 Simplified irrigation of the subretinal space. This flute needle is special because it allows attaching a syringe to it. When the surgeon's index finger blocks the silicone chamber's opening and the plunger is activated, fluid is injected through the flute needle, which has a soft tip. Not shown here: when the plunger is not pushed and the surgeon's finger is off the silicone chamber's opening, the device reverts back to a normal flute needle, draining the bloody fluid from the eye. The advantage of this method is that it does not require multiple instrument exchanges to achieve the evacuation of the material. (This idea originates with one of my nurses, Barbara Slupcznska-Sowka)

36.4 The Minimalistic Surgical Approach

- Complete the vitrectomy (especially, create a PVD).
- Using a 41 g microcannula, inject up to 50 µg tPA into the area of the clot.
  - One option is to wait up to an hour for the clot to liquefy, then irrigate the blood (see above), followed by a F-A-X and exchange of the air for gas. Prone positioning is usually recommended.
  - Another option is to forego the irrigation, and after the tPA injection, immediately perform a F-A-X and then exchange the air for gas.

Subretinal Biopsy

37

The most common condition in which transvitreal biopsy[1] is performed is a subretinal mass in the posterior pole; the surgeon is not sure from the appearance of the lesion whether he is faced with a tumor or, for example, an old hemorrhage.

- Complete the vitrectomy (especially, create a PVD).
- Carefully choose the retinotomy site, which should be over the lesion, as far from the major vessels as possible.
- Consider performing a light diathermy.[2]

Pearl
The mass may be a vascular tumor; having the endodiathermy probe available in case of a subretinal bleeding following the taking of the sample is advisable.

- Remove a small piece of the mass with forceps[3] or via aspiration into a 23 g flute needle.[4]
  - In general, the use of the probe is less favorable as the material may get damaged. If the probe needs to be employed, the aspiration should be done by a nurse using a syringe attached to the tubing of the probe. This avoids diluting the material.
- Typically, it is not necessary to perform a F-A-X. The retinotomy need not be lasered.[5]

[1] Only biopsy done *intraoperatively* is discussed here.
[2] Without diathermy, there is always a chance, however small, for bleeding.
[3] Harder mass may require the use of scissors.
[4] The yield is a much larger sample than with the nonsurgical "fine-needle aspiration" technique.
[5] Because of the mass underneath, such laser would be ineffective anyway.

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The sample should be sent to the pathologist according to the lab's requirements. The requirements must be known to the surgeon and the nurse prior to commencing with the procedure.

If a *vitreous* biopsy is needed, this does not require a full vitrectomy setup (see **Sect. 17.4**). Use of a small-gauge probe is preferred to using a needle to avoid traction if gel vitreous is encountered. There is no need to place an infusion.

Combined Surgery

38

There are advantages and disadvantages to combining cataract removal (and typically IOL implantation) with the vitrectomy (see **Table** 4.2). This chapter is primarily dedicated to the technical issues of combined surgery. The decision-making process regarding the type of lens removal technique is shown in **Fig.** 38.1.

The question whether a *clear* lens needs to be removed in the eye that has no (or only weak) accommodation has no straightforward answer. The surgeon must not hesitate to remove the lens if its presence would interfere with the success of the vitrectomy; otherwise, he should discuss it with the patient (see **Chap.** 5), although other issues are also at play (see **Sect.** 4.6).

Pearl
The condition of the retina and the ciliary body determines the operation's success, not whether the lens was preserved.

38.1 Phacoemulsification

The operation is done similar to how it is normally performed; only a few unique suggestions are made here. The cataract surgery precedes the vitrectomy unless special circumstances exist.

- Place the cannula for the infusion first[1]; whether the two additional cannulas are also inserted now or later is up to you. The infusion line need not be connected until the PPV commences.

[1] The eye becomes soft by the time the procedure is completed, making the cannula insertion difficult.

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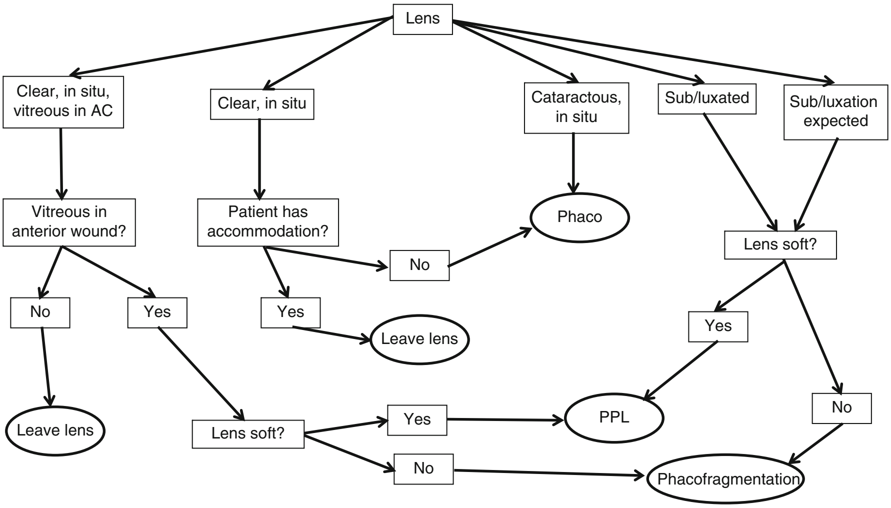

Fig. 38.1 Decision-making tree about the lens in the eyes undergoing VR surgery. See the text for more details

- Do not make the capsulorhexis larger than ~5 mm.
- Occasionally[2] it is best to keep the visco in the AC until the PPV has been completed.
- Always perform a posterior capsulectomy after the IOL has been implanted.

38.2 Lensectomy

If the surgeon knows that the lens capsules must also be removed (see below), the pars plana lensectomy approach offers familiarity in technique and access.[3] PPL is very effective as long as the lens material is soft[4]; otherwise, the probe will be able to remove the cortex but little of the nucleus.

[2] Such as shallow AC, floppy iris, constricting pupil, VH seeping anteriorly, silicone oil prolapsing.

[3] Use of the probe and entering the eye through the cannula, respectively.

[4] The cut-off age is ~55–60 years, but a lot of other factors (such as the intraocular pathologies and the type of equipment) also play a role.

38.2.1 Lens In Situ

- Always use the superotemporal sclerotomy for access.

Q&A

Q *Why not use the superonasal sclerotomy for lens in situ PPL or phacofragmentation*?

A The probe must be held horizontally, which is impossible if the nose is in the way. The surgeon should use a finger of his other hand to securely keep the probe in position (see **Fig. 2.1**).

- Insert a 23 g needle and slice the capsule open at the equator. The goal is to provide a resistance-free entrance into the lens for the blunt probe.[5]
- Push the probe into the lens. Turn the port sideways to avoid biting into either capsules.
- A soft lens requires aspiration only; the cutting function needs to be activated only if the lens nucleus is hard or the material obstructs the outflow.[6]
- It is very difficult to avoid injuring the posterior capsule. Small lens particles are likely to fall posteriorly, but they can easily be removed during the subsequent vitrectomy.

Pearl

The posterior capsule is virtually impossible to preserve during PPL. The infusion is not directly inflating the capsular bag, which therefore starts to collapse during lens removal and progressively moves closer and closer to the probe's tip. This, unlike the distance between the anterior capsule and the port, cannot be monitored.

- Aspirate the cortical material as if during standard phaco surgery.
- Decide whether the anterior capsule[7] needs to be retained (see below, **Sect. 38.6**). If yes, it must be thoroughly polished.

[5] The probe would otherwise tend to push the lens away, putting undue stress on the zonules.

[6] This will occur much more often than during phaco since the internal lumen of the probe is much smaller.

[7] And the remnant of the posterior capsule.

38.2.2 Lens in the Vitreous[8]

- Complete the vitrectomy first, including the creation of a PVD.
- Change the settings on the machine: lower the cut rate to 100–300 cps and increase the aspiration/flow as needed.[9]
  – If the cut rate is high and the lens material is hard, occlusion of the port becomes impossible and the lens fragment will keep being pushed away.
- Soft material[10] is easy to remove.
- If the nucleus is hard,[11] utilizing the light pipe as a "crusher" may obviate the need for ultrasound.
  – Using aspiration only and with the port turned toward the retina, lift the piece into the midvitreous cavity, at a safe distance from the retina.
  – Do not take your foot off the pedal; continue aspirating so that the piece does not fall back.
  – Turn the probe 180° so that it is now underneath the lens particle.
  – Use the light pipe to "force-feed" the lens material into the port (see **Fig. 38.2**). The particles may time-to-time clog the probe, requiring the nurse to flush it.
  – Repeat the entire sequence until all pieces are removed.
  – Alternatively, after you brought the hard piece into the midvitreous cavity, hold it there so that you can view it with the BIOM switched out, and exchange the light pipe for a forceps. Grab the piece so that its smallest dimension can be turned toward the probe, and feed it into the port.
- After all visible lens particles are gone, irrigate the vitreous cavity to bring into view and remove any previously hidden or miniscule, circulating pieces; these would increase the postoperative inflammation.

38.3 Phacofragmentation[12]

The indications to use a pars plana approach to remove the lens are similar to those listed under PPL (see above), as is the rule to utilize the temporal sclerotomy for lens removal.

Adjust the pedal function to operating the machine in phacofragmentation mode.[13]

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[8] Luxation in toto or lens particles lost during in situ PPL. Lens subluxation is discussed in **Sect. 63.6**.

[9] This is why the vitreous must be removed first; otherwise, VR traction is unavoidable.

[10] Cortex; nucleus in young people.

[11] Ultrasound may be required (see below, **Sect. 38.3**).

[12] Ultrasound is necessary when a nucleus is too hard for the probe, and even crushing does not work.

[13] My setup is similar to that used in vitreous removal: the initial pressing down with the pedal results in aspiration/flow; further pressing will activate the ultrasound (turning of the foot not required, see **Sect. 16.3**).

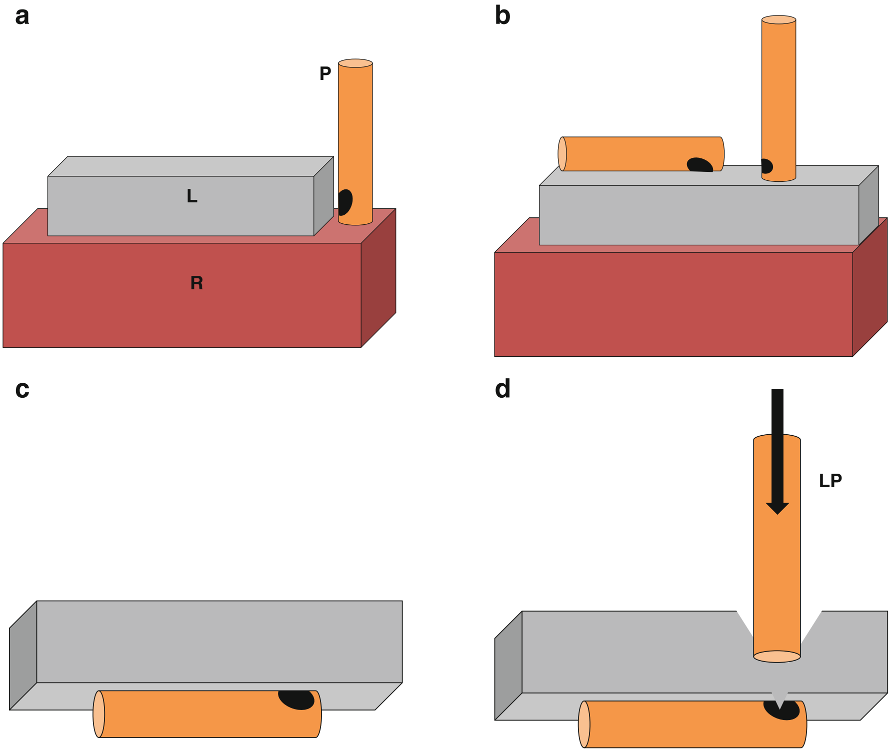

Fig. 38.2 **Schematic representation of removing hard lens particles from the vitreous cavity**. (**a**) The probe (*P*) is able to bite into the lens particle (*L*) only if it can attack it from the smallest dimension of the particle; however, this may be dangerous because the tip of the probe can be pushed into the retina (*R*). (**b**) It is easy to engage the particle from above (*left hand side*), but this does not allow any bite into the particle since the material is hard and the surface area too large. In addition, the high aspiration rate makes cutting in this position risky. On the *right hand side*, the cutter is unable to engage the tissue, whether it is the lens or a sheet of vitreous over the retina, because there is no edge. (**c**) Picking up the particle and bringing it away from the retina increase safety. The probe is rotated so that the port now faces the surgeon; the lens particle is not lost because the (high) aspiration/flow is maintained. However, the probe still cannot bite into the particle because it is hard and the area of contact is too large. (**d**) The light pipe (*LP*) is able to push the particle into the port. The particle is either gradually eaten (at a low cpm rate) or, more commonly, broken into smaller pieces. The pieces must have at least one side that is small enough to be fed into the port

38.3.1 Lens In Situ

- Place the cannula for the infusion and for the temporal working sclerotomy[14] first; whether the superonasal cannula is also inserted now or later is up to you.
- Do a judicious anterior vitrectomy.[15]

[14] If you are using a machine (such as the EVA by DORC, Zuidland, the Netherlands) that allows 23 g phacofragmentation; if only a 20 g phacofragmentor can be used, it is best to use a separate incision for it and then suture this sclerotomy before the vitrectomy is completed.

[15] It may be impossible to preoperatively recognize that the posterior capsule is broken; it is very difficult to recognize intraoperatively that vitreous has prolapsed into the lens. The risk is aspirating anterior vitreous and exerting traction on the retinal periphery (see **Sect. 63.6**).

- Insert the phacofragmentor and remove the lens material.
  - Use the "nibbling" technique, advancing the probe in small and gradual steps, *not* by making long tunnels in the lens. This technique increases the chance that the port is always occluded.
  - Try to avoid losing large nucleus pieces into the vitreous; if this occurs, follow the steps described below (**Sect. 38.4**).
  - Any lost cortical material will be removed during PPV.
- After the nucleus has been removed, the residual cortex can be extracted with the probe.
- Make a decision about the capsules (see **Sects. 38.2.1** and **38.6**).

38.3.2 Lens in Vitreous

- Complete the vitrectomy first, including the creation of a PVD.
  - Use TA to ensure that no vitreous is left on the posterior retina.
  - Remove all or at least most of the vitreous in the periphery (sub/total PPV).
- Adjust the machine settings.
  - Do not use phaco power exceeding 20%.
  - Temporarily increase the infusion pressure: if the phaco probe's tip is in BSS (i.e., not occluded by lens material), the eye may collapse.
- Insert the phacofragmentor. Using aspiration only, pick up the lens particles from the retinal surface, bring them in the midvitreous cavity, and only then activate the ultrasonic energy. Use the minimal amount of ultrasound.
  - The technique is very similar to that described above (**Sect. 38.2.2**), except that with ultrasonographic power, it is possible to break even hard lens particles into small pieces; however, crushing helps in minimizing the total amount of ultrasonic energy needed.
- Once all lens material is out, inspect the retinal periphery with indentation and (at least consider to) perform endolaser cerclage to reduce the risk of the postoperative RD.

38.4 IOL Implantation: Whether and When[16]

38.4.1 In-the-Bag IOL Implantation at the Conclusion of the Cataract Removal

This is the "default action," performed in all routine phaco cases.

[16] None of these is an absolute rule.

38.4.2 No IOL Implantation

- A (highly myopic) globe that is roughly emmetropic without implantation.[17]
- An eye that has lost the potential for both central *and* peripheral vision.
- It is impossible to predict whether the implanted silicone oil can be removed.[18]

38.4.3 Delayed IOL Implantation[19]

- The surgeon is uncertain preoperatively whether the anatomical situation in the posterior segment will justify the implantation.
- Extensive manipulations are necessary in the periphery.
  - No visual interference from the parallaxis around the IOL edge.
  - The IOL may get subluxated.

38.4.4 Secondary IOL Implantation[20]

- The surgeon is not certain that visual improvement can be expected even if the best anatomical outcome will have been achieved.
- It was impossible to preoperatively predict the power of the IOL.
- There is a very high risk of postoperative PVR development.

38.5 Capsule Removal

In some cases, it is best to remove the lens capsules.[21]

Q&A

Q *Is the removal of the lens capsules not a controversial issue*?

A For some ophthalmologists it is. My experience, however, is that it is extremely beneficial in many cases, even if the indication is rarely absolute. The option to implant an iris-claw IOL further lowered the bar in choosing capsule removal.

---

[17] The old adage that “the eye needs to be compartmentalized” is not true anymore.

[18] Once the question is definitely answered, an IOL may be implanted secondarily.

[19] Defined here as an IOL that is placed after the PPV has been completed, but in the same surgical session.

[20] Defined here as an IOL that is implanted in a separate procedure in the future.

[21] Remember, the default goal is *not* the implantation of an IOL in the bag. Instead, the aim is to restore the rest of the globe anatomy to the fullest possible. Long-term thinking is needed, which is why the capsules may have to be sacrificed or the IOL implantation foregone.

38.5.1 Indications

- A lens that is subluxated, whether spontaneously or due to trauma.
- Systemic conditions in which (sub)luxation is expected.[22]
- Weak zonules that may not hold the bag/IOL securely.
- Not enough posterior capsule is left to securely hold the IOL.
- Severe postoperative inflammation is expected with consequent synechiae development.
- High risk of postoperative PVR development.

38.5.2 Surgical Technique

- Complete the lens removal.
- Whichever capsule is present, make a central capsulectomy with the probe.
- Take a crocodile forceps,[23] grab the capsule, and do one of the following.
  – In young patients,[24] insert the probe through the other working sclerotomy, and pull the capsule with the forceps in one direction; rather than tear the zonules, use the probe to sever them. Repeat the process on the opposite side of the eye after switching instruments (see **Fig. 38.3**).
  – In older patients simply pull the capsule, and use your other hand to "spaghetti" the capsule so that the tension on the zonules is distributed over a larger area, delaying the moment when the capsule tears. Repeated grabbings, probably from both sclerotomies, are probably necessary.
- To be on the safe side, inspect the periphery with scleral indentation, and (at least consider to) perform endolaser cerclage.

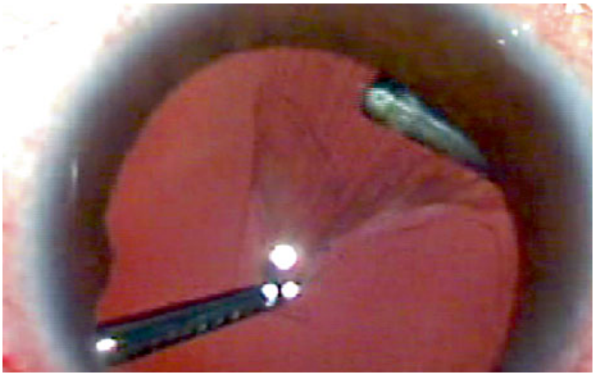

Fig. 38.3 Capsule removal in a young patient. Simply pulling on the zonules does result in their separation from the ciliary processes, but the risk of the traction force getting transmitted to the anterior retina is high. Use of the probe to cut, rather than manually tear, the zonules is an option that eliminates the risk

[22] Marfan syndrome, pseudoexfoliation, homocystinuria etc.

[23] So that you can grab as large a piece of the capsule as possible.

[24] Up to ~30 years; extra caution is in order, due to the strength of the zonules. The risk is that the ciliary processes may be damaged as the pull force is transmitted to them.

38.6 Implantation of an Iris-Claw IOL[25]

38.6.1 Advantages

Scleral-fixated or AC IOLs used to be the only options for eyes without (adequate) capsular support.

- The sutures used for the fixation of an IOL to the sclera are prone to break with time. Burying the IOL haptics in the sclera can be technically difficult if special forceps are unavailable.
- AC IOLs cannot be implanted in certain conditions, and endothelial cell loss threatens with time.

The iris-claw IOL has several advantages:

- It can (should) be placed behind the iris (see **Fig. 38.4**).[26]
- It can be used even if the iris has been damaged and had to be sutured.
- The lens is held securely by the iris; in case of a dislocation, repositioning is straightforward (see below).
- The pupil can readily be dilated.
- The implantation is fast and technically easy, and so is the refixing of the IOL (see below).

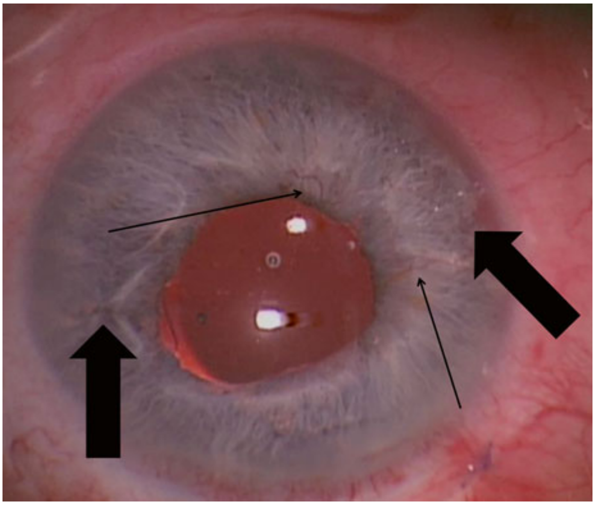

Fig. 38.4 **Iris-claw IOL implanted into the posterior chamber**. The capture of the iris is shown by the two *thick arrows*. The iris has dilated vessels (*thin arrows*), but no hemorrhage occurred during transplantation or postoperatively

[25] Artisan (Ophtec BV, Groningen, the Netherlands); also called iris-clip lens.

[26] Using an A constant of 116,5, not 115,4 (Holladay 2 or SRK/T formula).

38.6.2 Surgical Technique

- Remove the lens capsules.
- Consider creating a small iridectomy with the probe.[27]
- Prepare a small, *temporal* paracentesis so that a long and thin spatula can later be inserted.
- Open the conjunctiva and prepare the scleral incision.
  - Length: 6 mm for the regular and 3 mm for the foldable version.
  - Location: scleral tunnel or limbal. Use diathermy around the incision site to prevent blood seeping into the AC.
- Inject viscoelastic in the AC to protect the endothelium.
- Flip the lens so that its convex surface faces the vitreous cavity (see **Fig. 38.5**); insert it into the AC, rotate the lens 90°, and then use forceps to slide it behind the iris.
- Insert the spatula. Ensure that the IOL optic maintains its desired position,[28] tilt the *distal* (nasal) haptics upward, and simultaneously push the iris in-between the haptics; the iris-captures are at the ~3 and 9 o'clock positions.
  - Gently pull on the lens to make sure that it is securely in place; confirm that the optic is still at its desired position.
  - Pull the spatula out halfway so that you can repeat the procedure on the *temporal* side.
  - Again check that the IOL is firmly attached to the iris at both locations.
- Suture the limbal (scleral) wound.
- Irrigate the vitreous cavity in case a small hemorrhage has occurred.[29]

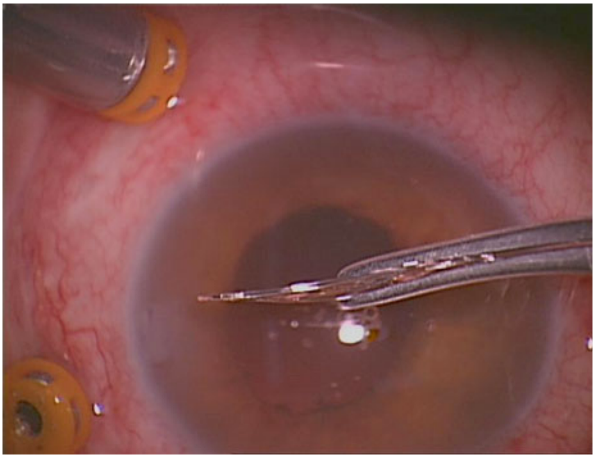

Fig. 38.5 **The "anatomy" of the iris-claw IOL**. The image shows the lens from the side; the convex surface should face the vitreous cavity if the IOL is implanted behind the iris

[27] Not all surgeons do this; pupillary-block glaucoma is indeed rare. The iridectomy is, however, highly recommended if the flat surface of the lens is against the iris.

[28] The IOL is well centered; it is rather easy to inadvertently move the lens in the horizontal plane as the claws are to be fixed to the iris.

[29] It is not uncommon that the VH occurs postoperatively, but it is almost always small and requires no intervention.

38.6.3 Subsequent Sub/luxation of an Iris-Claw IOL

One of the benefits of this lens is that it is very easy to refix it. The lens must be exchanged only if the claws have been damaged (twisted or badly misaligned) by the trauma that dislodged the IOL.

38.6.3.1 Subluxated Lens

- Create a temporal paracentesis for the spatula. A superior clear-corneal incision is also needed for the forceps.
- Use the spatula to lift the IOL back behind the iris from its vertical position.
- Grab the optic with the forceps and reattach the claws to the iris.

38.6.3.2 Luxated Lens

- Create three sclerotomies and insert the infusion.
- Create the paracentesis and the clear-corneal incision as described above.
- Grab the IOL with a vitrectomy forceps; this forceps should be inserted through the temporal cannula. Bring the IOL in the midvitreous cavity.
- Switch out the BIOM, and use the lens forceps to bring the IOL into the AC; make sure that it is the flat surface that is facing the iris. This maneuver is greatly facilitated if you remove the first forceps and insert the spatula through the temporal paracentesis.
- Inject visco on top of IOL; from here on the procedure is identical to that described above (**Sect. 38.6.2**).

AC Basics

39

39.1 Paracentesis

An often-utilized procedure, paracentesis is not complicated or difficult, but keeping a few fundamental rules in mind makes the surgeon's job easier and more effective.

- Choose the location carefully.
  - For intracameral manipulations, an entry point in the superotemporal quadrant is the most convenient. The infusion (AC maintainer) is best placed at an inferotemporal location (see below).
- Use a sharp blade to create the incision.[1]
  - The MVR blade is preferred to the "15° blade"; the size of the incision is precisely known with the former. With the latter it depends on how deep it is pushed into the AC (see **Fig. 39.1**).

[1] Not a needle, with the exception of using the paracentesis for an iris retractor or the removal of a PFCL droplet from the AC (see **Sect. 35.6**).

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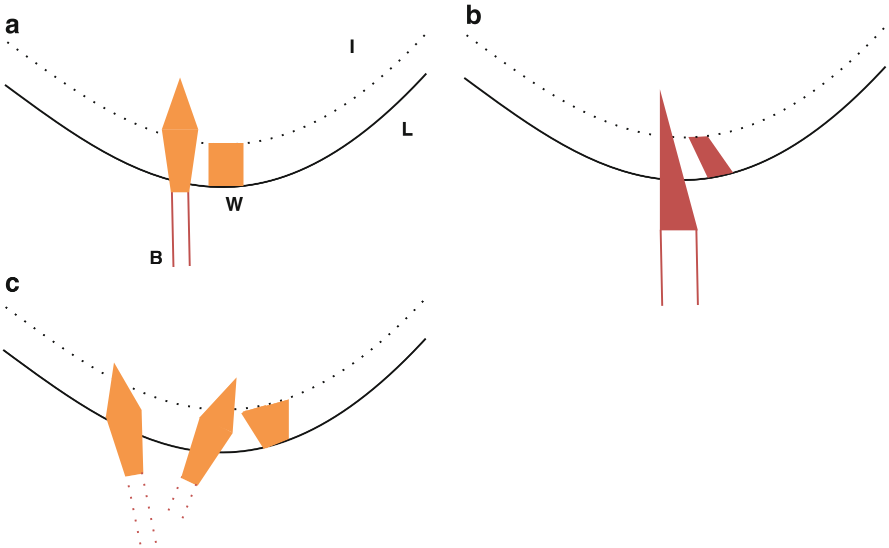

Fig. 39.1 **The effect of the blade's shape on the creation of a paracentesis**. (**a**) The MVR blade with its known dimensions is used to create the paracentesis. The internal opening of the tunnel has the same width as the external one, matching the largest diameter of the blade. (**b**) Using the 15° blade, the external opening of the tunnel is wider than the internal one (this is never needed in clinical practice; the opposite, however, rather often is), and neither is precisely known – it depends on how deep the surgeon penetrates into the AC with the blade. (**c**) If manipulations that take place far from the site and on both sides of the paracentesis, the surgeon can turn the MVR blade in the frontal plane in both directions, and widen the *internal* opening of the tunnel. This way the manipulations are easily performed without distorting the cornea, without the need to widen the external tunnel opening. *I* an imaginary line extended as if it were circle, along the path of the internal course of the tunnel ending; *L* limbus, the entry point for the tunnel; *W* the wound created by the blade (**b**)

Pearl

Do not grab the conjunctiva with forceps as you try to fix the eye to make the paracentesis. The conjunctiva is mobile; the grab will not result in a secure fixation; the tissue can also tear or bleed. Support the nasal side of the eye with your index finger (see **Fig.** 39.2), or use a pressure plate or corneal fixation ring.

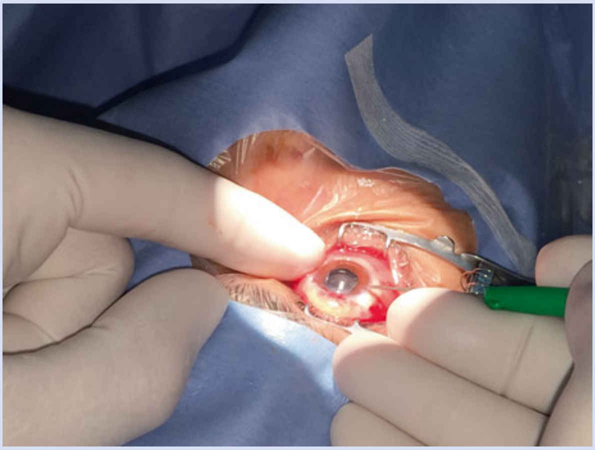

Fig. 39.2 **Use of the surgeon's finger as a surgical tool**. The globe can be secured against movement by the surgeon's finger during the creation of a paracentesis. The wound is made on the temporal side with an MVR blade held rather flat; the tool itself is supported by the surgeon's thumb, index and middle fingers. The ring and little fingers are pressed against the middle finger but also rest on the patient's forehead. The surgeon's other index finger secures the globe's position; the rest of his fingers of this hand are also pressed against the patient's forehead to prevent even the slightest movement of eye or tool

- The angle of blade entry[2] should be such that the wound will be self-sealing (this favors an almost frontal plane) yet allowing the surgeon to maneuver around in the AC with various instruments without distorting the cornea (this favors a more downward-pointing angle).
- If you plan to use a round tool,[3] take into consideration the cross-sectional area of the tool and make the paracentesis slightly wider than the diameter of the tool.
- The paracentesis for the AC maintainer should be prepared in the inferotemporal quadrant.
  - This site is chosen because the cannula should not be in the visual axis.
  - The direction of the intracorneal channel should be so that the cannula will be located over the iris; it should not be too close to the angle where the AC is shallow.
  - The cannula is ideally a threaded one, to prevent dislodging during rotation of the eyeball.

[2] Measured relative to the plane of the iris. The surgeon should remember the parallaxis phenomenon (see **Sect. 25.2.2.3**).

[3] Such as a cannula.

– The infusion line should be fixed to the drape the same way as if it were used through the pars plana. It is crucial to leave enough, but not too much, slack to eliminate the risk during eye movements of the cannula's tip hitting the lens or the endothelium.
– For the same reason, it is not advisable to use a sharp ("butterfly") needle instead of the cannula.

39.2 Iris Prolapse

In the vast majority of the cases the iris should be reposited, not excised. Its surface must first be cleaned mechanically,[4] to remove any potentially infectious material and all debris and stem cells[5].

- Except when the wound and the prolapse are very small, do not try to push the iris back.
  – In the rare cases when you do push the iris back, use a blunt instrument such as a spatula.
  – It is a futile effort to attempt to use visco injection to push the iris back.

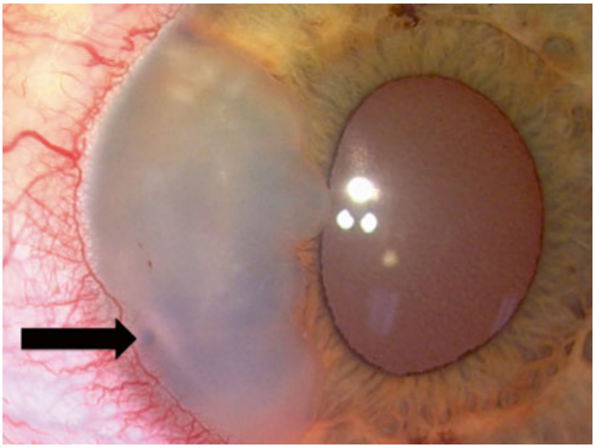

Fig. 39.3 Epithelial cyst in the AC. This patient presented with a "cosmetic" problem that greatly bothered him. The cyst was easily removed en block, using forceps. The *arrow* points to a small wooden IOFB that, the patient later recalled, he had suffered over 20 years earlier. There was no corneal entry site: the object penetrated through the limbus, transplanting viable stem cells inside the eye

[4] With Wechsel sponge and a jet stream from a syringe containing antibiotics.

[5] To prevent epithelial-cyst formation (see **Fig. 39.3**).

- To pull the iris back into the AC, create a separate paracentesis at a convenient location.[6]
  - Insert a long, blunt spatula and carefully pull the iris back into the AC.
  - With this technique you will not only reposition the iris in the least traumatic way but also prevent reopening of the wound; this assures maintaining the depth of the AC and eliminating the need for visco[7] (even if some aqueous has been lost, it will be rapidly replenished).

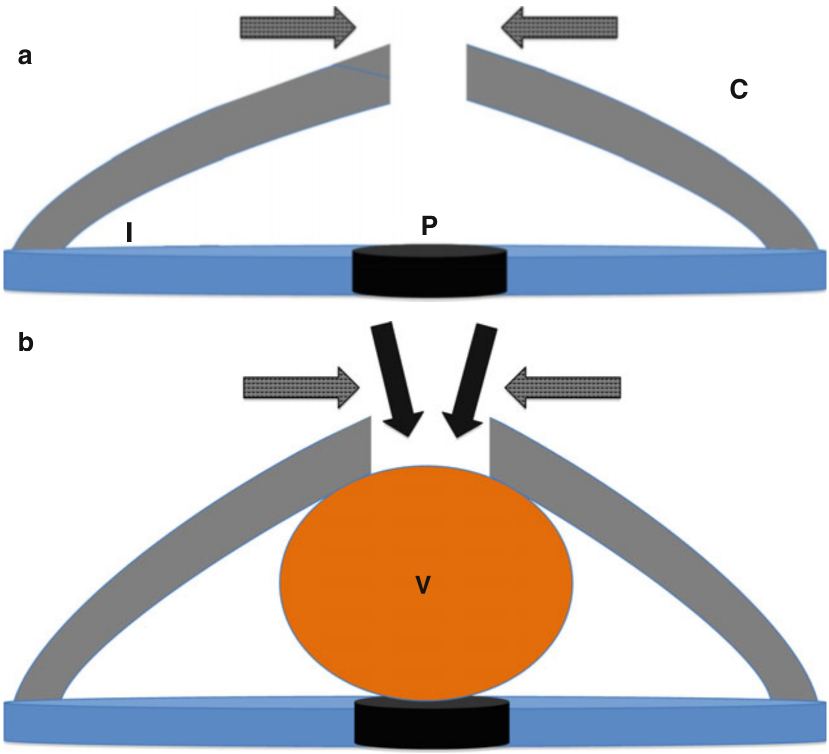

Fig. 39.4 Schematic representation showing the disadvantage of visco use in corneal wound suturing. (**a**) Almost all wounds close spontaneously, and the AC recovers at least some depth. Without visco use, the contour of the cornea is close to normal. Only minimal tension on the sutures is required to achieve sufficient compression, and this effect is mainly in the frontal plane (*gray arrows*; the wound, which always closes spontaneously, is shown here as wide open for demonstration purposes.). (**b**) With a large amount of visco injected (which is an often-seen error in clinical practice), the cornea bulges, and extra tension is needed on the sutures (overtightening) to achieve sufficient compression. The sutures must not only bring the wound edges together in the frontal plane but also work against the effect of the visco in the sagittal plane, resulting in permanent corneal distortion with consequent astigmia. *C* cornea, *I* iris, *P* pupil, *V* visco

[6] 90°–180° away from the site of the prolapse. Being too close reduces maneuverability.

[7] Visco use should be avoided so that the corneal contour is not distorted (see **Fig. 39.4**).

39.3 Anterior Synechia

Not all synechiae need to, or should, be released.

- If an *acute* synechia is encountered, use a *blunt* spatula (do not use visco – reduced control is the price you pay for the technical ease) to separate the iris from the cornea, and inject an air bubble to prevent readhesion. Such an air bubble is also effective if you want to prevent iris prolapse into a wound.
- If the iridocorneal adhesion is *chronic but small*, it is best to leave it alone to prevent bleeding or tissue damage such as tearing the iris root or Descemet's membrane.
- If the iridocorneal adhesion is *chronic and large*, consider the risk-benefit ratio. If there is a strong argument[8] in favor of releasing the iris, do not try blunt separation (see **Sect. 13.2**) but cut the iris (endodiathermy is recommended if vascularization is present or suspected). Some type of deep lamellar keratoplasty may become necessary, but this is outside the competence of the VR surgeon.
- If a true scar tissue is present, it should be left alone.

39.4 Posterior Synechia[9]

The most common reason to release an iridocapsular or irido-IOL adhesion is to allow pupillary dilation (see **Sect. 25.2.2.1**), occasionally to treat iris bombans.

Pearl
The same general rule applies to posterior as to anterior synechiae: use blunt tools in fresh cases (when the cohesion within the tissues is greater than the adhesion between them) and sharp dissection in chronic cases (when the adhesion is stronger than the cohesion). Visco use is always questionable; its use is typically contraindicated behind the iris (see below).

Should the lens capsule need to be preserved in a phakic eye, miniscule amounts of visco can be injected between the iris and the lens capsule on either side of the adhesion. This creates enough space for the blade of a VR scissors to be inserted to severe the adhesion. If the iris itself has to be cut, every effort should be made to restore the diaphragm, both for anatomical and functional purposes (see **Chap. 48**).

39.5 Material in the AC

Vitreous prolapse is discussed in **Sects. 27.5.3** and **63.6**, blood in **Chap. 47**, purulent material in **Chap. 45**, and IOFB in **Sect. 63.7.1**.

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[8] Such as photophobia, poor cosmesis, ectopic pupil, the need to implant an iris-claw IOL.

[9] See **Sect. 25.2.2.1** for more details.

Handling of Major Intraoperative Complications

40

40.1 Hemorrhage[1]

Of all possible intraoperative complications, this is the most threatening.

Pearl

Truly *expulsive* bleeding (ECH) does not occur during PPV since the operation is a closed-globe procedure. Nevertheless, a major bleeding can seriously interfere with the operation's original goals and cause significant tissue damage. The surgeon may be forced to completely change his original plan or even abandon the operation.

Because the IOP during PPV is actually higher than it otherwise would be, major arterial bleeding from the choroid is extremely rare; should it occur, the IOP must instantly be elevated[2] to stop the bleeding. See **Table 40.1** for all other types of hemorrhage.

[1] The management of a chronic suprachoroidal hemorrhage is discussed in **Chap. 60**.

[2] If an open wound is present, the immediate goal is to *close the wound* (see **Fig. 63.9**), regardless of the type of surgery being performed. This is an event for which planning must be done beforehand (how to prevent it and how to react if it does occur), but when it occurs, the surgeon's reaction must be automatic: no thinking, no strategizing, just instant wound closure.

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Q&A

Q: *Should patients on anticoagulation or antiplatelet treatment* (*aspirin*, *clopidogrel*, *warfarin*) *discontinue such treatment preoperatively*?

A: There is no absolute answer to this crucial question. Intraoperative bleeding may occur even if the medication is continued; conversely, severe systemic complications may threaten if the medication is discontinued. It is probably safe to continue taking aspirin, but with the other medications it is best for the VR to (personally) consult the patient's internist and make an individualized decision. (This is an advice for elective surgery; I will not delay an emergency operation [such as for endophthalmitis] if the patient is on, say, warfarin, but inform him about the risks of doing [and of *not* doing] the operation on an emergency basis.)

Table 40.1 Intraoperative hemorrhages and their management

Tissue		Comment and management[a]
Uvea	At sclerotomy site[b]	The bleeding is usually minimal, in which case no intervention is needed. If the bleeding is significant, use diathermy from the outside or from the inside[c]
	Iris	Most commonly it accompanies the creation of an iridectomy.[d] To prevent it, the surgeon may consider using diathermy but only if neovascular tissue is suspected behind the iris. The bleeding is usually minimal, in which case no intervention is needed. If the bleeding is significant, use diathermy, but be aware that it is applied blindly since the actual source is almost never visible
	Ciliary body	The bleeding can be profuse to the point that the exact location is impossible to find. Switch to air at high pressure, try to locate the source, and then diathermize it (see **Sect.** 32.5)
	Posterior choroid	Most commonly an iatrogenic injury occurred; the bleeding is usually self-limiting,[e] in which case no intervention is needed, other than subsequently removing the clot by aspiration or with forceps. If the bleeding is significant,[f] use diathermy, but make sure that the power is high and the duration long so that you do not cause an even more severe hemorrhage with the diathermy probe's sharp tip. The blood may have to be irrigated (see **Sect.** 36.3)
Retina	Major vessel	It is virtually always the result of an iatrogenic injury. Switch to air at high pressure and see if the bleeding stops. If not, try to inject PFCL or silicone oil to contain it. Note that the clot will need to be removed, which may restart the bleeding. Light diathermy may be employed, but be careful not to completely close the vessel, because this would lead to a different set of postoperative complications
	Small vessel	Most commonly seen in ILM peeling. The bleeding is usually minimal, in which case no intervention is needed (see **Sect.** 32.1.3)

(continued)

Table 40.1 (continued)

Tissue		Comment and management[a]
Proliferative/ neovascular[g]	Iris	Occurs when an adherent membrane or lens capsule is removed. If the bleeding is significant, use diathermy, but be aware that it is applied blindly since the bleeding vessel is not visible anteriorly
	Ciliary body	The hemorrhage may originate in the ciliary body itself or in the newly formed membranes; in the latter case the feeding vessel may lie very deep. The bleeding can be profuse to the point that the exact location is impossible to find (see above). Switch to air at high pressure, try to locate the source, and then diathermize it
	Retinal/intravitreal	In general, large vessels bleed more readily and for longer – but this does not mean that smaller vessels cannot cause profuse bleeding. Especially in eyes with anteriorly located proliferations, the feeding vessel may be more anterior than the lesion itself. Switch to air at high pressure, try to locate the source, and then diathermize it. Note that the clot will need to be removed, which may restart the bleeding
	Choroidal	The surgeon plays Russian roulette when lifting the membrane (**see** 32.4.2);[h] a profuse bleeding can occur if the feeding vessel is patent. Administer anti-VEGF therapy prior to the operation and raise the IOP during surgery before taking the CNV; if there is a bleeding, wait until it stops and then remove the clot, knowing that the bleeding can restart. Diathermy is usually not recommended at this location

[a]In each case, the surgeon should consider raising the IOP as the initial step; the more severe the bleeding, the more urgent it is and the higher the IOP should be. Raising the IOP using BSS is therefore not mentioned in the table.
[b]Typically it happens during reoperation, and neovascular proliferation underneath can be suspected.
[c]The latter requires scleral indentation and cannot be performed if the eye is phakic.
[d]Occurs more commonly during PPV than if the iridectomy had been performed at the slit lamp. The reason for the higher incidence is the increased blood flow during surgery.
[e]Tissue elasticity means that the bleeding is usually self-containing.
[f]Even then, it is a rather limited bleeding (not an “expulsive” type) since it will not be an arterial one.
[g]Bleeding from an abnormal vessel is more dangerous because self-containment is much less likely.
[h]As mentioned earlier, the patient must be fully aware of this risk before he agrees to the procedure; he must absolve the surgeon in advance since the bleeding does not occur due to any kind of negligence on the surgeon’s part.

The internist may suggest a switch from oral anticoagulants to intramuscular, short-acting heparin or enoxaparin. If in doubt, one can always check the INR level (should be lower than 3); the platelet count should be above 50,000.

40.2 Retinal Tear

The risk is mostly associated with the failure to recognize the tear intraoperatively. See **Fig. 40.1** for management suggestions. Unlike in 20 g surgery, the breaks in MIVS are found posterior to the vitreous base: the cannulas protect against the risk at the vitreous base since the instruments are not pushed through the gel repeatedly. The risk due to PVD, however, remains identical.

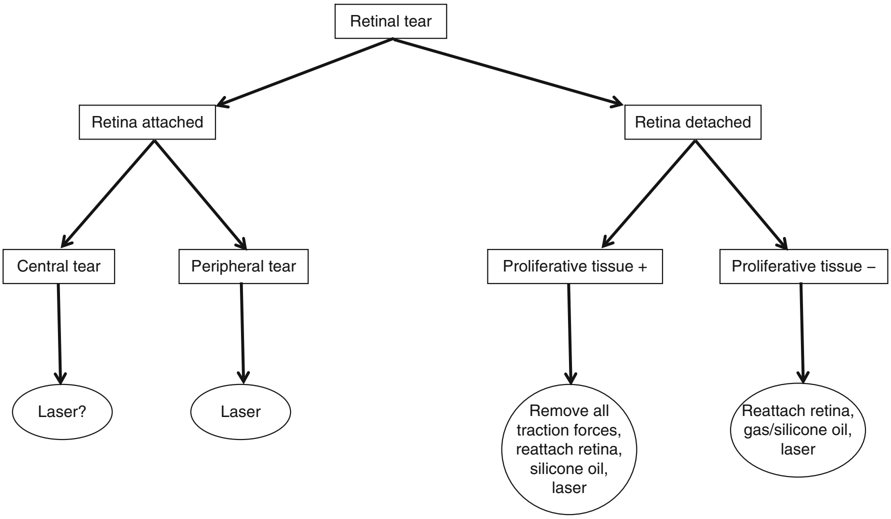

Fig. 40.1 Decision-making tree about the intraoperative management of an iatrogenic retinal tear. More details are presented in **Chapters 26, 27**, and **30**

40.3 Reopening of a Posterior Scleral Wound

If the posterior wound is large, unsutured, and PPV is done very early (see **Table 63.1**), the posterior wound may reopen. It is recognized by large radial folds,[3] which are caused by BSS that has been entering the orbit and compresses the eye from behind.[4]

- Stop the infusion.
- Switch to silicone oil, without going to air first.
  - Do *not* use PFCL.
- Discontinue the operation. The intraorbital fluid is likely to disappear by the next day, and surgery can resume then.

> **Pearl**
> The posterior wound is unlikely to reopen if the IOP is not raised and the wound edges are not touched by the surgeon.

[3] These are not retinal or choroidal but scleral folds.

[4] It is highly unlikely that the retina will be "blown" into the orbit.

- Alternatively, you can try suturing the scleral wound from inside.
  - Bimanual surgery is needed – insert a chandelier light.
  - Use just enough infusion to keep the globe inflated, but try not to force more BSS in the orbit. Cohesive viscoelastic may be used to cover the entire area.
  - Diathermize the retina and choroid around the wound edges to prevent hemorrhage during and proliferation after the operation (see **Sect. 33.3**).
  - Use 9-0 nylon sutures and two crocodile forceps to close the wound and tie the sutures.
  - Once the wound is closed, carry on with the vitrectomy as usual.

40.4 Lens/IOL Trauma

True intraoperative lens trauma is rare in experienced hands, and the consequences are not terrible even if it does occur. The management depends on whether only a touch occurred or the capsule has been violated (see **Sect. 25.2.3.1**).

The IOL may get dislocated, which is another very rare complication (see **Chap. 44** and **Sect. 38.6**). If there is sufficient capsular support and the IOL is only subluxated, the IOL may be repositioned. A needle inserted in the frontal plane (see **Fig. 40.2**.) helps prevent the IOL from luxated into the vitreous while the anterior manipulations are carried out.

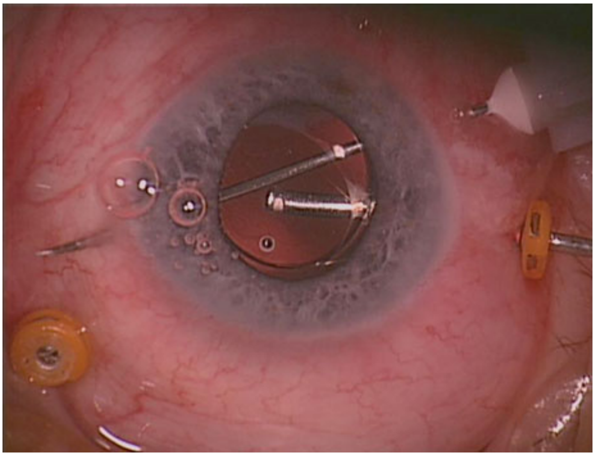

Fig. 40.2 Prevention of IOL luxation. A 27 g needle, typically bent just behind its cone, is inserted across the pars plana. It provides mechanical support for the IOL while the anterior vitrectomy is carried out, removing the gel from the AC and behind the remnant of the posterior capsule. Once the IOL is securely repositioned (or removed if the capsular support is insufficient), the needle is withdrawn

Pediatric Patients

41

The stereotype statement is true: A child is not a small adult. **Tables 41.1** and **41.2** list a few important differences the VR surgeon should keep in mind when operating on a child[1] vs on an adult patient.

Table 41.1 Age-dependent location of the sclerotomy

Age	Distance (mm)
<6 months	1.5
7–12 months	2
1–2 years	2.5
2–6 years	3
>6 years	3.5

[1] The age beyond which a child becomes an adult is not in stone. For the purpose of this chapter, the surgeon should look at a continuum between birth and age ~21 years, when the refraction normally reaches its final value. The eye grows to 85% of its axial length by age 2 years and continues to grow at 1% annually; the emmetropic eye stops growing after 12 years of age. The axial length at birth is 18–19 mm, increasing to 23 mm in 3 years.

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Table 41.2 The pediatric eye and the VR surgeon

Variable	Comment
Examination of both person and eyeball more difficult	Doubt history – try to find a witness in case of trauma Discard the white lab coat Consider restraining the unruly/restless child for examination or use short-acting narcosis
Amblyopia – timing of intervention	The eye typically reaches full vision capability by age 5 years; in those under ~8 years lack of a sharp image[a] leads to deprivation amblyopia This gives extra urgency to treating young children with a condition that would be less urgent in older children and adults
Healing-capacity and tolerance toward abnormalities higher	Ciliary body damage that would lead to hypotony or phthisis in adults may spare the child of both
Postoperative inflammation heavier, fibrin reaction more common	This is true in all, but especially in heavily pigmented eyes. Stronger-than-normal anti-inflammatory treatment is indicated
Both the orbit and the eyeball are small	Intraocular access is more difficult than in (most) adults. The surgeon may be limited in his choice of the lid speculum (see **Chap. 19**)
Cornea: less rigid	Sutures get loose faster and require removal earlier than in adults
Lens: anterior capsule thinner	Capsulorhexis more difficult; scissors are often needed in eyes with capsular scarring
Lens: zonules stronger	If the posterior capsule needs to be removed, the zonules must be severed, not torn (see **Sect. 38.5.2**), and an anterior vitrectomy (see below) must always precede the capsule removal
Lens: swelling	If the capsule is broken, the swelling may occur rapidly, and lead to very high IOP
Lens: cataract removal	Posterior capsulectomy and anterior vitrectomy should always be performed
Lens: nucleus soft	Aspiration is sufficient to remove it
Lens: IOL implantation	The age cut-off[b] is controversial Difficult to predict the IOL power
Pars plana: more anterior	See **Table 40.1**
Vitreous: more adherent to posterior lens capsule	If the posterior capsule needs to be removed, a judicious anterior vitrectomy must precede it
Vitreous: more adherent to posterior retina	It may be dangerous or even impossible to create a PVD; consider using ocriplasmin[c]
ILM peeling	It is technically more difficult and may be impossible to complete
PVR	The risk is higher; the pathology is more aggressive, presents earlier, and recurs more often. A child is many times more likely than an adult to lose vision if PVR occurs Often the ciliary body is also involved, with a much higher risk of phthisis development

[a]The refraction is determined after complete accommodation paralysis; the range of risk is between 1–2 D hyperopia and >3 D myopia.
[b]Under which implantation is not recommended.
[c]ThromboGenics (Leuven, Belgium). It is a very expensive medication.

The Highly Myopic Eye

42

42.1 The Risk of RD If Cataract Surgery Is Needed

One crucial question in these patients is the development of a cataract, whose removal further increases the RD risk: what is the safest management option? There are three alternatives to choose from:

- *The traditional approach.* Standard phacoemulsification and IOL placement are performed, even if the IOL has 0 D power (see **Table 3.3**). This option completely neglects the RD risk.[1]
- *The traditional approach + laser cerclage.* At least 1 month before the cataract is removed, the anterior retina is treated (see **Sect. 30.6**) to counter the existing and forthcoming traction. The problem is that the cataract may interfere with visualization and thus the completion of the treatment; furthermore, the laser scars may not be sufficient to resist the VR traction. Nevertheless, this option reduces the RD risk compared to the traditional approach.
- *The unorthodox approach: lensectomy, vitrectomy, and endolaser cerclage.* This is by far the most complex operation and one with an obvious risk for postoperative PVR development. However, once the PVR threat is over,[2] the risk of RD will be as close to zero as possible. IOL implantation may not be needed at all,[3] but if an IOL is implanted, the surgeon should consider the option of removing the capsules and implanting an iris-claw IOL (see **Chap. 38**).

[1] The problem is the VR surgeon's.

[2] ~3 months postvitrectomy (see **Sect. 53.1**).

[3] If the aphakic status yields an emmetropic situation or one close to it.

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42.2 Vitrectomy in the Highly Myopic Eye

The larger axial length has important implications for the VR surgeon (see **Table** 42.1).

Table 42.1 The highly myopic eye and the VR surgeon

Finding[a]	Comment
Axial length too large for some instruments	Especially the probe; in eyes over 32 mm it is either impossible to reach the posterior pole or the eyewall must be significantly indented. This can distort the image and make the creation of a PVD even more difficult
Blood circulation poorer (contributory factor in retina and choroid becoming thinner)	May be an additional reason for the increased RD risk and may explain why permanent visual deterioration can occur earlier if the macula detaches
Eyewall too thin	Easier to inadvertently penetrate with a needle during peribulbar anesthesia or SB[b] Postoperative thinning[c] with bluish discoloration of the sclera[d] is not uncommon
ILM peeling	More difficult and risky because the retina is so much thinner and because the loss of pigment in the RPE may mean lower contrast even if the staining is successful
IOL implantation	May be unnecessary if the refractive error does not need correction (see the text and **Sect.** 38.4.2)
Laser cerclage	Regardless of the etiology/indication for PPV, such laser should always be considered to reduce the risk of postoperative RD[e]
Lens: anterior displacement	Removal of the anterior hyaloid face may become technically easier
PVD	See above. Particularly in eyes with RD the surgeon must struggle with, but not give up on, the creation of a PVD[f]
Sclerotomy site	Should be a bit more posterior (~4 mm)
Staphyloma – spanning RD	See **Chap.** 56

[a]In alphabetical order.
[b]Creating scleral tunnels for fixing the band is *contraindicated* in these eyes (see **Sect.** 54.4.2.6).
[c]Especially after reoperations, and particularly, but not exclusively, in 20 g surgery.
[d]Obviously, this is the choroid's color, which becomes visible through the thin sclera.
[e]In fact laser cerclage should also be considered if the eye undergoes cataract extraction; removal of the lens adds a second risk factor for postoperative RD development (see the text for more details).
[f]I have never seen a highly myopic eye with a complete spontaneous PVD; they all have a vitreoschisis, although it may be very difficult to visualize the vitreous cushion on the posterior retina, even intraoperatively and even with TA use (see **Chap.** 56).

42.3 Posterior RD over a Staphyloma

This is detailed in **Chap.** 56.

Intravitreal Injections

43

This is not a surgical procedure, even though in many countries it must be done in the OR. I nevertheless include a very short to-do list (see **Table 43.1**) because the procedure is performed in increasingly great quantities.[1] The technique is very similar for intraocular implants with slow-release medications, except the use of a special applicator in lieu of the syringe.

Quo vadis, VR surgery?

For the VR surgeon there are additional implications due the rising number of intravitreally injected medications available for an increasing number of diseases. Studies that provide "level 1 evidence" regarding the efficacy of a treatment modality are very expensive; pharmaceutical companies, naturally, tend to support studies testing the *drug* they are manufacturing. If found effective, "they are in business," and this is understandable. However, this starts a cascade.

The physician soon finds that once a patient seeks treatment for a condition for which such a drug is available, he no longer has a choice; this drug is now *the* treatment option. Since companies that manufacture surgical devices can never offer the same level of financial support for a study showing the efficacy of *surgery* for the same condition, the VR surgeon is increasingly faced with two sad facts. First, diseases that *he* used to treat (and trained hard to do so) are now treated by colleagues whose expertise in the field is obviously more limited (the general ophthalmologist using intravitreal injections to treat ME caused by EMP). Second, he himself may be forced to slowly transit from being a *vitrector* to being an *injector*. Something is wrong with the (big) picture, but this goes beyond the scope of this book.

[1] This also puts severe strain on the institutions in terms of logistics, infrastructure, and finances.

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Table 43.1 The technique of intraocular injections

Step	Comment
Counseling	Explain all steps to the patient; inform him that he may experience pressure (but no pain). Discuss with him the importance of monitoring his postinjection vision and pain level (endophthalmitis!) and IOP[a]
Preoperative antibiotic drops	No benefit unless used (pre- and postinjection) for at least 5 days[b] If meibomianitis or chronic blepharitis is present, it is advisable to treat the condition before the injection is given[c]
Preparing the patient just prior to the injection	Topical analgesia drops[d] Povidone-iodine 10% on the periocular skin and the eyelashes Povidone-iodine 5% in the conjunctival sac Sterile speculum[e]
The injection itself[f]	Fix the eye with some tool.[g] How this is done depends mostly on how experienced the VR surgeon is
	Prepare the syringe with a 27 g needle for injection or the applicator for insertion. Do not have more material in the syringe than what needs to injected into the eye
	Penetrate the sclera 3.0–3.5 mm from the limbus[h]; the most typical location is inferotemporally.[i] The angle with the sclera should be ~30° and the needle advanced parallel to the limbus Once inside the eye, turn the syringe and aim toward the very center of the vitreous cavity
	Make sure you are able to see the tip
	Do not inject too fast[j]
	Withdraw the needle upon completion and check the IOP by either measuring it or checking with the IBO the patency of the blood circulation on the optic disc
If the IOP is high	Use a blade (less preferably a 27 g needle; see **Sect. 39.1**) and allow a little aqueous escape the AC. This should be done under the microscope or at the slit lamp (less preferably a loupe can be used)
Postoperative management	Patching is not necessary Antibiotic use: see above Steroid drops: should be used for a few days

[a]Obviously, patients who undergo repeated injections need less explanation.
[b]Shorter duration has no therapeutic benefit but does increase the risk of producing bacterial resistance.
[c]Sterile wipes (e.g., Blephaclean, Labtician Ophthalmics, Oakville, ONT, Canada) to be used by the patient for 3 days prior to the injection to clean the eyelid margins. Moist heat can also be applied, and any infection treated with antibiotic ointment for a sufficiently long period.
[d]It is also possible to inject the solution subconjunctivally. However, this requires preinjection drops anyway, and the bubble that forms may make the selecting of the exact location of the intravitreal injection (penetration of the sclera with the needle) more difficult.
[e]Draping is not mandatory.
[f]If the patient still has pain, soak a cotton-tip applicator in a sterile analgesic solution and keep the tip pressed against the conjunctiva at the planned location of the injection. If the solution is not sterile, repeat the irrigation of the conjunctival sac with Betadine.
[g]Caliper, cotton-tip applicator, pressure plate, or the surgeon's finger (see **Fig. 39.2**).
[h]Eyes that underwent PPV may require a more firm push with the syringe.
[i]The location may be varied, especially if repeated injections are given.
[j]Injecting TA allows the surgeon to see how strong a jet stream can be created by a too rapid push on the plunger.

Part V

Tissue Tactics in VR Surgery

Introduction

The primary focus of this part is the specific tissue tactics in VR surgery in the most common conditions, including dropped nucleus and IOL, endophthalmitis, retinal detachment of various types, macular disorders ranging from hole to edema, PVR, PDR, and trauma. Certain topics that may appear outside the VR surgeon's expertise yet are crucially important during his daily practice, such as iris reconstruction and scleroplasty, are also included, as is a summary of the most important issues in postoperative care. Some of the writings in each chapter, grouped per indication, resemble a checklist since the individual maneuvers (such as retinectomy or endolaser cerclage) have been covered in much detail in the previous parts. However – as throughout the entire book – a serious effort is made to provide the rationale ***why*** a particular step is recommended, not only ***how*** and ***when*** it is to be done.

Dropped Nucleus and Dislocated IOL

44

Dropped nucleus is an often-used term, but the material is commonly a nucleus still encased in (some) cortex.

44.1 General Considerations

44.1.1 Dropped Nucleus[1]

The sooner the lens material is removed, the less anxiety the patient suffers (see **Sect.** 5.1 and **Table** 9.1), and the inflammation the eye is exposed to is also reduced. If a VR surgeon is available, it is best if the cataract surgeon immediately consults him, and if possible, the VR surgeon immediately performs the operation. If this is impossible, heavy topical steroid treatment is needed and the surgery be done within weeks.

The cataract surgeon must not try fishing out lens particles from the vitreous.

Q&A

Q *What if the cataract surgeon wants to implant an IOL before the PPV is done?*

A This is fine.

[1] A lens that is subluxated due to trauma is discussed under **Sect.** 63.6.

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44.1.2 Dislocated IOL

Removal is not urgent; the more important question is whether the IOL can be repositioned or replaced.

Q&A

Q *What if the cataract surgeon wants to implant an IOL into an eye with a dislocated and retained IOL?*

A This is not fine. The dislocated IOL is bothersome to the patient and may cause retinal erosion with time; it also makes removal of the dislocated IOL much more difficult.

44.2 Surgical Technique

44.2.1 Dropped Nucleus

- Complete the PPV, including the creation of a PVD.
- Check whether vitreous prolapse into the AC has also occurred (see **Sect. 63.6**).
- Determine whether the lens material can be removed with the probe (PPL). If yes, complete the procedure without using ultrasound (see **Sect. 38.2.2**).
- Any material too hard for the probe must be removed via phacofragmentation (see **Sect. 38.3.2**).

44.2.2 Dislocated IOL[2]

- Complete the PPV, including the creation of a PVD.
- Determine whether the IOL needs to be removed. If it can be placed in the bag or in the sulcus, follow these steps:
  - Grab the *superior* haptic[3] of the IOL with a forceps[4] and bring it into the anterior vitreous. Do this with your nondominant hand.
  - Remove the light pipe and insert, with your dominant hand, another forceps. Grab the *distal* haptic so that the forceps is *underneath* the optic of the lens.[5]
  - Position the superior haptic and the optic into the AC or directly inside/over the capsular bag, then position the inferior haptic as well.

[2] See **Sect. 38.6** if an iris-claw IOL has luxated.

[3] The one that is closer to 12 o'clock in the patient's eye.

[4] An even better solution would be an endocryo probe, but this is not available in MIVS.

[5] If you have a forceps (Sunderland-type; Grieshaber, Schaffhausen, Switzerland) that can be easily rotated with your finger without you having to rotate your hand, you can directly grab the *distal* haptic, and turn the rotating dial 180° so that the IOL is *above* the forceps.

If the IOL needs to be removed,[6] follow these steps.

- Bring the dislocated IOL into the AC either by grabbing the superior haptic or the using the technique described above.
- Prepare the removal incision in the limbus or as a scleral tunnel.
- Coat the optic with viscoelastic and then remove the IOL through the incision.

Pearl

Whether the surgeon cuts a soft IOL in half or makes a larger extraction incision is primarily determined by the size of incision needed for the implantation of the new IOL. If a foldable lens is to be implanted, the size of the extraction incision is based on the surgeon's preference. If the IOL is cut in half, the endothelium needs extra visco-protection.

- Implant the new IOL.
  - The type and placement depend on the integrity of the capsule and on the surgeon's preference (see **Chap. 38**).

[6] Because it is damaged; it is the wrong type of IOL to be placed in the sulcus; there is insufficient capsular support etc.

Endophthalmitis

45

45.1 General Considerations

45.1.1 Etiology

Endophthalmitis may be postoperative,[1] posttraumatic, and endogenous; it is mostly caused by bacteria but may also be fungal.

Q&A

Q *Can endophthalmitis occur after closed-globe surgery?*

A In principle, no; in practice, yes. The simple explanation for this paradox is accidental perforation of the sclera with the needle during SB or squint operation.

The vast majority of the cases are acute[2]; the chronic cases are typically caused by fungi or organisms such as *Propionibacterium acnes* after cataract surgery.

Posttraumatic endophthalmitis is unique in its presentation since the typical signs are often masked by the injury, thus making the diagnosis more challenging. The organism is often more virulent; it is therefore even more important to intervene on an emergency basis and attempt to do a complete surgery (CEVE, see below).

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[1] Including cases associated with filtering blebs.

[2] This chapter is dedicated to these acute cases. The difference in the management of eyes with chronic endophthalmitis is that the surgery is not urgent and the capsules/IOL complex commonly needs to be removed; it is in the bag where the organisms hide.

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45.1.2 Clinical Diagnosis

The following are typical signs and symptoms.[3]

- Drop in visual acuity.
- Pain.
- Corneal edema.
- Hypopyon and fibrin in the AC.
- Small pupil.
- Reduction in, or loss of, the red reflex.
- If the retina is visible at all, it shows tortuous and sheathed blood vessels, stress hemorrhages, and widespread edema.

The diagnosis can be confirmed by obtaining a sample from the AC or via a vitreous tap.[4]

45.1.3 Timing

There is no other surgical indication in ophthalmology when the initiation of treatment is as urgent as in endophthalmitis.

> **Pearl**
> The easiest part of the management of a patient with acute endophthalmitis is timing. Medically and legally, it is very difficult to justify any delay in commencing the treatment, whichever treatment route is chosen.

As part of the management, the ophthalmologist should warn the patient against lying in bed. Being upright reduces the risk of the heavy purulent material settling on the macula.

45.1.4 Treatment Options and Management Philosophy

There are two basic options: medical and surgical.[5] In the first case the ophthalmologist chooses the "safe" route and follows an "evidence-based" recommendation[6]: if the VA is greater than LP, intravitreal and periocular antibiotics are given, but no systemic antibiotics are used and surgery is not performed.

---

[3] Not all of these need to be present in a given case. In posttraumatic cases other pathologies may mask the signs of endophthalmitis.

[4] The question is whether the ophthalmologist chooses to operate or inject first (see below). If the former option is chosen – which is my recommendation – there is no point taking a sample before the surgery; an ample amount of the infected material will be collected during surgery.

[5] "Surgical" in reality means a combination of vitrectomy *and* medical treatment.

[6] See the comment in the box in **Chap. 43**.

In my opinion the presence of pus inside the eye represents a surgical indication.[7] I also believe that a condition, which can rapidly lead to irreversible loss of vision, deserves all the weapons at the ophthalmologist's disposal to be utilized against it.[8] This includes the use of *systemic* antibiotics – and, primarily, surgery.

Vitrectomy is my default option, as long as the patient's systemic condition permits it.[9] The only exception is an endophthalmitis so early that retinal details can still be visualized. In such a case I am willing to use medical treatment (the maximum possible; see **Table 45.1**), but keep the patient under very close observation: hourly self-check[10] for pain and visual deterioration (see **Fig. 45.1** for the decision-making process).

Table 45.1 Medical treatment in endophthalmitis[*]

Route of administration; schedule	Drug	Dose (in a volume of)
Intravitreal[a]; the initial injection is given before or at the conclusion of surgery; repeated as needed	Vancomycin	2 mg (0.1 ml)
	Ceftazidime	2.25 mg (0.1 ml)
	Dexamethasone	0.4 mg (0.1 ml)
Intravenous; every 12 h	Vancomycin	1 g
	Ceftazidime	1 g
Subconjunctival; daily or as needed	Vancomycin	25 mg (0.5 ml)
	Ceftazidime	0.1 g (0.5 ml)
	Dexamethasone	12 mg (3 ml)
Topical; hourly or as needed	Moxifloxacine	0.5%
	Ofloxacin	0.3%
	Tobramycin	0.3%
	Steroid	Depends on availability; use the strongest one
	Pupil dilator	Atropine, tropicamide

[*]The medications need to be changed based on the results of the culture.
[a]If antibiotics and steroid need to be added to the infusion fluid during vitrectomy (silicone oil implantation is planned, see the text for more details), the same concentration should be used.

Q&A

Q *By going to surgery at such an early stage, will some of the eyes not undergo PPV unnecessarily (i.e., they would have improved on medical therapy alone)?*

A Yes, some of the eyes could have been cured by medical therapy alone – but it is impossible to predict at an early stage which these eyes would be. The surgeon gives up control (and risks a poorer outcome) by waiting; in addition, the earlier surgery is performed, the easier it is technically, which in turn means that the risk of surgery is very low.

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[7] *Ubi pus, ibi evacua.*

[8] Especially since initially it is not known what the organism is and whether a fulminant infection will occur.

[9] As explained in **Chap. 5**, it is the patient who must choose this option based on the ophthalmologist's impartial information.

[10] The patient is hospitalized, and the nurse also checks on the patient hourly. This schedule is continued throughout the night as well.

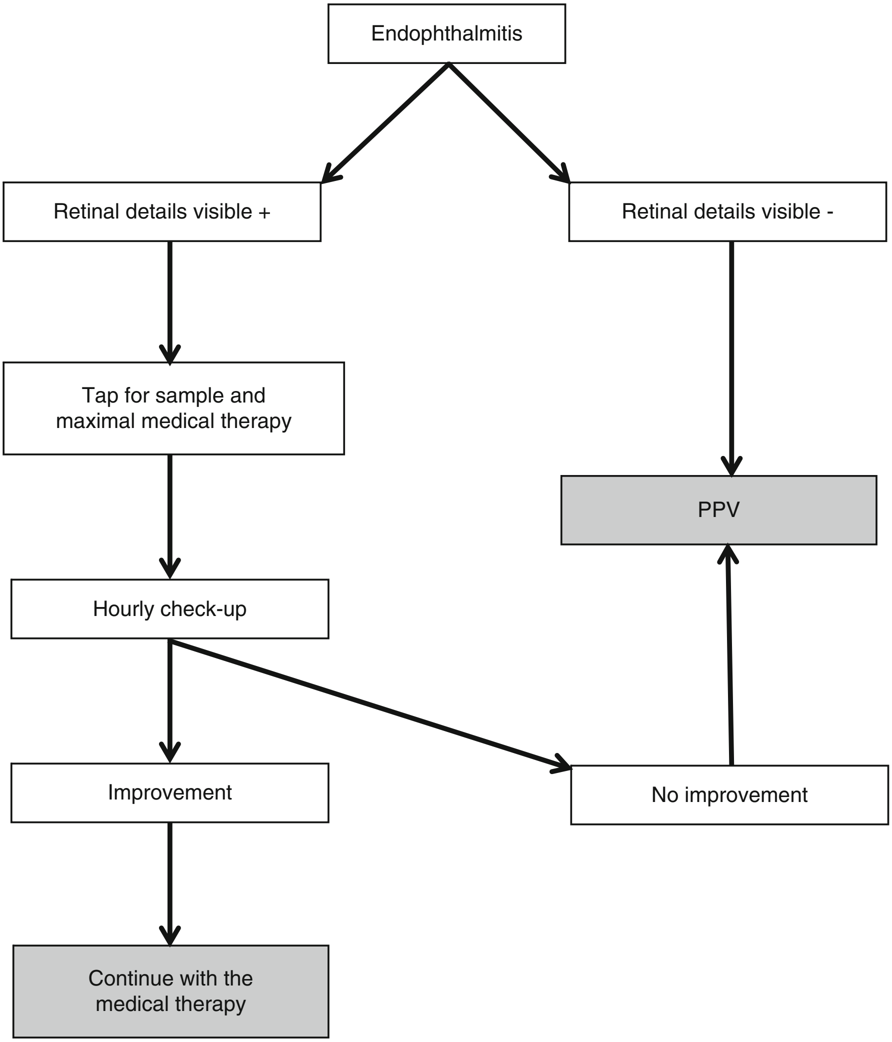

Fig. 45.1 **Decision-making tree to select the treatment in endophthalmitis**. Medical treatment is continued even if PPV is performed. See the text for more details.

If surgery needs to be delayed for any reason, full medical treatment is given, even if it will reduce the chance of having a positive yield of the subsequent culture. Surgery does not obviate the need for medical treatment (see above). Heavy topical steroid treatment must be started as soon as the patient has been examined to reduce the corneal edema and the eye's inflammatory reaction.

If the cornea is too hazy to allow safe PPV,[11] the surgeon still has a few options to choose from (see **Table 45.2**).[12]

Table 45.2 Management options if corneal opacity[a] interferes with visualization during PPV for endophthalmitis

Option	Endophthalmitis, semi-advanced[b]	Endophthalmitis, advanced
Give up on the surgical option altogether	Acceptable only if rapid progression (to advanced endophthalmitis) does not occur	Major damage threatens (loss of vision and eyeball)
Delay the surgery until the cornea clears[c]	Acceptable only if the delay is short. The chances of a meaningful reduction in the corneal haziness are not too high	Even if the delay lasts only for a few hours,[d] severe intraocular damage threatens
Do limited surgery	May be acceptable but rapid progression to advanced endophthalmitis remains a possibility	Partial vitrectomy is preferable to no vitrectomy. Conversely, poor visualization is not an excuse if the surgeon causes significant iatrogenic damage
TKP	Better than all the previous options, but it may be unnecessary ("overkill") because the cornea would eventually clear up spontaneously	Optimal solution since a PK will likely be necessary in the future anyway. The survival chance of the graft is over 90%
EAV	Optimal solution, but the surgeon must be very experienced in this technique	Optimal solution, although a PK will likely be necessary in the future anyway

[a]The corneal opacity is not a bacterial infiltration – if it is, the only acceptable option is TKP-PPV.
[b]Not early anymore, but not quite an advanced one yet.
[c]This will be sped up if topical steroids are used. Full antibacterial (fungal) therapy must be initiated without delay.
[d]It is unlikely that in an advanced case of endophthalmitis, the corneal edema sufficiently clears up in a few hours, even if the topical steroid is used every few minutes.

Completeness of the vitrectomy is the key to success. If a PVD is not created or the macular surface not vacuumed, the toxins and enzymes of the organism and the inflammatory debris (as a result of the body's immune reaction) will continue to damage the retina (see **Fig. 45.3**).

[11] Use of the BIOM is an especially great aid in endophthalmitis, allowing complete surgery in many eyes that otherwise would require TKP-PPV or EAV.

[12] The culprit may also be the material that accumulated in the AC; once the AC is cleaned, visibility dramatically improves (see **Fig. 45.2**). The problem here is that his may be impossible to determine preoperatively.

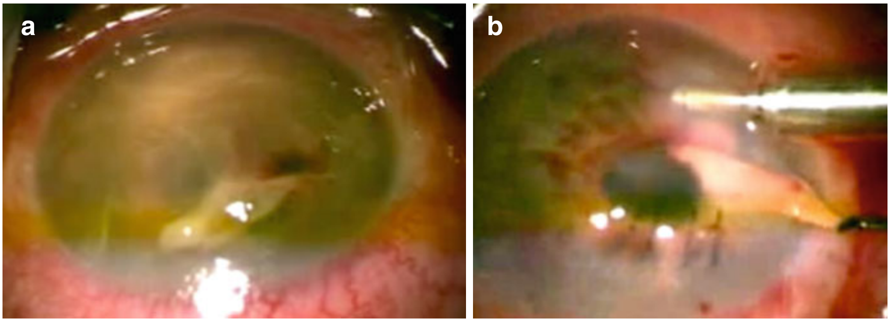

Fig. 45.2 **Cleaning the AC in an eye with traumatic endophthalmitis**. (**a**) In this patient with a 3-day-old traumatic endophthalmitis, the corneal wound has not been sutured since the patient did not seek help after the injury. The AC filled is with nontransparent material; it is not possible to determine how much the cornea would interfere with visibility during vitrectomy. (**b**) The corneal wound was closed with full-thickness sutures, the epithelium scraped, and an AC maintainer placed. The fibrinous membrane is being removed with forceps, the iris is now visible, and only a few minutes have elapsed since the taking of the picture seen on (**a**)

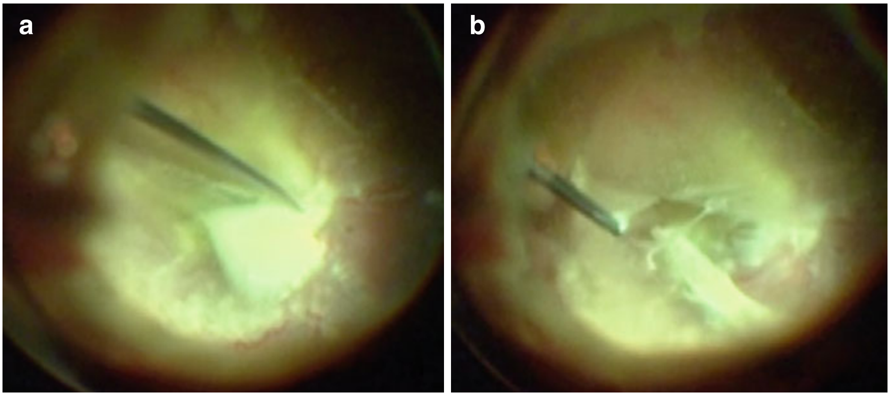

Fig. 45.3 **The posterior pole in an eye with advanced endophthalmitis**. (**a**) "Macular hypopyon": accumulation of pure pus overlying the deepest point of the eye in a patient who has been lying in bed for several days. (**b**) The posterior vitreous is still not detached, even though the injury is 3 weeks old. Without creating the PVD the surface of the posterior retina cannot be cleansed. The PVD, and the vacuuming of the bacterial colonies seen as white dots on the image, are technically difficult procedures at such a late stage, and the prognosis is very poor

45.2 Surgical Technique

CEVE is what I call the ideal solution. The goal is to remove as much of the purulent material as possible, consistent with safety, and do it basically as soon as the diagnosis has been made.

Table 45.3 provides details about the surgical procedure, which is the same irrespective of whether it is performed early or late. Surgery, however, is easy in the early and very difficult in the advances cases; either way, but especially in advanced cases, the surgeon must proceed in a step-by-step fashion from anterior to posterior. Skipping a step makes surgery even more difficult and risky.

Table 45.3 Surgical steps in PPV for endophthalmitis

Step	Comment
Preparation	Have the diagnostic equipment (for culturing) ready[a]
	Place the pars plana infusion cannula but do not open it unless you can definitely confirm/see that the tip is in the vitreous cavity; use an AC maintainer until (see below)
Cornea	Scrape the endothelium.[b] It is always edematous and greatly interferes with visualization
	If the stroma is also edematous, press a dry sponge against it or use high-concentration glucose topically (see **Sect. 25.1.4**)
	If folds are present in Descemet's membrane, clean the AC and then try to fill the AC tightly with cohesive visco (see below)
AC	It always has cells and a fibrinous membrane, even if true hypopyon is not visible[c] Prepare 2 paracenteses: The first one inferotemporally – insert an AC maintainer here The second one is superotemporal; this is used to aspirate all cellular elements Following the irrigation, insert a forceps or the probe, and grab or aspirate the fibrinous membrane. The membrane is adherent to tissues and requires some force to separate, but it is also elastic so it usually comes off in one piece Cave: the iris is "hot" and can easily bleed Make sure you remove the membrane from the angle Especially in children, the purulent material and the membrane may recur during surgery, and repeated removal may become necessary
Pupil	Make sure it is as wide as possible; you can try adrenaline, visco, or iris retractors (see **Sect. 25.2.2**)
Lens	It is rare that the crystalline lens that otherwise would be left in place needs to be removed so as to complete the PPV; however, the lens must be sacrificed if it in any way interferes with surgical success
IOL	It is rare that the IOL needs to be removed; it is done as a "routine" only in the eyes with chronic endophthalmitis Thoroughly clean both surfaces of the IOL (see **Sect. 25.2.3.2**)
Posterior capsule	Make a large capsulectomy and irrigate the capsular bag
Vitreous cavity if the retina is now visible	Proceed as in a normal case (P-A PPV). Make sure that you create a PVD, and vacuum the macular surface with the flute needle
Vitreous cavity if the retina is not or only barely visible	Proceed first in an anteroposterior order; reverse it only if a PVD has been created Clean the area behind the lens first and then the central vitreous, and do the creation of this "well" on the nasal side. The retina may be detached and necrotic: it would not necessarily bleed even if bitten into (see **Sect. 62.3**) Create a PVD,[d] vacuum the macular surface (see **Sect. 25.2.7.2**). The retina is very fragile and can easily be damaged. If some of the vitreous is extremely adherent to the surface, do not force its detachment Vacuum the macular surface as described above Once most of the vitreous cavity has been cleaned, continue with the vitrectomy in the periphery. Here you need to proceed with extreme caution. Usually there is a white, nontransparent ring of purulent vitreous there, which is best seen by scleral indentation, but it is not possible to see the retina behind it. This vitreous is best reduced in thickness but then left behind

[a]The best is to discuss beforehand the details with the lab where the samples will be sent.
[b]Even if the patient is diabetic – something that is unadvisable otherwise.
[c]If a small (1–2 mm) hypopyon was seen at the slit lamp, it may become invisible once the patient lies down.
[d]Never assume that the posterior hyaloid face has spontaneously detached.

Pearl
The *real* fear in endophthalmitis must concern the organism and the toxic, purulent material bathing the retina, *not* the risk of causing an RD.

If a retinal break is found or suspected, or RD is present, the completion of the surgery is different.

- Inject antibiotics and steroid into the infusion bottle. The dose is calculated so that the concentration in the bottle[13] is the same as the intravitreal injection's concentration would be.
- Complete the vitrectomy using this infusion fluid so that it irrigates the vitreous cavity to a sufficient extent and duration.
- Fill the vitreous cavity with silicone oil.
- Inject antibiotics and steroid into the oil, 1/3 of the usual dose.

45.3 Posttraumatic Endophthalmitis

Most of what is important has been described above; below is a list of some of the unique features of a trauma-related infection.

- The diagnosis may be much more difficult as the signs and symptoms of the endophthalmitis can be masked by those of the injury.
- The organism is often very virulent; the time to intervention should be kept to the minimum possible.
- The default intervention option is CEVE.
  - Compromise may be acceptable regarding certain elements of the surgery itself,[14] but no delay is acceptable: *posttraumatic endophthalmitis is an absolute emergency*.
- The full armamentarium of antimicrobial therapy has to be employed, and unless the organism is fungal, intravitreal steroid should also be injected.

[13] The drugs are expensive. A small amount of infusion fluid (say 50 ml) will suffice since most of the operation has been done by now.

[14] I.e., foregoing complete removal of the adherent vitreous from a necrotic retinal surface.

Floaters

46

46.1 General Considerations

Nontransparent material in the vitreous cavity casts a shadow on the retina; the closer the material to the tissue of vision, the more circumscribed (less fuzzy) the shadow. The visual disturbance is not objective; even more subjective is the way the individual's brain processes it. Some people are bothered by a single, tiny floater; others do not recognize the presence even of those that the ophthalmologist can readily see at the slit lamp. Persons with synchysis scintillans (asteroid hyalosis) may have so many of these calcium or cholesterol bodies that the fundus is impossible to examine in fine detail (see **Fig.** 46.1), yet they do not complain and many of them decline surgery.

- One of the unintended consequences of a vitrectomy that is "nonvitrectomizing," minimal, or core (see **Table** 27.2) is that vitreous is left behind, which – as part of a normal aging process or induced by the surgery itself – may develop floaters, potentially requiring another vitrectomy that would easily have been avoidable had a more complete vitreous been done the first time.
- YAG capsulectomy is a potential source of bothersome floaters.

46.1.1 Indication for Surgery

Many of the people complaining of vitreous floaters have full vision at the moment when the acuity is taken[1]; as a result, ophthalmologists often refuse to offer surgery, claiming that the risk-benefit ratio justifies this. This argument is wrong, for two

[1] Operating on an eye with full vision always raises the stakes, for the surgeon as well as for the patient. The VA will not improve after surgery; even in the best circumstances, it remains the same. However, the number of letters the patient reads on a visual chart is only one of the measures based on which indications should be considered.

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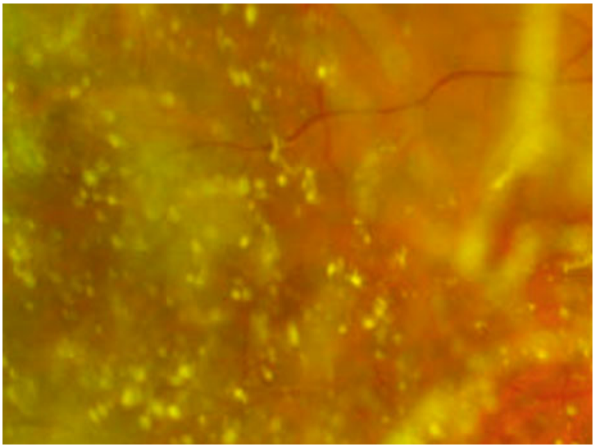

Fig. 46.1 **Vitreous opacity interfering with fundus visualization**. Why certain people, especially those with synchysis scintillans, are not bothered by floaters that actually prevent the ophthalmologist from seeing fine retinal details is rather mysterious

reasons. First, the vision is determined by whether the opacity is in the visual axis or not. If the floater is outside the visual axis, the VA is indeed full, but as the gel moves, a split second later, it may drop significantly. Second, the only person who can truly determine how this undulating vision is bothersome is the patient himself.

Every ophthalmologist/VR surgeon has the right to refuse vitrectomy for floaters – but then they will have to refer the person to a colleague who is willing to objectively discuss the benefits and risks with the patient and perform the operation if the patient so decides.

Pearl
A vitreous floater is the classic example of the "who owns the eyeball?" question: the person does. As long as the risks of PPV are properly explained and the person accepts them, surgery should not be denied just because the ophthalmologist considers the floater too insignificant a problem (see **Sect. 5.5**). Conversely, VR surgeons may feel an urge to remove the cloudy vitreous in synchysis scintillans because they cannot see retinal details or are unable to perform laser treatment (see above).

46.1.2 Timing of Surgery

This is as elective a surgery as it can be: select a date that is mutually agreeable.

46.2 Surgical Technique

A standard PPV is to be performed, with detachment of the posterior cortical vitreous. There is no need to aim for a total vitrectomy.

Hyphema

47

47.1 General Considerations

47.1.1 The Rationale for Surgical Removal

There are several reasons why the presence of blood in the AC should be taken seriously, especially if the hemorrhage is exacerbated by systemic conditions such as sickle cell disease. The risk of secondary complications is roughly proportional to the amount of blood present. The negative consequences of the hemorrhage, listed below, increase in case of a rebleeding:

- Risk of glaucoma.
  - The bleeding can also be the consequence of (neovascular) glaucoma.
- Risk of corneal blood staining (see **Sect.** 29.1.5).
- Development of posterior and/or peripheral anterior synechiae (see **Sects.** 39.3 and 39.4).
- Reduced vision for the patient.
- Lack of ability to visualize the retina for the ophthalmologist – this is especially a concern if the hyphema has been caused by trauma: up to half of these eyes have serious pathology in the posterior segment.

The medical treatment (see below) is aimed at preventing secondary complications and rebleeding. If they are ineffective, surgery is indicated, especially if the IOP cannot be controlled.

47.1.2 Medical Treatment

- Antiglaucoma therapy (β-blockers, carbonic anhydrase inhibitors, oral acetazolamide etc.).
- Antifibrinolytic agents (aminocaproic acid, tranexamic acid).

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- Dilation of the pupil.
- Topical corticosteroids.

47.2 Surgical Technique

If the patient is known to have rubeosis, inject bevacizumab into the AC the day before surgery.

47.2.1 Liquid Blood

The surgeon can choose between monomanual and bimanual techniques.

47.2.1.1 Monomanual Technique

- Make a paracentesis at a convenient location (see **Sect. 39.1**). The paracentesis should be slightly larger than the diameter of the cannula to be used.
- Use a cannula on a 5 or 10 ml syringe.
  - Smaller syringes can also be used, but this will increase the frequency of cannula reinsertion into the AC.
- Irrigate the AC; gape the wound by pressing down on its lower lip with the cannula.

> **Pearl**
> When irrigating the AC, never use too strong a jet stream, and never direct it toward the endothelium.

  - In a phakic eye, be careful not to injure the lens. Avoiding lens damage may be somewhat difficult if the blood is thick and completely blocks the view of the lens.
  - Once most of the blood is out, carefully irrigate the posterior chamber. It can be a reservoir, releasing more blood postoperatively.

47.2.1.2 Bimanual Technique

- Insert an AC maintainer and open the infusion.

> **Q&A**
> Q *What type of AC maintainer is the most optimal?*
> A As long as it is able to supply sufficient amounts of infusion, it does not matter. However, the “threaded” type (see **Sect. 39.1**) has a reduced risk of accidentally being pulled out as the surgeon rotates the eye during the irrigation.

- Prepare the working paracentesis superotemporally as described above.
- Insert the cannula and irrigate the AC as described above.

47.2.2 Clotted Blood

Only bimanual technique is possible (see **Fig. 47.1**; “bimanual” here means that are two tools in the AC).

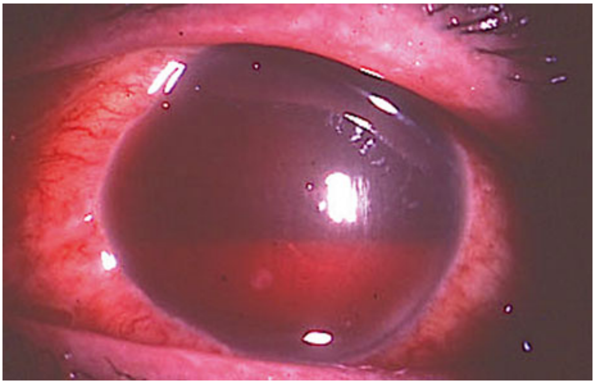

Fig. 47.1 The blood in the AC is partially clotted. While irrigation will result in partial removal of the hemorrhage, the blood seen inferiorly will require the use of the probe

- Insert an AC maintainer as described above.
- Prepare the working paracentesis superotemporally as described above.
- Insert a probe.[1]
  - Always keep it in the correct plane, avoiding both the corneal endothelium anterior and the iris/lens posterior to it (see **Fig. 2.1**).
  - Turn and keep the port *sideways*, never up or down.
  - Aspirate first, and do not activate the cutting function until the clot is firmly grasped (port well occluded). This avoids a sudden drop in the IOP with resulting collapse of the AC as well as prevents cutting into the iris or the lens.
  - Start in the epicenter where the AC is the deepest and gradually move toward the angle 360°.
- Irrigate the AC before the AC maintainer is withdrawn.

The blood in the AC is partially clotted. While irrigation will result in partial removal of the hemorrhage, the blood seen inferiorly will require the use of the probe.

[1] It is a futile attempt to remove the clot with a forceps.

Iris Abnormalities

48

48.1 General Considerations

48.1.1 The Important Functions of the Iris[1]

- Regulating the amount of light reaching the retina.
  - Persons with a permanently wide pupil (and good retinal function) complain of photophobia, which may be prohibitively bothersome.
- Separating the anterior and posterior compartments of the eye.
  - This used to be important to prevent VEGF-like factors from entering the AC and making new vessels grow anteriorly; now the main purpose is to prevent silicone oil touch.
- The iris is increasingly used as a secure platform to carry an IOL (see **Sect. 38.6**).
- Last but not least, the iris is important cosmetically.
  - Cosmesis is an often-neglected issue, although for many people it has great significance.

The VR surgeon is frequently the one who needs to restore the iris diaphragm, irrespective of whether the tissue has been traumatized by an injury or a therapeutic intervention.[2] Three conditions are discussed in detail in this chapter.

48.1.2 Timing of Iris Reconstruction

Too early constriction of the pupil, or making it too narrow, may interfere with subsequent examination of, or surgery on, the posterior segment. With one exception, the general rule is that surgery on the iris should be delayed until the retinal condition is assumed to be "final." The exception concerns the trauma-related "disappearance" of the iris (see **Fig. 48.1**).

[1] The shape, size, location, and mobility of the *pupil* are inseparable from the condition of the iris.

[2] Too intensive laser in the horizontal meridian (see **Sect. 30.3.3**) or damage during phaco.

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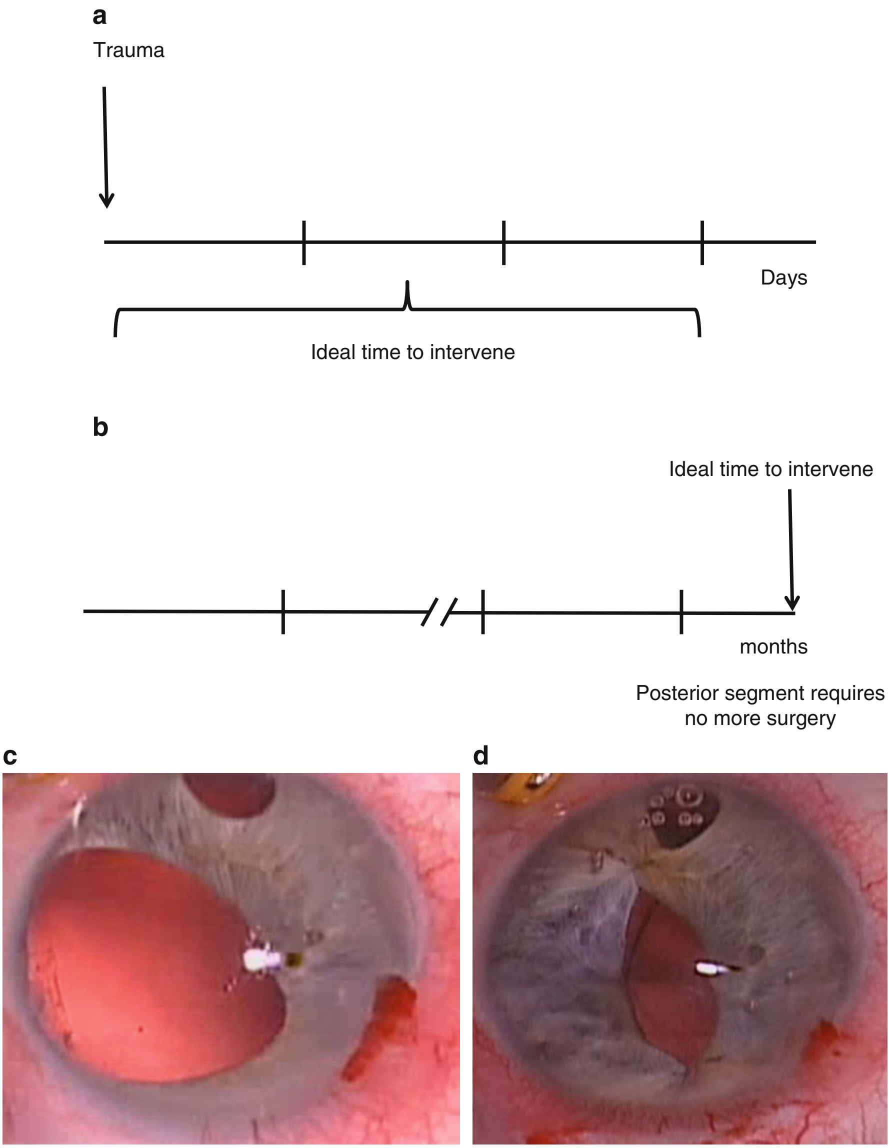


Fig. 48.1 **The "bimodal" timing of iris reconstruction**. (**a**) In a traumatized eye with a "disappeared" iris, the intervention should be very *early* to break the fibrinous membrane that retracts the tissue, using a forceps to pull the iris toward the center. (**b**) In all other cases of a too wide pupil, it is best to suture the dilated iris only *after* the condition of the posterior segment is reasonably deemed "final"; this may be weeks or months, possibly even years away. (**c**) An example of the "disappearing iris" after trauma; the eye underwent silicone oil explantation due to PVR years before. (**d**) Very early intervention (the iris was gently pulled with forceps) during the original surgery resulted in a cosmetically and functionally acceptable outcome. The iris was finally sutured after oil removal

Pearl

An iris that has disappeared after a severe open-globe injury may indeed have been expelled. However, it is often invisible simply because it retracted from view. This is a condition that needs to be addressed early; otherwise the *fibrinous* membrane, pulling the iris back toward its root, may become a *fibrotic* one. With a forceps the surgeon can gently pull the iris toward the center, 360°. Once the membrane turned fibrotic, the only solution left is the implantation of an iris prosthesis.

48.2 Surgical Technique

The most commonly used suture is a 10/0 (occasionally 9/0) polypropylene thread attached to a long straight (STC-6) or curved (CIF-4) needle.[3] The former is rather difficult to handle since the target tissue is typically quite far from the paracentesis; the further the tip of the needle is away from the fulcrum at the limbus, the more a small movement on the outside will cause a large one inside (see **Fig. 48.2**).

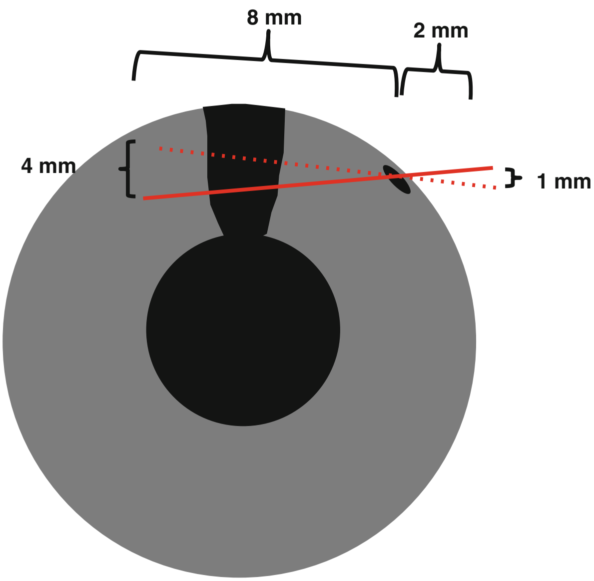


Fig. 48.2 **The needle-related difficulty of iris suturing**. If the intracameral portion of the needle is 4 times as long as the portion external to the limbus, a 1 mm needle movement on the outside will result in a 4 mm movement of the needle's tip – and in real life it is a three-dimensional issue. (The needle length is proportionally illustrated here)

[3] Ethicon/Johnson & Johnson, New Brunswick, NJ, USA. The application of these sutures is described in this chapter.

Pearl
The iris has no wound and therefore does not heal. The surgeon should never leave the suture under tension so that it cheesewires; it must hold the iris "till the end of times."

48.2.1 Iris Laceration[4]

- Enter the AC with the needle one side from the lesion (see **Fig. 48.3**). The entry point should be at some distance from the limbus.
- Pick up the iris on this and then on the other side of lesion; a single-armed suture suffices.
- Exit the AC central to the limbus on the other side of the lesion, with the location mirroring the entry point.
- Create a paracentesis over the lesion, roughly equidistant to the points of iris engagement.
  - Once both are securely out, cut the needle free – but not before. Leave the thread long so that it can be used for a second suture if needed.
- Use a small vitrectomy forceps[5] or a barbed[6] needle to withdraw the suture threads.
- Carefully tie the suture with several knots, trim it,[7] and release the iris.[8]
- Depending on the size of the lesion, multiple sutures may be necessary (see **Fig. 48.4**).

---

[4] In the phakic eye it is advisable to inject a small amount of visco underneath the iris where the needle's passage is expected, to avoid injuring the lens capsule (see **Sect. 39.4**).

[5] The jaws of the forceps cannot be opened if the suture is too close to the paracentesis (see **Fig. 13.3**); it must be the shaft of the forceps, not the jaws, that is inside the corneal opening – unless the paracentesis is made very long.

[6] Make the hook large enough not to lose the suture when you try to exit the AC with the needle.

[7] Leave a tiny part behind, do not trim it right at the knot.

[8] The iris is very elastic and in most cases will tolerate the stretching required for it to be drawn to the paracentesis upon tying the suture. If it does not, you can try to push down the cornea while typing/cutting the knot. The sliding knot does not work well because the iris is not fixed; the only other option is to use two paracenteses and repeatedly withdraw one thread for tying. This is a rather cumbersome and lengthy procedure.

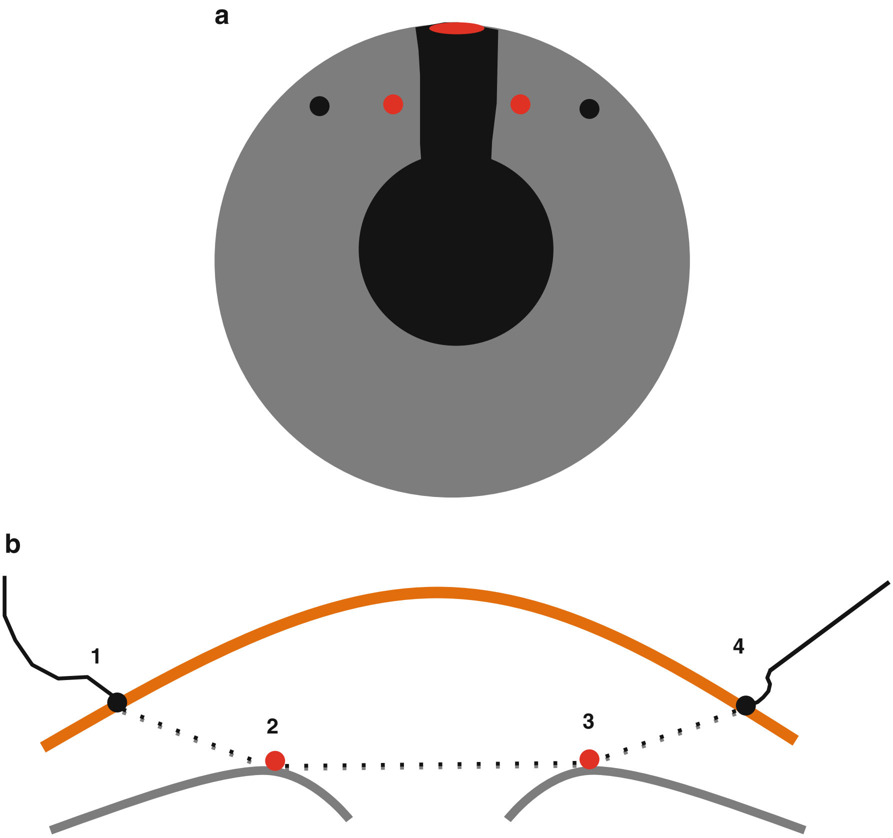


Fig. 48.3 **Schematic representation of suturing an iris laceration or coloboma**. (**a**) The red ellipsis shows the site of the paracentesis through which the suture threads will be withdrawn. The black dots show the points of needle entry/exit in the cornea and the red dots the points where the iris is engaged. Surgeon's view. (**b**) The same maneuver is shown on a cross-sectional view. The reason why the corneal entry (*1*) and exit (*4*) points are rather close to the iris engagement points (*3*, *4*) is because the thread, illustrated by the dashed line in the AC, lies at an angle to the iris plane, not parallel with it. (Traditionally, corneal entry/exit points at the limbus are recommended; in such a case, however, the suture is difficult to capture since the corneal and iris engagement points are almost on the same frontal plane.) While this certainly makes the introduction of the suture more difficult with the straight needle, it makes the catching of the suture much easier. This is less important if the paracentesis is superior or temporal, but very important if it is nasal or inferior

48.2.2 Iridodialysis

- Open the conjunctiva in the proximity of the iris lesion.
- Use a *double-armed* suture. Create a paracentesis on the opposite side from the lesion (**Fig. 48.5**).

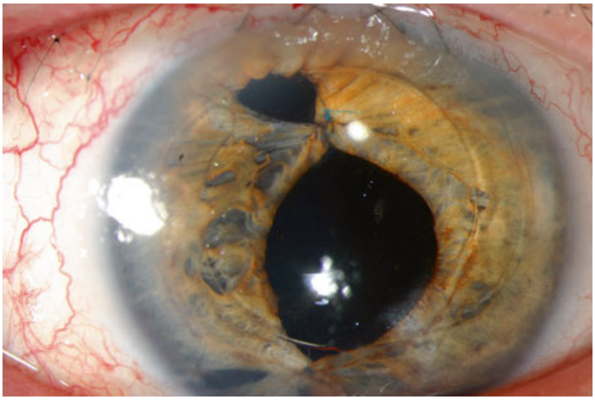


Fig. 48.4 **A large inferior iris lesion more than 10 years after suturing.** The sutures are still visible; a coloboma is also seen since the eye had a silicone oil fill before. An AC IOL has also been implanted at the time of iris reconstruction

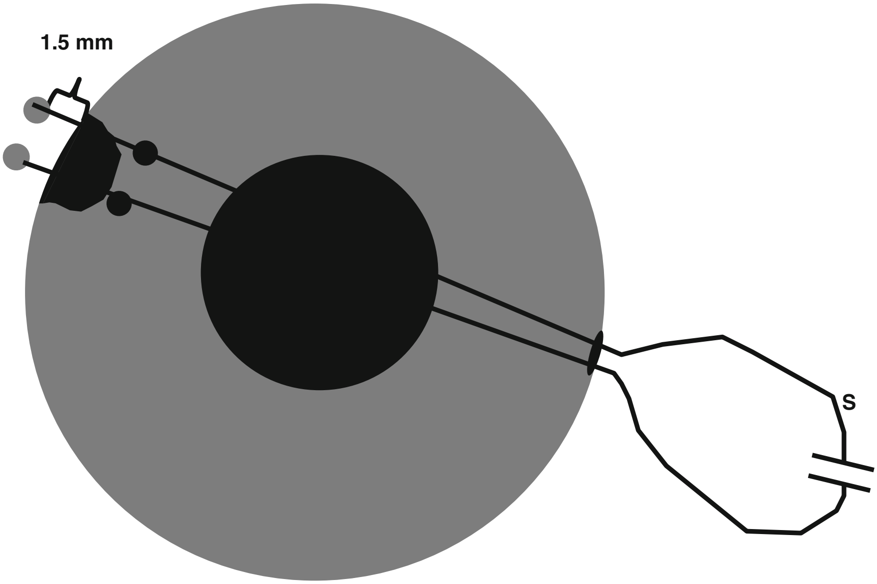


Fig. 48.5 **Schematic representation of suturing an iridodialysis**. The paracentesis is on the opposite side of the lesion. A double-armed needle is introduced, and the iris picked up close to its edge. The needles exit at ~1.5 mm from the limbus and the sutures are tied (see the text for more details; the needle length is proportionally illustrated here). The *black dots* show the needles' engagement points in the iris and the *gray* ones the exit points in the sclera. *S* suture-thread

- As you enter the AC with the needle, make it absolutely sure that you go through the paracentesis, not the cornea; it is very easy with the sharp needle to pick up corneal tissue. Wiggle the needle: if it is inside the wound, it moves freely; if it is caught in cornea, it does not.

- Pick up the iris close to the edge where it was torn, and then exit through the sclera about 1.5 mm from the limbus.
  - A scleral bed up half thickness may be first prepared here so that the knot can be covered.[9]
  - The needle may not be long enough to reach all the way; the sclera where the needle exits should be indented by the nurse so that the surgeon can grab the needle and pull it out.
  - Repeat the same thing with the other needle. The "moment of truth" is when the suture loop reaches the paracentesis: if either needle accidentally went through corneal tissue, the suture will be stuck here and must be discarded only for the entire procedure to be repeated.
- Tie the knot, trim the suture (turn it inside if it fits the intrascleral channel), and close the conjunctiva.

Depending on the size of the lesion, multiple sutures may be necessary.

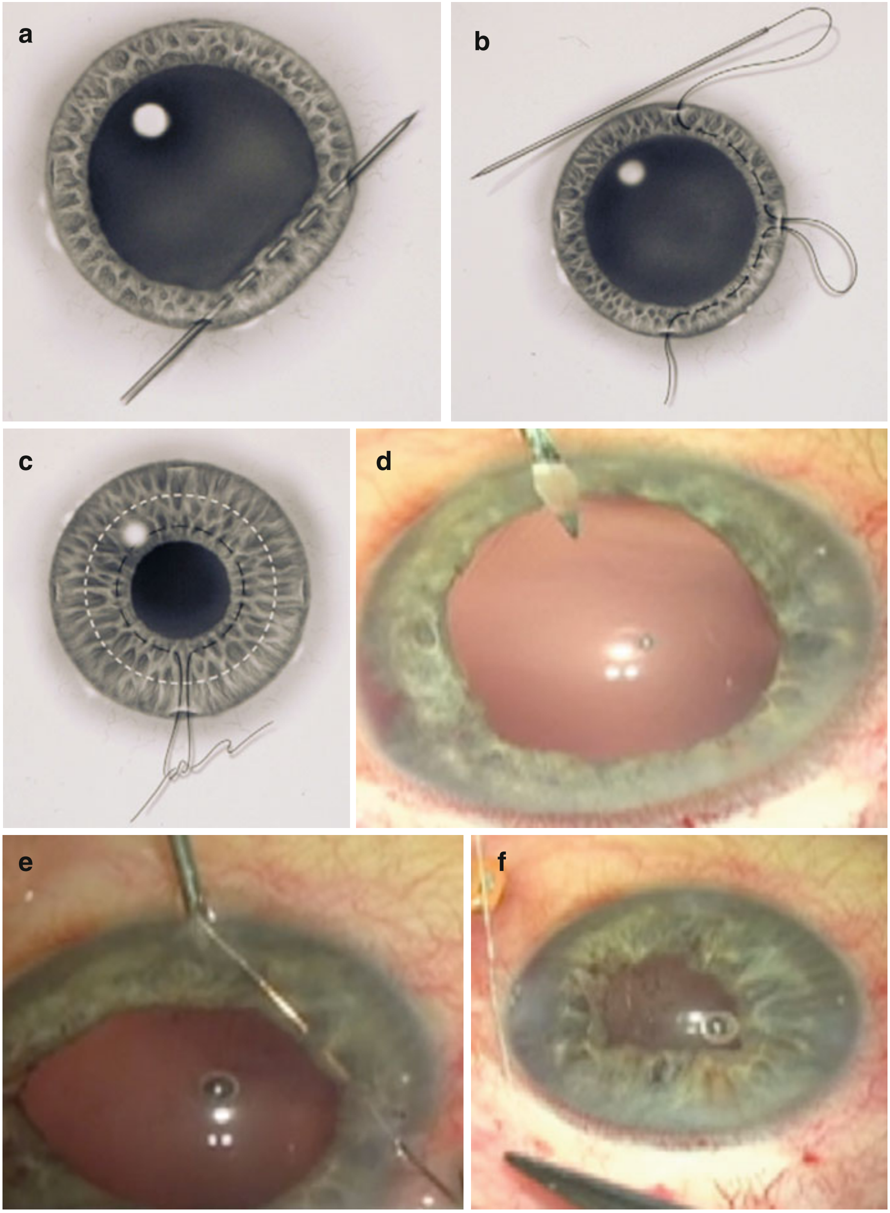
An alternative technique is to open the sclera over the lesion and suture the iris directly. Obviously, this technique has higher morbidity.

48.2.3 Permanent Mydriasis

The surgeon has two options. A few sutures as described above (**Sect. 48.2.1**) at two, opposite locations may constrict the pupil, but it will not be round (see **Fig. 48.1d**.). A more elegant, but technically very difficult, technique is the purse-string or iris cerclage suture (see **Fig. 48.6**).

- Create four paracenteses (at 3, 6, 9, and 12 h).
- Carefully enter one of these, wiggling the needle as described above (**Sect. 48.2.2**), and pick up the iris by weaving in-and-out of it, at two to four locations in the quadrant adjacent to this paracentesis (you can start in either direction). A vitrectomy forceps can be held in your nondominant hand to gently pull up the iris or guide the needle's path.
- Exit the AC at the paracentesis at the far end of the quadrant.
  - Insert a 27 g needle through the paracentesis and bring out the needle so that its tip is buried inside the bore of the 27 g needle, again to avoid penetrating into corneal tissue with the suture-needle.
    - Repeat the procedure in all four quadrants.
    - Tie and trim the suture as described above.

[9] I stopped doing this.



Figs. 48.6 **Iris cerclage**. (**a–c**) Schematic representation of the procedure; see the text for a detailed description. (**d**) The pupil remained wide after a severe contusion in this patient. The fourth paracentesis is made with the MVR blade; the inside of the tunnel will be made wider (not shown here; see **Fig. 39.1c**.). (**e**) The suture has been weaved into the iris in the first quadrant; at 6 o'clock a 27 g needle is used to guide the suture-needle out of the AC. (**f**) The knot is being made to permanently constrict the pupil

Macular Disorders: Edema

49

49.1 General Considerations

49.1.1 Etiology

Macular edema may be caused by a focal abnormality such as traction (see **Chap. 50**), a local condition such as cataract extraction, systemic diseases such as diabetes, and a combination of local and systemic abnormalities such as uveitis. The list of possible causes is very long.

If a definite cause is identified, it should be the primary target of the treatment. This basic principle, however, still leaves open the question of how best to directly treat the edema itself.

49.1.2 Indications for Treatment: Surgical or Nonsurgical?

The answer to this crucial question is controversial on several levels. There is little consensus even among ophthalmologists, and therapeutic decisions are increasingly influenced by insurance companies, health authorities, drug manufacturers, or even politicians (see **Sect. 4.6** and **Chap. 43**).[1] I raise only a few important points to help guide the decision-making process.

- Focal (grid) *laser*, laser maculopexy (see **Fig. 30.2**), and panretinal laser (see **Sect. 30.3.2**), alone or in combination with medical and/or surgical therapy, should always be considered in conditions such as diabetes or vein occlusion.

[1] Just think about the protracted battle fought in many countries over whether to use "Lucentis or Avastin?".

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- *Intraocular injections* represent the first line of treatment today in most cases, but they are a temporary solution for a permanent problem in a disease such as diabetes. Repeated injections must be given over extended periods of time, which involve, among others, the following:
  - Burden on the patient: continual seesawing of the visual function as well as mandated returns for an intraocular procedure to a medical facility. The physical and psychological implications of this rollercoaster must not be neglected (person vs tissue being treated; see **Sect. 5.1**).
  - Burden on the facility[2]: the need to organize the time, personnel, venue, materials (ordering and storage), patient scheduling, cash flow and reimbursement etc. The number of patients and injections seems to never stop increasing as more drugs come to the market and the indication list widens.
- No "level 1 evidence" study looked at the results of surgery vs a drug. All studies evaluated drug A vs drug B, their dosing, or their use based on the presenting VA level.
- The risk and severity of complications are undoubtedly greater with surgery than with an injection. It is, however, false to compare the complication risk between surgery vs a single injection. No patient receives a single intravitreal injection for ME.
- *Surgery* is much more difficult to unequivocally define than a drug's dose. If the surgical procedure proves to be ineffective, the blanket claim that "surgery does not work" is no more correct than suggesting that "drugs do not work" if a single medication is found ineffective.[3] The conclusion, correctly, is that "this kind of surgery does not work" or that "surgery at this late stage of the disease does not work."
- Surgery should not be considered as a last resort.[4] The prognosis is best when the intervention is done before the macula suffers irreversible damage.
  - Surgery, if done early[5] and well, has a very good chance of being a one-time cure.
  - If surgery fails, all other treatment options are still available.

49.2 Surgical Technique[6]

- If logistically feasible, dry the macula preoperatively.[7]
- Do a vitrectomy with TA-confirmed detachment of the posterior hyaloid.
- Stain and remove the ILM in the macular area.[8]

[2] It all can be summarized by the term "logistics": the detailed coordination of a complex operation involving many people, facilities, and supplies, as well as their financing.

[3] No sane person would declare that, based on his experience driving a Fiat Uno, "cars cannot exceed a speed of 200 km/h." Everybody knows that driving a Porsche 911 is an entirely different matter.

[4] When all else has failed.

[5] Surgery is considered as the initial treatment. The otherwise progressive condition is in its early stage and the vision is still good. In my own large series of patients who underwent PPV with ILM peeling and laser maculopexy, none required treatment for macular edema postoperatively if their visual acuity was 0.6 or greater preoperatively.

[6] See also **Chap. 50** and **Sect. 52.2.** The technique described here is most applicable in conditions such as diabetes, vein occlusion, uveitis etc.

[7] Intravitreal anti-VEGF or TA injection.

[8] See also **Sects. 32.1** and **34.3.**

Pearl
The retina in an eye with chronic macular edema is unhealthy: you must be much more delicate with your maneuvers than if the tissue were healthy (e.g., macular hole is the indication for ILM peeling).

– Start the peeling well away from the fovea (see **Fig. 49.1**).
– Be very slow when peeling over the fovea, especially if it has large cysts[9]: the top of the cyst is extremely thin, and you must avoid unroofing it.[10]

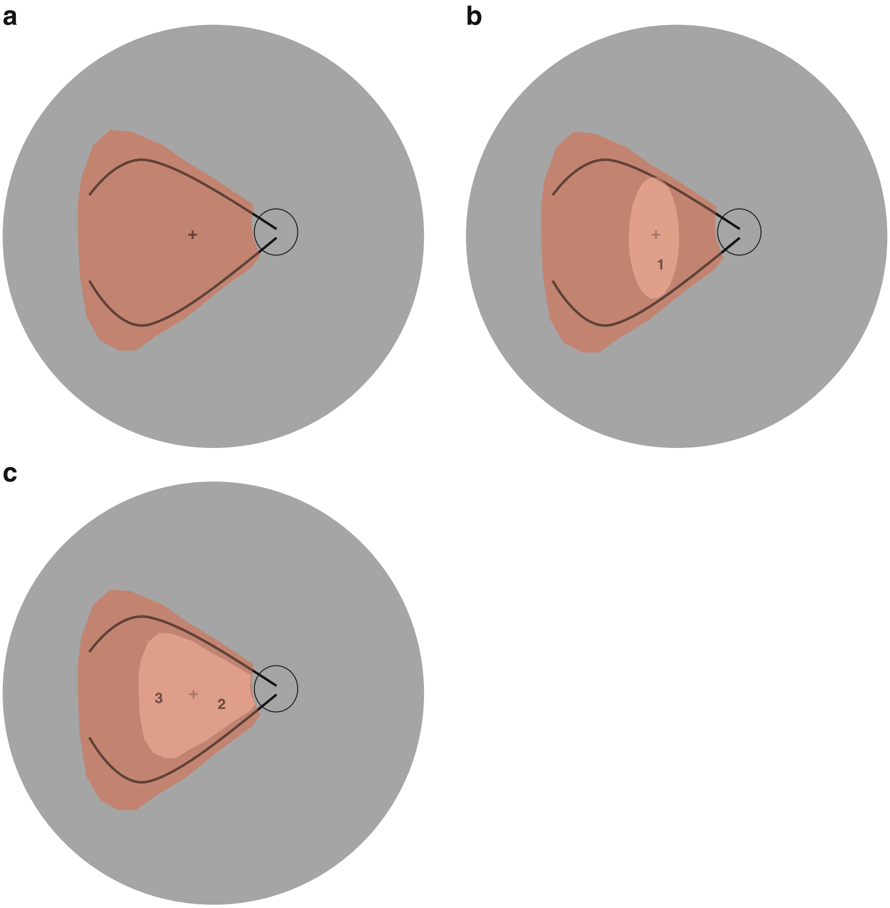

Fig. 49.1 **Peeling the ILM in an eye with severe diabetic macular edema** (this is my personal technique). (**a**) The red area shows the extent of the edema. (**b**) The initial peel is across the fovea (*1*), starting superiorly. (**c**) This is followed by two semicircles (*2*, *3*). It is not necessary to peel the entire area where edema is present, especially toward the temporal side

[9] The cysts appear to the surgeon as gray circles (see **Fig. 49.2**).
[10] If it does happen, a small amount of somewhat viscous fluid is seen entering the vitreous cavity.

– If the ILM is very adherent, it may elevate the retina slightly (tenting), and a fine white line is seen along the separation border between ILM lifted and still in situ (see **Fig. 49.3**). If such a white line is present, you should proceed even more cautiously, and the vector of the peeling should be even more parallel to the retina (see **Fig. 49.4**).

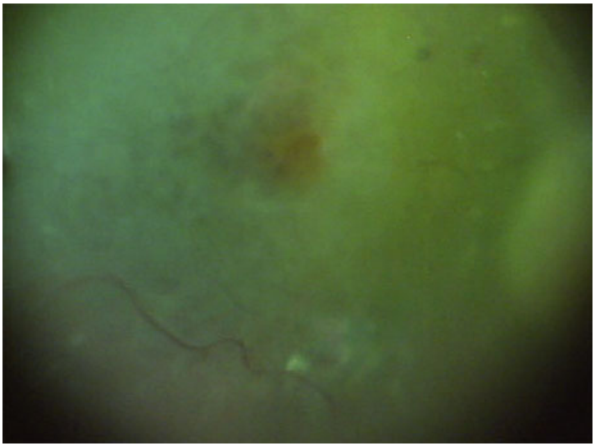

Fig. 49.2 Intraretinal cysts in macular edema. The cysts containing viscous fluid appear as *dark circles*, especially visible temporal to the fovea in this intraoperative image

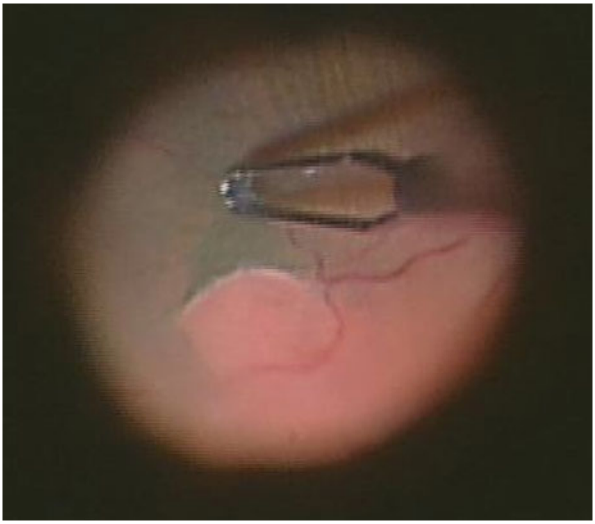

Fig. 49.3 Peeling the adherent ILM over an area of macular edema. The underlying retina is more fragile than in an eye without edema. The retina often tents as the forceps is pulling on the ILM; this is detected by the surgeon as a white line that snakes perpendicular to the main vector of the peeling. Such an image should make the surgeon even more careful to avoid tearing the retina or unroofing a cyst

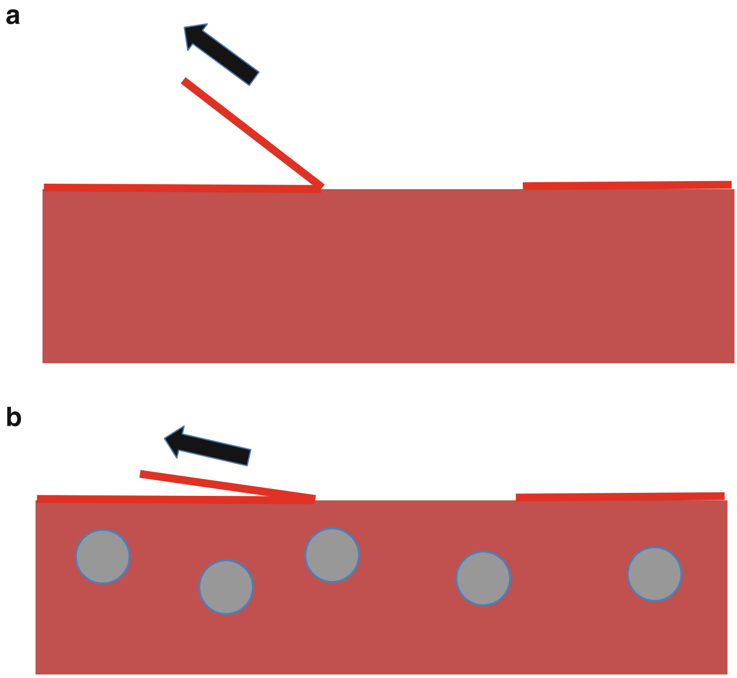

Fig. 49.4 **The vector of ILM peeling in normal and in edematous retina**. (**a**) The vector in an eye with healthy retina the vector is close to 30° (*arrow*). The ILM is represented by a *red line*; the forceps is not shown. (**a**) If the retina is edematous, and especially if it is cystic (represented by the *gray circles*), the vector must be much closer to being parallel to the retina. Remember that the surface is concave, and avoid bumping the retina with the forceps (see **Fig. 32.6**)

  - The retina has a convex, not a concave, contour: as you peel[11] toward the fovea, keep in mind that you must lift the forceps (up closer to yourself; see **Fig. 49.5**).
  - Peel up to the vascular arcades.
- Consider performing laser in all affected areas (see **Fig. 30.1**).

[11] Moving the tip of the forceps parallel to the surface and keeping it very close to it.

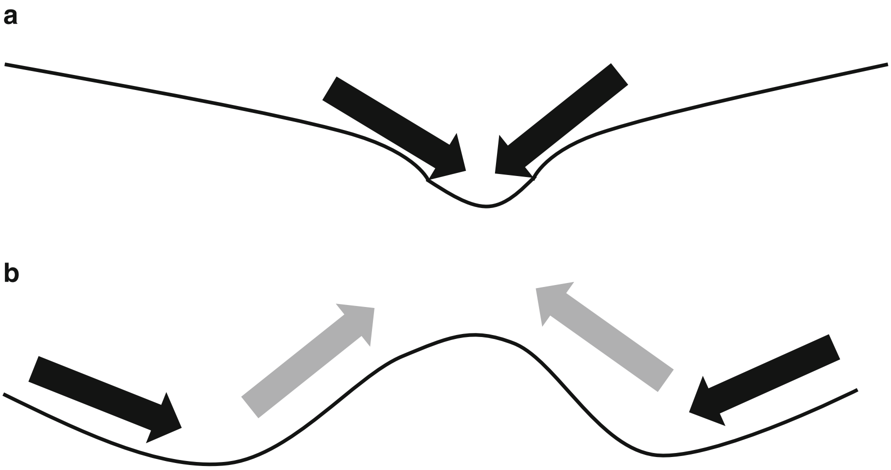

Fig. 49.5 **Peeling the ILM over a convex surface** (cross-sectional, schematic representation). (**a**) The normal macular contour is concave; when the ILM is peeled toward the foveola (centripetal direction), the tip of the forceps is moved further *away* from the surgeon ("downhill"; *black arrows*). (**b**) In severe edema, the macular contour is akin to an elevation. When the ILM is peeled toward the foveola, the tip of the forceps must be moved *toward/closer to* the midvitreous cavity; as seen from the surgeon's perspective, peel "uphill" (*gray arrows*). Since the surgeon views this from above, the change in the actual geography of the macula is difficult to appreciate. In a macula with a foveal thickness of 600 μ, the ILM is ~4× closer to the surgeon than it would be in an eye with normal retinal thickness

Macular Disorders Related to Traction: VMTS, Cellophane Maculopathy, EMP, Macular Hole

50

50.1 General Considerations

The question whether to surgically intervene for a macular condition should be decided based neither on the appearance of the posterior pole nor on the VA level.[1] Appearance can be deceiving in both directions: what looks like a horrible anatomical situation may still permit good vision; conversely, even a seemingly minor abnormality may cause severe visual loss.

Pearl

In macular diseases where traction plays a part, metamorphopsia is usually more important for the patient's quality of life than the VA; it is therefore imperative that the ophthalmologist not focus on the VA alone when determining the severity of the condition. This also helps to avoid the sadly common habit of using an arbitrary cutoff VA value to indicate or deny surgery (see **Chap. 5**).

50.1.1 VMTS

The condition is characterized by an anomalous PVD with strong focal residual adherences to the central retina. The central vitreous may prolapse through an opening in the posterior vitreous cortex and adhere to the foveal region. OCT is a great tool in showing the condition preoperatively and the results of surgery (see **Fig. 50.1**).[2] The posterior cortical vitreous has a sheet-like appearance, which can

[1] A very typical example of what should *not* be said by the ophthalmologist is this quote: "surgery is usually reserved for patients with vision worse than 20/40."

[2] The OCT image may show similarities to that seen in a central RD (see **Sect. 56.1**), and cataract extraction may exacerbate the traction by increasing the space available for vitreous movement.

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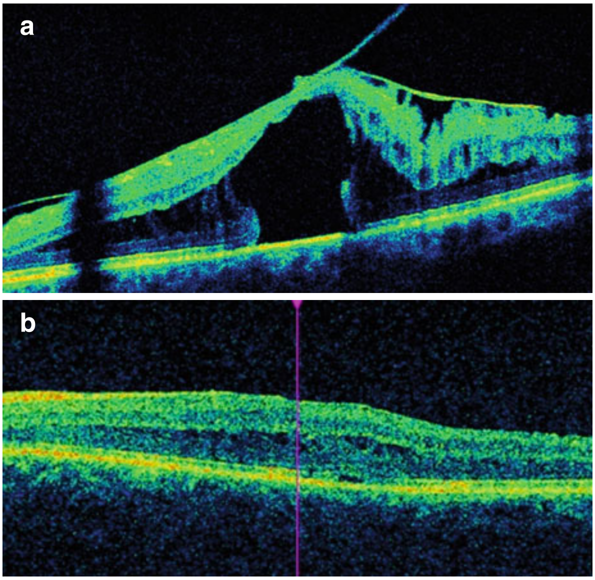

Fig. 50.1 **OCT imaging of an with VMTS**. (**a**) Preoperative image showing severe traction on the fovea. The retina is elevated and shows cystoid changes. The split in the posterior cortical vitreous is clearly seen (on the right of the image, a vitreoschisis cavity has formed). (**b**) The image 1 month postoperatively shows a much improved retinal contour; the functional improvement, however, is primarily determined by the duration of the pathology. Do the operation late and the vision will barely improve

be traced all the way to the vitreous base. The problem is therefore *not* confined to the posterior pole; the risk of causing a retinal tear is increased throughout the fundus.

In VMTS intravitreal ocriplasmin (enzymatic vitreolysis) has a decent chance of success, especially if the area of vitreomacular adhesion is less than 1,500 μ.[3]

50.1.2 Cellophane Maculopathy

Defined here as "surface-wrinkling maculopathy," it may be a standalone pathology or the initial step in the formation of a macular pucker. No scar tissue is visible but the retinal surface (ILM) is wrinkled (see **Fig. 50.2**), and the patient may experience metamorphopsia.

50.1.3 Macular Pucker

In this condition a true scar forms over the macular surface, which is why many surgeons call it a "mini PVR." The scar contracts and causes anatomical (edema, retinal folds, hemorrhages, ectopia, corkscrew-like configuration of blood vessels etc.; see **Fig. 50.3**) and functional (drop in VA, metamorphopsia) abnormalities. The

[3] The injection is very expensive; this and the rate of success must also be considered when the decision between observation, injection, and surgery is contemplated.

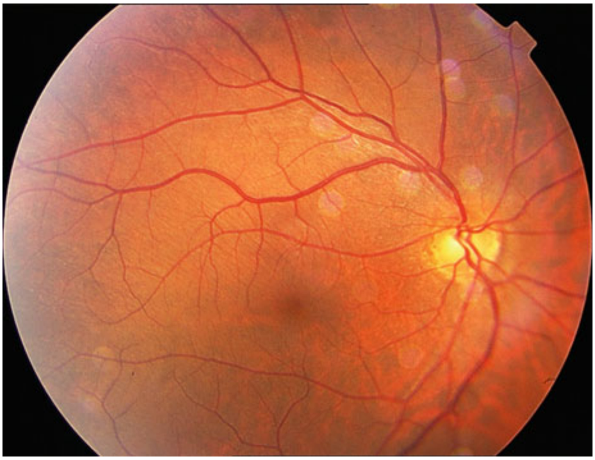

Fig. 50.2 Cellophane maculopathy, preoperative view. Very fine folding of the ILM is visible, especially in the superotemporal area. The folds are not full thickness as EMP-induced folds would be

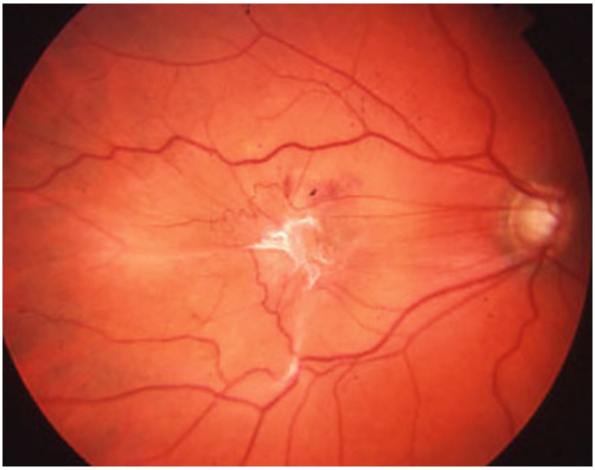

Fig. 50.3 EMP causing severe changes in the macular anatomy. This a rather centrally located scar, which is understandably responsible for a loss in VA. The metamorphopsia it also causes is explained by the traction the contracting scar exerts on the retina, leading to full-thickness folds, hemorrhages, and distorted vessels

membranes are made mostly of collagen with relatively few cells. They may be secondary to a disease[4] or treatment[5] but in most cases they are idiopathic.

Some ophthalmologists started giving patients with EMP intraocular anti-VEGF injections (see **Chap. 43**). This medication indeed helps temporarily if the edema is the main culprit in the reduction of the VA. However, recurrence of the fluid is inevitable, and the retinal changes that manifest themselves as metamorphopsia for the patient will not be addressed by any type of medication. The only chance for a definite cure is surgery.[6]

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[4] Such as RD, VH, and trauma.

[5] Such as SB, panretinal laser.

[6] Ocriplasmin is not a viable option since the condition is not caused by *VR* traction, and the vast majority of the cases already have a spontaneous PVD when the patient presents.

50.1.4 Macular Hole

VR as well as tangential (surface) traction causes the retraction of the retina from the epicenter; it is often accompanied by an EMP.[7]

50.2 Surgical Technique[8]

50.2.1 VMTS

- Start the vitrectomy in front of the posterior pole and create a small pocket just above the macula.
  - The fovea is already under severe traction: start cutting as soon as you start aspirating.[9]
- Inject a minimal amount of TA so that the vitreomacular interface is clearly delineated.
- Severe the connection between the posterior vitreous and the retina.
  - It may be necessary to use scissors if the posterior cortical vitreous has formed a strong, distinct sheet. There is greater control if the cutting is done with scissors. Use of the probe is limited anyway because it is impossible to "sink its teeth into the membrane" as no edge is available (see **Fig.** 38.2b, right hand side).
- Once the macula is freed from all vitreous adhesions, continue with a careful PVD.
  - As mentioned above (**Sect.** 50.1.1), strong adhesion between the membrane-like posterior hyaloid cortex and the retina can exist anywhere. Be slow with the PVD and do not try to carry it too far anterior; even then, the adhesion between retina and the cortical vitreous is similar to two sheets of paper glued together. The strength of this adhesion is shown by the appearance of small hemorrhages as you try to detach the hyaloid, forcing you to choose from two options: continue with the PVD and risk an intraoperative retinal tear formation, or leave the adhesion behind and risk that tears occur postoperatively.[10] The dilemma is similar to that described under **Sect.** 32.3.1.4, except that in the case of a VMTS retinectomy is not an option any surgeon would prefer choosing.
  - Be mindful that if the condition has been present for a long time, the central retina may a have convex, rather than concave, configuration.[11] This is important to keep in mind both for the creation of the PVD and the peeling of the ILM.

[7] If the latter is sparing the fovea, it is called a pseudohole; OCT enables the ophthalmologist to determine whether a true, partial-thickness, or pseudo-hole is present.

[8] See **Chap.** 32 for many additional details.

[9] Aspiration without simultaneous cutting, as is done during PVD, is contraindicated.

[10] Neither is an appealing choice. Logic would tell you that having the problem intraoperatively is favorable since at least no vitreous is left behind and the tear can immediately be treated. However, it may truly be impossible to separate the vitreous from the retina, which only aggravates the problem.

[11] Much like in an eye with severe macular edema (see **Fig.** 49.5).

- Trim the remaining vitreous as much as possible.
- Stain and peel the ILM up to the vascular arcades.
  – The retina may be fragile, especially if the condition is long-standing.
- Consider prophylactic laser cerclage (see **Sect. 30.3.3**).

50.2.2 Cellophane Maculopathy

- Perform a minimal to subtotal PPV.
- Stain (this makes the microfolds much more visible; see **Fig. 50.4**) and remove the ILM in the macular area.

Q&A

Q *Why are the ILM folds more visible after staining than before?*

A The dye pools in the "valleys" of the wrinkled surface while the ridges show only minimal staining (see **Sect. 34.3**).

  – The wrinkled ILM must never be grabbed with the forceps jaws being parallel to, only perpendicular with, the direction of the folds (see **Sect. 34.3** and **Fig. 32.10b**, **c**).

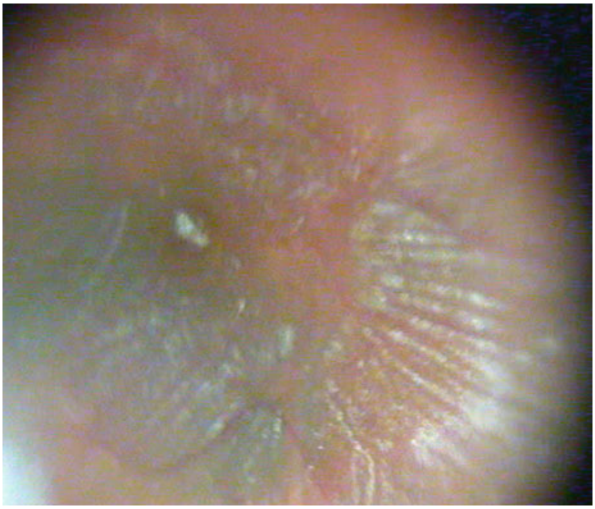

Fig. 50.4 **Cellophane maculopathy, intraoperative view**. The folds are more clearly visible after ILM staining; the remaining TA crystals are also helpful in showing the partial-thickness retinal folds

50.2.3 Macular Pucker

- Most of these eyes already have a PVD; still, make sure that a PVD has occurred.
- Perform a minimal to subtotal PPV.

- Remove the epimacular membrane (see **Sect. 32.2** for details).
  - If you want to see the true size of the membrane, switch the light pipe to the other hand; the light now arrives at a different angle and may give a better view of the membrane.[12]
- Stain and remove the ILM.
  - While this is not an absolutely necessary step, it ensures that no proliferation is left on the surface[13] and that no recurrence occurs.

Q&A

Q *Should you leave gas after the EMP has been removed?*

A If the ILM has been peeled, gas "tamponade" and positioning are really not necessary. There is nothing wrong employing them, however – except if the membrane has caused a true retinal elevation in the center and stretched the retina. If gas is used, this may cause a retinal fold.

50.2.4 Macular Hole

- Start the vitrectomy in front of the posterior pole and create a small pocket just above the macula.
- Create a PVD.
- Perform a minimal to subtotal PPV.
- Stain and remove the ILM.
  - The macula is usually healthy, making the ILM removal relatively easy.
  - Still, the hole may be enlarged if traction is exerted on the edge; always peel in a centripetal, never in a centrifugal, direction (see **Fig. 50.5**).
  - The ILM may be missing in a tiny circle around the hole.
  - Extend the peeling area up to vascular arcades.[14]
  - Some surgeons use a variation of this technique by peeling only on one side of the hole, turn upside-down the still-attached portion of the ILM, and cover the hole with it ("inverted flap").
- Perform a F-A-X.
  - I use a soft-tipped extrusion needle to drain all remaining subretinal fluid ("cuff"); this also prevents ICG from persisting subretinally (**Sect. 34.3.3.**). Such drainage should be done only if visualization is optimal, which requires adjusting the BIOM.[15] The RPE must never be touched with the silicone tubing; hold the tip just above the hole, never inside it (see **Fig. 50.6**).
  - Often the hole closes intraoperatively as a result of the aspiration.

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[12] A superior solution is to use the slit lamp for pucker removal (see **Sect. 17.2**).

[13] Remember, the EMP may be multilayered.

[14] Some surgeons peel a much smaller area. The fact that when the hole does not close after the first surgery and these very same surgeons peel in a larger area during reoperation suggests that the initial failure could have been avoided by a larger peel.

[15] Upward movement of the front lens (see **Sect. 31.2**).

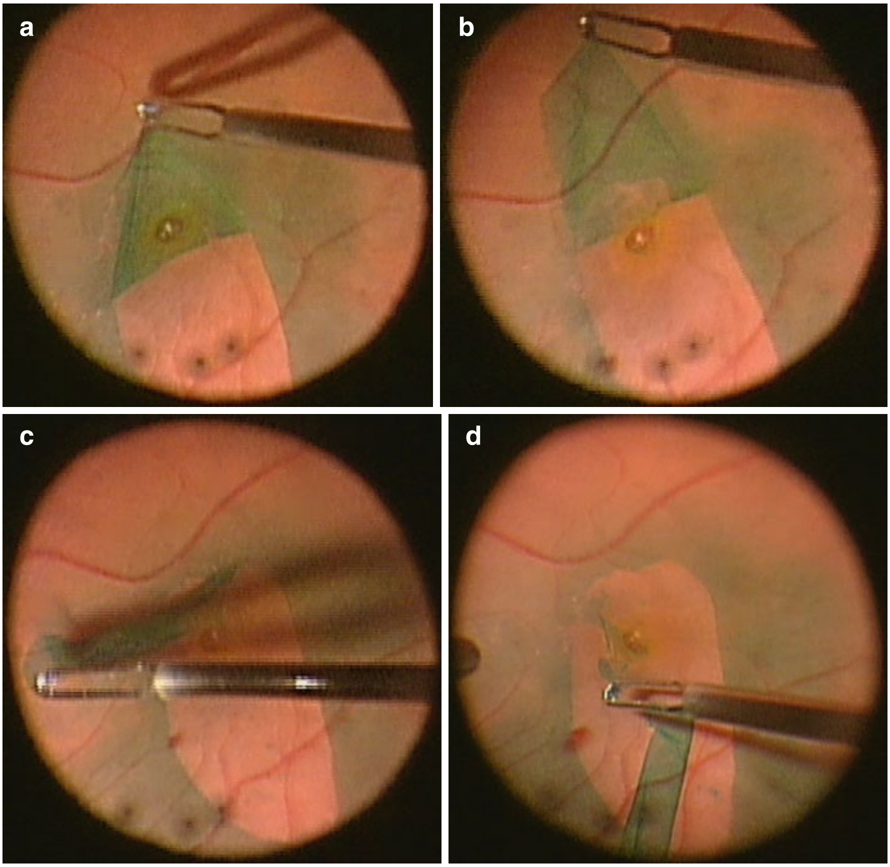

Fig. 50.5 **Peeling the ILM in an eye with a macular hole**. (**a**) The initial step is the creation of a vertical strip toward the hole (centripetal direction). (**b**) As soon as the ILM separation, which is done very slowly when being close to the fovea, reaches the hole, the peeling stops. (**c**) The direction of the peeling, which was from 12 o'clock toward 6 o'clock before, changes to a sideway direction (from 9 o'clock toward 3 o'clock from the surgeon's point of view). (**d**) Once the ILM has been separated at the inferior edge of the hole, the direction of the peeling is changed again, and the ILM is pulled toward 12 o'clock. With this motion, the ILM adjacent to the hole has been completely lifted; the peeling area can then be extended toward the vascular arcade (not shown here)

- Use gas for tamponade and repeat what you told the patient preoperatively about positioning.

Pearl
I ask them to be facedown for 1 week. It is possible that a shorter period also suffices, but I explain to my patients that this inconvenience is their contribution to the cure. They will not have to blame themselves postoperatively in case of a failure: "Maybe if I had indeed positioned longer…."

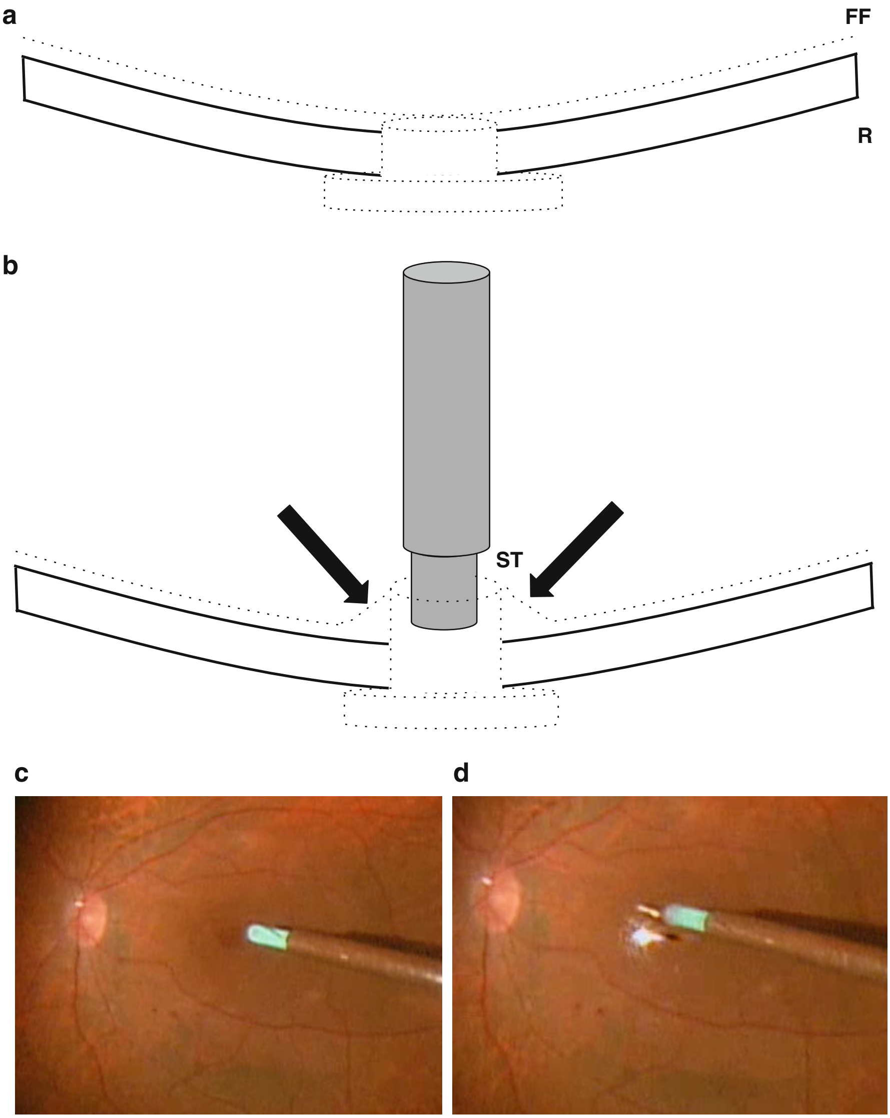

Fig. 50.6 **Draining the subretinal fluid through the macular hole**. (**a**) On this schematic image a thin fluid film (*FF*) still covers the retinal surface (*R*) after F-A-X. There is also fluid inside the hole and underneath the retinal edge around the hole ("cuff"). (**b**) The soft-tipped cannula (*ST*) is dipped into the fluid meniscus above the hole. The capillary action of the flute needle results in instant drainage. The contour of the fluid film changes from a purely retina-parallel one into a concave contour around the silicone tube (*arrows* pointing to the "shoulders" of the uplifted fluid), showing the cohesive attraction between the tube and the fluid. (**c**) Intraoperative image showing how the surgeon recognizes whether the tip of the silicone cannula "touched water" or is still in air, as in this picture. (**d**) Once the soft tip of the flute needle reaches the fluid film and its contour changes, light is reflected back from the fluid shoulders, instantly informing the surgeon that he must not push the cannula any deeper. As long as this position is maintained, the fluid will drain. However, because fluid keeps on flowing toward the fovea from the entire retinal surface, the maneuver must be repeated several times

  – Often it is easy to determine whether the patient followed the request or not; if he did position, debris can be seen on the endothelium (positional keratopathy; see **Fig. 50.7**).

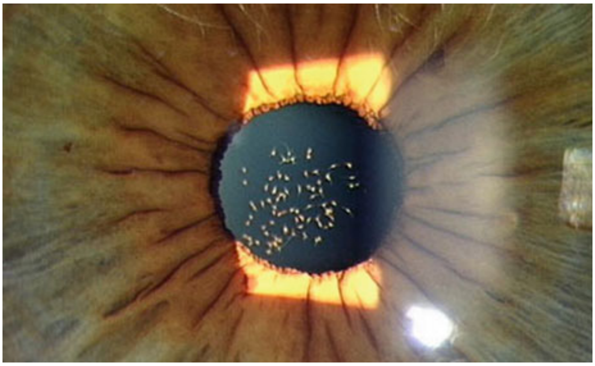

Fig. 50.7 Positional keratopathy. The debris is heavy, and it tends to settle around the deepest point of the cornea. Its presence is an indicator to the surgeon that the patient positioned and whether his head has truly been held in the horizontal plane. If he has "cheated" and the head has been held at an acute angle, the debris collects more inferiorly

- If a patient is unable or unwilling to position, silicone oil may be used as tamponade.
  – The oil may be removed within a few weeks.

50.2.5 If Surgery Failed for a Macular Hole

Even with the best technique and most cooperative patient, there are unsuccessful primary surgeries. Below is my personal technique in these cases. This approach is successful in ~2/3 of the cases.

- Restain the ILM to make sure that it was indeed peeled completely.
  – If an eye underwent surgery before with the inverted flap technique, I remove the ILM in the entire macular area, and then complete the procedure as if this were the first operation.
- Drain the subretinal fluid (see above).
- Take a 23–25 g needle and create 6–8 radial cuts of ~0.5 mm around the hole (see **Fig. 50.8**).
  – The cuts are planned to be of only minimal depth.
  – The goal is not to move the retina so that the hole closes on the table but to cause just enough trauma that leads to the formation of a very fine gliosis, which in turn closes the hole.
- Perform a meticulous F-A-X and then exchange the air to silicone oil.
  – No positioning is needed.
- Remove the oil in ~1 month.

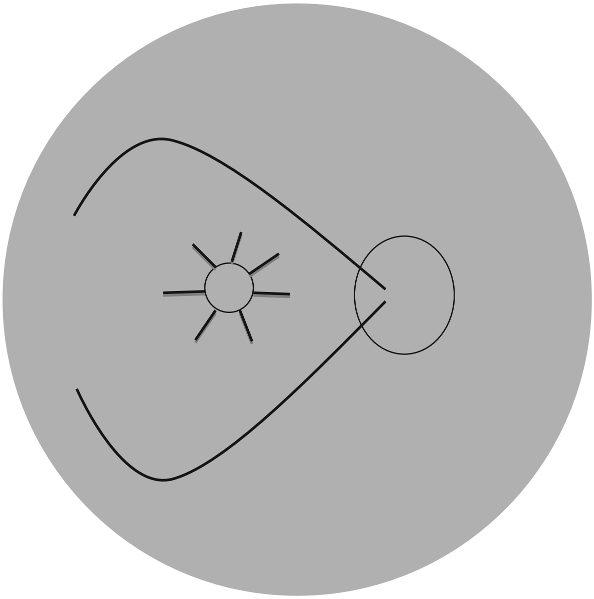

Fig. 50.8 Radial cuts around a macular hole in case of a reoperation. See the text for more details

Optic Pit

51

51.1 General Considerations

In this condition liquid is channeled through the optic pit[1] (see **Fig. 51.1**) under the macula and into the retina itself[2]; it is most probably liquor. The subretinal fluid is different in its composition from that in RD; the visual acuity can chronically remain excellent despite the serous detachment. Eventually, however, there will be extensive RPE abnormalities and permanent loss of vision (**Fig. 51.2**).

> **Pearl**
> The acute drop in VA, signifying the sudden accumulation of fluid under the previously dry macula, often follows straining; Valsalva maneuvers should be strongly discouraged in patients with optic pit.

Observation is thus a reasonable option for a while, but extended periods[3] of persistent or often-recurring subretinal fluid strongly argue in favor of surgery, as does the development of a macular hole. There are numerous variations in the type of surgery; the technique I am describing below has a very high chance of permanent success.

[1] The correct term is "optic disc pit." In clinical practice this short version is used.

[2] This leads to calling it "retinoschisis" by certain authors. In reality it is simply edema, not a schisis: the nerve connections are not severed, there is no absolute scotoma, and improvement with timely treatment is full.

[3] Several months.

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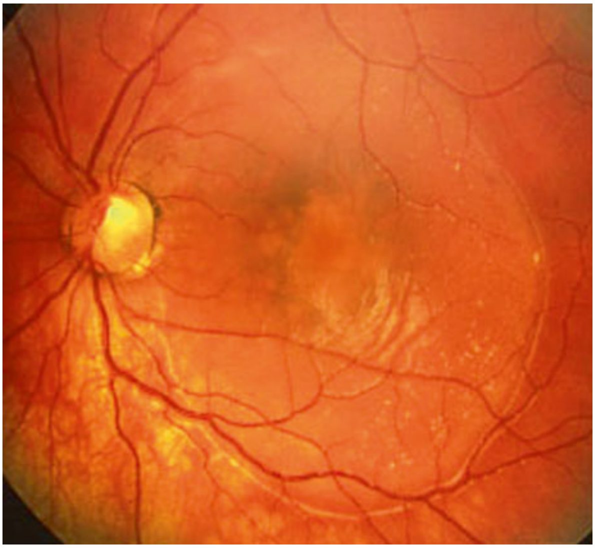

Fig. 51.1 Optic pit and related serous detachment of the macula. The pit, visible as small whitish-grayish area just temporal to the emergence of the blood vessels on the disc, caused a long-standing macular detachment. The border of the detached is clearly delineated; the chronicity of the condition is shown by the secondary pigmentary changes around the fovea and the presence of subretinal precipitates

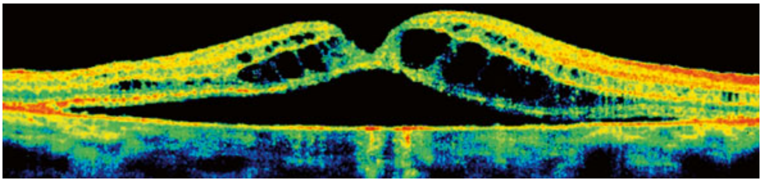

Fig. 51.2 OCT image of the macular changes in an eye with optic pit. There is subretinal and intraretinal fluid. Obviously, the condition is not a true retinoschisis, simply large areas of (confluent) cystic retina

51.2 Surgical Technique

- Perform a subtotal PPV with the creation of a PVD.
  – PVD is not easy in these eyes[4] but must carefully be completed nevertheless.
- Perform laser treatment at the disc margin (see **Fig. 51.3**).
  – The goal of the laser treatment is to "close the gate" and prevent the fluid to be channeled from the pit cavity into the sub- and intraretinal spaces. Without proper laser walling-off, the recurrence rate is much higher.

[4] The widespread, strong posterior vitreoretinal adhesion tempted several surgeons to suggest a role for VR traction in the pathogenesis. It is more likely, though, that the phenomenon is explained by the young age of the patients; traction in other diseases very rarely leads to the accumulation of *subretinal* fluid.

Fig. 51.3 **Laser treatment for an optic pit-related macular detachment**. The treatment should consist of confluent spots, at least two rows, and carried beyond the vertical line bisecting the disc between 6 o'clock and 12 o'clock (between 11 and 7 o'clock in this picture). If a smaller area is treated (only a *semicircle*), the fluid may find its way around it and cause a recurrence

  – In eyes with a long history of subretinal fluid (many months, even years), the fluid is very thick and will not absorb for months; the laser treatment will thus be ineffective. In these eyes it is necessary to create a small retinotomy inferotemporally to the fovea in the macular area and actively aspirate the fluid.
  – The laser spots should not be very strong; the nerve fibers are thus spared and the only consequence to the patient is an enlarged blind spot.
- Gas tamponade should be considered to help push the subretinal fluid inferiorly (see **Fig. 51.4**), out of the visual center and out of the area adjacent to the temporal disc margin (see **Sect. 30.3.1**).

Fig. 51.4 **Postoperative appearance of an optic pit-related detachment with residual subretinal fluid**. The gas bubble (not visible anymore) has successfully pushed the fluid out of the maculopapillary bundle, but the fluid still persists inferiorly. If the submacular fluid recurs, the surgeon knows that the initial surgery should have included drainage of the subretinal fluid through a small retinotomy

PDR

52

52.1 General Considerations

52.1.1 Indications

There are several possible indications for PPV in patients with diabetes: macular edema (see **Chap. 49**), vitreous hemorrhage (see **Sect. 25.2.7.1** and **Chap. 62**), and proliferative disease with the newly formed membranes threatening or actually causing TRD.

In eyes with the TRD involving the macula,[1] the decision to indicate surgery is easy; it is much more of a dilemma when the macula itself is spared, the VA is full (see **Sect. 46.1.1**), but the ophthalmologist notices that the TRD is gradually approaching the center. Based on extensive counseling, the patient has to choose between two options, neither of which is really reassuring.

- *Wait until the macula is also detached.* By this time the VA already dropped and may not be fully restored even if all goes well during surgery.
- *Operate before the macula detaches.* Vision may still be full, apparently threatened more by the operation than the disease.

Pearl
As a general rule, the earlier surgery is performed in an eye with PDR, the better the chances of a good anatomical and functional outcome.

[1] The disease is rarely allowed to progress this far in developed countries with well-organized screening and treatment protocols, but is surprisingly common in most other societies.

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52.1.2 Preoperative Considerations

- Panretinal laser treatment should be performed in all eyes with proliferative disease.[2]
  - Once you have TRD, only areas without membranes[3] should be treated, to avoid causing iatrogenic contraction of the tractional membranes.
- Intravitreal anti-VEGF medication (bevacizumab) should be injected 2–3 days preoperatively.
  - The main goal is to reduce the risk of intraoperative bleeding, but the drug also makes separation of the proliferative membrane from the retina easier.
  - To avoid a rebound effect after the injection, the patient must be warned that the operation *must* take place as scheduled. If for whatever reason it has to be postponed, the injection should be repeated every week or so until the surgery can go ahead.
  - Monitoring the patient's systemic condition (glycemic control, blood pressure etc.) is a crucial part of the management.
- Commonly, the indication for surgery is a combination of TRD, ME, and VH. The patient must be advised that any of these may recur, even if surgery was a complete success. The VH is especially prone to recurring, even if no treatable pathology is present (see **Sect.** **35.4.3.2**).

Pearl
The diseased vessel wall is the reason for VH in eyes with diabetic retinopathy. Even in the absence of neovascularization, the vessel may be unable to resist the elevated blood pressure, explaining why the rebleeding frequently occurs shortly after waking up. Such a "morning hemorrhage" may occur even if the blood pressure is well controlled.

52.2 Surgical Technique

Much of this has been described in **Sect.** **32.3.2**; only certain aspects of the surgery are discussed here.

The typical appearance of the posterior segment in an eye with PDR is a relatively spared macula,[4] which is surrounded by thick white membranes along the

[2] My personal experience taught me to consider such panretinal treatment *early* in progressive *nonproliferative* disease.

[3] And, obviously, attached retina.

[4] The macula is covered by a fine epiretinal membrane (which is usually the nondetached posterior hyaloid face), but spared by the thick, white, vasoproliferative membrane.

major vessels. This membrane may be vascularized and at certain spots have strong adhesions to the retina. Depending the contractile properties of the membranes, TRD and secondary retinal breaks can develop (see **Chap. 55**). The membrane often blocks the actual visualization of the TRD.

Intraoperatively the first thing the surgeon has to decide is the order of attack. The technical option I have found most useful is described below.

- Make an opening in the central area, above the macula, to release the traction on the macula as well as the tangential force acting upon the major adhesion line, along the vascular arcades.
- Cut 360° into the thick, white membrane (see **Fig. 52.1**), anterior to the vascular arcades; this will separate the major proliferations from the rest of the vitreous and retina and help reduce the traction both on the anterior and posterior retina.
  – Remember that you are almost always dealing with a vitreoschisis. The tissue you just cut is the anterior wall of the schisis cavity.

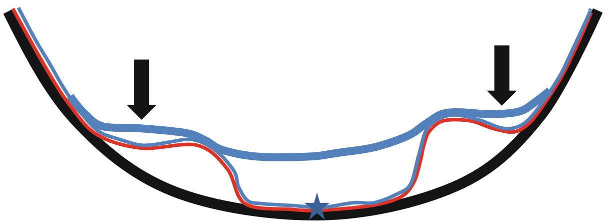

Fig. 52.1 Schematic representation of the proliferative membranes causing TRD in an eye with PDR. The retina (*red line*) is partially detached from the eyewall (*thick black line*). The traction is exerted primarily by the centrally located proliferative membrane (*thick blue line*), which maintains some distance from the retina at most locations. This membrane causes a mostly P-A traction. However, another tractional force (*thin blue line*) is also present, even if this is much less conspicuous to the surgeon. This membrane causes a mostly tangential traction. Representing the still-attached posterior cortical vitreous, this membrane is very adherent to the retina, and the thick proliferative membrane reinserts into it anteriorly. Several vitreoschisis cavities are thus formed. The arrows show the initial location where the separation of the proliferative membranes from the retina would take place. If the macula (*blue star*) were also involved in the detachment, the initial step would be to separate it so that the inevitable traction exerted during surgery will not involve it. More details are provided in the text

- Extend the vitreous removal all the way to the periphery. With scleral indentation, complete the vitreous removal at the base.
  – This still leaves the cortical vitreous on the retina; see below.
- Also remove the anterior hyaloid face.
- Return to the posterior retina and deal with the thick, white proliferative tissue: delamination or segmentation, using various instruments.

- Whether you are attacking these membranes in a centrifugal or centripetal direction, make sure that you pick up the posterior wall of the vitreoschisis cavity. This is the delicate membrane that is still adherent to the retina, and it can be followed all the way to the vitreous base.
  – This membrane is usually more difficult to deal with than with the thick, white proliferation. It may tear or even detach the retina; extreme caution is required. The membrane may also be multilayered (see **Fig. 52.2**); unless the layer closest to the retina is identified and lifted, you will struggle to complete the vitrectomy.
  – If too strong laser treatment has been applied before,[5] the cortical vitreous and the retina are "burned" into inseparable tissues (see **Sect. 30.1**); in such cases the PVD is impossible.

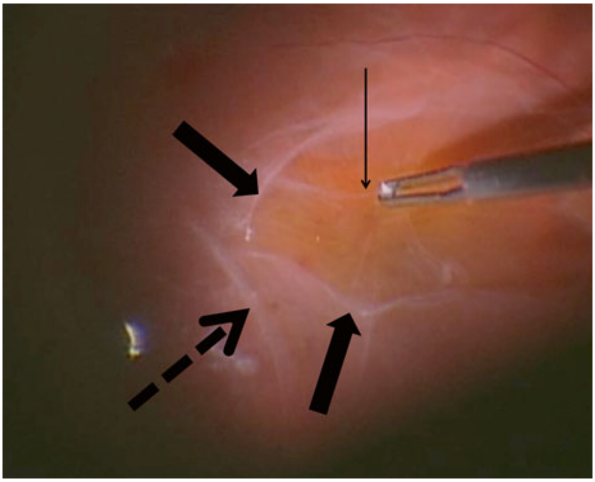

Fig. 52.2 **Multilayered membrane in PDR**. Three different layers of the proliferative membrane are seen on this image. The one closest to the retina (*thin arrow*) is very delicate and adheres to it entirely, representing the posterior cortical vitreous; it is being peeled with forceps. The middle layer is a much more well-formed membrane (*thick arrows*), showing adherence to the other two layers as well as, through the membrane beneath it, to the retina. The most superficial membrane (*dashed arrow*) is the thickest; this is the one that is most evident and easiest to peel

- Even if anti-VEGF treatment has been used, fresh bleeding is not uncommon. I prefer cauterizing these vessels (see **Sect. 12.1.10**) rather than merely hope that they stop intraoperatively and not recur postoperatively (see **Sect. 3.2**).
- Once you dealt with all tractions, perform panretinal laser treatment.

[5] This is recognized by the presence of large areas of black pigmentation and the lack of visible retinal structure.

- Also consider removing the ILM, even if the macula is dry.[6]
  - If the macula is edematous, the ILM is commonly very adherent in these eyes (see **Sect. 49.2**).
  - I do not peel the ILM if the retina is ischemic and thin.
- Complete the operation with gas or silicone oil tamponade. The latter has the advantage of preventing the VH from recurring.

There are some additional issues to keep in mind.

- In certain locations it may be impossible to separate the membrane from the retina. Make sure to completely circumscribe the remaining white stalk so that it does cause traction in the future.
  - If the ILM has extreme adherence to the retina, exerting strong traction, abandon the peeling.

Pearl
Cutting a membrane that is very adherent to the retina requires the use of scissors, usually retina-parallel or curved; these are not easy to manipulate without undue risk of pushing their sharp tip into the retina and choroid. An easier technique is offered by the probe; the surgeon should activate the cutting first, before being close to the membrane, and use low aspiration/flow when he approaches the membrane.

- If a retinal break is also present,[7] the risk of postoperative RD increases: the more the retina is liberated from the tractional forces, the worse the risk.
  - The creation of iatrogenic retinal breaks, although far from ideal, may still be preferable to leaving traction behind. In case of a break it is of utmost importance to remove *all* tractional forces.
- If a large retinal break is present or retinectomy is needed, consider prophylactic chorioretinectomy to reduce the risk of PVR development (see **Sect. 33.3**).
- Consider silicone oil implantion (see **Sect. 35.4**) to achieve/maintain retinal attachment and/or prevent (recurring) VH (see **Sect. 62.4**).

[6] See also **Sect. 49.2**.

[7] Whether it has been there preoperatively or created during surgery.

PVR

53

53.1 General Considerations

PVR is “public enemy #1” for the VR surgeon, the most common cause of failure in RD surgery and a potential threat after every vitrectomy, irrespective of its indication. Inflammation involving the posterior segment and VH (see **Chaps. 61** and **62**) are among the risk factors for PVR development.

Q&A

Q *How can the VR surgeon explain PVR as the cause of the surgery’s failure?*

A PVR is not the surgeon’s fault; it is a normal scar-formation reaction by the body. The scar is useful and necessary to heal a skin wound but highly undesired inside the eyeball. Whether it develops is due neither to the surgeon nor can it be influenced by the patient (lifestyle, food intake, environment). Hormonal factors determine it, and even these can change with time in the same individual or have a different risk in the two eyes (i.e., just because it occurred in one eye, it does not mean the fellow eye will react similarly and vice versa).

- An eye with an RD is at elevated PVR risk if the vitreous is full of pigments (PVR A; see **Fig. 53.1**). This is a more ominous sign than having a retinal tear with an inverted flap (PVR B).
- PVR in an eye with chronic RD has a somewhat restrained rate of progression.
- PVR may develop following (due to) surgery. Such a PVR may have a moderate rate of progression but may also be very aggressive.
- PVR developing after trauma typically shows the most aggressive form of the disease, especially in the young (see **Chap. 41**).

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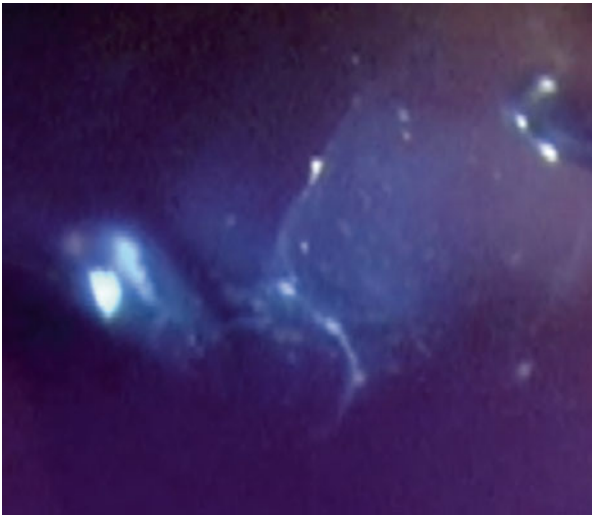

Fig. 53.1 **Pigment in the vitreous in an eye with PVR**. The presence of pigment clumps seen at the slit lamp (shown here intraoperatively) should raise the suspicion that an RD or at least a retinal break has occurred. This finding (called Shafer's sign) is also important because it raises the risk of postoperative PVR development (See the text for more details)

53.1.1 The Timing of Surgery

PVR has a life cycle, typically considered to be ~3 months. If surgery for an ongoing PVR is performed before this "deadline" passes, the PVR process may continue unabated. This raises a difficult issue regarding timing: operate despite this known risk or follow the general rule in PPV and operate early?

- Delaying the operation is technically beneficial because you will then deal with membranes that are visible and mature. Conversely, there is a risk that the macula will be involved in the process, with permanent visual loss.
- Operating early increases the chance that a reoperation will be needed. If so, this is not PVR recurrence, the disease is just completing its "unfinished business".

It is not easy to balance these two extremes. An individual timing decision is needed, based on the actual findings and the patient's wishes.

53.1.2 The Recurrence of PVR

The recurrence may appear within weeks or as late as several months after the initial surgery. In general, the sooner it presents, the more severe it is. Eventually, the tendency of PVR to recur diminishes then disappears – but by this time the retina may have been destroyed.

Pearl
The best chance the surgeon has to treat an eye with PVR is the initial surgery. The task gets increasingly more difficult and the prognosis increasingly poorer with each operation ("more surgery for less vision").

53.2 Surgical Technique

A few principles are presented here; for the actual details, see **Sect. 32.3.1** and **Chap. 35**.

- A complete PVD must always be performed.
- All preretinal membranes must be removed; subretinal membranes may be left behind if they do not interfere with intraoperative retinal reattachment as determined using the air test (see **Sect. 31.1.2**).
  - The bent needle is an excellent tool to pick up membranes from the surface (see **Fig. 13.8e, f**), especially in areas with star folds (see **Fig. 32.14**), but caution is in order.[1]
  - Fine, immature membranes are identified by staining (see **Chap. 34**) or by noticing the shiny reflex from the surface; this often requires changes in the angle of illumination. The immature membranes are best lifted with the scraper.
  - What appears as a subretinal strand (i.e., a white line is seen) may simply be a retinal fold (see **Sect. 32.4.1**).
- The air test (see **Sect. 31.1.2**) should be done with close visual control. A shortened retina will not stretch properly and can get torn by the air. If the retina seems to resist the effect of the air, stop the exchange and deal with the retinal shortening (see below).
- Anterior PVR is more difficult to deal with than a posterior one.
- Anterior PVR threatens not only loss of vision but also loss of the eyeball, due to phthisis.[2]

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[1] When working on mobile retina, the risk of causing a full-thickness iatrogenic tear is higher with a sharp tool than with the scraper. The retina moves away and the surgeon must "follow" it, combining two vectors: one perpendicular to and the other parallel with the surface; the first is to stay with the mobile retina and the second to pick up the membrane, all the while trying to avoid tearing the retina itself. Paradoxically, the more membranes are removed, the harder the task gets, precisely because the retina is increasingly more mobile.

[2] This is why it is so crucial to clean the vitreous base and the ciliary body in eyes with RD (see **Sect. 32.5**).

- Silicone oil tamponade and chorioretinectomy are currently the only effective tools in our armamentarium to reduce the PVR risk; using oil and not long-acting gas has therefore many benefits (see **Table 35.1**).
  - If silicone oil is used, it is especially important not to leave blood on the retinal surface; this is one of the risk factors the surgeon can actually do something about.
  - It may be easier to remove blood from the retinal surface under oil than under BSS or air.
- In the periphery, it may be impossible to separate the vitreous from the retina or the retina may be shortened.[3]
  - If the vitreous is inseparable from the retina, the surgeon may elect to trim as much of the vitreous as possible, do a retinectomy, or use an encircling band to counter the effect of existing or developing traction.
  - Retinectomy must never be done if vitreous and/or membranes are left on the posterior (remaining) retina (see **Sect. 33.1**).
- Laser must always be applied around all anterior breaks. Conversely, a posterior break may not need any "pexy" since no VR traction is present (see **Sect. 30.3.5**).
  - Always consider a 360° laser cerclage for additional security (see **Sect. 30.3.3**).
  - The force of PVR, however, will still detach the retina that has been lasered.
  - It has benefits to laser along the edge of a retinectomy since it seals the retina so that subsequent fluid currents will not cause an RD (see **Sect. 30.3.5**). However, it also increases the loss of the visual field and, as just mentioned, will not prevent a redetachment if it is caused by PVR.
- ILM peeling prevents, in the event of a recurrence, the newly formed membranes from growing over the macula.
- With the use of regular oil, the RD recurrence is inferior.
- In eyes with PVR or at high risk of PVR development, the silicone oil should not be removed earlier than 4 months. Keeping it even longer is much less risky than removing it early (see **Sect. 35.4.6.1**).
- If reoperation is needed and there is still silicone oil in the eye, consider removing it as the initial step of the reoperation (see **Sect. 35.4.5.1**).

Pearl
Patients with PVR are "married to their VR surgeon": they routinely come back for a follow-up, at least during the first year.

[3] In the latter case retinectomy is the best option (see **Sect. 33.1**).

Retinal Detachment

54

RD[1] is defined as a condition in which the neuroretina is separated from the RPE. Based on the etiology and characteristics, several types are distinguished; these are summarized in **Table 54.1**.

54.1 The Pathophysiology of RD[2]

Separation of the neuroretina from the RPE is used to be a blinding condition.[3] It is thus not surprising that so many misconceptions related to this condition have been born. Many of these live on, even though our knowledge of the pathophysiology of RD has greatly expanded since (see **Table 54.2**).

In the vast majority of cases, regardless of the etiology, the cascade of events leading to RD development is identical[4] (see **Sect. 26.1.2** and **Fig. 54.1**). While dynamic VR traction is the cause of break formation, the type of the break has important implications regarding the events to come, including management (see **Table 54.3**), as does the condition of the vitreous and the VR interface (see **Figs. 26.1** and **54.2**).

[1] This chapter is much longer than the others in this part, due to the clinical significance of RD, the numerous controversies related to it, and the no fewer then 3 available treatment options, which need to be discussed in detail (even then, space limitations forced me to be rather brief; compare the length of this chapter to a great book on RD [see further reading], which has 1,138 pages). The reader is also reminded that this chapter is about *rhegmatogenous* detachment only.

[2] Retinal detachments that are nonrhegmatogenous are discussed in **Chaps. 51, 52, 53, 55**, and **56**.

[3] In 1912, a large study reported a surgical success rate of 0.1%.

[4] One notable exception is trauma causing a direct retinal lesion: here the formation of the break precedes the changes in the vitreous. However, even in these eyes the vitreous changes *will* occur prior to the development of the RD.

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Table 54.1 Detachment of the retina: types and characteristics*

Detachment	Comment
Rhegmatogenous (“RD”)	A retinal break (“rhegma”) is present, but the primary culprit is VR traction, which is *dynamic*[a] The configuration is convex
Tractional (“TRD”)[b]	There is very strong VR or subretinal traction, but no break. The traction is *static*[c] The configuration is concave
Combined rhegmatogenous and tractional	The tractional component dominates, even though a break is also present. The tractional element precedes the development of the break The configuration is concave
Central (posterior, staphyloma spanning)[d]	Although VR traction is present[e], the main culprit is the staphyloma; the rigid ILM does not allow the otherwise elastic retina to conform to the scleral bulge A macular hole may be present, but it is likely to be the consequence, not the cause of the RD The configuration is convex or concave, depending on the size of the staphyloma and the height of the RD
Exudative/serous	There is no traction, simply secretion of fluid into the subretinal space. The fluid is either too voluminous or too viscous for the RPE to remove. Examples include optic pit (surgical intervention is worth considering, see **Chap. 51**) and central serous chorioretinopathy (not a surgical indication) The configuration is convex
Hemorrhagic	There is no traction; the bleeding is typically traumatic in origin or associated with AMD The configuration is initially convex but can become uneven as the blood start to absorb

*This condition (see below, **Sect. 54.5.2.4**) virtually never occurs if PPV is employed.
[a]That is, its direction and strength are dependent on, and change with, movements of the eyeball and head. The configuration of the detachment changes if the head position changes.
[b]See **Chap. 55.**
[c]That is, its direction and strength are independent of, and do not change (or only insignificantly) with movements of the eyeball and head, nor will a head-position change impact the configuration of the detachment.
[d]See **Chap. 56.**
[e]There is no PVD.

54.1.1 RD Due to a Horseshoe or Giant Tear

The initial step is a change in the structure of the vitreous gel (see **Sect. 26.1.2**). With the vitreous cavity containing both gel and fluid-filled pockets, it becomes possible for the gel to become mobile. With every movement of the eyeball or head, traction forces act on the retina at all sites of vitreoretinal adhesion (see **Sect. 26.1.1**).[5]

[5] A patient recently asked me whether he can go skiing since he recently underwent laser treatment for 2 retinal tears that developed after he saw flashes. He has numerous floaters in the eye and still sees flashes. I told him he has a higher risk developing RD due to reading than skiing. Movements of the eye are extensive when reading (or watching in person [not on TV] a tennis match) but rare while on skis.

Table 54.2 RD pathophysiology and treatment: traditional and revised concepts*

Variable	Traditional concept	Revised concept
PVD in old age in an eye with attached retina	Very likely to be present	May or may not be present
PVD progressing in an eye with attached retina	The highest risk for RD development	True – except that the PVD may be anomalous
If VR traction is not seen at the slit lamp or on OCT	There is no VR traction	VR traction still may be present, but it is undetectable with current methodology and technology
PVD as a preoperative diagnosis	Straightforward to make as at least one of the following is present: 1. On biomicroscopy (or on OCT) a surface, distant from the posterior retina 2. Weiss ring	Impossible to make with any kind of certainty: 1. The distant surface seen on biomicroscopy (or on OCT) may indeed be PVD but may also be the anterior wall of a *vitreoschisis* cavity[a] 2. The Weiss ring indicates that the vitreous is detached at the disc, but not necessarily that it also detached elsewhere in the posterior pole
PVD in an eye with RD	Always present	May be complete, partial, or completely absent
Primary causative pathology in RD	The retinal break (the RD is "retinogenic")	VR traction (the RD is "vitreogenic"); the retinal break is secondary to the traction
The initial element in the cascade leading to break/RD development	PVD	Syneresis
Whether a retinal break leads to RD	Depends on the size of the break (and possibly the strength of the VR traction)	Depends on the strength of the VR traction as well as on the RPE pump, the strength of the IPM, and the resistance (tensile strength) of the retina itself The volume of the incoming fluid must exceed the capacity of the RPE to remove it
Presence of an operculum[b]	Signals strong traction and thus significant RD risk	Signals strong *past* traction and thus reduced RD risk
PVD in a highly myopic eye with posterior RD[c]	Present	What is seen as a PVD is in reality a vitreoschisis
PVD in PDR[d]	Present, anteriorly ("table-top RD")	A vitreoschisis is present, not a PVD
The VR interface in an eye with RD	There is a complete PVD *posterior* to the break but complete vitreous adherence to the retina *anterior* to the break	The "PVD posterior to the break, but no PVD anterior to the break" statement *may* hold true for the eye just examined However, the PVD may also be *incomplete* (anomalous) or *nonexistent*

(continued)

Table 54.2 (continued)

Variable	Traditional concept	Revised concept
PVD-associated[e] retinal tear	Located at the posterior edge of the vitreous base	Located between the vitreous base and the equator, occasionally even more posteriorly
Primary target of treatment	The retinal break	The VR traction
Gas use for RD in PPV	The effect is a tamponade, with two goals in mind: Prevent fluid from getting under the retina Press the retina against the RPE until the "pexy" takes effect	The effect is partially a tamponade but also a reduction in fluidic shearing By occupying space in the vitreous cavity, limit the shearing the fluid would cause on the retinal surface, thereby reducing the risk of retinal separation from the RPE Press the retina against the RPE until the "pexy" takes effect
Vitreous removal in an eye with RD	It is crucial to do a complete (total) vitrectomy in the periphery	Several steps are crucial Creation of a PVD if it has not occurred before Total vitrectomy in the periphery Removal of the anterior vitreous face

[*]See the text for more details. RDs that are nonrhegmatogenous are also included.
[a]The anterior (inner) wall of the vitreoschisis cavity is mobile (hence the similarity in appearance to a PVD), but its posterior (outer) wall is static (see **Fig.** 26.2).
[b]Defined as a piece of the retina (i.e., the formal tear) that is now floating in the vitreous, with no direct connection to the rest of the retina.
[c]It is not a true rhegmatogenous retinal detachment, even if a macular hole is present.
[d]Obviously, this is not an eye with rhegmatogenous retinal detachment (see **Chap.** 52).
[e]PVD, which may be true PVD or anomalous.

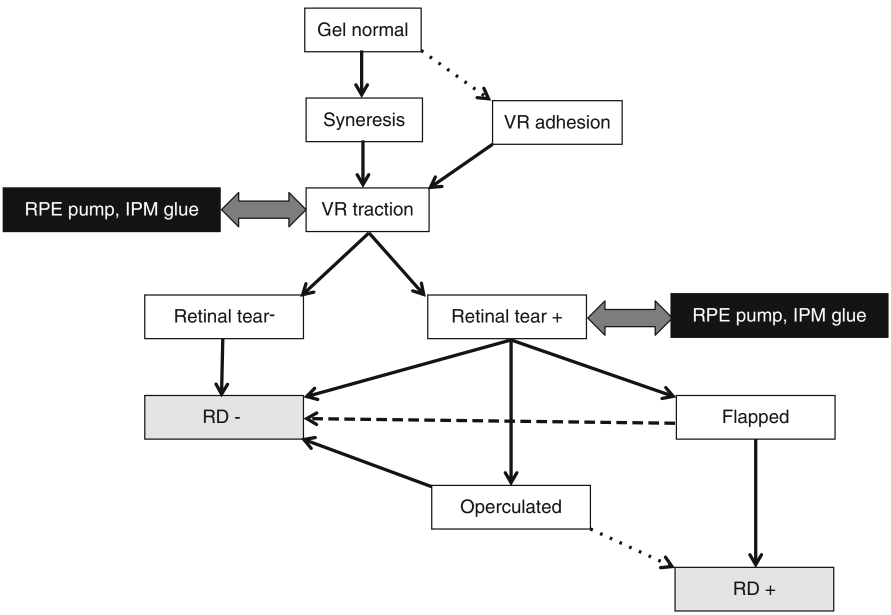


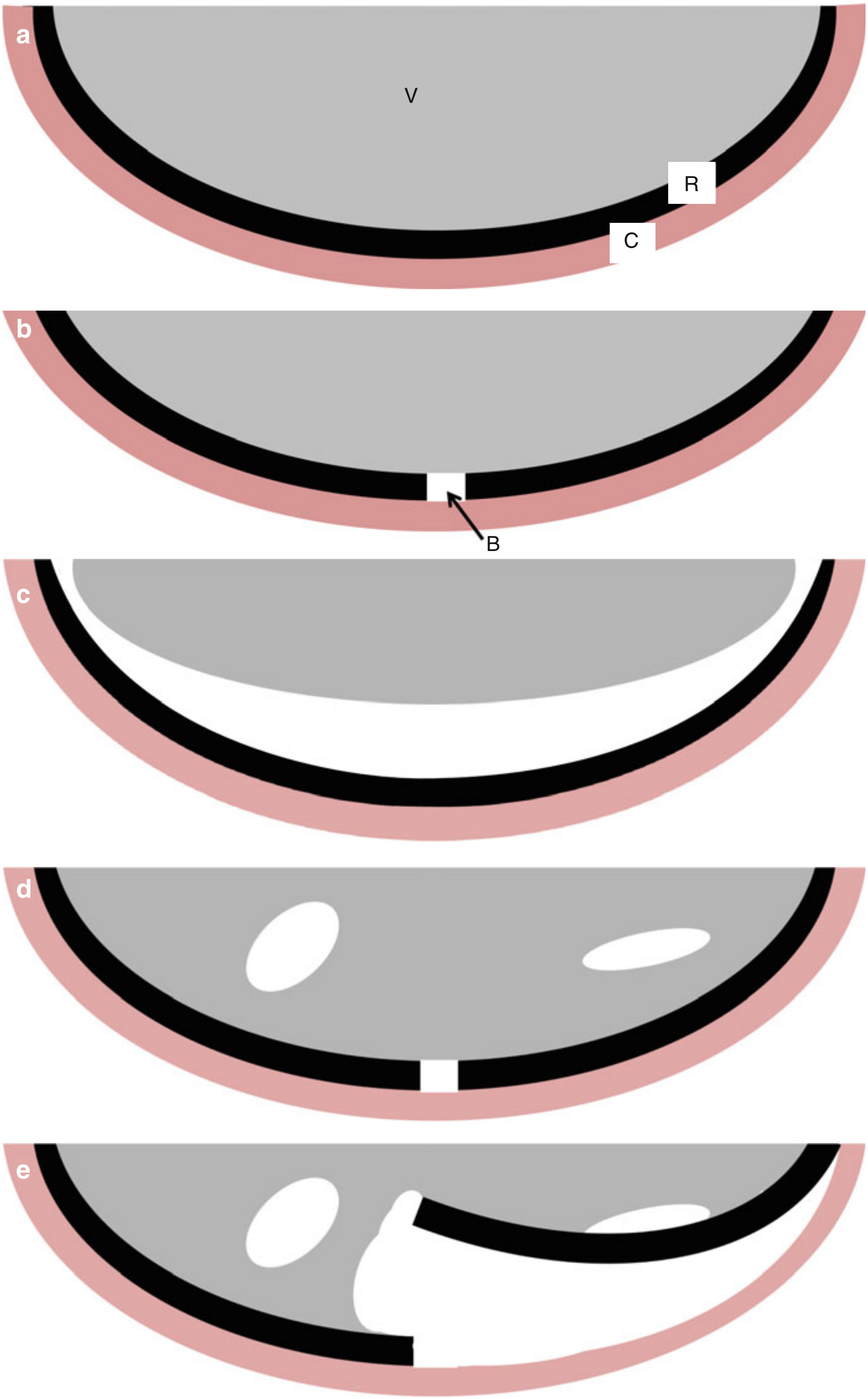
Table 54.3 Classification of retinal breaks and its implications for treatment

Break[a]	Comment	Management implication
Hole, round	A necrotic type: the retina dissolves. Clinically detectable traction may also be present – this is the case when the hole is in an area of lattice degeneration	SB is an efficient method of treatment
Hole, macular	It is not perceived as a true RD since only of a small ring of subretinal fluid is present around the hole ("fluid cuff")[b]	A unique operation is needed (see **Sect.** 50.2.4)
Hole, macular, in a highly myopic eye	There is a high risk of central RD; in fact, the RD often – if not always – precedes the formation of the hole	A unique operation is needed (see **Sect.** 56.2)
Dialysis	Usually caused by contusion, the retina separates at the ora serrata; since the vitreous is healthy at the time of the injury, the progression to RD is usually slow[c]	SB and PPV are equally efficient methods of treatment; both have their own advantages, risks, and side effects
Tear, horseshoe/flap	Caused by VR traction, the opening in the retina faces the posterior pole (the base of the flap is anterior). This is the most common cause of RD	Depending on the location, strength of traction, pigment content in the vitreous and many other variables, SB and PPV may or may not be equally efficient methods of treatment. If PPV is performed, the flap must be removed to completely alleviate the traction that caused it (see the text for more details)
Giant tear	A tear that runs parallel to the limbus and exceeds 3 clock hours in length; the central edge is often inverted	PPV is the treatment of choice; adding a buckle may increase the risk of slippage[d]. The curled central edge must be completely cut and silicone oil implanted due to the high risk of PVR

[a]A break is defined as an interruption in the contiguity of the neuroretina.
[b]See **Chap.** 50.
[c]In other words, a healthy vitreous tamponades the break; once vitreous movement becomes possible as a result of syneresis, the RD risk dramatically increases.
[d]The central retinal edge moves posteriorly, preventing retinal reattachment.

Fig. 54.1 **The cascade of events leading to RD.**[6] (as a reminder, rhegmatogenous, not tractional, RD is discussed here). In areas of VR adhesion, a syneretic vitreous will cause VR traction, but it does not inevitably lead to the formation of a retinal break because the RPE pump and the IPM (plus the retina's own tensile strength and the IOP, not shown here) are able to overcome the effect of the dynamic traction. Even if a break does develop, the RPE pump and the IPM may be able to counter the effect of the dynamic traction. If the torn retina becomes operculated, the risk of RD is dramatically reduced but not completely eliminated since there still may be VR traction on the retina surrounding the break. RD results only when the traction force overpowers the effect of the RPE pump and the IPM

[6] As a reminder, rhegmatogenous, not tractional, RD is discussed here.


a
V
R
C
b
B
c
d
e

Traction that caused a retinal tear is also able to keep the break open so that fluid from the vitreous has direct access to the (so far virtual) subretinal space.[9] Once the volume of fluid entering exceeds the capacity of the RPE to remove it, an RD ensues.

Pearl

The operculation of the retinal tear means that traction in the area of the break itself has ceased to exist. The torn-out piece of the retina is suspended in the gel or is "swimming" in a pool of fluid in the syneretic pocket (see **Fig. 54.3**). The retina remains attached if there is no remaining traction in the vicinity but may detach if there is sufficiently strong traction on the retinal edge. The operculum is thus a relative, not an absolute, contraindication against prophylactic laser (see below, **Sect. 54.2.4**).

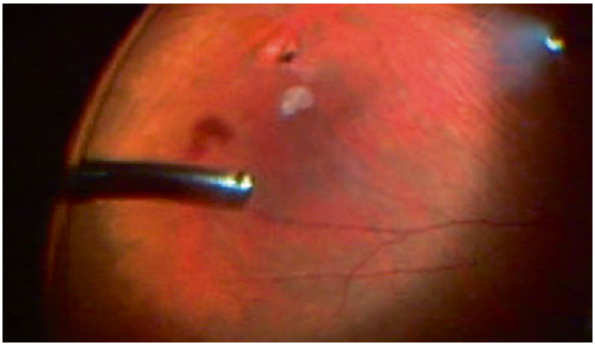


Fig. 54.3 The operculum in the vitreous cavity. The operculum is visible as a little gray spot; the shadow it casts on the retina is seen just above the port of the probe. The area of degeneration where the small piece of retina was torn from is obvious from the pigmentation there

Fig. 54.2 Relationship between the vitreoretinal interface, a retinal break, and RD. (**a**) If the vitreous is a healthy gel and there is no retinal break, RD does not occur. (**b**) Even if a retinal break (*arrow*) does occur, as long as the vitreous is a healthy gel, RD does not occur.[7] (**c**) Even if a retinal break does occur, should a total PVD also be present, RD does not occur. (**d**) In the presence of a retinal break and a syneretic gel, there is a risk of traction at the edge of the break. (**e**) If the VR traction overcomes the sum of forces holding the retina in place (mainly the RPE pump and the IPM), an RD develops.[8] *V* vitreous, *R* retina, *C* choroid, *B* retinal break

[7] The vitreous acts as a plug over the break.

[8] The vitreous acts as a corkscrew.

[9] Think about a door held open to allow access to the room.

A *giant tear* develops in the same way but is defined as one of at least 3 clock hours in length. Its significance lies in the different surgical technique required to treat it[10] and its increased PVR risk.

54.1.2 RD Due to a Dialysis

Seen most commonly after contusion, the retina is torn at the ora serrata where it is inseparable from the vitreous. The vitreous gel may appear healthy initially, but with time, it starts to degenerate, slowly detaching the adherent retina as the dynamic traction grows.

54.1.3 RD Due to a Round Hole

In at least half of the cases there is marked, visible VR traction.[11] Even in the remaining cases, no RD is expected unless traction develops[12] – this is often recognized by the patient as flashes – or the RPE pump is deficient (see **Sect. 26.3.1**).

54.1.4 RD Due to a Staphyloma

Typically, this is a nonrhegmatogenous detachment[13] (see **Chap. 56**).

54.2 Additional Information About RD

Any ophthalmologist but especially the VR surgeon should keep in mind the following during the decision-making process.

54.2.1 History

- The typical – and the only one that is pathognomic – complaint is that of a *curtain*, due to the visual-field loss corresponding to the quadrant that has detached.
- *Loss of the entire visual field* suddenly occurs if a VH accompanies the tearing of the retina. ~20% of RDs are accompanied by VH.
- *Flashes* are spontaneously communicated by relatively few patients, although often confirmed by them when asked (see below). The flashes are caused by dynamic VR traction (see below), whether as part of a PVD or not.[14]
- The small floater that is occasionally described by the patient is rarely the operculum; it is usually a small hemorrhage or simply a vitreous opacity.

[10] The central edge of the retinal break is curled or inverted; there may also be vitreous behind the retina.

[11] The hole is inside or at the border of lattice degeneration.

[12] As mentioned before, dynamic traction is present once the vitreous loses its normal gel structure.

[13] Even if a macular hole is present, it is typically the consequence, not the cause, of the RD.

[14] The seeing of light (phosphene) is the only response the retina has, regardless of what kind the stimulus is.

- ~10% of the patients have bilateral RD, but only 20% of these occur simultaneously. These are the numbers that justify treating the fellow eye prophylactically (see below, **Sect. 54.2.4.2**).

54.2.2 Examination[15]

- Even before the ophthalmologist looks at the retina, the presence of pigment clumps in the anterior vitreous (see **Fig. 53.1**) should raise the possibility of a retinal break, even an RD.
- In a *fresh RD*, the retina can be very bullous and its surface rather smooth; however, it may be folded, too. The latter gives the false appearance of subretinal strands. Even intraoperatively, the distinction, at least until the surgeon touches the retina with an instrument, may be very difficult (see **Sect. 32.4.1**).
- *Chronic RD*s are recognized by the presence of the following:[16]
  - High-water marks: lines of pigmentation, signaling the temporary stoppage of the progression of the detachment in the past.
  - Intraretinal cysts.
  - Calcium oxalate crystals in the posterior pole.[17]
  - Multiple breaks, present in ~40% of eyes.
  - The IOP is characteristically low, due to increased uveal outflow.
  - Retinal thinning – resembling retinoschisis.[18]
- The configuration of the RD suggests the location of the break (see **Fig. 54.4**).

54.2.3 Clinical Course

Faster progression is expected in the following cases:

- Superior break (the effect of gravity[19]).
- Large break (more traction, increased amount of incoming fluid).
- Vitreous gel that has massive structural breakdown (more traction).
- Vitrectomized eye (no gel tamponading the retina).
- Poor efficacy of the RPE pump and the IPM (reduced fluid outflow and retinal adhesion).[20]
- Lack of strong chorioretinal adhesions (e.g., scars fixating the retina).

Occasionally the RD progression stops spontaneously. It is, however, much more common for the RD to not just progress but lead, if untreated, to PVR development (see **Chap. 53**).

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[15] Only selected, less commonly discussed signs are mentioned here.

[16] Obviously, not all will be found in a single eye.

[17] These are small, yellowish dots intra- and subretinally, signaling degeneration of the retina.

[18] In a fresh RD the retina is thickened, due to the edema.

[19] This is the most important element. The more superior the break, the faster the RD becomes total; in theory, a break at 12 o'clock is the worst.

[20] These are largely unknown factors.

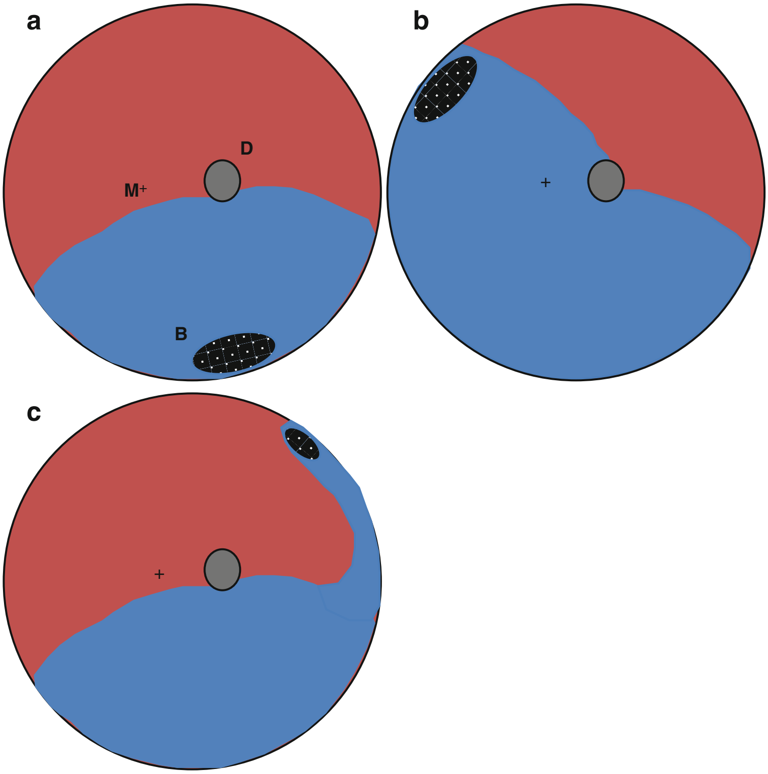

Fig. 54.4 **The configuration of the RD and the expected location of the retinal break**. (**a**) If the detachment is inferior and reaches only somewhat higher on one side of the disc, the break is likely to be found inferiorly, close to the center, on the side where the RD is higher. (**b**) If the detachment is mostly inferior and much higher on one side, the break is likely to be found superiorly on the high side. It is rare that the break is at the border of detached–attached retina; it is usually surrounded by detached retina completely[22]. (**c**) Occasionally the retina does not show a wide area of detachment and remains attached central to the break; the bilateral, inferior detachment has a fingerlike, peripheral protrusion, pointing superiorly. This makes discovery of the break difficult and shows why the laser treatment must always be extended all the way to the ora serrata. *D* optic disc, *M* macula, *B* break (the area is shown by a *black area* with *white dots*). The *red* shows the attached, the *blue* the detached retina

54.2.4 Using Laser to Prevent RD Development

Treatment with laser is defined as sealing the edge of a retinal break. *Prophylaxis* is interpreted as lasering areas with a pathology that might in the future lead to RD or lasering retina that is healthy.[21]

[21] It must be mentioned that prevention via methods other than laser is also possible: prophylactic SB is rather commonly employed, and even PPV is occasionally performed, such as when cataract surgery is needed in a highly myopic patient (see **Chap. 42**).

[22] I.e., there is a small area of detached retina superior to the break.

54.2.4.1 Prophylaxis in the Affected Eye (RD, Current or Past)

- The surgeon may elect to treat only the visible retinal lesion/s. The argument for this approach is that retinal breaks are detected in up to 20% of eyes with attached retina. Especially if the break remains asymptomatic, long-term follow-up proves that the risk of RD remains small.
  - "Observing" these patients after such *focal* treatment typically means a detailed fundus examination every 3 months. This is taxing for patient, ophthalmologist, and facility. It is also without any sound scientific basis: why 3 months and not 2 or 5?[23]
  - The argument that a break does not necessarily justify treatment is false for another reason. In an eye that has, or has had, an RD, the risk of a future RD may be elevated if the VR traction has not been eliminated.
  - My preference is to always perform a 360° *laser cerclage* (see **Sect. 30.3.3**) during surgery, and I offer this option to each patient who presents with an attached retina but a history of RD. The presence or absence of a retinal tear does not influence this protocol since the RD often originates in an area that appeared healthy previously. This is the final argument against the "focal laser only" type of prophylaxis (see below).

54.2.4.2 Prophylaxis in the Fellow Eye

If one eye had an RD and the fellow eye has the same risk for RD,[24] it is akin to playing Russian roulette not to perform prophylactic laser in the fellow eye as well. My personal guidelines regarding prophylactic laser treatment are summarized in **Table 54.4**.

> **Pearl**
> Unless the patient has a unilateral condition (such as pseudophakia, high myopia, trauma), the fellow eye has the same risk for RD development and should always be carefully examined. The patient needs to be informed about the risk, and the issue of prophylactic treatment (see **Sect. 30.3.3**) must be raised, detailing the risks and benefits.

54.2.4.3 The Patient with a History of a Retinal Tear (No RD)

My rationale is identical to that outlined above. Even in the absence of a history of an RD, a retinal tear signifies traction, and there is a risk of RD.[25] Laser cerclage has a high enough success rate to more than offset its complication risk. I therefore offer the prophylaxis to the patient, but accept it if he declines the treatment – as long as he understands the implications. First, the focal treatment does

[23] See below for more details.

[24] Both are equally myopic; both are pseudophakic; both have the same vitreoretinal degeneration etc.

[25] Especially true if the tear is symptomatic.

not decrease the RD risk; second, he is supposed to undergo a detailed fundus examination every few months for the rest of his life.

Table 54.4 RD prophylaxis in persons with a retinal break in one eye and various conditions in the fellow eye[*]

Variable[a]	Fellow eye	Comment[b]
Round hole, asymptomatic[c]	No pathology/history	No treatment
	RD	Laser cerclage, focal laser, observation
Round hole, symptomatic	No pathology/history	Laser cerclage, focal laser, observation
	RD	Laser cerclage
Dialysis	No pathology/history	Laser walling-off
Flap (horseshoe) tear, asymptomatic	No pathology/history	Focal laser, observation
	RD	Laser cerclage
Flap (horseshoe) tear, symptomatic	No pathology/history	Laser cerclage, focal laser, observation
	RD	Laser cerclage
Giant tear	No pathology/RD	Laser cerclage[d]

[*]No or only clinical RD is present in the eye with the break in question.
[a]To keep it simple, additional risk factors (high myopia, pseudophakia, hereditary vitreoretinal degenerations etc.) are not listed there; however, these should also be taken into account when the ophthalmologist considers treatment vs observation.
[b]If more than one option is listed, my personal preference is the option listed first; the rest are in decreasing order. The actual decision rests with the patient.
[c]The ophthalmologist should always be cautious when interpreting "asymptomatic." Quite a few patients have symptoms but do not recognize them until specifically asked ("have you seen flashes of light when you were in a dark environment and you moved your gaze/eye around?").
[d]Or PPV; it is unlikely that RD is not present.

Q&A

Q *Why laser cerclage and not focal laser?*

A Clinical experience shows that the RD often originates in areas that had appeared normal in prior examinations. Focal treatment does not offer extra protection when compared to observation.

54.3 Treatment Principles

54.3.1 The Timing of Surgery[26]

In principle, as soon as possible, but certain other factors must also be incorporated into the decision-making process.

[26] See also above, **Sect. 54.2.3** and **Table 9.1**.

Q&A

Q *What if the patient with an RD arrives Friday afternoon?*

A With rare exceptions (see below), surgery can safely be postponed until Monday morning, when all is available to give it the best chance of success. The patient has to understand the risks if he is unwilling to remain in bed until the operation (counseling, see **Chap. 5**).

- Patching both eyes is highly inconvenient for the patient, but it eliminates eye/head movement and thus greatly reduces the height of the detachment – less crucial if PPV is performed, but very helpful in bullous RDs if the surgeon plans to do SB.
- If the macula is on, the patient should be positioned so that the fluid does not get in the macula.
- The rods recover rather well,[27] even if the RD is long standing.
- The cones do not recover that well, but even if the macula is off for a few days, the chance of recovering reading vision is still 70%.
- The most urgent situation is an RD that is just about to reach into the fovea.

54.3.2 The Goals of Surgery

The surgeon's goals with surgery, irrespective of its type, are the following:

- Address the traction.[28]
- Bring the neuroretina in apposition with the RPE.
- Prevent fluid re-entry into the subretinal space through the break.[29]

The surgeon can choose between 3 different treatment options.[30] Of these *SB* and *pneumatic retinopexy* are mostly exterior[31] procedures; *PPV* is solely internal. **Table 54.5** presents a comparison between SB and PPV, which are occasionally used in combination.

[27] That is, the visual field.

[28] As mentioned above, it is extremely rare for VR traction not to be the underlying cause of the RD. Consequently, this must be the primary target of the surgery (whichever of the 3 options is chosen), with the break being a close second.

[29] Akin to closing and locking the door and thus preventing access to a room.

[30] There is a fourth option, a temporary buckle (balloon), but it is out of favor today.

[31] Except that a gas tamponade is always used in pneumatic retinopexy and often in SB. In the latter, drainage also makes it an intraocular procedure.

Table 54.5 Comparison of SB versus PPV for RD*

Variable	SB	PPV
Surgery rational?	No: an internal problem is addressed by an external procedure. The eyewall is pushed toward the detached retina, causing a permanent deformation in the contour of the eyewall	Yes: an internal problem is addressed by an internal procedure. The detached retina is pushed toward its normal resting place, maintaining the original contour of the eyewall
Main purpose of surgery	Weakening of the traction force to the point that the traction becomes ineffective	Elimination of the traction force
Able to address nonrhegmatogenous RD?	No, or with significant morbidity (posterior break or staphyloma-spanning RD in high myopes)	Yes
Can be employed if severe PVR or subretinal component is present?	No	Yes
What if the sclera is thin?	Thin sclera must not be sutured; if the ectatic sclera cannot be avoided, SB is either contraindicated or a scleral patch needs to be placed first	The thin area should not be selected as a sclerotomy site
Need for *detailed* preoperative examination (to identify the VR traction and the location of the retinal break/s)	Yes	No
Surgery doable if significant VH present?	No	Yes
Difficulty of intraoperatively identifying VR traction	Somewhat to very difficult	Easy
Multiple breaks in multiple quadrants	Causes decision-dilemma and technical difficulties	Does not change the surgical planning or the essence of surgery
Difficulty of intraoperatively identifying retinal break	May be impossible in pseudophakic eyes with capsular opacity, especially if the break is small	Virtually always possible
Separation of hyaloid from the retina	Not needed	A major goal of surgery but impossible in some cases
Draining of subretinal fluid	External – if performed at all	Internal – almost always through the original break

(continued)

Table 54.5 (continued)

Variable	SB	PPV
Complete draining of subretinal fluid	May be difficult or impossible to do and risks subretinal bleeding	Almost always possible (see the text for technical details)
Possibility of treating concurrent problems such as macular hole, EMP	No	Yes
Cryopexy	Even though a risk factor for PVR development, it may be necessary if the drainage was incomplete or indirect ophthalmoscopic laser is unavailable (see **Chap. 29**)	No (laser instead; see the text for more details)
Intravitreal gas (air) tamponade	Risks causing secondary retinal break/s	Straightforward
Leftover fluid under fovea	Rather common	No
PVR risk	Low (if cryopexy is not applied or is done properly)	Low, but may be higher than with SB
PVR prophylaxis	Not possible	Silicone oil use, chorioretinectomy, and the avoidance of cryopexy may help
Possibility of preventing future EMP formation	No	Yes (see below)
Side effect	Permanent deformation of the eyewall (myopia, astigmatism)	Cataract in phakic eyes (will eventually occur even if the patient is young)
Intraoperative complications	Long list (see textbooks for details)	Long list (see textbooks for details)
Postoperative complications[a]	Long list (see textbooks for details)	Long list (see textbooks for details)
Difficulty to do optimal surgery	High ("it's an art")	High (it is just as much an art as SB is, not a "blue-collar job")
Patients' preference	No	Yes (eye more "comfortable" both during surgery and postoperatively)

[*]Although this has been a strong trend in recent years, I have no intention here to suggest that surgeons should abandon SB and switch to PPV. Every surgeon must make his own decision based on his own preferences, rationale, and comfort zone, as well as the specifics of the case. This table is provided to help with the decision-making process, not as an argument in favor of one option over another.
[a]EMP, as one example, can occur in up to half of eyes undergoing SB and in up to a third of eyes undergoing PPV. The latter offers prevention of this complication if the ILM is removed during the original RD surgery (see **Sect. 50.2.3**).

Q&A

Q *What is the rationale for adding a SB when PPV is performed for RD?*

A In reality, there is none. Studies consistently show that the results are not improved by adding a buckle. If PPV is performed properly (leaving no VR traction), the SB becomes superfluous. A subconscious thought process is also at play: When the surgeon performing PPV knows he will also add a buckle, he may fail to do a truly total PPV (the subpar quality of his vitrectomy will be compensated for by the buckle; see also **Sect. 35.4.6.1**).

Table 54.6 lists the traditional arguments favoring one procedure over the others[32]; pneumatic retinopexy is a procedure that has the lowest initial success rate, but, should it fail, it is "benign" enough not to worsen the prognosis of the reoperation.

Table 54.6 Selection of the surgical procedure for RD

Variable	SB	Pneumatic retinopexy	PPV
Significant vitreous hemorrhage	–	–	+
Mild ("no") VR traction[a]	+	+	+
Significant traction/early signs of PVR	–	– – –	+
PVR grade C or greater	–/+[b]	–	+++
Inferior break	+	–	+
Multiple breaks	+[c]	–	+++
Posterior break	–	+	+
Round hole	+++	+++	+
Giant tear	–[d]	–	+
Dialysis	+	–	+
Pseudophakia	–/+	–	+++
High myopia	–	–	+
RD border is right across the foveola	–	–	+[e]
Open-globe injury as etiology	–/+	–	+++
Thin sclera	–	+	+

[a]In reality, no traction = no RD.
[b]Only as an additional (to PPV) element, not as a stand-alone procedure.
[c]If these are fairly equidistant from the limbus.
[d]Adding it as element during PPV increases the risk of retinal slippage.
[e]The surgeon must be careful to avoid creating a retinal fold, which would severely disturb the patient's vision and is difficult to treat once it is established.

[32] All three surgical procedures are discussed in detail below.

54.3.3 Prognosis

When employed as the initial surgery, both SB and PPV yield a ~80% permanent retinal reattachment rate.[33] In the unsuccessful eyes, the culprit is either PVR (~2/3 of the eyes) or a retinal break.[34] If proliferation is the cause of failure, PPV is the natural choice for reoperation (see **Chap. 53**). If a retinal break is at fault, either option may be selected.

54.4 Scleral Buckling[35]

54.4.1 Preoperatively

- Examine the sclera for any area of structural thinning (see **Fig. 21.3a**). In the presence of such thinning, SB is contraindicated,[36] even if the buckle were to be placed elsewhere.
- Perform a careful, detailed examination to determine the strength and range of VR traction and the location of the retinal break/s.
  - Slit lamp with a 90 D lens and/or 3-mirror contact lens.
  - IBO with scleral indentation.[37]
- Make a drawing, and indicate all major findings.[38]
- Decide what kind of buckle you want to use and how many of them (see **Table 54.7**).
- If the RD is bullous, discuss with the patient that for a day or two he stays in bed preoperatively, with both eyes patched, so that the height of the detachment is decreased (see above).

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[33] This is a very rough number. Many factors have significant impact on whether the retina remains permanently attached after the operation (e.g., the duration of the RD, experience of the surgeon).

[34] Commonly referred to as "new or previously unrecognized." The distinction is academic because you can never determine whether the identified break is one or the other, and it has no influence on the treatment.

[35] See **Sect. 26.2** for a reminder of some important anatomic facts.

[36] Especially in case of a systemic disease that lasts a lifetime (see planning, **Sect. 3.1**).

[37] This allows a dynamic evaluation of the VR traction, especially on the edges of the retinal breaks. The magnification is rather small, and the patient may experience pain.

[38] It is not a piece of artwork that is required, simply a document that shows the area or the detachment and the crucial retinal and VR pathologies.

Table 54.7 Types of scleral buckle*

Type	Comment
Encircling; silicone band of different sizes.[a] The most common is width is 2 mm	The primary goal is less the support of an individual retinal break; it is intended to support the vitreous base and thus often gets employed as a prophylactic measure. Some VR surgeons also use it during PPV for its scleral indentation effect
Encircling; silicone band with tire[b]	The added, wide element is able to support a retinal break
Segmental; silicone sponge[c]	This limbus-parallel indentation has a focal effect to support a break
Segmental; silicone sponge with a grooved element	The added, wide element is able to support a break
Radial; silicone sponge[d]	The direction of the buckle is perpendicular to the limbus
Radial; silicone sponge with a grooved element[e]	The added, wide element is able to support a break
Combined	An encircling band is used on top of a radial sponge

*Only the main variants are listed here.
[a]Some surgeons use a sponge that is split in half. This requires an entirely different technique to make it work: while the band is stretched *after* the sutures were put in place, the sponge needs to be stretched each time *before* the suture is tied. The band will cause an evenly distributed indentation; in case of the sponge the indentation will differ per stretching between two sutures (the indentation is also influenced by other factors such as bite width, see below).
[b]The tire comes in various shapes and sizes.
[c]The sponge comes in various shapes and sizes.
[d]Some surgeons prefer using multiple radial buckles if there are multiple breaks in different locations.
[e]The grooved element comes in various shapes and sizes.

Pearl
There is no better empirical evidence to show the importance of VR traction than the behavior of the RD when the patient's eyes and head are immobile: the retina almost always reattaches, usually rapidly.

54.4.2 Intraoperatively[39]

54.4.2.1 Initial Steps

- Make sure that if local anesthesia is used, the analgesia is full; the operation, especially manipulations involving the extraocular muscles, can be very painful.[40]
- Open the conjunctiva at the limbus and then make radial incisions.

[39] The order of certain steps may be different with some surgeons. Most commonly, the buckle is placed prior to drainage; I do not prefer this because, especially if the detachment was high, the final resting point of the retinal break may be at a location different from the expected. The main reason why to employ the buckle-first-then-drain sequence is the fear of hypotony after the drainage. I restore the IOP using an intravitreal BSS injection; see below.

[40] This is one of the reasons why patients prefer PPV to SB.

  - If a segmental buckle is planned, make sure that the opening is wide enough to expose at least 2 extraocular muscles. If an encircling band[41] is to be used, the entire conjunctiva needs to be incised at the limbus. In either case, two radial cuts of ~10 mm in length are needed.
  - Bluntly dissect the conjunctiva to have good direct visualization of the naked sclera and unhindered access to all the exposed rectus muscles in the entire operative field.
- Using a fenestrated muscle hook,[42] introduce a retraction suture[43] under each exposed muscle.[44]
  - Clamp a hemostat onto each suture; this makes manipulations of the eye much easier.
- Localize the retinal break/s and mark each one on the sclera with a sterile pen.
  - If the break is large or radially oriented, mark the *posterior* edge: the buckle will have to extend beyond this point (see **Fig. 54.5**). The reason why it is best to avoid having to deal with a bullous RD[45] is that the break appears more posterior that it really is.
  - In case of a giant tear or dialysis, mark both ends as well as the central edge in the middle of the break. If the dialysis is narrow, as shown above, there is no need to mark its central extension.

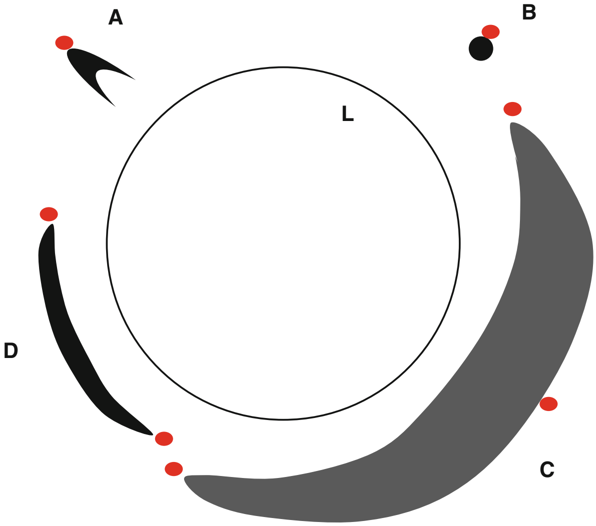

Fig. 54.5 Marking on the sclera the location of the retinal break. In case of a flap tear (*A*) or round hole (*B*), a single mark (*red dot*) is sufficient; it should be placed at the posterior border of the break. If a giant tear (*C*) or a dialysis (*D*) is encountered, both their length (width) and central-most extension should be identified. If PPV is performed, the exact same locations should be marked, on the retina, by diathermy. *L* limbus

[41] Called "cerclage" in many countries.

[42] With a hole at its tip to loop a suture through it.

[43] Such as 2-0 silk; it should be black for easy identification.

[44] Alternatively, a needle equipped with the suture may also be used, but reverse it – advance under the muscle the suture with its blunt (suture-) end forward.

[45] Bedrest with bilateral patching (see above) or drainage (see below).

Q&A

Q *What is the optimal viewing technique for SB?*

A The operating microscope offers the best view, increasing control and thus safety. The alternative is to use the IBO for the internal structures (break localization etc.) and either the naked eye or, preferably a loupe, for the external procedures (suturing etc.).

54.4.2.2 Creating a Chorioretinal Adhesion

The surgeon may use cryopexy (see **Sect. 29.2**) or laser (see **Sect. 30.3.4**). Laser is generally preferred since it reduces the risk of PVR development; however, the retina must be attached first (see below). The surgeon may want to drain the subretinal fluid first and apply the laser afterward.

Conversely, cryopexy may be used even if the retina is detached and even if the indentation actually reaches only as deep as the RPE. The effect, however, is more difficult to monitor, making this a less preferable option (see **Table 29.1**).

54.4.2.3 Drainage of the Subretinal Fluid

Some surgeons always, others never drain; most decide on a case-by-case basis.

- Locate the area with the highest elevation of the RD.
- Use a *diathermy needle*, if one is available, to penetrate as posterior as possible the sclera and choroid directly while applying cautery.
  - If there is no diathermy needle at hand, create a *radial sclerotomy* of 1–2 mm in length, diathermize the choroid, and then use a small needle or blade to penetrate the choroid.[46]
- Use a cotton-tip applicator or a muscle hook/scleral depressor to press the subretinal fluid from further-away areas toward the incision site.
- When the drainage is complete,[47] either suture the sclerotomy or leave it open.[48]
- As the fluid egresses, the IOP drops. An intravitreal BSS injection may be needed to reduce the risk of intraocular bleeding and the difficulty of suturing the sclera in the soft eye (see **Sect. 63.5**).

An alternative drainage technique involves the oblique insertion of a *needle* (25–27 g)[49] directly into the subretinal space. It requires constant monitoring via the IBO of the needle tip to withdraw it as the retina is flattening. This technique also leaves the occurrence of a choroidal bleeding up to chance (see **Sect. 3.2**), and if the subretinal fluid is very thick, it may clog the needle.

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[46] Remember, the choroid is elastic. If the opening is small, it may spontaneously close even when there still would be subretinal fluid “willing” to drain (see **Fig. 21.10**).

[47] The retina is completely attached or the remaining subretinal fluid is too posterior to drain.

[48] It can be left unsutured if it is small and will be right underneath the buckle.

[49] For easy handling, the needle is connected to a syringe whose plunger is removed: the drainage is passive.

54.4.2.4 Selecting and Placing the Buckle[50]

The goal is to place the buckle so that the retinal break is on its ridge or slightly *anterior* to it. If the buckle is misplaced, the break remains open, the intravitreal fluid is still able to access the subretinal space, chorioretinal adhesion will not form, and the RD persists.

It is possible to do buckle placement and suturing without additional helping hands – but the surgeon is much better off if he has a trained nurse to assist, especially during suturing.

> **Pearl**
> To counter the *traction*, the indentation's *height* is more important than the width. To provide a solid mechanical foundation for the *break*, the buckle's *width* is crucial: the surgeon must make sure that the entire break (i.e., the area of the naked RPE) is supported.

- If an *encircling band* is employed, have two anatomic forceps[51] to place the band. One forceps is used to advance the forceps under the muscle; the other one is to pull it out/through from the other side.
  - Make sure that the band is not twisted.
  - The two ends of the band must meet in the quadrant the surgeon selects. You can choose the one that offers the easiest access to it (e.g., inferotemporal) or the one that has the retinal break.
  - Insert the two ends of the band into a sleeve of proper size.[52] Once the sutures have been placed (see below) and the band properly stretched, cut the superfluous endings with a ~1 mm overhang.
- If a *segmental sponge* is employed, you have two options: keep the order as described above or place the sutures first and then insert the sponge under the muscle, the sutures, and then the other muscle.

> **Pearl**
> Make sure the muscle moves freely over a sponge. If a very thick sponge is used, it must be buried rather deep (i.e., the indentation should be high).

- If a *radial sponge* is employed, it will have no contact with the muscle; place the sutures first.

Buckles that are "high and broad" are associated with severe complications (see below).

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[50] Again, this is one possible option; other surgeons may use very different techniques.

[51] Preferably with a bent tip to ease maneuvering (e.g., Jameson muscle forceps or Kelman–McPherson tying forceps).

[52] The sleeve forceps has reversed action.

54.4.2.5 Suturing

The traction sutures are ideal for rotating the eyeball and provide access, but they do not fixate the globe sufficiently so as to allow needle insertion into the sclera, which has significant resistance against the passage of the needle.

- Always hold the eyeball firmly by grabbing the sclera with tooth forceps, and choose a location close to where the needle is supposed to enter the sclera.
  - If possible, grab the sclera *behind* the needle (the needle's direction is away from the grabbing point). This gives you more control than grabbing the sclera beyond the needle's exit point and does not interfere with the local anatomy (see **Fig. 54.6**).

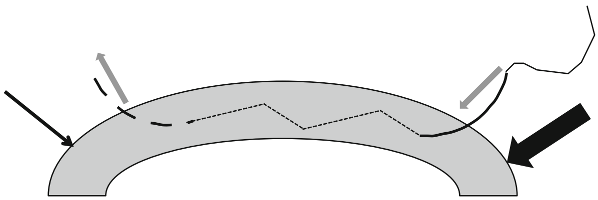

Fig. 54.6 **Securely holding the sclera and the introduction of scleral sutures**. The ideal site of grabbing the sclera is behind the entry of the needle (*thick black arrow*), not in front of the exit point (*thin black arrow*; the *grey arrows* show the direction of the needle). This allows the surgeon to apply proper counterforce without changing the scleral contour – especially important if the sclera is thin. The needle is inserted at an acute angle, which helps advancing it intrasclerally, along 2, separately applied vectors: slightly forward and up (outward) and then slightly forward and down (inward)[54]. In principle, the longer the intrascleral path of the needle, the more secure it is, reducing the risk of tearing the sclera when the suture is tightened

- When working anteriorly, the surgeon has easy access to the field. The more posterior he works, such as with a long radial buckle, however, the more difficult it becomes, and the nurse must be able to act as a third (and fourth) hand.
  - The nurse uses one hand to rotate the eye with the traction suture.[53]
- Her second hand holds the orbital spatula to keep the orbital fat away from the sclera. The spatula must not interfere with suture introduction. As the surgeon advances the needle, the spatula must be moved so that the needle can be extracted at its exit point. All this requires coordination between the surgeon and nurse – the nurse must be able to see what the surgeon is actually doing.[55]

[53] This may occasionally be substituted by clamping the two adjacent hemostats to the drape.

[54] In this schematic drawing reality is distorted to help illustrate the movement and path of the needle. (The intrascleral channel created by the needle obviously cannot exceed the length of the needle.)

[55] Another reason why SB is best viewed through the microscope and why the nurse should have her own ocular.

Q&A

Q *Why is placing the suture for the SB such a struggle for the inexperienced surgeon?*

A Because the suture can be neither too shallow (it would tear the sclera when the suture is tied) nor too deep (the sclera would be punctured, see below). To place it "just right" is very difficult because it cannot be with a single, continuous movement. The sclera is convex and the needle concave. The surgeon must advance the needle in a seesaw motion (see **Fig. 54.6**) and do it without being able to see the tip of the needle. This is indeed difficult, even in eyes with a normal sclera, and extremely challenging in a highly myopic eye with thin sclera (even a normal sclera is thin, no more than 0.5 mm in the area where the buckles [sutures] are placed, see **Sect. 26.2**).

- That the needle penetrated too deep is obvious by the presence of dark pigment on the emerging needle. Subretinal fluid drains only when there is fluid underneath *and* the IOP is high enough to press the fluid out.
- The suture should always be a mattress one (see **Fig. 54.7**), irrespective of buckle orientation.
- If an encircling band is used, the vitreous base can also be supported if a "double-mattress" suture is used (see **Fig. 54.8**).
- The suture bites should be ~2 mm from the side of the buckle material.[56]
  – At a given tension on the suture, the further apart the bites, the higher the indentation effect.
- The suture material must be nonabsorbable and preferably 5-0, and the needle a spatulated one with cutting tips.

There are fundamental differences in the function of the suture depending on whether a band or a sponge is used.

- With an *encircling band*, the role of the suture is simply to hold the band in place. The sutures are not tight so that the indentation created by the band remains adjustable (see below).
- With a *sponge*, it is the tension on the suture that creates the indentation, hence the need for the suture to lie deep in the sclera and have as long an intrascleral channel as possible.

[56] Some surgeons recommend that the suture bite exceed the width of the buckle by 50%. The rationale for a wider band/sponge requiring a proportionally wider suture placement is questionable.

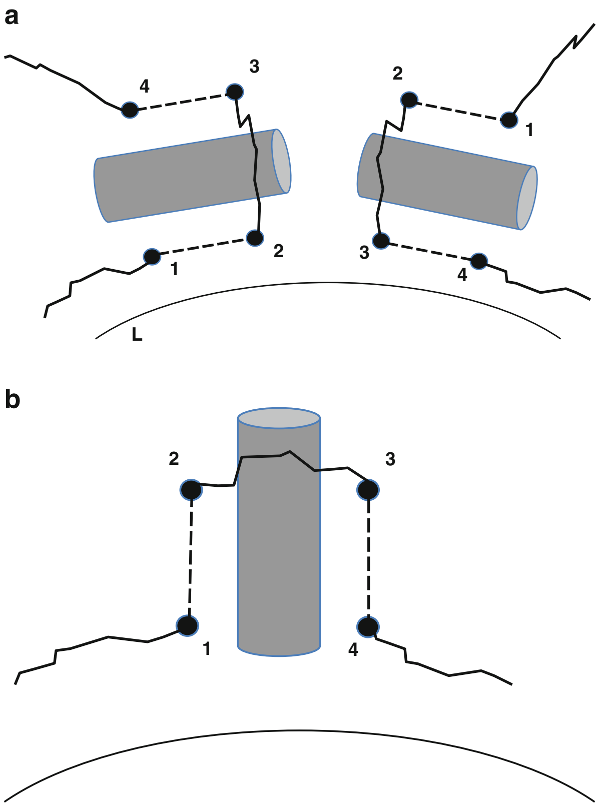

Fig. 54.7 **Placing the mattress suture in SB**. (**a**) In a limbus-parallel, segmental buckle the scleral entry (*1*, *3*) and exit (*2*, *4*) points by the needle on each side of the buckle are parallel to the limbus. It makes no difference whether the suturing is started on the anterior or posterior side of the buckle[57] (i.e., points 2 and 3 are interchangeable); neither does it make a difference whether the initial suture is away or toward the surgeon[58]. The same type of suture is used to secure an encircling band. (**b**) In a radial buckle, it also makes no difference on which side of the buckle the surgeon starts (*1* and *4* are interchangeable). However, the surgeon should always start at the limbal end so that when he ties the knot, it is closer to him[59] (this is less important when working anteriorly but becomes very important when the furthest-away knot is tied). *L* limbus

54.4.2.6 Alternative Methods to Secure the Buckle

Scleral pockets and tunnels can also be used to hold the buckle. Their sole advantage is that no suturing is needed.[60] This is, however, more than offset by several disadvantages.

[57] I.e., points 2 and 3 are interchangeable.

[58] The latter is important, though, for the nurse to know: she has to hand over the needle-holder accordingly. Typically a suture is introduced toward the surgeon (right-hand side on the image); if the initial entry is at point 1 (left-hand side on the image), the surgeon should ask the nurse to hand him the needle holder in the away position.

[59] This is less important when working anteriorly, but becomes very important when the furthest-away knot is tied.

[60] No risk that the suture releases in the coming months or years (this very rarely happens). However, even if this does occur with the traditional technique described above, the indentation

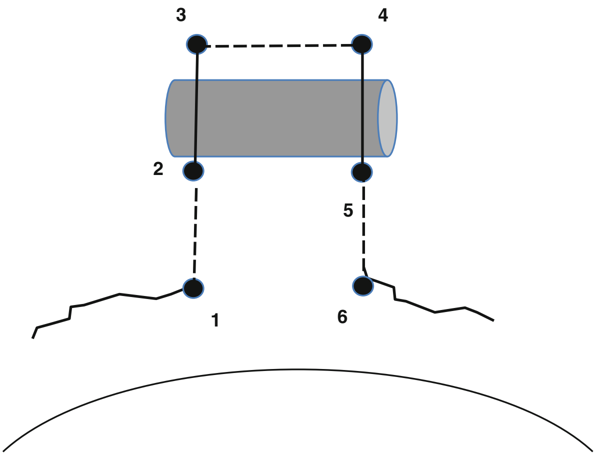

Fig. 54.8 **The double-mattress suture**. The suture supports both the encircling band and the vitreous base peripheral to it. If this type of suture is used, it must be rather tight, making the adjustment of the tightness of the band more difficult than with the customary single-mattress suture. The numbers represent the order of suture advancement

- The method is not applicable in many cases, including eyes with high myopia (see **Table 42.1**).
- It is more complicated and dangerous to create a tunnel in the sclera than placing a suture.
- The location is permanent; no readjustment is possible. A suture can easily be relocated.
- The scleral bed is thin under the buckle; internal erosion is much more common.[61]

54.4.2.7 Adjusting the Buckle

There are two characteristics that determine the efficacy of the SB: location and height.

Q&A

Q *How high should the indentation be?*

A Enough to allow retinal reattachment (fully countering the VR traction) but not too high so as to cause anterior segment ischemia with an encircling band, major astigma with a radial buckle, and fishmouthing with a segmental one. This is easier said than done, especially considering that the retina is usually detached when the buckle is placed and the IOP may be low before the sutures (buckle) are tightened. All these have a direct impact on the final contour of the eyewall when the IOP normalizes.

- Once you placed the *encircling band*, the sutures, and the sleeve, tighten the band gradually, inspecting the retina repeatedly.

---

does not disappear: the scar tissue that develops around the buckle keeps the scleral contour unchanged. Sponges create more scar tissue than bands.

[61] I did have to remove a couple of buckles from inside the vitreous cavity. True, external (transconjunctival) erosion of the buckle does not occur with a pocket, but an external erosion is much less dangerous than the internal one.

  - You can adjust the indentation higher (tightening the band) or lower (loosening the band).
  - The location can be changed only by replacing the suture.
- With a *sponge*, it is not possible to know the indentation's final effect until the sutures are tightened, at which point neither the location nor the height can be adjusted without removing and replacing the sutures.
  - The nurse should grab the two ends of the sponge and gently stretch it. The surgeon ties the suture with an initial double or triple throw; the nurse grabs the knot with a smooth forceps and holds it until the second double throw is in place. This prevents loosening of the knot while it is being tied. A final throw (double or simple) may be used as an absolute reassurance.
  - This is then repeated for each suture. The nurse must be careful not to pull the sponge through a suture loop that is already in place.

54.4.2.8 Closing the Conjunctiva

Vicryl suture is used; the drainage sclerotomy needs a (single) suture only if it is outside the bed of the buckle. In this case try a preplaced suture[62] and tie it right after the drainage has been completed.

54.4.2.9 Gas Tamponade

The gas is injected into a vitreous cavity that still has a considerable amount of gel. No more than 0.5 ml of pure gas should be injected, the IOP monitored, and the patient be asked to position so that the gas bubble's buoyancy pushes the retina around the break against the RPE (see **Sect. 35.2.3**).

The gas should not be injected through an inferior location to avoid the fish-egg formation and subretinally trapping the gas (see **Fig. 54.9**).[63] The needle is best kept inside the enlarging bubble.

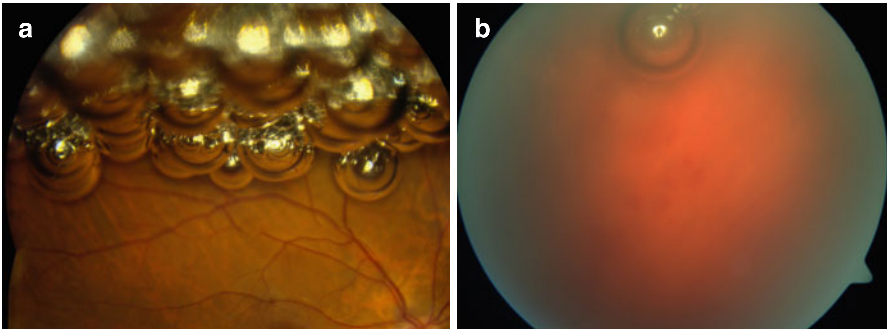

Fig. 54.9 **Complications as a result of the injected gas**. (**a**) Bubbles in the vitreous cavity – the intraocular penetration of the needle was too inferior. (**b**) One small gas bubble is trapped subretinally, under attached retina. The bubble need not be removed, it will absorb spontaneously; still, it is best to avoid this complication by injecting the gas properly (see the text for details)

[62] So you do not have to suture the sclera while the eye is soft.

[63] Occurs less frequently than with air (see **Sect. 14.2**).

54.4.3 Major Intraoperative Complications of SB

See **Table 54.8** for details.

Table 54.8 Major intraoperative complications of SB*

Complication	Comment
Anterior segment ischemia[a]	The cause is an encircling band/buckle that is too high (and possibly too broad)
Fishmouthing	The cause is a buckle that is too high; the break is on the posterior slope of the buckle
High IOP	The cause may be one the following: An encircling band/buckle that is too high Gas that is injected into an eye that already had higher IOP Too much gas injected, with consequent rapid expansion
Misplaced buckle	The retinal detachment was high, and the final "resting place" of the retinal break is different from the location originally assumed
Retinal incarceration	During drainage, rapid fluid outflow may drag the retina with it. Unless the sclerotomy and the choroidal opening are very large, the retina will not be externalized. The condition is recognized, via IBO, by the presence of retinal folds radiating from the drainage site. Chorioretinectomy is recommended (see **Sect.** 33.3)
Sandglass-shaped eye[b]	The cause is an encircling band/buckle that is too high (see **Fig.** 54.10)
Scleral puncture with the suture-needle	There is a risk of choroidal hemorrhage (see below) If the retina is detached, inadvertent drainage of the subretinal fluid occurs If the retina is attached, a retinal break (rarely also a hemorrhage) may be caused
Scleral tearing	In eyes with thin sclera or with a suture track that is too shallow, cheesewiring may be seen upon tightening the suture
Subretinal gas (fish eggs)	If the break is large and superior, and if the surgeon injects the gas in tiny increments, the gas bubbles may not coalesce (**Fig.** 54.9a), and a bubble may enter the subretinal space (**Fig.** 54.9b)
Subretinal hemorrhage	The most significant intraoperative complication of SB surgery. During drainage or with a too-deep suture, there is always a risk that such a bleeding occurs. Immediately increasing the IOP usually stops it. The patient's head must be positioned so that the blood does not become submacular

*In alphabetical order.
[a]This is really a postoperative, not intraoperative, complication but is mentioned here because it must be prevented intraoperatively, by not tightening the band too heavily.
[b]I had the misfortune of having to reoperate on eyes where it was very difficult to move the instruments in the vitreous cavity, due to the extreme height of the circular indentation.

54.5 Vitrectomy

As mentioned above, there are more arguments favoring PPV than SB (see **Table** 54.5). Still, I am not trying to convince the reader to opt for vitrectomy; I simply describe my PPV technique.

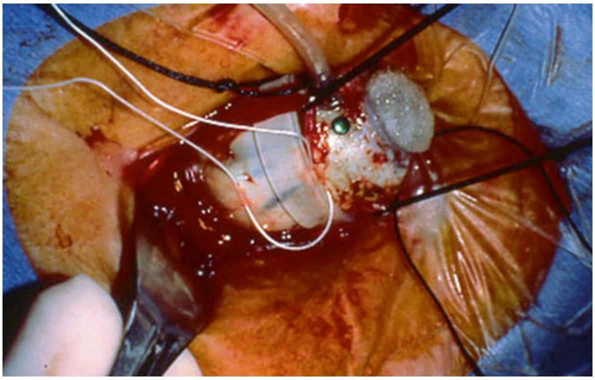

Fig. 54.10 A buckle too high. This eye has a high chance of developing anterior segment ischemia, becomes (even more) myopic, and shows a hourglass appearance because the wide band is pulled too tight. The technical problem with an eye having such a distorted contour is that there are many areas inside the vitreous cavity that remain inaccessible to the surgeon

54.5.1 Preoperative Examination

- This can be kept to the minimum: making the diagnosis.[64] In sharp contrast to the needs of SB or pneumatic retinopexy, the fine details can be established intraoperatively.[65]
- It is important, though, to determine whether the macula is off (timing, see above, **Sect.** 54.3.1) and if it is, whether it is partial (to avoid causing a macular fold; see **Sect.** 31.1.2).

54.5.2 Surgical Steps

54.5.2.1 Sclerotomies

The position of the break/s does not influence their placement. If the RD is bullous, be careful not to insert the cannula under the retina (see **Sect.** 21.6).

54.5.2.2 Vitreous Removal

- Determine if the media are sufficiently clear to visualize the posterior retina. In the rare cases with severe VH, assume the retina is just behind the probe and proceed very cautiously from anterior to posterior; otherwise, the standard P-A approach is employed.
- The vitreous removal must be complete (see **Chap.** 27), starting with a PVD (using TA to mark it),[66] which should be extended as far anterior as possible. More than half of the eyes will *not* have a PVD posterior to the retinal tear.

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[64] History (flashes, curtain etc.); slit lamp/IBO; ultrasonography in the presence of fundus-blocking media opacity – but keep in mind that in up to a fifth of the eyes with VH, the diagnosis of RD may be false.

[65] These details will also be much more accurate than any preoperative examination would allow.

[66] The lack of PVD does not become evident unless the surgeon actively searches for the presence of vitreous on the posterior retina.

Pearl

The key to surgical success is removal of the entire vitreous. Redetachment in the absence of PVR is almost always caused by traction exerted by the residual vitreous.

– Indirect evidence of vitreous being present on the retinal surface posterior to the tear is provided by the retina moving *toward* the probe when aspiration/flow is activated. Conversely, if gel, rather just fluid, is present and the probe is pushed toward the detached retina, the retina will *move away* from the probe (see **Sect.** 27.3.1).

Q&A

Q *How far anteriorly should the vitreous be separated from the retina?*

A In principle, the further anteriorly, the better. In some eyes it is at the equator where they become inseparable; in others it is more anteriorly. Using two instruments (such as the light pipe as the second one) can help with the separation, but eventually it becomes either impossible to detach the vitreous or its cost is too high because additional retinal tears form. This is the line at which the vitreous must be left behind but shaved to as close to the retina as possible (the rather drastic alternative is a retinectomy; see **Sects.** 27.2 and 33.1).

- The vitreous may be so adherent to the still-attached retina that if separation is attempted by using high aspiration/flow, the 2 tissues do not separate, but the choroid is pulled off.[67]
- If the retina is very mobile, the risk of eating into it with the probe is high, even when using a high cut rate at a low flow/aspiration. Scleral indentation and/or the use of PFCL helps reduce the movement of the retina. Draining the subretinal fluid does not help because the IMP is broken (see **Sect.** 26.3.2).
- If a flapped tear is present, it must be excised[68] so that the remaining retinal edge is flush. The entire area must be traction-free.
- 360° scleral indentation is used to complete the peripheral vitrectomy. Even in a phakic eye, this is relatively easy to accomplish without risking lens integrity – provided the sclerotomies were placed correctly (see **Sect.** 21.2). Pneumovitrectomy (see **Fig.** 14.1 and **Sect.** 27.3.2) is a safe and effective technique to allow maximal gel removal at the vitreous base.
- Finally, the vitreous must be removed from behind the lens (see **Sect.** 27.5.3).

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[67] Should this occur, the separation attempt must immediately be abandoned. The choroid will with time re-adhere to the sclera; there is no need for any special intervention. The choroidal detachment is more common in eyes with severe injury or if a subretinal strand (see **Sect.** 32.4.1) is being pulled.

[68] Obviously, any blood vessel bridging the tear and the retina must be cauterized first.

With the vitrectomy complete, the surgeon must decide whether to peel the ILM (see **Table 54.9**).

Table 54.9 ILM removal in eyes with RD

Issue	Comment
Removal or not?	Due to the RD and to the surgery itself, there is an up to 10% risk of EMP development; in addition, there is a ~5–10% PVR risk. A macula denuded of its ILM cover will be spared of either type of surface proliferation
Removal in each case?	Although the risk of a complication due to ILM removal is very low, it is not zero. For this reason, I peel the ILM only in eyes where the macula is off[a]
Surgical technique – principles	Remove the ILM in as large an area as possible. Usually, it is easier to separate the ILM from over a retina that is detached as the adhesion between them seems, in my clinical experience, to be less strong than over an attached retina. The difficulty lies in the fact that the detached retina moves as the ILM is peeled
Surgical technique – practice	See **Sect. 32.1.6**

[a]This is one area where I can foresee my philosophy change in the future and remove the ILM in every case.

A bullous retina is a challenge during vitreous removal because it threatens to enter the port. Low flow/aspiration, high cut rate, scleral indentation, and keeping the retina away with the light pipe are all helpful in reducing the risk.

Pearl
A retinal break that is inferior is not by itself an indication for placing an inferior scleral buckle or using silicone oil. If the sclerotomies were properly placed (see **Sect. 21.2.2**) and all traction has been eliminated around the break, the risk of redetachment is not higher than with a superior break.

54.5.2.3 Intraoperative Retinal Reattachment

See **Sect. 31.1.2** for details of draining the subretinal fluid (F-A-X). Only a few additional issues are mentioned here.

- I always mark the *posterior* edge of all retinal breaks[69] with diathermy so that they are easily visible in an air-filled eye.[70]
  – The reason to mark the posterior edge is to indicate the central-most point for the laser treatment (which is done under air) so that at least 2 rows will be placed posterior to it.
  – If the break is large, its extension on the frontal plane must also be marked, identical to the markings seen on **Fig. 54.5**.

[69] Except if they are in a cluster and at equidistance from the ora serrata; here a single mark is sufficient.

[70] Unless it is giant tear, breaks tend to become invisible under air.

Q&A

Q *Should PFCL be routinely used in retinal detachment surgery?*

A It is the individual surgeon' decision. PFCL does make maneuvers such as the draining of the subretinal fluid easier, unless the break is very central and especially if it is still under traction (see **Sect. 35.3.1.1**). Conversely, PFCL is expensive, and there is a risk that it will not be fully removed. I use PFCL only as an exception, when the break is very peripheral.

- One of the benefits of performing PPV for RD is that it is extremely rare[71] to have subretinal fluid persist under the fovea (see **Fig. 54.11**).

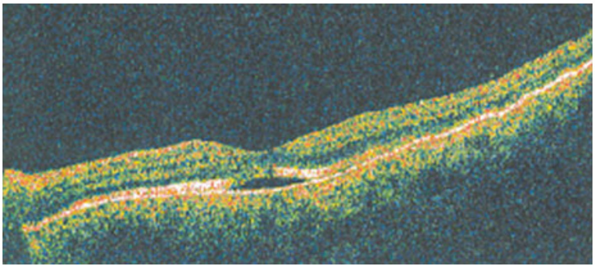

Fig. 54.11 **Persisting subfoveal fluid after successful retinal reattachment with SB**

54.5.2.4 Laser Retinopexy

Laser serves two purposes in my practice:

- First, 2–3 rows of confluent laser spots around the break to seal its edge.[72]
- Second, laser cerclage (see **Sect. 30.3.3**) to create a barrier between the equator and the ora serrata to counter the effects of any residual/developing VR traction.

Pearl

Cryopexy is as (if not more) effective in creating a chorioretinal adhesion as laser. However, even if not overdone (and some surgeons do just that "to achieve maximum scar strength" and thus release RPE cells into the vitreous) and done correctly to surround the break without freezing the naked RPE, cryopexy causes massive inflammation. This is a known risk factor for PVR. Laser is always preferred to cryopexy (see **Chap. 29** for more details).

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[71] It is much more common with SB.

[72] In case a small amount of vitreous has been left behind; this may contract subsequently, lifting the retinal edge. The shearing caused by the eye/head movements can then redetach the retina.

54.5.2.5 Intraocular Tamponade

In most cases a short-term "tamponade" (see below, **Sect. 54.5.2.6**) is sufficient: by the time the bubble allows a significant amount of fluid to accumulate in the vitreous cavity, the lesion will have been sealed by the laser treatment. If longer-term tamponade is necessary, I prefer silicone oil to a long-acting gas such as C_3F_8 (see **Sect. 35.4** and **Table 35.1**).

Q&A

Q *When to use silicone oil, rather than gas tamponade, in RD surgery?*

A Silicone oil requires a second operation for removal, but it offers several benefits. The retina is visible from day 1; the retina remains attached until the laser spots reach maximum strength; if additional laser is needed, it can be easily added at any time; if the fill is 100%, the risk of PVR is reduced; if PVR occurs, the retina cannot rapidly collapse into a closed funnel.

The lens is likely to opacify sooner rather than later if in contact with silicone oil. To maintain retinal visualization throughout the entire period while the silicone oil is in the eye, it makes sense to remove the lens prior to oil implantation.

Q&A

Q *What is the rationale to use heavy silicone oil?*

A To spare the inferior retina, by switching the location of PVR development superiorly. Unfortunately, it is much more difficult to operate on the superior than on the inferior retina.

The timing of silicone oil removal is more controversial. Unless some circumstance[73] forces me, I do not remove the silicone oil earlier than 4 months: I have seen PVR to develop after the silicone oil was removed at 3 months. Others feel comfortable removing the oil earlier.

54.5.2.6 Postoperative Positioning

- If the vitreous removal has truly been complete, there is no real need for positioning in a *gas*-filled eye.[74] Should the surgeon, however, be less confident that he left no tractional force behind, a few days of positioning may be beneficial.[75]

[73] High IOP due to overfill (almost never happens), subsequent intraocular hemorrhage (very rare), early emulsification (quite common). If the emulsification occurs before the plan calls for oil removal, oil exchange is indicated.

[74] The goal of gas use is less for tamponading the break; rather, it occupies space in the vitreous cavity, depriving the slowly accumulating intravitreal fluid of its ability to cause shearing on the edge of the retinal break (see **Sect. 14.1**).

[75] Just remember that positioning is very inconvenient and uncomfortable to the patient.

  – It is wrong, though, to issue a blanket instruction of "be facedown," which would soon expose an equatorial break as the gas bubble shrinks. The surgeon should carefully think in each case about what head position will provide the longest possible period of gas/break contact.
- Whether gas or *oil* has been used, a patient with a phakic or aphakic eye should avoid the supine position, especially in the first few days.[76] In case of pseudophakia, this is less important.

54.5.3 Follow-Up Visits

Typically, the risk of redetachment has two peaks. The first is usually early, as the gas absorbs; this RD is break related.[77] The second one is several weeks later, as PVR develops. The patient should be counseled about this and the symptoms preceding (flashes) or accompanying (curtain) the detachment.

54.5.4 Prognosis

If the macula was on, excellent outcome is to be expected. If it was off, the functional result is difficult to predict since it is influenced by many factors: duration of the detachment, height of the detachment, ability to drain all the submacular fluid, and individual factors such as the condition of the patient's systemic circulation, the degree of myopia etc.

54.5.5 RD After Silicone Oil Removal

In up to a fifth of the eyes, the retina redetaches within a few weeks after the oil has been removed.[78] Often a small retinal break is found during the reoperation (see **Fig. 35.5**), which in turn is most commonly caused by residual vitreous. If no break is identifiable, the surgeon must wonder whether the RPE and/or the IPM are at fault. In the latter case, the oil must be reimplanted.

54.6 Pneumatic Retinopexy

The principle behind the procedure is that a chorioretinal adhesion is created around the break, either by cryopexy of laser, and a pure gas bubble is employed to reattach the retina.

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[76] To defer as much as possible the development of cataract in the phakic eye and to avoid silicone oil prolapse into the AC in the aphakic eye.

[77] However, in some cases it takes a lot longer for the residual traction to open the break and cause an RD.

[78] This is a risk every patient must know in advance.

54.6.1 General Considerations

- Unlike with PPV, the VR traction is not eliminated.
- To state, as many surgeons do, that pneumatic retinopexy does not address the VR traction, is erroneous. Much like SB, it weakens the traction that caused the retinal break, but, unlike SB, it also creates traction elsewhere.

Pearl

Injecting an expanding gas bubble into an eye that still has gel vitreous has two consequences. The VR traction in the area of the break weakens, much like a rubber band will lose some of its elasticity when held in an expanded state for extended periods. Conversely, the gas compresses the gel throughout the vitreous cavity, accelerating the syneresis process and yielding more room for gel movement once the gas bubble disappears. This result is more VR traction postoperatively, explaining the high incidence of re-RD due to a ("new or previously undiagnosed") break.

54.6.2 Patient Selection

The failure of pneumatic retinopexy to properly deal with VR traction limits the type of cases in which it can be employed. The following are good candidates for the procedure:[79]

- A patient who understands that positioning is crucial and failure to do so[80] will have a major negative impact on the success of the operation.
- Minimal VR traction as detected on careful biomicroscopy.
- An RD of only one quadrant.
- A break that is superior.[81]
- A break that is small.
- Single break or if multiple breaks are present, they are clustered within 1 o'clock.

54.6.3 Surgical Options

54.6.3.1 Cryopexy, Followed by Gas Injection

- A paracentesis prior to gas injection helps prevent the rise in IOP.
- The most commonly used gas is 0.5 ml SF_6.

[79] Those advocating this procedure gradually increase the list of potential candidates.

[80] Positioning and positioning as long as the gas bubble is present or the surgeon says he should. In this case the tamponade is truly that.

[81] Between 10 and 2 o'clock.

- Fish-egg formation must be avoided when injecting the gas (see above).
- It is best to inject the gas in a quadrant where the retina is attached and use a steamroller[82] maneuver to press the subretinal fluid into the vitreous cavity, not under the macula.

54.6.3.2 Gas Injection, Followed by Laser

As soon as the retina in the vicinity of the retinal break reattaches, laser is applied around the break. The patient's head must be positioned so that the gas bubble does not interfere with the laser.

54.7 Reoperation

Regardless of the type of surgery for RD, there is a certain percentage of the eyes where a second operation is necessary. The failure may be primary (lack of retinal reattachment; almost never happens with PPV) or secondary (redetachment, most commonly with pneumatic retinopexy).

Table 54.10 provides some guidelines regarding the type of surgery in cases the first one failed.

Table 54.10 If reoperation for RD is needed for a failed first surgery*

Primary surgery	Pneumatic retinopexy		SB		PPV	
Primary surgery's failure is due to	RB	PVR[a]	RB	PVR	RB	PVR
Recommended 2nd surgery: SB	+	–	+	–	+	–
Recommended 2nd surgery: PPV	+	+	+	+	+	+

**RB* retinal break.
[a]This is extremely rare.

[82] The patient's head is positioned and then turned so that the gas is initially in contact with attached retina, moving over the detached retina only subsequently. As the bubble advances toward the detached retina where the break is, it pushes the subretinal fluid into the vitreous cavity.

RD, Tractional and Combined

55

55.1 General Considerations[1]

55.1.1 Characteristics of the RD

Tractional RDs are recognized by the presence of pre- or subretinal membranes (bands/strands)[2] and by the concave profile of the detached retina. The traction exerted by the membranes is stationary; the height and shape of the RD do not change with the position/movement of the eye/head.

Such membrane-related traction is also the dominant element in a *combined* RD; the presence of the retinal break does not determine the appearance or behavior of the RD, but it does have management implications (see below).

- If the eye had no surgery, the secondary break is usually small and often hidden underneath a membrane.
- In an operated eye[3] the newly developed break is usually larger and has a typically oval shape (see **Fig. 14.4**).

[1] As discussed in **Chap. 54** and shown in **Table 54.1**, even a rhegmatogenous RD is almost always caused by traction, but, traditionally, the term "tractional RD" is preserved for eyes in which there are clearly visible membranes or strands in front or underneath the retina. These elastic structures lead to the RD, without the need for, and presence of, a retinal break.

[2] For simplicity, all these structures, regardless of their size and shape, are referred to as "membrane" in this chapter.

[3] That is, recurring RD.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_55

55.1.2 Management Principles

Because the traction is not dynamic, bedrest and bilateral patching do not change the height or size of the detachment. For the same reason, the progression of the RD is slow, even if a break is present.

Surgery is thus even less urgent than in eyes with a rhegmatogenous RD; conversely, it is even more crucial in these eyes than in those with a rhegmatogenous RD to completely eliminate the preretinal traction. Subretinal membranes do not require complete removal, breaking them into two may be sufficient, and those that may stretch enough to allow retinal reattachment in spite of their presence may be left behind (see **Sect.** 32.4).

> **Pearl**
> The proliferative process in front of the retina, as opposed to one that is subretinal, has a higher tendency to spread and recur.

If the membranes are vascularized, 2–3 days preoperatively an intravitreal bevacizumab injection should be given (see **Sect.** 52.1).

55.2 Surgical Technique[4]

- Always perform a total vitrectomy.
  - Depending on the etiology, a PVD may be complete, anomalous, or absent.
- Identify all preretinal membranes and remove them in their entirety.
- Before trying to remove the subretinal membranes, make sure that all preretinal membranes have been removed. This is especially important if a retinectomy is required.

> **Pearl**
> Increased mobility of the retina, which in an eye with rhegmatogenous RD makes the surgery technically more difficult, is a good sign in an eye with TRD: it is a sign that the tractional forces have been eliminated.

- In the periphery it may be impossible to separate the vitreous from the retina. In such cases a retinotomy must be performed central to the line of no separation, and the entire peripheral retina-vitreous-membrane complex needs to be removed (see **Sect.** 33.1).

[4] More details are found in **Chap.** 32 as well as in **Chaps.** 52 and 53.

- The ciliary body must be thoroughly cleaned to reduce the risk of any future scar tissue destroying it and leading to phthisis (see **Sect. 32.5**).
- If the retina is shortened, retinectomy and SB are the two options to consider.
- Once an iatrogenic break is caused in an eye undergoing surgery for a TRD,[5] it becomes an absolute necessity to remove all tractional forces in the vicinity of this break, even at the cost of causing more breaks.
- Unless the detachment is very shallow, the subretinal fluid should be drained through the existing break or through a newly created retinotomy.

Q&A

Q *What are the criteria for selecting the site for the drainage retinotomy?*

A It should be superior to the horizontal meridian, in a location that is central enough to allow complete drainage during a F-A-X yet peripheral enough for the resulting absolute scotoma not to be noticeable by the patient. It should be as far away from major blood vessels as possible (see also **Sect. 32.4.1**).

  – As a reminder, always use diathermy to create the retinotomy. It not only prevents bleeding but also allows easy identification of the break in the air-filled eye.
- The air-test (see **Sect. 31.1.2**) helps determine whether a subretinal membrane will prevent retinal reattachment.
- For tamponade, silicone oil should be the default option[6] since it has several advantages, including the following (see also **Sect. 35.4.3**):
  – Prevention of postoperative bleeding.
  – Allowing a clear retinal view from postoperative day 1.
  – Reduction in the recurrence rate.
  – Prevention of rapid retinal collapse in case of a recurrence.

[5] That is, making it a combined RD.

[6] If the RD involves only a small area and no break is present, there is no need to use oil.

RD, Central

56

56.1 General Considerations

In eyes with a posterior staphyloma, the rigid ILM does not allow the otherwise elastic retina to stretch and conform to the highly concave contour of the scleral bulge (see **Fig. 56.1**).[1] The detachment typically develops over the entire area of the staphyloma, and a secondary macular hole may eventually also form.

> **Pearl**
> In all other forms of RD the *primary* cause is either in front of the retina (VR traction), below it (subretinal traction or mass), occasionally inside the retina (shortening), or fluid production (optic pit); here the cause is an anatomical abnormality in the eyewall.

One possible surgical option is to place a buckle over the macula. I prefer performing PPV for this condition; the technique is described below. The main goal is to relieve the central retina of the two forces that prevent retinal reattachment: the posterior cortical vitreous[2] and the ILM.

56.2 Surgical Technique

- Perform a subtotal vitrectomy.
- Create a PVD.
  - A vitreoschisis is found in these eyes, not a PVD.
  - It is very difficult to visualize the posterior cortical vitreous, even with TA, because there is little or no contrast between the white crystals and the posterior pole. The pigment content of the retina and choroid is very low, and often it is

[1] Except for the lack of the scleral bulge, VMTS may cause a rather similar OCT image (see **Sect. 50.1.1**).
[2] Which, contrary to the traditional description, is not detached in these eyes.

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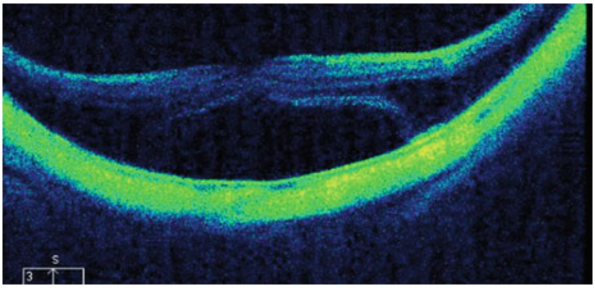

Fig. 56.1 **OCT image of an eye with a central RD over a posterior staphyloma**. The retina is unable to follow the large bulging of the eyewall and the neuroretina gets detached from the choroid/RPE with serous fluid present in the subretinal space. The curved line of the hyper-reflective RPE layer is due to the posterior staphyloma

the light reflex from the white the sclera that dominates the background. The staphyloma-spanning RD is one possible indication for staining the posterior vitreous cortex with ICG (see **Sect.** 27.3.3 and **Fig.** 34.1), which may allow the surgeon to actually see that vitreous is indeed still attached to the retina.
  - Unlike in eyes without a posterior staphyloma, it is crucial to understand that the port of the probe can *directly* face the retina (see **Sect.** 24.1) in certain locations, potentially risking retinal injury while attempting the PVD. The vitreous is very adherent, the retina is thin, and even in areas with attached retina the forces preventing RD development (see **Sect.** 26.3) may be weaker.
  - It may be impossible to reach the posterior pole with a standard-sized probe without indenting the eyewall (see **Table** 42.1).
- Perform a 360° laser cerclage to reduce the risk of postoperative RD due to a peripheral tear (see **Sect.** 30.3.3).
- Stain the ILM with ICG.
  - Keep the dye in the eye for a good 20 s to achieve maximum staining.
  - Peel the ILM in as large an area as possible. I always try to do this up to, or even beyond, the rim of the staphyloma.

Q&A

Q *Why is it so difficult to peel the ILM in a highly myopic eye?*

A There are several reasons. There may still be cortical vitreous on the retinal surface; the ILM may stain rather well, but the contrast will still be poor due to the white background; the retina may be as thin as 1/3 of its normal thickness; and the ILM has a high tendency to tear.

- If a true macular hole is present, drain the submacular fluid carefully, using a soft-tipped flute needle.
  - If there is no macular hole, do not create a retinotomy, simply leave the subretinal fluid behind.
- Use a gas tamponade and ask the patient to strictly position facedown for as long as the gas bubble is present, but at least for 5 days.

If this surgery is unsuccessful, silicone oil may be implanted or a SB used.

Retinoschisis

57

57.1 General Considerations[1]

57.1.1 Anatomy and Pathophysiology

The typically bilateral lesion appears in the inferotemporal, occasionally superotemporal, quadrant, and results in an absolute scotoma as the layers of the neuroretina are split[2] and the nerve connections are broken.[3]

Clinical recognition of the condition is somewhat difficult because a chronically detached retina bears some similarity to it, although the latter does not show the "beaten metal" appearance of a retinoschisis. OCT gives the definite answer in differential diagnostics.

The retinoschisis may be stationary or progressive; the latter may be partially explained by the fact that these eyes very rarely have a PVD, resulting in a constant, dynamic traction acting upon the inner wall of the cavity. RD may also develop if breaks are present both in the anterior and posterior walls of the retinoschisis cavity (see **Fig. 57.1**), and the RD may also be progressive.

57.1.2 Prophylactic Laser Treatment

It is very difficult to argue against the concept of walling-off the retinoschisis (see **Sect. 30.3.4**) since such laser treatment is quite effective. Conversely, the progression of the condition, whether it is the enlargement of the retinoschisis cavity or of the resulting RD, threatens with severe visual loss, and the prognosis of surgery is poor.

[1] Senile (degenerative), not juvenile, type of retinoschisis is discussed here.

[2] At the outer plexiform layer.

[3] This is why the term "retinoschisis" should not be used in eyes with an optic pit (see **Sect. 51.1**).

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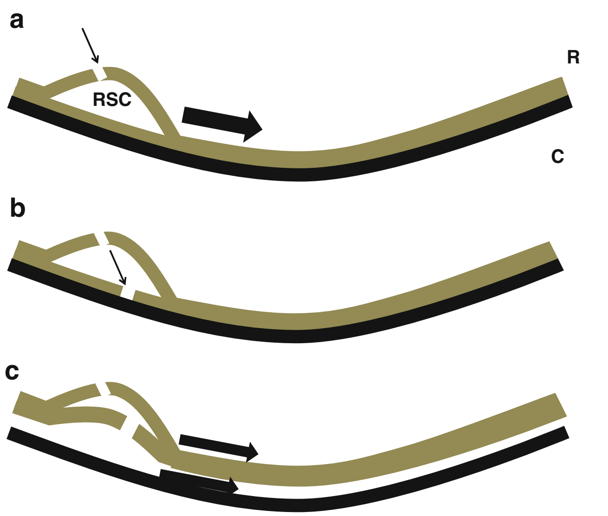

Fig. 57.1 **Schematic representation of the progression of retinoschisis**. (**a**) With a break (*thin arrow*) in the inner wall of the retinoschisis cavity, there is a risk that the lesion spreads (*thick arrow*) toward the macula (not shown here). (**b**) With an additional break (*thin arrow*) in the outer wall of the retinoschisis cavity, there is a risk that the fluid from the vitreous cavity also spreads through the retina into the subretinal space. (**c**) What was only a threat on (**b**) has become a reality; now the macula is at risk from both the retinoschisis and a true RD (*thick arrows*). *RSC* retinoschisis cavity, *R* retina, *C* choroid

The goal of the laser retinopexy is to create a firm chorioretinal adhesion in the normal retina to prevent the pathology from breaking through. This requires treatment with rather strong laser spots so that the inner retinal layers are also incorporated into the scar.

If the retinoschisis itself or the RD is progressing toward the macula, surgery is the only option left. This is a rather difficult operation because the posterior cortical vitreous is very adherent to the thin inner wall of the cavity. PVR is a rather common postoperative complication; therefore, the VR surgeon should be rather pessimistic during counseling.

Pearl
Retinoschisis is a condition where PPV is best avoided, rather than recommended; however, progression of the pathology may make PPV unavoidable.

57.2 Surgical Technique

- Perform a total or subtotal vitrectomy.
  - Try to create a PVD. It may be very difficult or impossible to accomplish over the retinoschisis.
  - It may be necessary to remove the inner wall of the cavity to eliminate the traction of the retina.[4]
- Drain the schisis cavity as well as, if present, the subretinal fluid (F-A-X).
- Apply laser both of the walling-off type (see above) and over the entire schisis area, the latter with stronger-than-usual spots to try the incorporate the inner retinal layers.
- Use silicone oil as tamponade.

[4] The traction, even in the absence of PVR development, may lead to progression of the condition once the silicone oil will have been removed.

RVO

58

58.1 General Considerations

A retinal vein is occluded by thrombus formation, occasionally by external compression, or due to a disease involving the vein wall (e.g., vasculitis).

58.1.1 Treatment Options

As a result of the occlusion, whether it involves a branch or the central retinal vein, the retina in the affected area becomes hemorrhagic and edematous. The loss of vision may be the result of the VH, the macular edema, the accompanying ischemia, and/or consequent neovascularization; TRD may also occur. The new vessels can be present both in the retina and the anterior segment; the latter may lead to the development of neovascular glaucoma, which is another potential source of visual loss.

There are numerous treatment modalities ranging from observation[1] to grid and/or panretinal laser, intravitreal injections,[2] and implants to radial optic neurotomy, as well as vitrectomy. **Table 58.1** provides a few thoughts on the different treatment modalities. The technique described below reflects my typical approach; the other treatment options are not discussed in this book.

58.1.2 The Vitrectomy Option

Vitrectomy is most effective when it is done *early*, not as one used when all else fails. The advantage of PPV is that, unlike the intravitreal injections, it is usually a one-time intervention; it also avoids the emotional seesaw the patient who

[1] Convenience or ease should not be the primary criterion when deciding whether intraocular injections or surgery is chosen as the treatment option (see **Sect. 8.2**).

[2] Steroid, anti-VEGF.

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Table 58.1 Treatment options in RVO

Treatment modality	Comment
Laser, grid/sectoral	Better than observation in eyes with BRVO
Laser, panretinal	Somewhat effective in preventing neovascular glaucoma
Intravitreal steroid, injection/implant	Effective, but only on a temporary basis, in treating macular edema
Anti-VEGF, injection	Effective, but only on a temporary basis, in treating macular edema
Radial optic neurotomy	Controversial regarding indications and efficacy
Vitrectomy	Generally considered effective for anatomic but not necessarily for functional improvement[a]. Primary PPV offers several benefits (see the text for details)

[a]The problem with most studies is that vitrectomy was applied as a last resort, not as an early weapon.

experience vision increases then drops with the injections (see **Sect. 49.1.2**). Furthermore, injections remain a viable option in those relatively few cases when PPV was unsuccessful.

Vitrectomy is able to reduce or cure the macular edema and allow the proper laser treatment to be done intraoperatively.[3] Timely removal of the gel is also likely to prevent the severe fibrovascular reaction that occurs in some eyes with CRVO. Once such a TRD occurs, the prognosis is very poor (see below), and PPV is the only remaining option.

58.2 Surgical Technique

- Give intravitreal anti-VEGF (or steroid injection) at 3 months, 2 months, and 1 week prior to the planned surgery.
  - If proliferative membranes are present or suspected in an eye with VH, give the anti-VEGF injection 2–3 days before surgery.
- Perform a subtotal or total vitrectomy.
  - Because this results in an increased oxygen level in the vitrectomized eye, it is advisable to remove as much of the gel as possible.
  - PVD is often lacking, and even if it is present, it may be anomalous. In eyes with significant VH, PVD creation is commonly difficult and risky: at certain locations the VR adhesion can be very strong. If the surgeon, assuming that the PVD is complete, proceeds without proper caution, he may cause a retinal tear or even intraoperative RD.

Pearl

In eyes with no or late surgery after CRVO, it is not uncommon for severe fibrovascular proliferation to develop. TRD may ensue, which is difficult to deal with because the retina is often ischemic and thus fragile; separation of the nondetached posterior vitreous is all but impossible.

[3] Which is a significant benefit since eyes with CRVO often have nonresorbing VH, making laser treatment impossible or unnecessarily delayed.

- In eyes with proliferative membranes and TRD, consider silicone oil implantation.
  - If a retinal vessel loops into vitreous,[4] cut the proliferation around it but leave the vessel alone.
- Peel the ILM in the macula (see **Sect. 49.2**).
  - In eyes with BRVO, also peel the ILM over the arteriovenous crossing if the artery lies anteriorly; the fibrous capsule may also have to be cut with a blade or sharp[5] needle (sheathotomy).
- Perform laser treatment.[6]
  - If there are many retinal hemorrhages, the laser treatment should be completed when most of the blood has been absorbed.
- If TRD has developed (see **Chap. 55**), a compromise must be found between doing too much (which may involve removing large parts of the retina if the adherent vitreous is inseparable) and too little (leaving behind much of the vitreous, which later may contract).

[4] The proliferation slowly drags the retinal vessel above the surface; the vessel has time to adapt since the process is slow. Even when the “loop” is freed from the membrane responsible for the dragging, the vessel will never reinsert into the retina.

[5] No barb on the needle.

[6] Grid and in a sector along the occluded vessel in BRVO, panretinal in CRVO.

Scleroplasty

59

59.1 General Considerations

Although scleromalacia is much less likely to occur following MIVS than after 20 g vitrectomy, there may be other causes[1] of the VR surgeon having to face a sclera that is so thin that rupture threatens.

> **Pearl**
> Thinning of the sclera is the strongest argument against using scleral pockets to fixate a buckling element (see **Sect.** **54.4.2.6**).

If vitrectomy needs to be performed on an eye that has an area of scleral thinning, even if it is not in an area where cannulas would be placed, the VR surgeon must consider using a patch (see **Sect.** **21.2.4** and **Fig.** **21.3**). He can choose from several materials,[2] but the technique of applying it is similar.

59.2 Surgical Technique

- If possible, use general anesthesia to eliminate the risk of causing direct injury with the needle used for the periocular injection and from the extra pressure on the eyeball as a result of the fluid injected into the orbit.
- Never use oculocompression.
- During the entire operation, avoid any external pressure on the globe.
- Open the conjunctiva at the limbus, in a sufficiently large area. Make two radial cuts so that the entire area of thinning, plus an adequately wide healthy scleral margin on each side, is exposed.

[1] Autoimmune diseases, eyes with high myopia, chronic glaucoma etc.

[2] Homologous sclera, periosteum, dura mater etc.

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- Be extremely careful when dissecting the conjunctiva; always use blunt scissors.

- Apply light diathermy, preferably with a probe that has a blunt tip, to shrink the prolapsing uvea. This may have to be repeated multiple times as the bulging may recur.
  - Too much shrinking may result in an irregular pupil as the uvea is drawn toward the diathermy site – do not overdo the diathermy!
- Measure the area to be patched; add ~2 mm on all sides, and cut the graft tissue according to size and shape.

Q&A

Q *What do you do when the graft abuts the cornea?*

A The graft must be fashioned so that it terminates at the limbus; 10-0 nylon sutures are to be used to fixate the graft here. All knots must be properly buried.

- The graft is laid over the thin sclera; no wound is prepared (**Fig. 59.1**).
- Use interrupted 7-0 or 8-0 vicryl sutures to secure the graft to the sclera.
  - Enter the recipient sclera first, about 2 mm from the edge of the graft, and then exit through the graft, without the needle going through the thin part of the sclera. This technique allows suturing without the need to grasp the donor tissue with a forceps, reducing the trauma to the tissue. As the needle enters and then exits the graft, hold the graft in place by laying the jaws of the forceps onto the tissue, holding it down, and having the needle exit between the forceps jaws (see **Table 63.3**).
- Make sure the graft is not stretched by the sutures.
  - The knots of the vicryl sutures do not have to be buried.
- Meticulously cover the graft with Tenon's capsule and the conjunctiva.
  - At the limbus where the graft abuts it, leave a 1 mm band of conjunctiva to extend over the cornea. This will slide off spontaneously with time.
- Control the postoperative inflammation and IOP very closely.

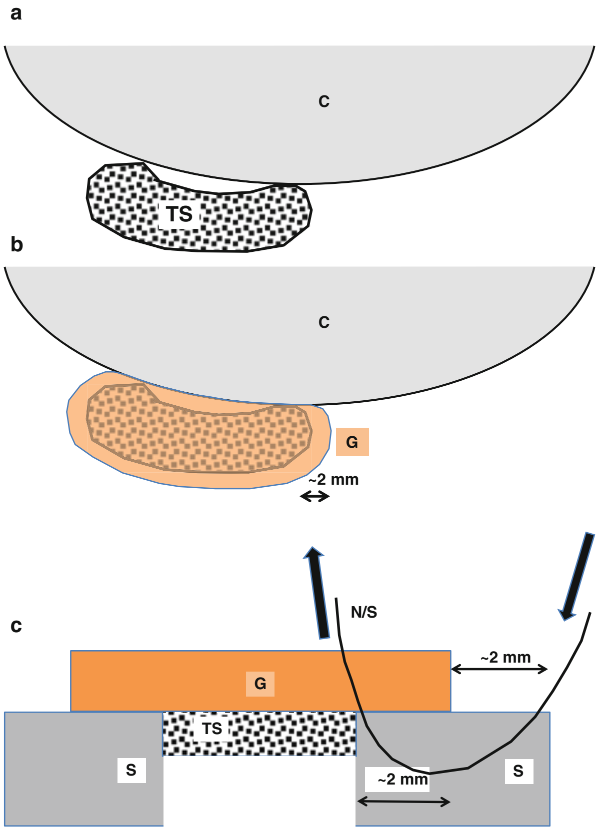

Fig. 59.1 **Schematic representation of suturing a scleral patch**. (**a**) The area of thin sclera abuts the limbus. (**b**) The patch is fashioned so that it overlays the thin area by ~2 mm, except at the limbus. (Unlike in real life, the thin area is shown here for demonstration purposes even after the graft has been laid over the sclera.) (**c**) Cross-sectional view to demonstrate the introduction of the vicryl suture to hold the graft. The *thick arrows* show the direction of the suture. *C* cornea, *TS* thin sclera, *G* graft, *N/S* needle-suture, *S* sclera

Suprachoroidal Hemorrhage

60

60.1 General Considerations[1]

60.1.1 Indications for Surgery

This arterial bleeding is sight-threatening if it occurs intraoperatively (ECH; see **Sect. 40.1**). If a limited amount of blood is present in the suprachoroidal space, the first question to answer is whether surgical intervention is necessary at all. Drainage (and PPV) should be considered in the following conditions:

- “Kissing” choroidals: the hemorrhage involves opposing quadrants, and they are so high that there is retina-to-retina touch (see below and **Fig. 60.1**).

> **Pearl**
> If surgery is not performed early after retina-to-retina touch developed, the adhesion between the two surfaces can quickly become so strong that they are inseparable.

- High and medically uncontrollable IOP, with or without severe pain.[2]
- Breakthrough hemorrhage: with blood in the vitreous, it is impossible to visualize the retina.
- Suprachoroidal blood involving the submacular area.
- Anterior displacement of the retina, with possible lens touch.
- Retinal detachment.

[1] This chapter is dedicated to the management of suprachoroidal hemorrhage in its chronic phase.

[2] As the ciliary nerves can be stretched by the solid mass, intolerable pain may be present even in lack of high IOP.

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Fig. 60.1 Ultrasonography following a suprachoroidal hemorrhage. Kissing choroidals accompanied by an RD. Draining the blood is a necessary step in treating the eye, but intravitreal surgery is also needed (see the text for more details), although from this image it is impossible to determine whether what appears to be an RD is indeed a detachment (or an incomplete PVD)

60.1.2 Timing of Surgery

There is a window within which it is inadvisable to operate: once the blood is clotted, it is difficult or impossible to remove it. The intervention thus has to be either immediate[3] or delayed until the blood liquefies, which typically takes ~10 days. Ultrasonography is helpful in determining whether liquefaction has indeed occurred.

If the blood is clotted but it must nevertheless be removed, a large scleral opening is necessary and the probe is used to shave the clot.[4]

60.2 Surgical Technique

- Determine the highest point of elevation preoperatively.[5]
- Place an infusion; never attempt to drain without continually pressurizing the globe.

---

[3] On the operating table when the bleeding is recognized.

[4] This is a rather dangerous maneuver because the choroid is right underneath the clot.

[5] Ultrasonography, if direct visualization is impossible.

  - If the suprachoroidal blood is posterior to the ora serrata or the cannula can be visualized, the standard pars plana location is recommended; in all other cases use an AC maintainer.
  - AC infusion is also possible in phakic eyes: the fluid will find its way posteriorly through the zonules (see **Sect.** 17.1). Keep in mind, though, that the lens will be pushed a little more posterior relative to its normal position.
- Do a peritomy in the quadrant where the choroidal detachment is the highest. Consider placing retraction sutures (see **Sect.** 54.4.2.1) underneath the adjacent muscles.
- With a blade, make a radial cut in the sclera as posterior as possible (see **Fig.** 60.2a).
  - The incision should be at least 2 mm long.
- Use a diathermy needle or, less preferably, a blade, to open the choroid.
  - Use a tooth forceps to gape the wound. Chocolate-colored fluid should drain (see **Fig.** 60.2b).

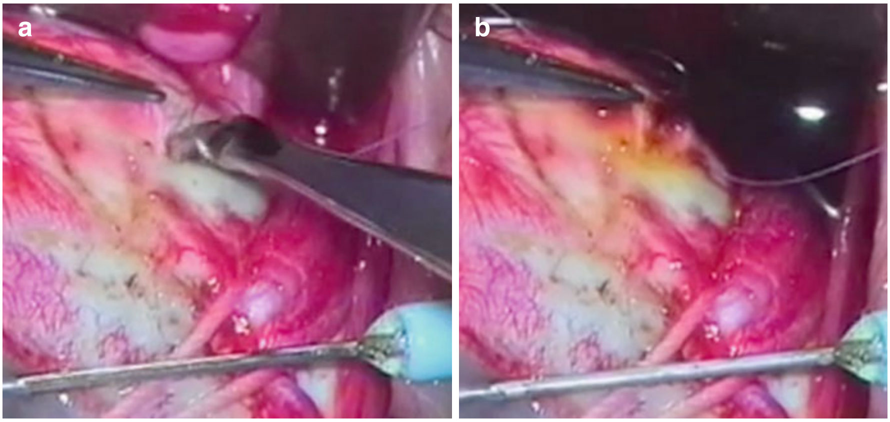

Fig. 60.2 **The technique of draining a suprachoroidal hemorrhage**. (**a**) A radial incision is made in the sclera. An anterior chamber maintainer is visible inferiorly. (**b**) Chocolate-colored suprachoroidal blood is being drained. The scleral incision is gaped with forceps. The incision is small enough not to require suturing

- Use a scleral depressor or a muscle hook to indent the sclera at some distance from the incision and roll the instrument toward the incision to press more blood toward it.
- Repeat the procedure in additional quadrants as required.
- If VH or RD is present, perform a subtotal or total vitrectomy.
  - If an AC maintainer has been used before, switch to the standard pars plana infusion as soon as the cannula can be visualized (see **Sect.** 21.6).
  - If the infusion is through the pars plana, air (if the suprachoroidal blood is more posterior) or PFCL (if the suprachoroidal blood is more anterior) can be used.
  - The specific maneuvers in the vitreous cavity are determined by the intraocular pathology.

Q&A

Q *What to do if kissing choroidals are present and there is retina-to-retina touch?*

A Once the vitreous has been removed in front of the detached retina, find some space and insert a blunt spatula between the two retinal crescents. Slowly maneuver the spatula into the area of contact and try to separate them. If the adhesion is not yet too strong, separation will succeed; once true adhesion has formed, this will not work, and retinectomy may have to be performed. The prognosis is extremely poor.

- Internally draining the suprachoroidal blood that proved too posterior to allow external removal is an appealing idea. The challenge is that this requires a retinotomy as well as a choriodotomy. The latter is elastic, and it will shrink if diathermy is used to open it; if diathermy is not used, there is a risk of additional bleeding.

61 Uveitis, Posterior

Uveitis has many possible etiologies, but whatever the cause, the intraocular consequences[1] that can lead to loss of vision are rather similar:

- Abnormal IOP, both high and low.
- Cataract.[2]
- Vitreous opacity, ranging from floaters to hemorrhage. The debris may get stuck to the lens capsule.
- EMP.
- ME.
- RD: tractional, exudative, occasionally rhegmatogenous.

Traditionally, the treatment is medical: local[3] steroids, intravitreal steroid injections and implants, and systemic steroids and immunosuppressive drugs. PPV is often not even listed as an option (and then only as a late, if-all-else-fails choice), although it has tangible benefits:

- Yielding a diagnostic specimen.
- Removal of the vitreous gel.[4]
- Treatment of virtually all of the coexisting or consequent pathologies (VH, ME, RD etc.).
- Reduction in, often complete elimination of, the frequency and severity of the recurrences.
- The possibility that the systemic medications, which often have very serious side effects, can be withdrawn or maintained at a reduced dose.[5]

---

[1] The severity of the anatomical and functional abnormalities shows a wide range.

[2] The treatment (steroids) may also play a role here.

[3] Topical, subconjunctival, peribulbar.

[4] A reservoir for the inflammatory debris, including mediators and immunocompetent cells.

[5] See the **Appendix**, **Part 2**.

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Pearl
The key to the success of PPV for uveitis is to do it early, not as a last resort when nothing else seems to work or when severe TRD has already occurred.

Surgery is fairly straightforward; only a few caveats are mentioned here:

- The systemic therapy must be increased prior to the operation so that the eye is not "hot."
- To avoid a rebound effect, the systemic medication/s should be tapered slowly.
- The vitreous gel appears to have more structure to it, and its removal takes longer than usual.
- The vitrectomy should be subtotal or total.
  – Remove the posterior cortical vitreous and all preretinal membranes, the anterior cortical vitreous (which may be thickened), and all membranes covering the ciliary body (see **Fig. 61.1**).[6]

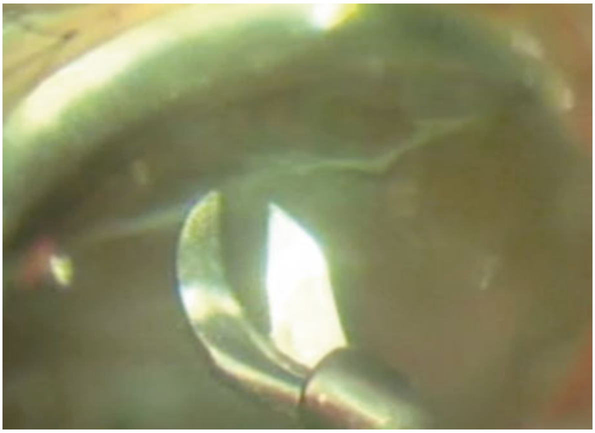

Fig. 61.1 **Debulking of the ciliary body**. Scissors (as well as forceps and the probe, neither shown here) is used to separate a cyclitic membrane (seen as a *whitish line*) from the ciliary body. Leaving such membranes, which can contract or develop into real scar tissue, on the tissue is a possible cause of hypotony and phthisis. The scissors used here is a 20 g vertical one; it has long blades and the shaft does not bend

  – Pay special attention when working close to the retinal surface: avoid causing any iatrogenic retinal injury since this increases the risk of PVR.[7]
  – Whether you should also remove the subretinal membranes or exudates is less straightforward and requires an individual decision (see **Sect. 32.4**), especially because a retinotomy would be necessary.

[6] These may be so severe as to cause detachment of the ciliary body; aqueous production can cease with time.

[7] PVR in these eyes may be extremely fulminant, cause irreversible damage fast, and be inoperable even at first presentation. This clinical observation confirms the role inflammation plays in the pathogenesis of PVR.

- Consider as a destructive force laser treatment or cryopexy, especially at the vitreous base.
- Have a low bar to silicone oil tamponade.
- Leave steroid in the vitreous cavity at the conclusion of the surgery, either as an injection or as a slow-release implant.

Vitreous Hemorrhage

62

62.1 General Considerations

Blood in the vitreous cavity, regardless of the cause of the bleeding, interferes with vision and prevents the ophthalmologist from having a direct view of the retina. The VH[1] may cause a long list of secondary complications ranging from siderosis to ghost cell glaucoma and even PVR.

Removal is nevertheless rarely urgent unless the bleeding is caused by a torn retinal vessel bridging retinal tear,[2] or the VH is related to open-globe trauma.[3] Conversely, the risk of PPV is low enough today that this alone should not serve as a contraindication to early surgery.[4]

Bleeding may also occur in a vitrectomized eye[5]; in such cases the blood usually, but not always, absorbs faster than as if the gel were still present.

> **Pearl**
> People with an incurable systemic disease must understand that vitrectomy (and removal of the blood) may reduce the risk of a postoperative bleeding, but it does not eliminate it. To reduce the risk to the minimum, oil should be implanted (see **Sect. 35.4**).

[1] The term refers to the presence of blood in the vitreous cavity. The blood may be intra- or retrohyaloidal, rarely even between the anterior hyaloid face and the posterior lens capsule.

[2] By the time the pathology is visible, an intact retinal vessel connects the flap tear to the retina proper. The condition easily can lead to RD.

[3] Keep in mind that the diagnosis of an RD in an eye with severe VH is rather unreliable (see **Table 7.1**).

[4] The traditional strategy "let's wait 3 months to give the blood a chance to spontaneously absorb" is especially questionable: why 3 months?

[5] In fact, this is rather common in people whose systemic condition (e.g., diabetes) predisposes them to bleeding.

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Surgery for VH is usually rather straightforward, but it is not without caveats.

- Massive bleeding into the gel in a young person[6] may make surgery very difficult (see below).
- In general, the older the hemorrhage, the more likely that its color changes from red to yellow. However, blood trapped between layers of vitreous gel may remain red for months (see below).
- Partial PVD can trick the surgeon into proceeding too fast, only to discover the hidden presence of strong VR adhesions (see **Sect. 58.2**). This is especially common in CRVO, and preoperative ultrasonography may be unable to warn the surgeon about the danger.
- The VH may be accompanied by intraretinal (a submembranous cyst[7] in a patient with Terson syndrome) or subretinal blood (CNV). Even when the surgeon is unaware of the etiology, he must be prepared to deal with these conditions as well – one of the reasons for my resistance to agree with the statement that "PPV for VH is an easy surgery."

Pearl

Multiple conditions may coexist in a single eye: a patient who has diabetes can also develop an RVO, or one with high blood pressure an RD. The VR surgeon should not assume, based on history or preoperative tests, that he knows the etiology of the VH in that particular eye; he must accept that all he has is a (strong) *suspicion*, but evidence will be provided only *during surgery*.

The issues raised above make it clear that the indication and timing of PPV remain somewhat controversial (except, as mentioned above, in the context of open-globe injury or the development of a retinal break). In all other cases, intensive consultation with the patient is necessary (see **Chap. 5**), but no artificial deadlines should be imposed ("if the bleeding does not resolve in 3 months," see above). The risk of surgery is very small, possibly smaller than leaving the blood to persist for months, while the potential benefits are tangible.[8]

[6] This occurs most commonly in trauma.

[7] The blood is under the ILM.

[8] Instant visual rehabilitation for the patient and the possibility of treating the cause as well as the additional consequences of the condition: ME, EMP etc. The condition of the other eye has an obvious influence on the decision-making: early visual rehabilitation becomes more important if the fellow eye has poor vision.

62.2 Surgical Technique

- If the bleeding is severe enough to prevent visualization of the retina, proceed in an anteroposterior direction.
  - Start with vitrectomy in the middle of the vitreous cavity and rather close to the lens.
- Gradually proceed more posteriorly, and carefully create a PVD.
  - Be prepared to encounter areas of unexpected, and unexpectedly strong, VR adhesions.
  - There may be blood covering the posterior retina. If it can be easily vacuumed, you can be certain that a PVD is present. Conversely, if the blood resists evacuation, it is because vitreous gel is still present (see **Sect. 25.2.7.1**).
  - If a large amount of blood has been trapped subhyaloidally,[9] drain it once you made an opening in the posterior cortical vitreous. This will make the creation of the PVD easier.
- Be careful when removing blood-soaked vitreous gel in the periphery since the retina may be invisible initially.
- Deal with the pathology that caused the hemorrhage – although often this will not be found[10] or is not directly amenable to treatment.[11]

62.3 Severe Bleeding in a Young Patient

It may be impossible for the surgeon to visually distinguish a layer of vitreous from a detached retina (see **Fig. 62.1**).[12]

- The vitreous layer may have streaks of red blood; therefore, it *resembles retina*. Blood is trapped between the vitreous layers, and when the probe reaches such a pool and releases the blood, the surgeon's impression is that he caused a fresh retinal hemorrhage.
- The retina may have occluded blood vessels and does not bleed when bitten into; therefore, it *resembles vitreous*. Large portions of the retina may be eaten with the probe before the surgeon realizes that the probe is now in the subretinal space. This is why the suggestion to "carefully remove the vitreous layer by layer via moving the probe in the frontal plane and gradually dig deeper"[13] sounds reasonable at first, but in reality it is very dangerous.

[9] Rather common in diabetes.

[10] For example, hypertension or diabetes, where the exact source (location) of the bleeding remains unknown.

[11] For example, CRVO.

[12] There is such a mess inside the vitreous cavity that even ultrasonography cannot, with any certainty, answer the most important question: Is there an RD?

[13] I call this maneuver *horizontal sweeping*.

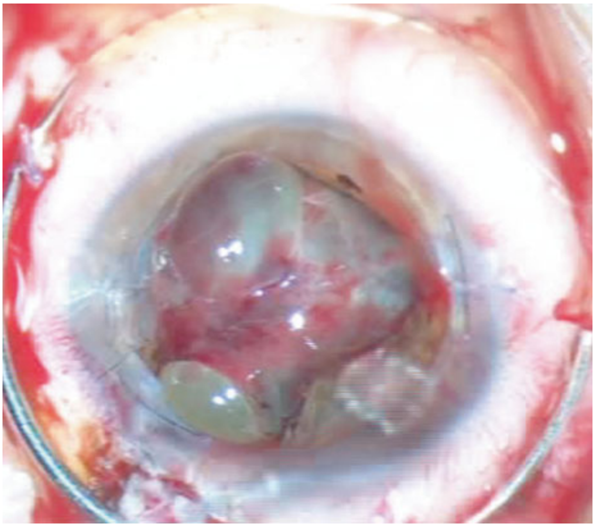

Fig. 62.1 A diagnostic dilemma: vitreous or retina? For illustration purposes, an open-globe image is shown here, just before the TKP is placed (the distinction between retina and vitreous is even more difficult when surgery is performed in the standard, closed-globe fashion). It is not possible to determine with absolute certainty whether the mass is made up of only vitreous or the retina is also involved

I have been using for many years the opposite technique, which I call *vertical digging* (see **Fig. 62.2**). A funnel or well is created on the nasal side until the retina becomes visible. If an unintentional retinectomy has been caused, it is relatively

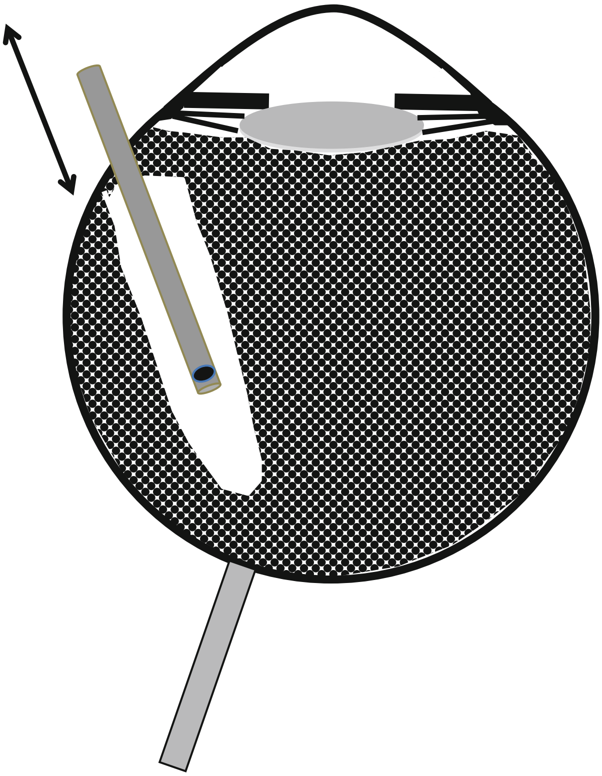

Fig. 62.2 Vertical digging. The probe's main initial movement is shown by the *double arrow* (see the text for more details)

small and is in the less-important part of the retina. Once the position of the retina is clarified, surgery can proceed as it normally would, and the retinal break and detachment subsequently treated as usual.

62.4 Rebleeding in a Vitrectomized Eye

This is not uncommon, especially in eyes with an incurable systemic condition such as diabetes. The blood may spontaneously disappear or require removal; the latter may be done in two ways:

- *Lavage*. A single syringe filled with air is used to inject air into the vitreous. An inferior entry side is chosen,[14] and after some air has been injected, fluid is withdrawn. More air injection and fluid removal follows until the syringe is full with bloody fluid: basically an "external" F-A-X is performed.
- *Standard re-PPV*. This option provides the surgeon with a chance to identify and treat the source of the bleeding. If need be, silicone oil can also be implanted to reduce the risk of future bleedings (see above).

[14] The patient is lying on his side; therefore, the temporal pars plana location is in effect inferior.

Trauma

63

Trauma is the most exciting and challenging subspecialty in ophthalmology. Much of it is (and should be) handled by the VR surgeon[1] because of the expertise needed; vitrectomy instrumentation may be necessary in many conditions. Only a selected few topics are detailed in this chapter; hyphema is discussed in **Chap. 47**, the iris in **Sect. 39.2** and **Chap. 48**, the lens below (see **Sect. 63.6**) and in **Chaps. 38** and **44**, suprachoroidal hemorrhage in **Chap. 60**, VH in **Chap. 62**, RD in **Chaps. 54** and **55**, subretinal hemorrhage in **Chap. 36**, PVR in **Chap. 53**, and endophthalmitis in **Chap. 45**.

63.1 The Timing of Surgery

It is a much more complex question than it initially appears. **Table 63.1** provides some guidelines based on which the individual surgeon can make a decision for the particular patient.

63.2 Contusion

The most common acute complication of this closed globe injury is *VH*. Traditionally, a 3-month waiting period has been recommended before vitrectomy would be considered.

About half of the eyes with a severe contusion will develop *RD* in the first 2 years. Surgery is able to restore the patient's vision instantly and allow the surgeon to treat and/or prevent most retinal complications.

[1] A 360-page book was published in 1998 on vitrectomy for trauma, not to mention general books dedicated to injuries of the eyeball (see Further Reading). This chapter discusses only a few selected issues and even those only very briefly.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_63

Table 63.1 The timing of surgery for the injured eye

Variable[a]	Comment
Child/elderly patient	In general, the earlier the better
Endophthalmitis, high risk	Emergency surgery is needed: wound closure and PPV in the same session. With certain organisms[b], the time from "no symptom" to a fulminant, retina-destroying infection may be only a few hours
Endophthalmitis, present	Emergency surgery is needed: wound closure and PPV in the same session
General anesthesia, availability	If the patient ate or drank in the previous 6 h[c], the surgeon should discuss the options with the anesthesiologist. If the anesthesiologist, for whatever reason, will not be able use general anesthesia and the surgery is otherwise urgent, some type of local anesthesia (see **Chap. 15**) should be used. The surgeon himself should administer the periocular injection
Hyphema	In adults, the primary factors are whether the retina can be visualized and the IOP can be kept in the normal range. High IOP in the presence of full hyphema is an urgent indication; the surgeon should err on the side of early intervention
Hypotony	Early removal of vitreous, fibrin, and any capsular remnant[d] from the surface of the ciliary body can prevent scarring, which in turn is irreversible
IOFB	Some of the mechanical damage has already been done, but there is an immediate risk of infection (and chalcosis if the object is copper), further mechanical injury due to the body's scar-producing reaction, as well as the longer-term threat of chemical trauma (siderosis)
IOL implantation	In a child of the amblyopic age, this can be urgent (in those under 2 years, a contact lens may be a better option[e]). In virtually all other cases, deferral of the implantation may be preferable
Iris, retraction ("missing iris")	The sooner the better. Once the fibrinous membrane turns into a scar tissue, the condition becomes irreversible
Lens, damage to either capsules	In adults, there is no urgency In children, the lens may swell in hours, leading to pupillary block glaucoma with extremely high IOP: urgent lens removal is needed
Lens, cataract	In adults, the primary factor is whether the retina can be visualized; otherwise there is no urgency In children, amblyopia is the key factor: the younger the child, the more urgent the visual rehabilitation is
Perforating injury	Immediate or early surgery is needed to prevent PVR and retinal incarceration
PVR	Early surgery is recommended if the macula is involved or threatened; otherwise it may be preferable to delay the PPV until the PVR cycle is complete
RD	PPV is urgent but not necessarily an emergency
Rupture	Especially if the wound is posterior to the muscle insertions, immediate or early surgery is needed to prevent PVR and retinal incarceration
Subretinal hemorrhage	Usually, no action is needed unless the blood is under the macula. If it is, removal or at least displacement should be done as soon as possible

(continued)

Table 63.1 (continued)

Variable[a]	Comment
Suprachoroidal hemorrhage	If it occurs intraoperatively, the wound/s must be closed immediately and the IOP raised. Otherwise, surgery is urgent only if a kissing choroidal is present, the blood is underneath the macula, or an RD accompanies the bleeding
Surgery, secondary (reconstructive)	In general, the earlier the better; if the infrastructure[f] is in place and the surgeon is aware of the possibility and handling of ECH, comprehensive primary reconstruction may be performed. If the traditional staged (2-step) approach is chosen, it is best to apply heavy topical steroid therapy and perform the PPV within 4 days
Systemic condition of the patient	Hypertension and agitation in patients[g] with open-globe injury make the surgery more urgent Anxious patients should be operated earlier, but this is not an absolute requirement (antianxiety medications may be needed if the surgery is delayed). Proper counseling may have a calming effect
VH, contusion	There is no urgency to remove the blood, but leaving it in the eye for an extended period is unjustifiable today (see the text for more details)
VH, open-globe injury	The sooner the blood is removed, the better. The blood not only prevents visualization of the retina but is a strong inciting factor in PVR development
Wound, corneal	Close it as soon as possible, although it may be acceptable to postpone it from the middle of the night till the morning hours[h] if the wound is small and the proper infrastructure (see above) is not unavailable The longer the wound, the more urgent the need for early closure
Wound, scleral	The longer the wound, the more urgent the need for early closure The more anterior the wound, the more urgent the need for early closure

[a]In alphabetical order. Many additional details are provided in the appropriate chapters.
[b]For example, *Bacillus* species.
[c]The typical cutoff time for most anesthesiologists.
[d]Provided the lens is also removed.
[e]This is a very controversial topic and the answer keeps evolving.
[f]Instruments, materials, OR personnel, surgical expertise.
[g]Especially if these cannot be controlled medically.
[h]In children or uncooperative adults, delaying the closure may be dangerous.

Q&A

Q *What is the rationale for waiting 3 months to remove a contusion-related VH?*

A There is none. The 3-month period has no scientific basis at all, and the blood may represent more risk than its removal (see **Chap. 62**).

Additional, rather common, complications include lens dislocation (see **Sect. 44.2.1**) and a macular hole (see **Sect. 50.2.4**).

Pearl
Surgery for a traumatic macular hole is often delayed because there have been reports of spontaneous closure. This is certainly true, but the surgeon has to consider two opposing options. On one hand, spontaneous closure indeed occurs – but it is impossible to predict what the likelihood in that particular patient is. On the other hand, the sooner the hole is closed, the greater the chance of excellent recovery – but surgery is obviously not risk-free.

Finally, the vitreous may prolapse into the AC, even if the lens is only mildly subluxated. It is extremely rare that the prolapse causes glaucoma or endothelial damage, but the presence of vitreous in the AC changes the surgical technique of lens removal (see below).

63.3 Wound Toilette

As a general rule, the wound should not be sutured until all debris and tissue that have prolapsed into (through) the wound edges have been cleaned.[2] The technique of dealing with the material found in the wound depends on the material's nature (see **Table 63.2**).

63.4 Suturing the Cornea[3]

There are basic rules that should be followed so as to minimize the additional trauma to the cornea and therefore reduce the edema in the early, and astigmatism in the late, postoperative period. The creation of a watertight wound is the minimum necessary goal of the surgery, but it is only one of the mandatory goals. The suture placement must be carefully planned; random suture introduction is unacceptable (see **Fig. 63.1**).

The fundamental rules and goals are summarized in **Table 63.3**.

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[2] The only exception is an ECH occurring during wound closure. In such cases instant closure, suturing through the prolapsed iris if necessary, is the only chance to save the eye. The wound toilette is deferred.

[3] More than half of eyes with a corneal wound require posterior segment surgery. There are several reasons why the VR surgeon is best suited to suture the wound: he may complete the VR surgery in the same session, and he may determine that even if the vitrectomy is postponed, the lens must be removed primarily and PPL is the most optimal method. Finally, he is the one to select from all the suboptimal choices (see below, **Sect. 63.10**) in case the wound was improperly closed.

Table 63.2 Wound toilette

Material in the wound[a]	Surgical to-do
Blood, fibrin, foreign material	Mechanical cleaning with a Wechsel sponge, antibiotic jet spray, occasionally forceps
Choroid	Do *not* excise it; if it bulges[b], gentle diathermy will shrink it sufficiently
Iris	Pull the iris back into the AC through a paracentesis (see **Sect.** 39.2). The iris almost always can be saved; excision is restricted to cases when the iris is severely macerated or soiled to the point that it cannot be cleaned
Retina	Try to prevent it from prolapsing; if it did prolapse, try to keep it back with a blunt instrument, held by the assistant, while you are suturing. Address the incarceration from the inside as soon as possible (see below)
Vitreous	External prolapse: Do *not* use a Wechsel sponge because it may cause traction on the anterior vitreous; the probe is the ideal instrument to deal with the prolapse. If a Wechsel sponge must be used, at least do not lift it up from the eye surface; keep it dipped into the vitreous and use the scissors to first push down on the eyewall and then cut the vitreous Internal prolapse: Inject TA to identify the vitreous in the AC. If the eye is phakic, use a paracentesis for probe entry; in the aphakic eye, the pars plana approach is preferable since it gives better access to the vitreous. In the pseudophakic eye an individual decision must be made. If the eye is phakic, it may be impossible to completely remove the vitreous; at least sever the connection between the remaining prolapsed vitreous and the gel proper

[a]In alphabetical order.
[b]Which is extremely rare.

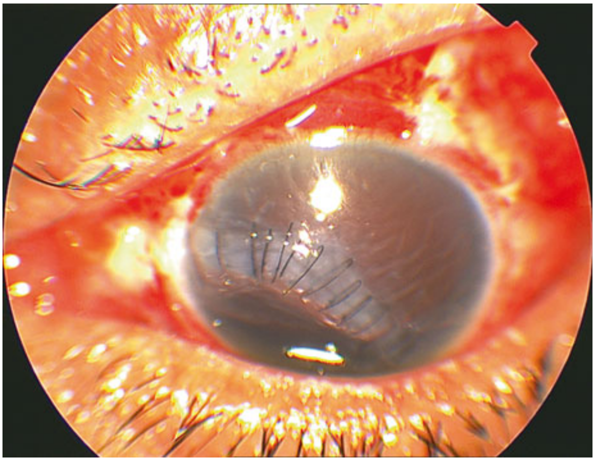

Fig. 63.1 Poorly sutured corneal wound. The suture bites are of more or less equal length and their spacing is haphazard. The healing will be poor and take a long time. TKP-PPV (possibly EAV, even though a PK will most probably be needed anyway) is unavoidable since the posterior segment surgery cannot be delayed indefinitely

Table 63.3 The basics in corneal wound closure

Variable	Rule	Comment
Timing	As early as possible	Delaying the wound closure is a crucially important risk factor in endophthalmitis development. Still, in certain cases[a] it may be acceptable, after proper counseling, to delay the closure for a few hours[b]
Making the wound watertight	Absolutely yes	A leaking wound has difficulty healing, and there is an increased endophthalmitis risk
Excision of loose fragments	Never	The suture must be placed so that the fragment is preserved; otherwise either a gap will be present or the suture needs to be overtightened to close it
Type of suture material	10-0 nylon	It is small enough not interfere with vision, does not cause any reaction, and is nonabsorbable
Visco use	Avoid if possible	The only true indication is an AC so flat that there is no space for needle entry (see **Fig.** 39.4), an extremely rare occurrence
Forceps use	No	The needle is sufficiently sharp so that counterforce against needle movement is not needed (see **Sect.** 14.6). Grabbing the cornea with forceps further traumatizes the tissue, increasing the time until the tissue becomes clear again. In the rare cases with difficulty at the point of needle entry, the conjunctiva may be grabbed *behind* the needle (see the concept on **Fig.** 54.6)[c]; if the difficulty is during the exit of the needle, the jaws of the forceps can be placed over the cornea so that the needle emerges between the forceps jaws (see the concept under **Sect.** 59.2)
Depth of the suture	100%	The suture loop should encompass the entire thickness of the cornea (see **Fig.** 63.2)[d]. This instantly stops aqueous supply to the stroma, which often clears up within minutes, allowing excellent visibility of the posterior structures. The only risk of the full-thickness suture is endophthalmitis at the time of suture removal (see below) The needle should penetrate the cornea at a 90° angle and then turned so that it can be advanced parallel to the cornea. What convinces the surgeon that the needle is in the AC is his ability to move the tip of the needle freely
Order of suture placement	Depends on the location of the wound	If the wound crosses the limbus, the first suture is at the limbus, then the cornea, and finally the scleral part is closed An angled wound requires the initial suture to be placed at the angle[e] A small wound may be closed according to the 50% rule: the wound is always split into 2 equal parts until it is completely closed For large, transcorneal wound, the Rowsey-Hays rule applies: start from the 2 endpoints at the limbus and gradually progress toward the center from both directions (**Fig.** 63.3)

(continued)

Table 63.3 (continued)

Variable	Rule	Comment
Type of suture	Interrupted, except in the limbus	All running sutures in a dome-shaped tissue result in flattening the arch, something that must be avoided in the cornea so that the AC depth is maintained. Conversely, when applied in the limbus, the running suture causes elevation of the apex (i.e., increasing the AC depth), which is beneficial
Length of bite	The closer the suture to the limbus, the longer the bite should be	A wound that is closed with uniformly placed sutures may appear aesthetic, but it causes flattening of the dome shape (see above). A longer bite involves a greater compression zone[f]; therefore wider spacing will suffice (**Figs.** 63.1 and 63.3)
Knot construction	3-2-1 or slipknot	3-2-1: The initial throw is a triple one; the hands must be turned 180° to make the thread architecture smooth; it is tightened parallel to the suture. The second throw is double; it is tightened parallel to the wound[g]. The final throw is singular; it is tightened parallel to the suture Slipknot: A single throw is used first, followed by a second singular one in the same direction. When this is tightened, the short thread must be lifted to send the knot toward the tissue[h]. The final, third, also singular knot is thrown in reverse; this locks the knot[i]
Burying of the knot	Always (see **Fig.** 63.5)	The knot with either technique above is small enough to allow easy burial of the suture in the corneal channel in either direction. The process can be facilitated by using a forceps with a flat jaw to compress the knot
Timing of suture removal[j]	Depends on the length of the wound and the age of the person	Wound length: the shorter the wound, the earlier the suture can be removed Age of the person: In children, early removal (~3 months) is recommended since the sutures become loose, due to increased tissue elasticity. In adults 6 months is the norm, but the sutures can be left behind for longer periods if need be
Preparation for suture removal	As if the eye were going to be operated on	The endophthalmitis risk (see above) is high since what was on the corneal surface (outside) may be turned inside during suture removal, possibly introducing organisms into the AC

[a]Small wound, low endophthalmitis risk, cooperative patient.
[b]Operate the next morning rather than at night.
[c]To prevent rotation of the eye in the direction of needle movement.
[d]That is, the thread is in the AC.
[e]If this is left last, the tip of the angle is retracted toward its base, forcing the surgeon to put extra tension (compression) on this last suture, which severely distorts the cornea.
[f]The area along the wound within which the suture effectively closes the wound. The two adjacent compression zones must completely close the gap between them; this is how the wound becomes watertight.
[g]Once the suture is turned 90°, the knot is locked: it cannot be loosened anymore.
[h]This knot can still be tightened or loosened according to the needs of the wound.
[i]"Pull the short end to *slip* and the long end to *lock*".
[j]The cornea, being an avascular tissue, requires a long time to heal; the scar never reaches the strength of the undamaged tissue.

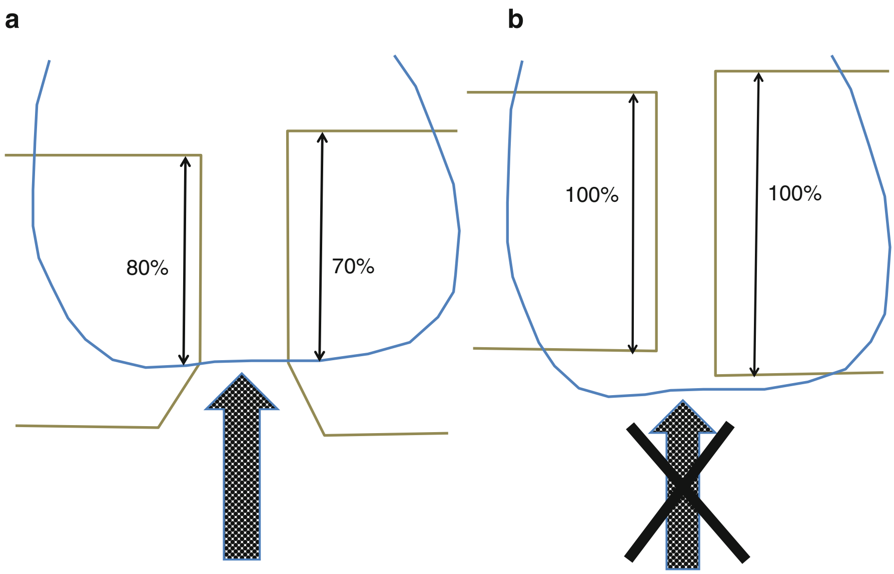

Fig. 63.2 **The advantages of the full-thickness corneal suture**. (**a**) The typical recommendation is for a suture to be "90%" (80%, 2/3 etc.) deep. The problem with any of these suggestions is that the back of the wound remains open for a while, providing aqueous access to the stroma (*arrow*). Furthermore, the 2 edges of the wound, which are already edematous, are of different thickness, due to the different amount of edema: a suture that is of 80% deep on one side may be only 70% deep on the other side. This results in a permanent distortion (the effect does not disappear upon suture removal). (**b**) With a full-thickness suture, the posterior "door" is instantly closed, and the stroma rapidly dries. The suture is 100% deep, irrespective of the difference in the thickness of the 2 wound edges

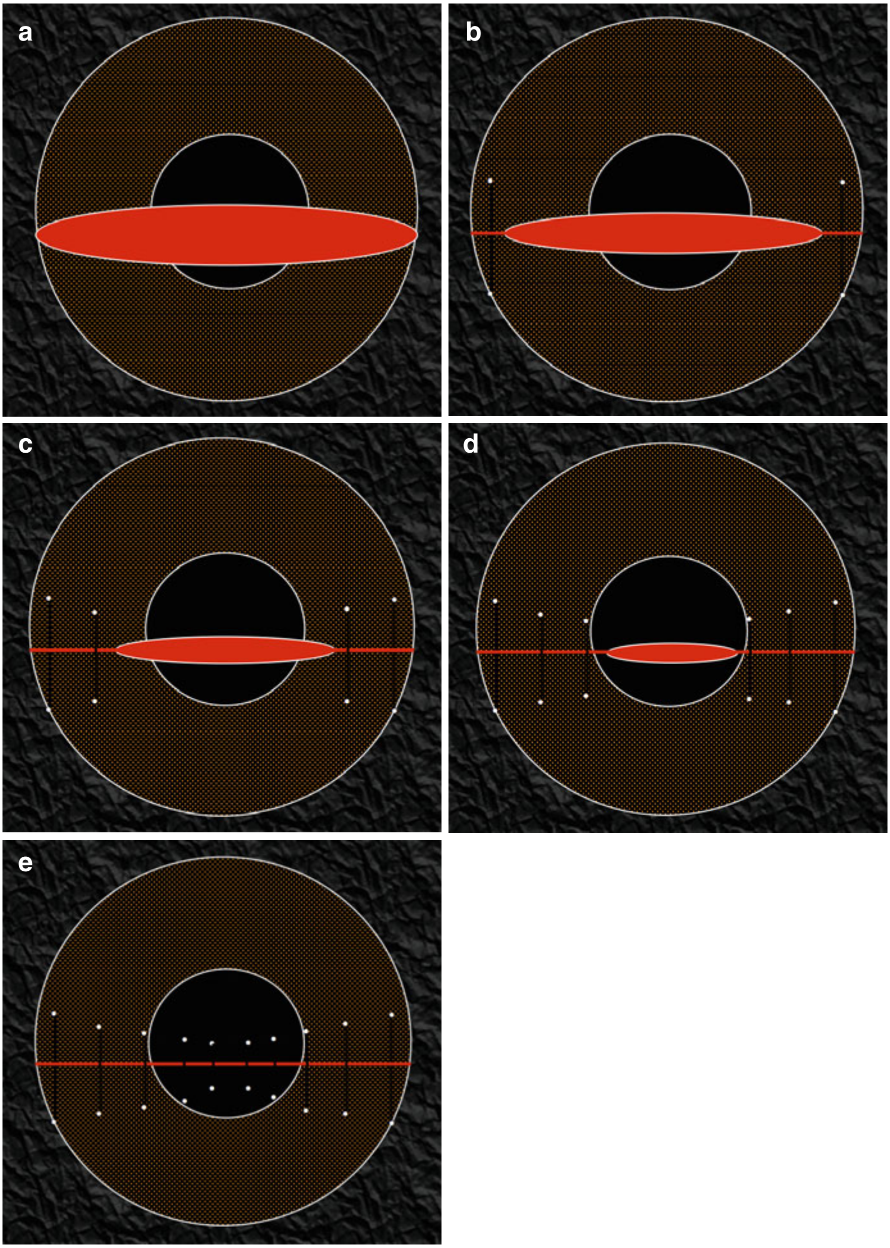

Fig. 63.3 Sequence of suture-introduction for a transcorneal wound. (**a**–**d**) The wound is limbus to limbus. The suturing commences from the 2 endpoints at the limbus and gradually approaches the center of the wound with ever-shorter bites. (**e**) There is no suture at the epicenter of the wound since it wound interfere with the visual axis

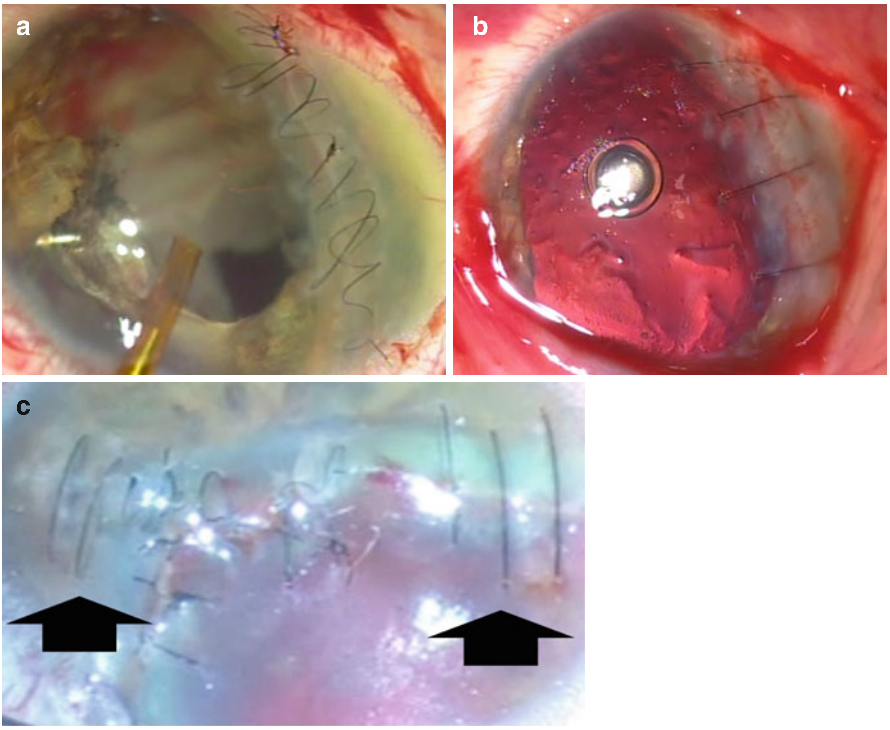

Fig. 63.4 **Suturing and resuturing a corneal wound.** (**a**) The long wound was originally closed with a running suture. The result is an AC with significantly reduced depth; in addition, the eye is inflamed since the knots are not buried. (**b**) Resuturing was necessary. Note how few (full-thickness) sutures, all with long bites, were sufficient to make the wound watertight, without the risk of shallowing the AC. During the original surgery, the cornea was too edematous to allow safe removal of the traumatic cataract (seen on **a**). Conversely, once the wound was resutured, both the cataract removal and the vitrectomy could be completed. (**c**) An extremely poorly sutured wound. Because the initial closure was done 10 days earlier and the eye needed urgent vitrectomy, a TKP had to be used. To trephine the cornea, however, the still-leaking wound had to be partially resutured, using 5 10-0 nylon sutures (*thick arrows*)

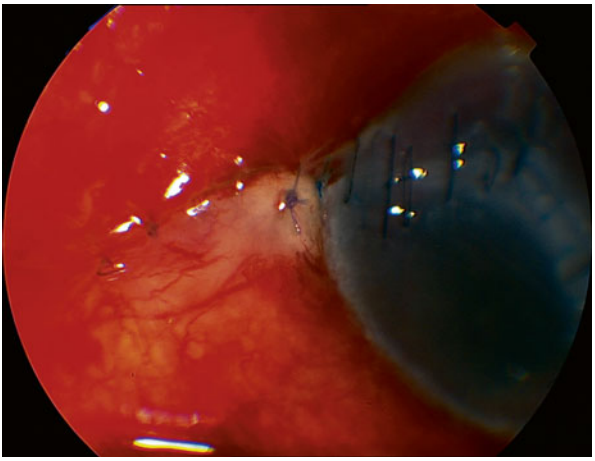

Fig. 63.5 **Unburied suture knot at the limbus.** Leaving the knot and the trimmed suture endings unburied results in major irritation to the patient and increases the eye's inflammatory reaction as well as the risk of corneal vascularization

63.5 Suturing the Sclera

The natural wound-closing process starts immediately after the injury, and within hours it results in a surprisingly firm closure – unless uveal tissue or vitreous has been incarcerated (**Fig.** 63.6). In such cases the wound never truly heals, and the sclera may get macerated by the oozing aqueous.

The sclera is a hard tissue, with rather significant resistance against the needle the surgeon uses to suture it. This provides excellent tactile feedback, informing the surgeon whether, when introducing a transconjunctival suture, he indeed engaged the sclera or just the conjunctiva. However, when the eye is soft, this feedback completely disappears: the surgeon should restore the normal IOP[4] before he can take advantage of this feedback (see also **Sect.** 54.4.2.3).

Proper suturing achieves proper healing and reduces the risk of PVR by preventing primary incarceration (see below). **Table** 63.4 provides an overview of the most important rules in scleral wound closure.[5]

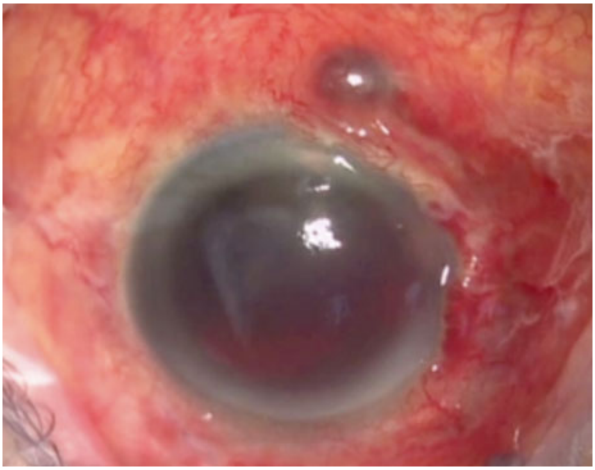

Fig. 63.6 **Unsutured scleral wound.** A 4-week-old injury. There is obvious uveal prolapse, yet the patient's original ophthalmologist decided not to explore the eye and suture the wound. The IOP is normal since the wound is not open, but neither has it healed. During closure, the iris had to be excised because it was overgrown by epithelium and it was scarred to the sclera. Large bites were used with the vicryl suture to prevent cheesewiring in the macerated tissue

[4] Injecting BSS into the vitreous cavity with a 27 g needle.

[5] Especially if the wound is posterior to the muscle insertions, it should be the VR surgeon who closes the wound: he understands best the consequences of improper closure and not performing timely vitrectomy.

Table 63.4 Closure of scleral wounds

Variable	Comment
Occult wound	The sclera may have ruptured even when the conjunctiva over it is intact. Thick subconjunctival hemorrhage or a scleral step sign[a] is usually present, but the IOP may be lower or higher than normal[b] If the slightest doubt persists despite the physical examination and CT, exploratory surgery should be performed
Anterior[c] wound	The entire wound should be inspected by carefully dissecting the conjunctiva. Closure is according to the 50% rule (see **Table** 63.3)
Posterior wound	The more posterior the wound, the more difficult it is to access it; consequently, the risk of not being able to keep prolapsing tissues out of the surgical field[d] also increases The wound should not be exposed in its entirety; the anterior part is inspected and closed first, and the conjunctiva is not opened further posteriorly until the visible, anterior part of the scleral wound is sutured (close-as-you-go technique; see **Fig.** 63.7) The assistant may have to hold a blunt instrument[e] between the wound edges to keep the prolapsing intraocular tissue/s back The suture introduction may have to be done separately in the 2 wound edges to further reduce the risk of primary incarceration (see below and **Fig.** 63.8) Once it becomes very difficult to reach the wound because it is so posterior, the procedure should be abandoned, leaving the wound open (see **Fig.** 63.7). The risk of endophthalmitis is not increased since the conjunctiva will be closed; the wound will rapidly close spontaneously (eliminating the risk of bleeding); and the problem of incarceration and PVR will be addressed from the inside (see below)
Suture material	7-0 or 8-0 vicryl[f]
Forceps use	Mandatory

[a]Running a finger carefully over the anesthetized conjunctiva, the surgeon feels a little bump if one edge of the scleral wound is not in level with the other edge.
[b]Higher because the prolapsing tissue tamponades the wound and the intraocular hemorrhage is not stopped immediately; lower because the ciliary body may have shut down.
[c]The border between "anterior" and "posterior" is not well defined, but the equator is a good approximation.
[d]Orbital fat outside the eyeball; the vitreous, retina, and choroid as intraocular tissues.
[e]Such as a spatula.
[f]It is a braided suture, which may occasionally result in an entanglement of the thread. It is absorbable, but, contrary to earlier concerns, this does not represent any risk for wound reopening: by the time the suture starts to degrade, the wound will have healed.

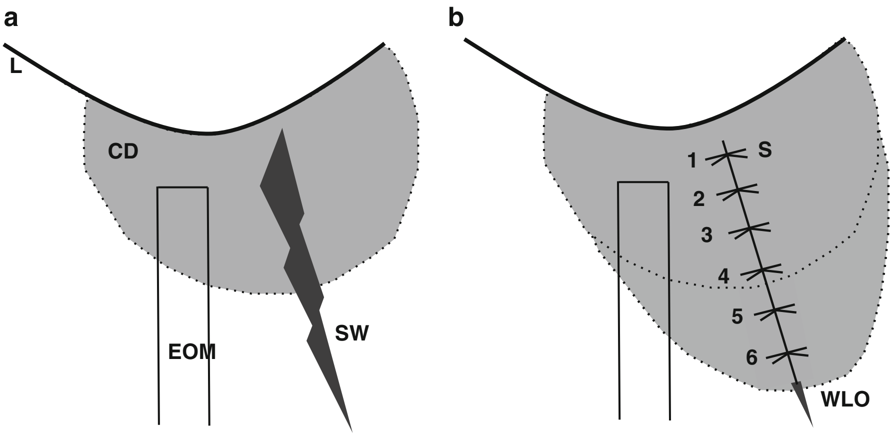

Fig. 63.7 **The close-as-you-go technique to suture a posterior scleral wound.** (**a**) The conjunctiva is opened anteriorly to expose the part of the scleral wound that is fairly anterior and relatively easy to access. (**b**) Once the initial 4 sutures are placed, the conjunctiva is dissected in a larger (more posterior) area, and sutures #5 and #6 are placed. The rest of the scleral wound is too posterior for safe closure and is thus left open. *L* limbus, *CD* conjunctival dissection, *SW* scleral wound, *EOM* extraocular muscle, *S* suture, *WLO* wound left open. The numbers represent the order of suture placement

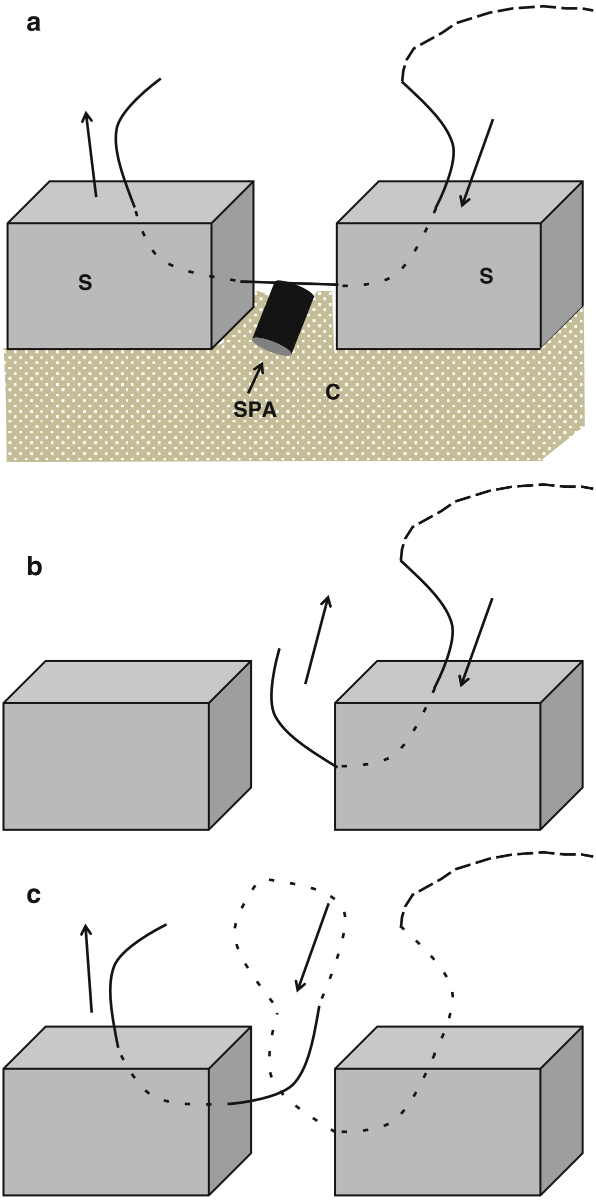

Fig. 63.8 **Sequential placement of a scleral suture.** (**a**) In most cases, a blunt instrument such as a spatula is sufficient to hold the prolapsing tissue back, and the needle can be introduced with a single motion, into both wound edges, as shown by the arrows. (**b**) If tissue prolapses despite the effort to hold it back, the needle is first inserted into one wound edge and then pulled out through the wound. (**c**) The needle is then reinserted into the opposing wound edge, thereby avoiding direct incarceration of the prolapsing tissue (the latter and the spatula, which still needs to be used, are not shown here and on (**b**) for simplicity). *S* sclera, *SPA* spatula, *C* choroid

63.6 Subluxated Lens

If, according to the patient, the lens still allows acceptable vision, there is no need to intervene. If there is significant interference with vision,[6] removal is indicated. How the lens is extracted depends on many factors (see **Chap. 38**).[7] However, if there is vitreous prolapse into the AC – and this needs to be evaluated using TA[8] – this must be addressed first.

- Use an AC maintainer.
- Through a temporal paracentesis, remove the vitreous using the probe. The port should not be directed downward to avoid injuring the iris.
  - If the vitreous is strongly adherent to the iris or the endothelium, do not force its complete removal; just be sure that you severed the connection between the remaining vitreous and the gel behind the lens/iris (see the comments under **Sect. 47.2.2**).

63.7 IOFB

63.7.1 AC

Whether and how the object is removed depends on many factors; in general, it should be removed unless it is small, inert, smooth, noncontaminated, and outside the visual axis (see **Fig. 39.3**).

- If the IOFB needs to be extracted, the paracentesis for delivery should be at some distance (typically, minimum 90° away) from the location of the object.
- Very rarely, an AC maintainer, occasionally even visco, may be needed to maintain the depth of the AC and avoid iatrogenic injury to the lens (see **Fig. 39.4**). None of these, however, should be default options; it is truly exceptional that either is needed.
- Depending on the iron content of the IOFB, a small IOM or forceps needs to be used.

[6] Even monocular diplopia is possible.

[7] The one caveat that is important to emphasize here is to not use a capsular tension ring; even if all looks great at the end of surgery, the remaining, possibly also injured, zonules are now under increased tension and may subsequently break (see **Table 3.3**).

[8] An air bubble can also show the presence of vitreous in the AC (see **Sect. 31.3**).

63.7.2 Posterior Segment

The mechanical injury caused by the IOFB occurs instantly; from this viewpoint, the injury does not differ from one without a retained foreign object. What sets the IOFB trauma apart are the following:

- Anxiety for both patient and ophthalmologist, resulting in a reflexive urge to remove the object.
- The risk of endophthalmitis is increased:
  - The object had been in contact with soil before entering the eye.
  - The IOFB is organic.
  - The patient is over 50 and the lens is also injured.
- The risk of retinal incarceration if the IOFB caused a deep impact (see **Sect.** 33.3 and **Fig.** 63.9).[9]

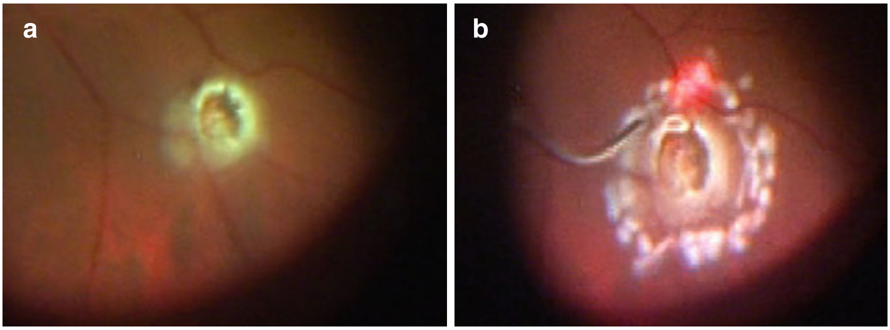

Fig. 63.9 **An IOFB injury with deep impact.** (**a**) Since the impact caused choroidal and subretinal hemorrhage, once the blood was irrigated, a chorioretinectomy was also performed. (**b**) The lesion is at the equator; therefore it was advisable to surround it with 2 rows of laser

The management depends on several factors; these are shown in **Table** 63.5. The use of the permanent intraocular magnet is described under **Sect.** 13.2.3.4.

63.8 Perforating Trauma and Ruptures

The major risk, just as in the case of an IOFB with deep impact (see above), is retinal incarceration (see **Table** 63.6). The risk of PVR in these eyes is around 60%.

The most effective therapeutic option is prevention, which requires a prophylactic chorioretinectomy underneath the area of the (posterior) scleral rupture, around the exit wound, or surrounding the site of the deep IOFB impact (see **Sect.** 33.3). If

[9] Involving not only the retina but also the choroid and possibly the sclera.

Table 63.5 Management of a patient with an acute IOFB injury

Variable[a]	Treatment considerations
Endophthalmitis risk is high	Immediate PPV with complete vitreous removal and comprehensive antibiotic treatment[b] is needed
Endophthalmitis risk is average	PPV may be performed on an emergency basis or delayed for a few days while the patient is closely monitored and prophylactic antibiotic therapy[c] is employed
IOFB intralenticular	There is a chance that the cataract will not progress. Conversely, siderosis can still be caused: an individual decision needs to be made
IOFB in vitreous, but no VH or retinal damage is present[d]	The IOFB may be extracted with an intraocular magnet (if ferrous) or a forceps (if nonmagnetic), under IBO control, without performing vitrectomy Conversely, if PPV is performed, it should always be at least subtotal; a PVD must be created unless the patient is a young child and it is technically impossible or very dangerous (see **Table** 41.2)
The IOFB is ferrous	There is a risk of chemical injury (siderosis); the IOFB should be removed unless very strong arguments can be made against the removal[e]; a strong intraocular (permanent) magnet is the best tool to use
The IOFB is made of copper[f]	Urgent removal is needed to prevent chalcosis; at least subtotal PPV is recommended
There is severe VH	Urgent removal is needed. IOFB removal without visual control[g] must never be attempted. Total PPV is recommended
The IOFB is lying on the retina but there is no deep impact	There is no need for laser around the IOFB site
The IOFB caused a deep impact	Chorioretinectomy is recommended (see **Sect.** 33.3)
The IOFB is subretinal	If the retina is detached and a break is present, the extraction of the IOFB should be done through the break If there is no break, a retinotomy should be prepared right over the IOFB; choroidal bleeding may occur if the IOFB is stuck to the tissue, in which case chorioretinectomy is needed first
The IOFB is surrounded by a fibrous capsule	The capsule must be opened with a sharp instrument first so that the IOFB is completely free before it is removed
The IOFB is very large	In most cases a 4th sclerotomy is prepared to remove the IOFB. This opening is sutured and then the surgery is completed. If the IOFB is very large, removal of the entire lens[h] should be considered so that the IOFB can be extracted through a limbal wound

[a]See the text for more details.
[b]Intravitreal, periocular, systemic; steroids should also be used (see **Chap.** 45).
[c]Systemic and intravitreal; (at least topical) steroids should also be used.
[d]This is the only scenario where a posterior IOFB may be extracted while leaving the vitreous behind.
[e]The patient refuses or is in such a poor general condition that surgery is contraindicated.
[f]Most commonly a piece of wiring.
[g]Blind extraction with the external electromagnet (see the **Appendix**, **Part 2**).
[h]Occasionally it is possible to preserve the posterior capsule and pull the IOFB through the posterior capsulectomy.

Table 63.6 Incarceration of the retina in severe trauma

Incarceration type	Comment
Primary	The incarceration is direct: the surgeon catches the prolapsing retina with his needle as he closes the scleral wound[a]. The incarceration occurs by an *inside-out* mechanism; the most typical clinical examples are a posterior rupture or, less commonly, a laceration
Secondary	As the scleral wound is scarring over from the episclera, moderated mainly by the fibroblasts, the process does not stop at the inner edge of the sclera but continues inside the eye, along the retinal surface[b]. The incarceration occurs by an *outside-in* mechanism; the most typical clinical examples are a posterior rupture or, less commonly, a laceration. Incarceration of the retina into the exit wound of a perforating injury may also have this mechanism
Tertiary	The injured RPE cells react with proliferation and secretion of collagen fibers. The incarceration occurs by an *inside-in* mechanism; the most typical clinical examples are an IOFB injury with a deep impact or the exit wound of a perforating injury

[a]Hence the recommendation not to attempt suturing a wound that is very posterior (see above, **Sect. 63.5**): pressure exerted on the eyeball during suturing causes the prolapse or makes it more pronounced.
[b]Mainly the inner surface and then into the vitreous (the typical appearance of PVR) but also on the outer surface (subretinal proliferation).

a closed funnel is encountered because surgery was delayed,[10] a special technique is needed to deal with it (see **Sect. 32.3.1.5**).

63.9 NLP and Sympathetic Ophthalmia

The risk of sympathetic ophthalmia is often cited as the reason why not to perform vitrectomy on an injured eye if the VA is NLP.

- While NLP is indeed an indicator of poor outcome, it is *not* an absolute one; in a large series of eyes, our team[11] achieved an improvement rate of 57%.[12]
  - If it is possible to suture the eye together, even loss of retinal tissue does not justify abandoning or enucleating it.
  - An eye with NLP vision after trauma represents an urgent indication (see **Fig. 9.1**); the best (in fact, only) chance of success is a vitrectomy that is done within the first few days. If the cornea does not allow visualization of

[10]I rather often see eyes in which no surgery other than the initial wound closure was performed, even though the injury obviously had a high risk for retinal incarceration and thus PVR development. This always causes astonishment and anger on my part; what was the original ophthalmologist hoping to achieve by waiting ("observation")?

[11]Includes Robert Morris, MD, and C. Douglas Witherspoon, MD.

[12]The final function ranged from LP to reading vision.

the deeper structures, deferring surgery is not an option. Either the endoscope may have to be utilized (EAV, see **Sect. 17.3**) or TKP is indicated (see below).

- Citing the risk of, and fear from, sympathetic ophthalmia to justify primary or early secondary[13] enucleation is absolutely unacceptable.
  - The patient must be properly informed that sympathetic ophthalmia, however rarely, may occur after severe trauma.[14] Based on proper counseling, the patient should make the decision whether enucleation or reconstruction should be done.[15]
  - If the patient chooses reconstruction, the signs and symptoms of sympathetic ophthalmia must be explained so that treatment can immediately be initiated.

63.10 TKP-PPV

This is a very complex surgery and only an experienced VR surgeon should undertake it. Often an improper wound closure, not the presence of the wound itself, is the reason why the cornea needs to be replaced (see **Table 45.2** for the options if the visualization is poor). Only a few comments are made here about the surgery:

- Ideally, it is the VR surgeon who does the entire surgery, including removal of the damaged cornea and suturing the graft at the end of the procedure.
- The trephine chosen to cut the cornea should be ½ mm greater than the barrel of the TKP, irrespective of its type.
  - Insertion of the TKP into the eye with low IOP is easier if the fit is not tight. The sutures will hold it in place without leakage.[16]
- The time when the eye is open should be as short as possible (see **Fig. 62.1**).
- The full armamentarium of VR surgery is likely to be needed.
  - The lens either has been lost during the injury or needs to be surgically removed.
  - The iris should not be reconstructed at this point as further surgeries are likely to be necessary (see **Sect. 48.1.2**).

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[13] During the first few days or weeks. Late enucleation of a blind, painful, or cosmetically disturbing eye is of course acceptable. Remember, enucleation is an amputation, with severe psychological implications for the patient.

[14] The risk is less than 1 in 2–3,000 cases; conversely, sympathetic ophthalmia can also occur after routine elective surgery.

[15] The key word is *proper*. A patient who is frightened by the information his ophthalmologist told him (because he does not want to dedicate the time and effort to operate on the injured eye) will obviously choose enucleation. A patient who is given truthful, factual information (which includes the risks and benefits of both enucleation and surgery as well as the prognosis with *proper* treatment should sympathetic ophthalmia occur) will choose reconstruction.

[16] A tiny amount of leakage is also not a problem; the IOP will still be maintained throughout the procedure.

Pearl
Performing maneuvers in the anterior segment is technically much easier in an open-sky manner, but the risk of a major hemorrhage (ECH) is great. Should such a bleeding occur, the eye is probably lost (see **Fig.** 63.10).

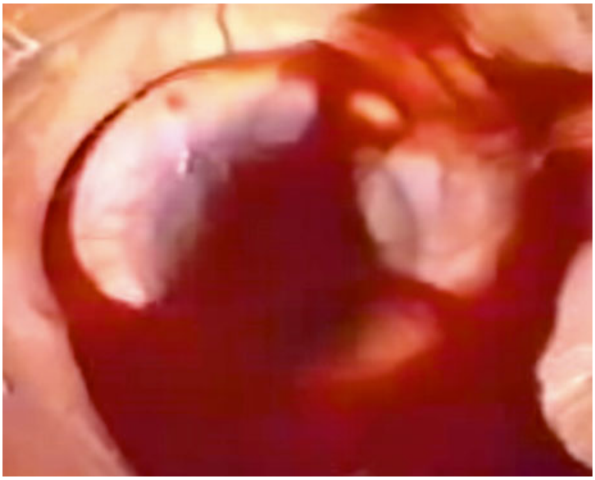

Fig. 63.10 **ECH in an eye undergoing a PK.** There is prolapse of the vitreous and extensive and ever-increasing breakthrough bleeding from the choroid; this will rapidly be followed by expulsion of the retina. The hemorrhage occurred during extensive open-sky maneuvers. The chances of restoring vision or even preserving the eyeball at this point are very close to zero. The only way to avoid this scenario is to immediately close they eye when the vitreous prolapses

- The donor cornea should be at least ½ mm greater than the size of the trephination: it is important to make the AC deep.
  – Using full-thickness sutures (see above, **Sect.** 63.4) helps keep the graft clear.
- Silicone oil should be implanted at the end of the procedure.
  – The full-thickness sutures allow the F-A-X to be performed safely, under proper visual control. Since oil will be used, the BSS must completely be drained.
- Even in a severely traumatized eye, the graft has an over 90% chance of survival.

63.11 Hemorrhagic RD

The principles and surgical technique do not differ from those described in **Chap.** 36, although in an injured eye, paradoxically, it may be easier to access the blood because of the existing retinal injuries (see **Fig.** 36.1).

63.12 Additional Considerations

Only a few general comments are made here.

Q&A

Q *Can primary IOL implantation be performed in an eye with posterior segment injury?*

A Yes – if the risk of PVR is low (and the biometry could safely and reliably be done). Conversely, there is rarely a need to implant that urgently. Remember, the ciliary body and the posterior retina determine the visual outcome, not the presence (or absence) of the IOL (see below).

- It is not only the vitrectomy that needs to be truly complete in trauma, but the ciliary body must also be thoroughly cleansed (see **Sect. 32.5**).
  - One of the most commonly seen errors in VR surgery for a severely injured eye is the attempt to preserve the posterior capsule so that "in-the-bag IOL implantation" will remain an option in the future.[17]
- Silicone oil implantation, even if considered as prophylactic when no major VR pathology is seen at the time of the vitrectomy, should be the default option.[18]
  - The oil should be kept in these eyes for longer than in most other indications (see **Sect. 35.4.6.1**).

Quo Vadis, Medicina?

Sadly, many experienced VR surgeons abandon the field of traumatology, leaving the management of these complex, difficult cases to the least experienced, often ill-trained, surgeon. It is obviously devastating for the patient who thus faces a worse prognosis. It is also terrible for the fellow, whose surgical efforts are doomed, even if this is not his fault. As mentioned in **Chaps. 1** and **2**, such failures have a doubly devastating impact: the fellow will not learn how to properly deal with injured eyes, and his confidence also suffers repeated blows.

[17] The same ideology is employed by the phacologist who in an eye with severe endophthalmitis argues against the removal of the capsule and the implanted IOL (see **Part 2** in the **Appendix**).

[18] "Default" is defined as *the* choice unless strong arguments can be made against it.

- Being able to successfully operate on complex trauma cases is a very rewarding experience, compensating for those cases where success has proved elusive.
- At an institution where multiple VR surgeons work, a few should specialize in ocular traumatology and do most of the cases. If all surgeons do a few cases each, the outcomes will be suboptimal.
- Among all subfields in VR surgery, traumatology is where the surgeon can be most innovative since very few absolute rules exist.
- If the VR surgeon – or any ophthalmologist – is unable or unwilling to offer the proper treatment to the patient with an injury, the only acceptable option is to *immediately* refer the patient to a VR surgeon who is willing and able to do what is necessary (see **Sect. 3.10**).
  – Delaying the referral is also unacceptable: it should be the VR surgeon who makes the decision regarding timing, not the referring ophthalmologist.

Postoperative Care

64

A patient who just underwent VR surgery may require very little attention afterward or may have to be monitored very closely for extended periods. If it is not the surgeon who follows the patient, the surgeon must at least make sure that the ophthalmologist who does the follow-up is competent and will refer the patient back to him if a serious issue arises.

- If no serious complication occurred intraoperatively and none is expected postoperatively, the treatment is mostly anti-inflammatory; in this case a visit shortly after the surgery is needed, followed by another visit scheduled for a few weeks later and a final follow-up at 3–6 months.
- The patient must always be advised about the possibility and symptoms of the most important complications and the need to seek help outside the normal follow-up routine if any symptom occurs.
- If complications are present or expected, frequent follow-up visits should be scheduled.

Q&A

Q *Can PPV safely be performed on an outpatient basis?*

A In principle, yes. However, it requires a patient who has been properly informed about positioning, medications, and the consequences he will face if the instructions are not followed. It also requires at least one visit to the surgeon the day after surgery and a knowledgeable ophthalmologist who will follow the patient in his office.

In this chapter a brief summary is provided of the most common possible complications and their therapy (see **Table 64.1**).

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Table 64.1 Postvitrectomy complications

Complication (sign or symptom)	Early (E) vs late (L)[a] presentation	Comment	Treatment
Pain	E/L	E: corneal erosion[b] A lid speculum that was spread too wide. Extensive pulling on the extraocular muscles[c] Elevated IOP[d] Patients who underwent repeated surgeries, especially if these closely follow each other, experience more pain and irritation L: elevated IOP (see below)	Erosion: topical steroid is needed in the first 10 days; in addition: artificial tears, corneal gels, therapeutic contact lens, amniotic membrane. Especially if the erosion recurs, surgical intervention may be indicated[e] Elevated IOP: according to the etiology (see below) plus antiglaucoma drops, acetazolamide tablets, surgery
Loss of vision[f]	E	A tight scleral suture, especially after 20 g surgery, can also cause astigmatism Presence of air or gas tamponade Intraocular hemorrhage Cataract[g] High IOP due to gas expansion Intraorbital hemorrhage[h]	None or according to the etiology
Endophthalmitis	E	See **Chap. 45**	
Inflammation	E	May be a normal reaction; in some cases it may be very strong	Topical, occasionally systemic, steroid
Irritation	E	Repeated surgeries (see above) Suture on the eyeball's surface, which may cause neovascularization and granuloma Subconjunctival silicone oil	Suture removal if ointment is insufficient to deal with the irritation The subconjunctival oil should be removed when the intraocular oil is removed[i]
Corneal edema	E	Especially after scraping the epithelium, which may not heal for extended periods in diabetics	Topical steroid
Zonular opacity (band keratopathy)	L	Silicone oil touch is the most common culprit, but many other, systemic or local, causes may also be responsible	According to the etiology; EDTA and abrasion

(continued)

Table 64.1 (continued)

Complication (sign or symptom)	Early (E) vs late (L)[a] presentation	Comment	Treatment
Positional keratopathy[j]	E	Pigment and other debris on the corneal endothelium. Not really a complication; it simply shows that the patient complied with the positioning instructions	None needed
Hypotony	E/L	E: Wound leakage, choroidal detachment L: Ciliary body shutdown	E: Closure of the wound; drainage; viscoelastic or pure SF_6 gas implantation into the AC L: Ciliary body debulking, silicone oil implantation
Anterior segment ischemia	L	May occur after encircling band placement if the band is very tight[k]	Cutting the band
Hyphema	E/L	Much more common as an E complication; if it is L, the cause may be the original disease[l] or rubeosis	None or, if the IOP is high, irrigation or clot removal with the probe (see **Chap.** 47)
Permanently dilated pupil	E	Extensive lasering over the long ciliary nerves	Pilocarpine drops, surgery to constrict the pupil
Glaucoma	E/L	There are different mechanisms how the IOP can get elevated: extensive inflammation, hemorrhage[m], lens-related[n], epithelial ingrowth etc.	According to the etiology. In neovascular glaucoma anti-VEGF injection into the AC is of great benefit
Cataract[o]	E/L	With the rare exception of iatrogenic rupture of the posterior capsule, the cataract is usually a L complication – or, in truth, a side effect. With time all eyes undergoing PPV will develop cataract, most probably due to the increased O_2 level in the vitreous. The cataract is typically nuclear, which is best seen with the naked eye, not at the slit lamp (see **Table** 7.1)	Extraction

(continued)

Table 64.1 (continued)

Complication (sign or symptom)	Early (E) vs late (L)[a] presentation	Comment	Treatment
VH	E/L	The E is much more common; it obscures the fundus at a time when it would be the most important to inspect it	None, lavage, or re-PPV (see **Sect. 62.4**)
EMP	L	May occur primarily[p] or recur; ILM peeling prevents both	None or re-PPV
RD	E/L	May be caused by inappropriate surgery[q] or a secondary break; it also occurs in up to a fifth of eyes after silicone oil removal	Re-PPV (see **Sect. 54.7**)
PVR	L	The most dreaded L complication of PPV	Re-PPV with silicone oil implantation (see **Chap. 53**)

[a]The cutoff between them is not straightforward. “Early” here means days or a few weeks; “late” means several weeks or months (occasionally even years) postoperatively.
[b]Typically after scraping the epithelium.
[c]During SB.
[d]Gas tamponade with expanding gas, silicone oil overfill, and significant intraocular hemorrhage.
[e]These are best handled by a cornea specialist.
[f]The patient may simply say “I can’t see,” but the range extends from slight worsening to NLP. The complaint should prompt immediate questioning regarding the specifics of the visual symptoms.
[g]If caused by a broken posterior capsule.
[h]The last two represent emergencies since the vision may irreversibly drop to NLP.
[i]A simple needle puncture and some compression are usually sufficient.
[j]These patients may also complain about lower back or neck ache.
[k]Additional complications after SB (diplopia, myopia, infection, extrusion etc.) are not discussed here.
[l]Such as diabetes.
[m]This alone has different mechanisms such as hemolytic, hemosiderotic, and ghost cell.
[n]Pupillary block due to swelling or subluxation; phacolytic, phacoanaphylactic.
[o]The “gas cataract” is a temporary feathering of the lens, which disappears when the gas does.
[p]Especially after extensive laser treatment.
[q]Causing an iatrogenic break.

Further Reading

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Appendix

Part 1. A Few Words to the Mentor[1]

Assisting a fellow in VR surgery is easy; assisting him in a way that the fellow learns the most *and* the patient's vision is not compromised – that is a very difficult job.

Q&A

Q *What is really a mentor in VR surgery?*

A Basically, a coach for a trainee called fellow; a pair of external eyeballs connected to a brain in overdrive. As you are closely observing the case, you are keenly aware of what is going well during the operation and what is going wrong; it is your job to tell your fellow both, and do it in the most productive way. There must be proper positive reinforcement for what is going well and an effective list of corrective actions to improve on what is going wrong.

You have seen many cases similar to the current one. You:

- Know exactly what needs to be done and how.[2]
- Are constantly comparing in your brain two things: what *needs to be done* vs *is being done.*
- Know what errors the fellow is likely to commit and what errors he is indeed making.
- Know what he should do to prevent those errors.
- Know that you could do this surgery better.
- Know that you could complete the operation faster.

[1] These comments are restricted to the experienced VR surgeon's *intraoperative* activities as he is assisting the fellow. Being the primary person responsible to train "the next you" involves a lot more than what can be discussed in this book.

[2] Driving from point A to point B (see **Sect. 3.1**).

Despite all of these facts, you must:

- Pay very close attention to the case the entire time, no matter how boring and repetitious it gets.
- Remain very patient[3] and not immediately voice every suggestion that your brain flashes up, even if the suggestion would surely improve the efficiency of the surgical maneuver in question and reduce the time of the operation.
- Resist, at least temporarily, the temptation to tell the fellow to switch places so that you can demonstrate how it's done.
- Use encouraging words for things well done and suggest corrective actions as need be, finding a balance between the two since.
  - Too much or undeserved praise unnecessarily boosts the fellow's ego, which can lead to overconfidence (see **Sect. 4.7**).
  - A nonstop flow of commands to do something differently kills the fellow's initiative and indeed thinking.
- Make a decision every time you notice the fellow is struggling, whether you are going to:
  - Let him find the answer himself (this is the ideal option as long as it does not risk a significant complication).
  - Suggest *the* solution (*a* solution) if the fellow does not seem to find it.
  - Take it over if the maneuver is too difficult for his level or if you yourself cannot determine what the next step should be.
- Switch places if the situation in the eye threatens with a major complication so that you demonstrate what needs to be done.
- Be ready to answer any and all questions the fellow has; in fact, you must encourage him to keep asking questions, no matter how trivial they may seem to be.

Pearl
This is what I tell my fellows, at the very beginning of the training process, and repeatedly prior to the operation: You can ask any question at any time, whether you are doing the case or I am. There is no such thing as a stupid question, only a stupid person who does have a question but does not voice it.

During an operation or the training process in general, you may come across something that needs an extensive discussion; it may turn out to be a positive or, more commonly, a negative feedback. Do not spare the time; sit down with the fellow in private – never shame him in front of others, whether it is a patient, a nurse, a colleague, or a visitor. Go over the issue in detail. Find a solution together with the fellow: not merely suggesting one but arriving at it together.

[3] Even though virtually every maneuver will take longer for the fellow to complete than for you, you have to dedicate sufficient time to allow him to actually do it. Observing is passive knowledge, doing it is active; we all know from every walk of life (just think about learning a language) that the active knowledge is many times more important and useful.

Being the "surgical coach" has much higher stakes than coaching in sports, even if there are many similarities. In your case somebody's sight can be ruined or another person's professional goals dashed if you do not act properly, and if you are not willing to do the training properly, get out of this business (see **Sect. 3.5**).

Pearl
Never lose sight of the fact that some time ago you were a beginner surgeon yourself. You also struggled with what you perform so (seemingly) effortlessly today, so always act toward your fellow the way you wished your mentor would have acted toward you back then.

Part 2. Important Personal Experiences

As we look back at our lives, both personal and professional, we all remember events that had a profound effect on us and shaped us, turning us into what we became. Below is a collection of events that had a major impact on my own professional life.

A Person, Not a Diagnosis
As a medical student, I once woke up with terrible pain in my right shoulder and soon realized that I was unable to lift my arm above the horizontal. My father, who was the chairman of the Radiology Department at the same university, took me to the Neurosurgery Department.

I spent the next two weeks there as a patient. I was a "VIP" because of the family connection, because I was a medical student just before graduation, and because I had known my treating physicians for a long time. Yet during all that time nobody ever spoke to me about the diagnosis, the potential consequences, the medications I had to take, and the prognosis, not even the diagnostic procedures I was facing (the latter is a less pressing issue in the era of CT and MRI, but back then pneumoencephalography [see http://www.ncbi.nlm.nih.gov/pmc/articles/PMC494289/] was just one of the horrors a patient had to face). And because none of my physicians talked to me, I did not dare asking questions myself.

The bottom line

That was when I made the conscious decision that if I ever become a physician, I will be a *doctor*, a doctor to whom the patient is not a case, an organ, a tissue, a condition, but a person. With time, I went one step further and have practiced what is described in **Chap. 5**: I counsel, the patient decides.

The Welcome Message

The first day I showed up for work at the university hospital, the chairman of ophthalmology took me to a ward where a middle-aged female ophthalmologist (Dr. S.) was in charge. The chairman asked her to take me under her wings and train me as best as possible. I had never met Dr. S. before; her first words to me were an instruction to "go and fetch Mr. X." I concluded Mr. X had to be a patient so I went to the nurse and asked her where I could find him and then took the patient to the exam room.

Dr. S. told me to take the (direct) ophthalmoscope and describe the macula. I replied that this is an impossible task; the only time I had the direct ophthalmoscope in my hand was 2 years earlier as a medical student, and even then for 1 min only. I, as my fellow students, was very happy to catch sight of the disc – no hope for the macula. Dr. S. told me to move over to the desk and write in the chart what she dictates. I tried my best, but she used technical words I was unable to understand. When she finished, she told me, in an icy voice and in front of the patient: "You see, I can dictate half a page about something you are unable to even see."

The bottom line

Do not expect that all your colleagues have the same interest as you do in advancing your career.

Vision or the Removal of the IOFB?

Within weeks into my residency, a young male patient arrived with a small IOFB lodged into the posterior retina. Amazingly, he had full vision and no VH. As usual, it was the chief of the department who removed the IOFB, using a large external electromagnet; for some reason the procedure was not done under general anesthesia. All 17 ophthalmologists of the department were present when the extraction took place, and everybody was visibly relieved when the IOFB finally "jumped out of the eye"; some of my colleagues even clapped their hands. Nobody seemed to be bothered by the scream of the patient: "I can't see anymore." I asked an experienced "attending" what may have happened and was told that the patient probably suffered a VH – this before the age of vitrectomy. (Eventually, the eye became blind and phthisical and was enucleated.)

In the late afternoon hours that day I went to the chief's office and told him what I could not understand: we seem to be so happy that the IOFB was successfully removed, even though the patient just lost vision. The chief stood up behind his desk, pointed at me, and in a very threatening voice asked a question: "who are you to question what we have been doing for a hundred years?"

The bottom line

That was the moment when I decided that from now on, I will question everything, irrespective of who says or does it. (As a corollary: decades later I heard a lecture about 4,444 IOFB operations with a "99% success rate." The answer to my question ["what is the definition of success?"] confirmed my suspicion: success is defined by IOFB removal. The study did not even look at visual outcomes.)

It's Not My Business

While on duty at the hospital, I had a patient who was in a car accident. His facial bones were broken and his right hand in a cast, although he had only corneal erosions as globe injury. I asked him what happened, and he told me that he likes to keep his hand rested on the middle of the steering wheel, and when the airbag deployed, it threw his hand against his face.

Years later I was riding in a taxi and noticed that the driver also kept his hand in the middle of the steering wheel. After some hesitation I told him the story of my patient; I said I knew it was not my business how he drives, but my consciousness would not be at peace if I had not informed him about the danger.

He immediately took his hand off the steering wheel and thanked me.

The bottom line

It *is* your business to inform; whether the other party accepts it or not is not your worry anymore, but you at least did what you could.

Blame Yourself, Not the Nurse

I once had to operate with a very inexperienced nurse. I had the probe in my hand, operating on an eye with an EMP; there was no PVD and the detachment was very difficult. I was working under the contact lens, which kept sliding off the cornea, and I had to ask the nurse numerous times to adjust the lens. I got very frustrated and eventually decided to adjust the contact lens without asking the nurse or pulling the probe out of the eye first (a big no-no!). Much to my horror, I accidentally bumped the probe into the posterior retina, causing a tear – just a mm from the fovea. There was no long-term consequence, fortunately – but I will never forget the sinking feeling I had at the moment when I discovered the tear and its proximity to the fovea.

The bottom line

Never keep instruments in the vitreous cavity if your attention is focused elsewhere. I faced the same scenario multiple times after this experience but would not even contemplate repeating that stupidity.

It Is Not the "Who" but the "What"

I used to work in a country that back then had a totalitarian society and a very rigid hierarchy in medicine. It was in another country, which had a free spirit both within the profession and in general, that I attended the lecture of a Harvard professor (Hp) at the university where I now worked. He was given 45 min to discuss a vision-related basic-science topic, followed by 15 min of questions. All the nobilities of the university were in attendance; being a professor at Harvard deserves that. I was shocked to hear a sentence during the lecture, in which the Hp acknowledged a problem he cannot solve – in that totalitarian country someone of even lesser stature would never admit that a problem for which he has no solution can exist. I was also astonished that the Hp finished on time – in many countries such a title allows you to go overtime.

When the Q&A session started, a very young female colleague from my home country, who also worked at the same university, put up her hand. She did not have a question: in her broken English she explained to the Hp that she may have a solution to his problem. I was watching the facial expression of the Hp as she was talking – from polite it turned to the one when “the lightbulb was just switched on.” The Hp bypassed the university nobilities, came to the young colleague just in front of me, and said the following words: “I think you solved my problem. Would you explain your solution one more time?”

The bottom line

What matters is not the number of stars on your shoulder or the age on your ID card. Your deeds and how you express yourself are all that count.

The IOL vs the Eyeball

I returned home from a long trip late on a Friday afternoon and went straight to the hospital. The nurse informed me about a young female patient who had cataract surgery a week before and now had endophthalmitis. I examined her and immediately offered the possibility of performing vitrectomy, which she, after proper counseling, accepted. During surgery – her eye was full of pus – the original cataract surgeon showed up; he may have been notified by the nurse. He protested when I decided to remove the IOL and the capsule (I deemed it impossible to properly clean the capsular bag): “But then the eye will not have an IOL!” I said only this: “And otherwise there will be no eyeball.”

The patient ended up with full vision and a secondary implant, and I fell out of favor with that phacologist.

The bottom line

Never lose sight of what tissues determine vision and globe integrity: the posterior retina and the ciliary body. The capsule is the attachment to the eye, not the other way around.

Operate When the Anatomy and Function Are Normal?

I remember several patients who were taking immunosuppressive drugs plus systemic steroids for uveitis, but needed PPV because their vitreous was almost totally cloudy. The doses of the systemic medications were temporarily increased prior to surgery so as to reduce the inflammatory reaction the vitrectomy causes. When the patients showed up for the operation, their vitreous cleared up, the macular edema went away, and their vision was full. I was hesitant to go ahead with surgery – one cannot improve vision at that point, only make it worse if a complication occurs. I therefore counseled all of these patients to forego the operation.

Every single patient, independently of all the others, told me that they would risk surgery as long as this gives a chance – not a promise! – that the systemic medications will no longer be needed or can be reduced. They understood and accepted the risks of the operation, but considered the side effects of the systemic drugs too high to keep the ocular inflammation under control. They also realized that once the systemic medications, which could not be maintained at that high dose anyway, are tapered, the ocular complications of the disease will recur.

Fortunately, all of these cases ended up well, but the patients themselves reassured me: even if something goes wrong, they will not blame me.

The bottom line

There is no justification for a physician to consider only the condition of a tissue when treatment decisions are made. There is no alternative to making the decisions together with the patient.

When Your Patient Dies on the Operating Table

I saw a patient who had rather poor vision due to a macular condition. After proper counseling surgery was scheduled; she requested general anesthesia. During the operation I all of a sudden noticed that the color of the fundus is bluish. I immediately warned the (male) anesthesiologist, who was sitting in the far corner of the OR, intensively talking to his new, very pretty female anesthesiologist nurse.

It turned out that the anesthesiologist was focused on the nurse, not on the patient, and let the oxygen tank run empty – back then neither a central oxygen line nor a finger oximetry sensor was available. The resuscitation effort was unsuccessful and the patient died.

The bottom line

For a very long time I could not recover from this tragic event and felt guilty: why did I agree to do the surgery? Slowly I got over it as rational thinking got the better of my emotions, but the event haunts me to this day. The surgeon must always keep in mind the threatening truth in Murphy's law: *If anything can go wrong, it will.*