



# Endoscopic vitrectomy

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## Purpose of review

To update on the recent developments and surgical applications of intraocular endoscopy, and highlight its role in the modern era of microincision vitreoretinal surgery.

## Recent findings

Recent progress in our understanding of the unique intraocular illumination properties of endoscopy, specifically the use of reflected (coaxial) versus conventional transmitted (dissociated) light, is redefining its role in vitreoretinal surgery. Indications for endoscope-enabled intraoperative viewing during pars plana vitrectomy include posterior segment disease with significant anterior segment opacity, difficult-to-access retroirideal diseases involving the sclerotomy, pars plana, pars plicata, ciliary sulcus, ciliary body, or peripheral lens, and complex anterior retinal detachments, particularly in diseases in children. The recent introduction of 23-gauge endoscope that works with standard microcannulas increases its utility.

## Summary

Endoscopic vitrectomy, particularly with the recent advent of 23-gauge technology, expands our surgical armamentarium, making it a useful complement to conventional viewing systems.

## Keywords

complex surgery, endoscopic vitrectomy, endoscopy, pars plana vitrectomy

## INTRODUCTION

Vitreoretinal surgeons are confronted with a wide spectrum of diseases with highly variable complexities. Attainment of the best possible surgical outcomes is facilitated by having access to the full surgical armamentarium. Endoscopy has a distinctive place in the surgical armamentarium because of its unique optical properties, arguably making it highly complementary to conventional viewing systems. The recent advent of 23-gauge endoscopy increases utility of this technique in the current era of microincision vitrectomy surgery (MIVS).

## DEVELOPMENT OF THE ENDOSCOPE

Endoscope is derived from the following two Greek words – *endon*, meaning inside, and *skopin*, meaning to view. In 1934, the first ophthalmic endoscope was developed [1]. This had an integrated forceps for intraocular foreign body removal, although it required a separate illumination source. The first illuminated endoscope was developed shortly thereafter, measuring 6.5 mm wide, with visualization through an eyepiece attached to the external end of the endoscope [2]. Over 40 years later, Norris and Cleasby [3] developed a 1.7 mm diameter intraocular endoscope. In 1990, the first modern-day flexible 20-gauge endoscopes, otherwise known as

videoendoscopes or ophthalmoscopes, were developed for vitreoretinal surgery [4,5]. As with current technology, the intraocular image was projected onto an electronic monitor. Volkov *et al.* [4] showed in a series of 23 eyes, the feasibility of using pars plana endoscope-enabled vitrectomy to circumvent cornea and lens opacities.

The underlying principle of the endoscope is that it acts as an optical conduit, capturing light through an objective lens at its distal end within the human body, transferring the image through an image relay system, that is then viewed by the operator/surgeon. There are two different ophthalmic endoscope designs, the principal difference of which lies in the image relay system. First, GRIN, or gradient index lens systems, uses a shorter rigid housing. This has the option of an eyepiece instead of a camera at its proximal end for direct viewing.

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## KEY POINTS

- Endoscopic vitrectomy is highly complementary to conventional viewing systems because of its unique properties of being able to better visualize vitreous, bypass anterior segment opacities and enable unrivaled access to anterior and retroirideal diseases.
- Endoscopy enables potentially more timely vitrectomy in the context of anterior segment opacities.
- Unique access to anterior and retroirideal diseases facilitates surgery and optimizes outcomes in a range of adult and pediatric vitreoretinopathies.
- A 23-gauge endoscopy is compatible with standard microcannulas.

The GRIN system transmits more light and has a higher image quality, but is handicapped by the limited intraoperative maneuverability and field of view (FOV), and thus its utility. Second, flexible fiberoptic systems have significant advantages of smaller diameter instruments and longer flexible fibers, culminating in greater maneuverability, and are thus much more widely used.

### Current intraocular endoscopes

The Endo Optiks (Little Silver, New Jersey, USA) fiberoptic systems (E2 or E4 models) appear to be the most widely used internationally. In 2011, they introduced a 23-gauge endoscope [6]. Other endoscope systems, for example, by FiberTech Co. Ltd (Tokyo, Japan), are less commonly available, particularly in North America and Europe. At the time of writing, FiberTech does not have Food and Drug Administration (USA) approval or a CE mark (Ogawa G, Maekawa Y. Fibertech Co. Ltd, 17 November 2013, personal communication).

Endoscopes are available in 19-gauge, 20-gauge, and 23-gauge, the latter of which fits through standard MIVS microcannulas. They are trifunctional, incorporating illumination, viewing (through imaging fibers), and laser [7<sup>••</sup>,8<sup>••</sup>]. These functions are enabled by a control unit (box) containing a xenon light source, a charge-coupled device (CCD) camera, which captures the image from the fiberoptic and projects it on a monitor, and an 810 nm laser. The choice of gauge size is important, as it determines the pixel density, thus image resolution, as well as the FOV. The intergauge differences are as follows: 19-gauge – 17 000 pixels, 140° FOV; 20-gauge – 10 000 pixels, 110° FOV; and 23-gauge – 6000 pixels, 90° FOV. For the majority of cases, such as trauma, endophthalmitis, and rhegmatogenous retinal

detachment (RRD), the resolution and FOV of the 23-gauge endoscope suffices [9,10]. In the authors' experience, the 19-gauge endoscope has a distinct role in more complex cases, such as pediatric traction retinal detachments (TRDs) in retinopathy of prematurity (ROP) and familial exudative vitreoretinopathy (FEVR), benefiting from the additional resolution of 19-gauge endoscopes, facilitating more aggressive dissection of very anterior and retroirideal membranes [7<sup>••</sup>,8<sup>••</sup>].

### UNIQUE INTRAOCULAR OPTICAL PROPERTIES

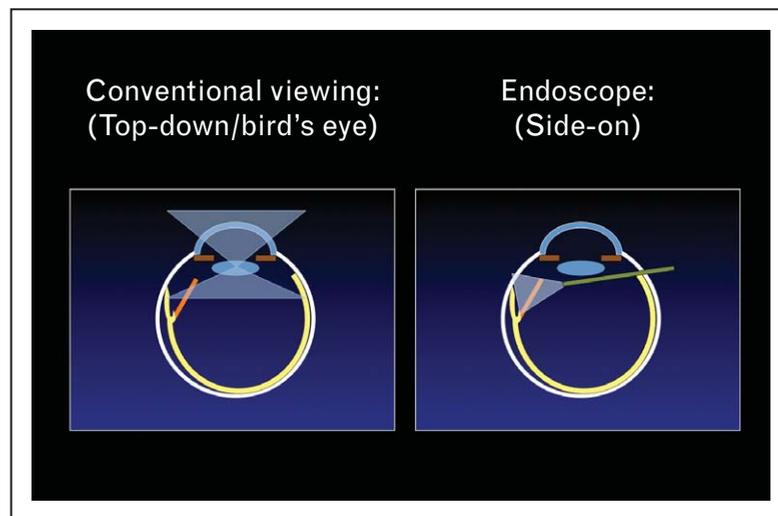
The endoscope's unique place in the surgical armamentarium is underpinned by its optical properties. In particular, there are three highly clinically relevant features that are not available with any other viewing system and setup. A good understanding of these key features will enable one to optimize the utility of the endoscope.

#### Circumventing anterior segment opacities

The intraoperative view with conventional microscope-based viewing systems [e.g., BIOM (Oculus, Wetzlar, Germany) or RESIGHT (Carl Zeiss Meditec., Jena, Germany)] is reliant upon being able to visualize the posterior segment through a clear anterior segment. The endoscope captures the intraoperative view directly from its tip in the posterior segment, bypassing the anterior segment altogether. This obviates the need for a clear optical media, a significant advantage in time-sensitive vitreoretinal diseases complicated by significant anterior segment opacities, for example, RRD in the context of corneal trauma, endophthalmitis, or anterior segment dysgenesis.

#### Surgeon's perspective

The endoscope confers a unique intraoperative view that is up to 90° off the conventional viewing axis of microscope-based systems. This derives from the point at which the intraoperative view is captured, that is, at the internal tip of the endoscope in the vitreous cavity, as opposed to over the top of the patient's cornea with a conventional microscope-based system. This corresponds to a side-on versus a top-down (or bird's eye) perspective. Ophthalmologists are very comfortable with the conventional top-down perspective, as this is also the all-familiar standard view with slit-lamp funduscopy and indirect ophthalmoscopy. The side-on perspective conferred by the endoscope, unfamiliar to first-time users, is advantageous in the following scenarios (Fig. 1).



**FIGURE 1.** Surgeon's perspective: illustrative comparison between conventional top-down (bird's eye) wide-angle viewing system and endoscopic side-on view, that is, 90° apart.

### Visualization of very anterior disease

Conventional viewing systems are in general limited by being able to visualize as far anteriorly as the vitreous base. Scleral indentation can bring the pars plana into view, and ciliary body or retroirideal diseases essentially outside the FOV and thus inaccessible. Endoscopy enables unobstructed and undistorted views of the space between vitreous base and posterior iris. Importantly, the quality of the intraoperative view is identical regardless of its position in the eye, that is, at the posterior pole or immediately behind the iris, particularly as there is no degradation of image quality at the edge of the image circle (i.e., no lens-related aberrations). This sets it apart from conventional viewing systems. Clinical scenarios in which the improved anterior access is applicable include removal of retained ciliary sulcus lens matter causing chronic uveitis [9], anterior scleral penetrating injury causing secondary vitreoretinal incarceration, and proliferative vitreoretinopathy (PVR)-related ciliary body and cyclitic membrane formation causing ciliary body detachment and chronic hypotony. Posterior tube shunt placement is another example in which endoscopy enables visualization of the tube in its natural (true) pars plana position; scleral depression during conventional vitrectomy inevitably causes some distortion of the anatomy, potentially masking residual anterior and postirideal vitreous and thus the risk of tube occlusion.

### Improved visualization of anteroposteriorly oriented disease

A highly relevant example is TRD in ROP or FEVR, in which there is typically significant anterior retinal detachment extension toward the anterior hyaloid

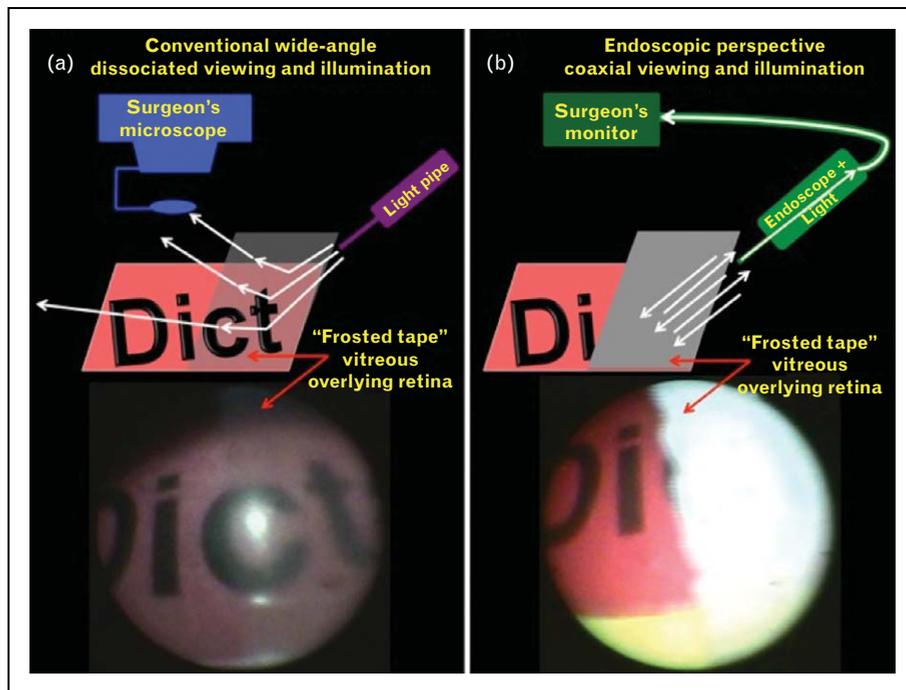
and lens, somewhat parallel to the viewing axis of conventional microscope-based systems. With a surgeon's perspective that is up to a 90° off-axis, endoscopy enables significantly greater visualization of the side profile of the retinal detachment, versus looking at the top edge of the retinal detachment with a conventional top-down view, thereby facilitating more direct and potentially more complete tissue dissection [7<sup>\*\*\*</sup>].

### Differential light use: reflected (coaxial) versus transmitted (dissociated)

Illumination and viewing are coaxial with endoscopy, as the same endoscope tip is the point at which both light emission and capture (of light reflecting off ocular tissues) occur. Conversely, with conventional microscope-based viewing systems, illumination and viewing are dissociated, determined by the disparate positions at which light emission (in the vitreous cavity) and capture (of light transmitted through the patient's anterior segment into the operating microscope) occur. There is evidence to suggest that the use of endoscopy-enabled reflected light helps the visualization of vitreous and membranes by making them appear more opaque [7<sup>\*\*\*</sup>] (Fig. 2) [11].

### CLINICAL OUTCOMES

The applicability and the efficacy of endoscopic vitrectomy have been demonstrated in a wide spectrum of diseases [9,12–23,24<sup>\*\*\*</sup>,25<sup>\*\*\*</sup>,26–30]. Table 1 summarizes the outcomes of 18 case series, with participant numbers ranging from 5 to 74. Case reports and smaller case series have been excluded.



**FIGURE 2.** Cellophane tape experiment simulating the view of the vitreous during pars plana vitrectomy, differentiating transmitted (a) from reflected light (b). Conventional wide-angle microscope-enabled viewing perspective (a) dissociates the surgeon's visual axis and source of illumination. Light is transmitted through the patient's clear vitreous. The vitreous appears largely transparent, as demonstrated by good view of the underlying alphabets. In contrast, with endoscopy (b), illumination and light capture are coaxial. Light is reflected back into endoscope, making the vitreous appear more opaque, as demonstrated by the obscuration of the underlying alphabets. (Image reproduced with permission from [11]).

## Indications

The following are indications for endoscopic vitrectomy.

### Anterior segment opacities and temporary keratoprosthesis

Any vitreoretinal disease that is difficult to access or optimally visualize with conventional microscope-based systems, may benefit from an endoscopic approach [31]. Classically, endoscopy is used to bypass anterior segment opacity that is sufficiently dense to preclude adequate visualization of the vitreous cavity using conventional viewing systems, for example, dense corneal stromal edema, corneal scarring, or eight-ball hyphema with endothelial staining. A recent comparative study [25<sup>\*\*\*</sup>] supports the use of endoscopy in favor of temporary keratoprosthesis in the context of severe ocular trauma (Table 1). In that study, time to surgery was shorter with endoscopy (median reduction 24 days), with a reduced likelihood of progression to retinal detachment by the time of primary surgery. By avoiding the need for temporary keratoprosthesis, endoscopic surgical times were shorter (median reduction 5.6 h). In another study, it was suggested that endoscopy enables timely vitrectomy surgery

while providing additional time for potential corneal recovery, avoiding temporary keratoprosthesis and thus a penetrating keratoplasty altogether [32].

### Difficult-to-access diseases

Endoscopy is uniquely placed in the vitreoretinal surgical armamentarium, enabling direct visualization of following difficult-to-access areas (Fig. 3) [33]. First area is the ciliary sulcus. Chronic uveitis in pseudophakes can be due to retained lens matter in the ciliary sulcus or chronic endophthalmitis. By directly visualizing the ciliary sulcus, endoscopy can help in clarifying the diagnosis [10], thus potentially avoiding a more complex in-the-bag intraocular lens explantation. In addition, vitreolensotomies in patients with uveitis benefit from a complete capsulectomy, particularly in children, which the endoscope can facilitate and ensure through direct visualization. Second area is the sclerotomy. At the internal lip of a sclerotomy, vitreous incarceration can be uniquely visualized as vitreous folds (Fig. 4) [11]. Endoscope-directed complete vitreous release with a vitrector can be performed. Third area is the ciliary body and behind the iris. Probably, the most likely disease to be encountered in this is PVR-related cyclitic membranes causing ciliary

**Table 1.** Summary of studies on endoscopic vitrectomy for various indications

Author/s (year)	Indication (no. of eyes)	Endoscopic procedure	Result/s	Follow-up (months)	Complications (no. of eyes)
Uram [12]	Neovascular glaucoma (10)	Ciliary body photocoagulation	90% with IOP <21 mmHg	9	None
Uram [13]	RRD with anterior PVR (10)	PPV	60% retinal reattachment	9	None
Boscher <i>et al.</i> [14]	Retained lens fragments and/or posterior IOL dislocation (30)	PPV	63% final visual acuity $\geq 20/40$	21	Retinal tear (2), CME (2), retinal detachment (2)
Ciardella <i>et al.</i> [15]	Complicated proliferative diabetic retinopathy (9)	PPV	75% visual improvement	11	Retinal tear (1)
Hammer and Grizzard [16] <sup>a</sup>	Chronic hypotony (9)	PPV + ciliary body dissection	67% postoperative IOP >5 mmHg	Not available	None
Faude and Wiedemann [29]	Ciliary body involvement in severe proliferative vitreoretinopathy (PVR stage CA 6–12) after large retinectomies (5)	PPV + endoscopic assessment of ciliary body	Direct visualization of ciliary body fibrosis +/- detachment in hypotonous eyes.	Not applicable	None
Sasahara [17]	Intraocular lens dislocation (26)	PPV + transscleral IOL sulcus suture fixation	96% stable or improved visual acuity 0% postoperative IOL dislocation; 0% CME	$\geq 3$	IOP elevation (1)
De Smet and Carlborg [18]	Endophthalmitis with coexistent corneal opacities (15)	PPV	100% final retinal reattachment 100% stable or improved vision	$\geq 6$	Retinal detachment (2)
Sonoda <i>et al.</i> [19]	Subretinal fluid drainage during PPV for RRD (10)	Subretinal fluid drainage	100% retinal reattachment	6	Transient retinal heme (2)
De Smet and Mura (2008) [20]	RRD with media opacities (9)	PPV	89% retinal reattachment 100% stable or improved visual acuity	11	Retinal detachment (1)
Olsen and Pribila [21]	Sutured posterior chamber IOL implantation (74)	Transscleral sulcus suture fixation	4% IOL decentration 0.7 logMAR (children) and 0.6 logMAR (adult) average postoperative visual acuity improvement	29	IOP elevation (11); corneal decompensation (6); transient vitreous heme (2)
Tarantola <i>et al.</i> [22]	Uncontrolled chronic angle closure glaucoma (19)	PPV + pars plana tube shunt placement	Significant reduction in IOP from 31.3 to 11.4 mmHg ( $P < 0.001$ ) at final follow-up visit	62	Phthisis (2), shunt retraction (1), shunt blockage (3), suprachoroidal hemorrhage (1)

(Continued)

Table 1 (Continued)

Author/s (year)	Indication (no. of eyes)	Endoscopic procedure	Result/s	Follow-up (months)	Complications (no. of eyes)
Kita and Yoshimura [23]	RRD with undetected breaks (20)	PPV	Breaks found in 19/20 (95%) eyes 100% retinal reattachment 100% stable or improved vision	24	None
Sabti and Raizada [24 <sup>***</sup> ]	Ocular trauma (50)	PPV	82% visual acuity improvement 90% retinal reattachment	14	Not available
Chun <i>et al.</i> [25 <sup>***</sup> ]	Ocular trauma: endoscopy (9) compared to temporary keratoprosthesis (8)	PPV	Endoscopy versus keratoprosthesis Shorter time to surgery: median 14 versus 38 days Shorter surgical time: median 2.8 versus 8.4 h Anatomic success: 44% (4/9) versus 25% (2/8), $P=0.64$	6	Failure: 0% (endoscopy) versus 38% (3/8) (keratoprosthesis), $P=0.082$
Heier [9]	RRD (19), vitreous hemorrhage (4), chronic hypotony (5), severe endophthalmitis (2), uncontrolled glaucoma (3)	PPV + pars plana tube shunt (in uncontrolled glaucoma cases)	79% (15/19) retinal reattachment 100% (4/4) vitreous hemorrhage resolution 40% (2/5) hypotony resolution 50% (1/2) endophthalmitis resolution and recovery of hand motions vision 100% (3/3) successful tube shunt placement	Not available	None
Ren <i>et al.</i> [26]	Endophthalmitis and RD (21)	PPV	62% visual acuity better than LP	≥18	Recurrent infection (2)
Wong <i>et al.</i> [27]	Complex RD in retinopathy of prematurity (37): stage 4A (17, macular sparing traction retinal detachment), 4B (12, macular involving traction retinal detachment), 5 (8, total traction retinal detachment) [5-CTRRD subgroup (5)]	Vitrectomy using pars plicata or scleral limbal approach	Anatomic: 68% (25/37) primary success (partial or complete reattachment)	37	Phthisis (6)

80% (4/5) in stage 5-CTRRD  
 78% (29/37) qualified success  
 (stabilization or reattachment)  
 100% (5/5) in stage 5-CTRRD

Vision

70% (23/33) FF or better  
 85% (28/23) LP or better  
 100% (5/5) LP for better in  
 stage 5-CTRRD: 40% (2/5) LP,  
 60% (3/5) FF

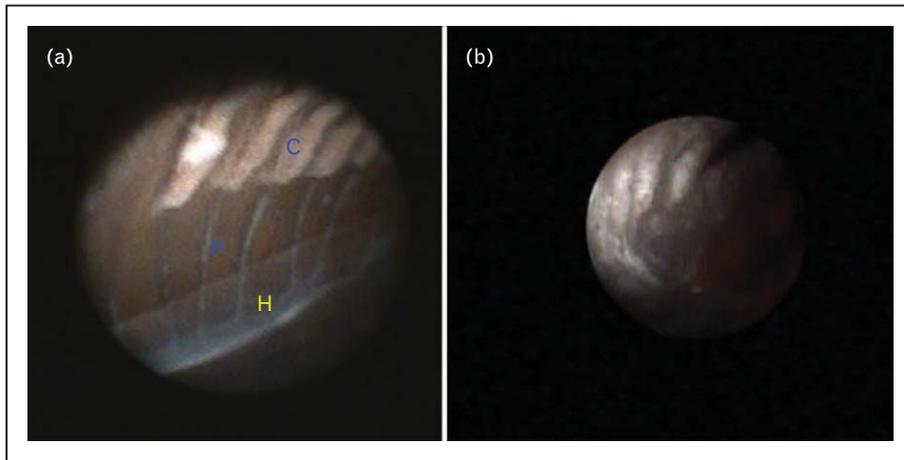
CME, cystoid macular edema; CTRRD, combined traction rhegmatogenous retinal detachment; FF, fix and follow; IOL, intraocular lens; IOP, intraocular pressure; LP, light perception; PPV, pars plana vitrectomy; PVR, proliferative vitreoretinopathy; RD, retinal detachment; RRD, rhegmatogenous retinal detachment.  
 \*This series used a GRIN type endoscope; all other series were performed with fiberoptic endoscopes.

body detachment, chronic hypotony, and potentially phthisis bulbi. Fourth area is the pars plicata and pars plana. Sutured haptics of malpositioned intraocular lenses can become entrapped within significant fibrosis adjacent to the vitreous base, hidden from conventional views (Fig. 5) [11]. The risk is, thus, unrecognized traumatic haptic removal, iatrogenic retinal break formation, and RRD. Pars plana glaucoma shunts can become occluded by vitreous or residual lens material, despite careful conventional vitrectomy with scleral indentation. As discussed above [10], conventional vitrectomy with indentation distorts the natural anatomy potentially masking residual vitreous. Endoscopy enables direct visualization of the shunt in its natural position, avoiding the need for scleral indentation, facilitating more complete vitreous clearance in the immediate vicinity. Fifth area is the subretinal. Subretinal surgery may occasionally be required to excise clinically relevant PVR bands (Fig. 6) [11]. With the endoscope, subretinal bands can be directly accessed from a remote and relatively small retinotomy (Fig. 6). Sixth area is the clear corneal surgery. Clinical scenarios in which sclerotomy placement is contraindicated include significant scleromalacia, history of necrotizing scleritis, total TRD in ROP or FEVR, and retinal detachment in postretinoblastoma-treated eyes [34]. Clear corneal surgery with conventional microscope-based systems can be difficult, as the viewing lens [contact or noncontact (e.g., BIOM (Oculus) or RESIGHT (Carl Zeiss Meditec.))] can get in the way of vertically positioned instruments when manipulation of more posterior disease is required. Endoscopy avoids the need for additional viewing lenses, thus circumventing this problem.

Endoscopic cyclophotocoagulation is a technique for directly ablating ciliary processes and ciliary epithelium as a means for reducing aqueous production and achieving long-term intraocular pressure control. It is typically done from the anterior segment, with or without cataract surgery [35–37]. In highly refractory glaucoma, more extensive ciliary process ablation ('endoscopic cyclophotocoagulation-plus') can be performed by vitreoretinal surgeons from the vitreous cavity, by lengthening the extent of laser from the posterior edge of the ciliary processes into the pars plicata.

### Pediatric vitreoretinal surgery

Endoscopy has recently been recognized to have an important and distinctive role in pediatric vitreoretinal surgery [7<sup>22</sup>, 8<sup>22</sup>, 27]. Highly elevated TRDs can occur in complex pediatric vitreoretinopathies, for example, in ROP, FEVR, and posterior persistent fetal vascular syndrome. In ROP and FEVR, extensive retrolental plaque can occur in advanced

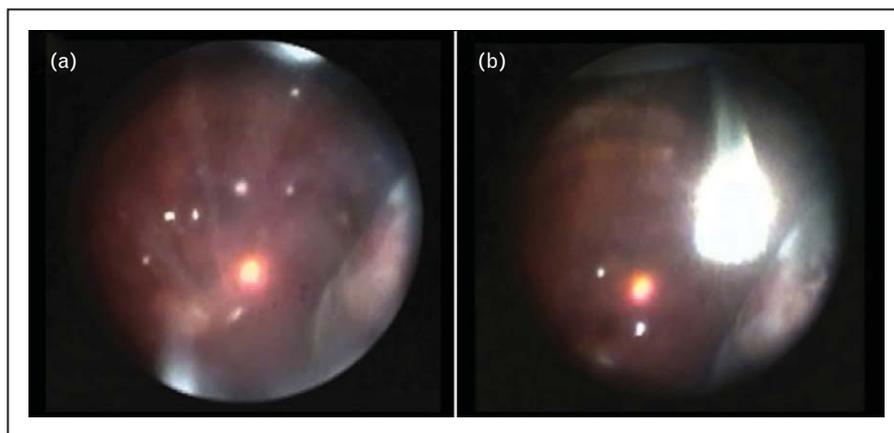


**FIGURE 3.** Intraoperative view with a 19-gauge endoscope. (a) This is a case of a child with aphakic glaucoma and rhegmatogenous retinal detachment. Normal anterior anatomical structures are clearly visualized. C, ciliary processes; H, hyaloid (anterior hyaloid face); P, pars plana. Note that the anterior hyaloid face is seen very clearly, because of the use of reflected rather than transmitted light. (b) Intraoperative view with a 23-gauge endoscope. This is a case of an adult patient with a view of the pars plicata. (Image reproduced with permission from [33]).

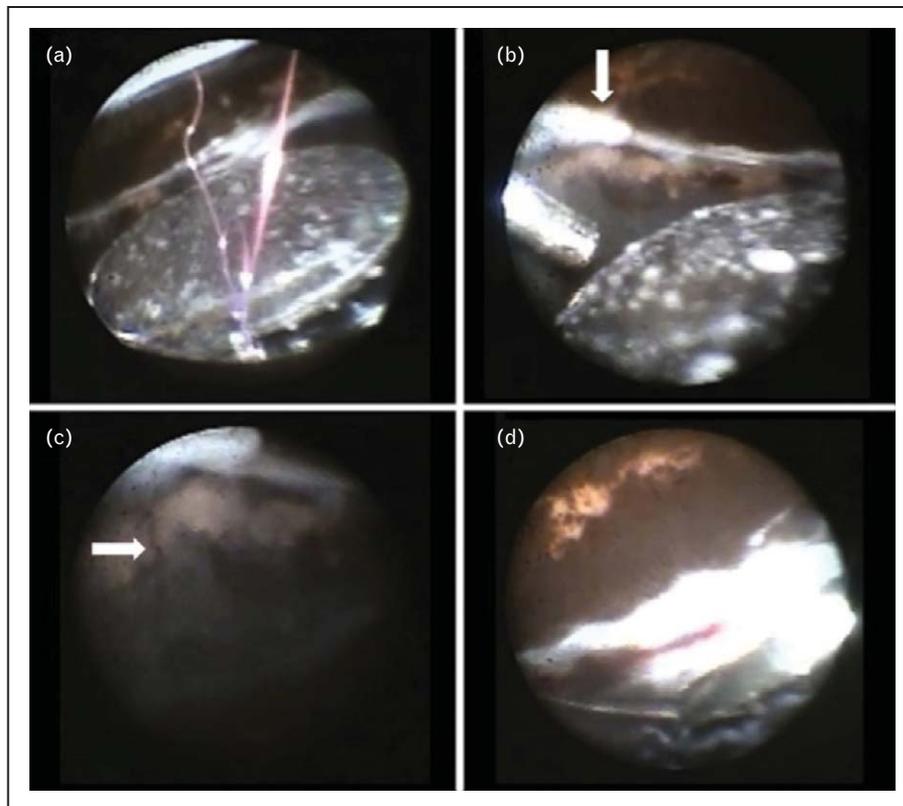
disease, obscuring direct visualization of the underlying retina. Incising through the opaque plaque is fraught with risks as folds of retina come up toward the plaque, and it is almost impossible to determine with certainty the peaks and troughs of these folds. Avoiding an iatrogenic retinal break is critical in such cases, as surgical failure is otherwise almost inevitable [38], bearing in mind that it is practically impossible to cleanly separate vitreous from the retinal surface in young children. In persistent fetal vascular syndrome of the posterior subtype, retina can be drawn up along the hyaloidal stalk. It is critical to identify the limit of the retina along the stalk to allow for safe transection. The bird's eye view of conventional microscope-based systems

only allows for a less-than-ideal view of the top end of the stalk, particularly when compounded with a retrolental plaque. Endoscopy can circumvent these problems (Fig. 7) [11], by enabling direct visualization of and access to the peaks and troughs of retinal folds under retrolental plaques, as well as revealing the entire side profile of a hyaloidal stalk and its relationship to the retina.

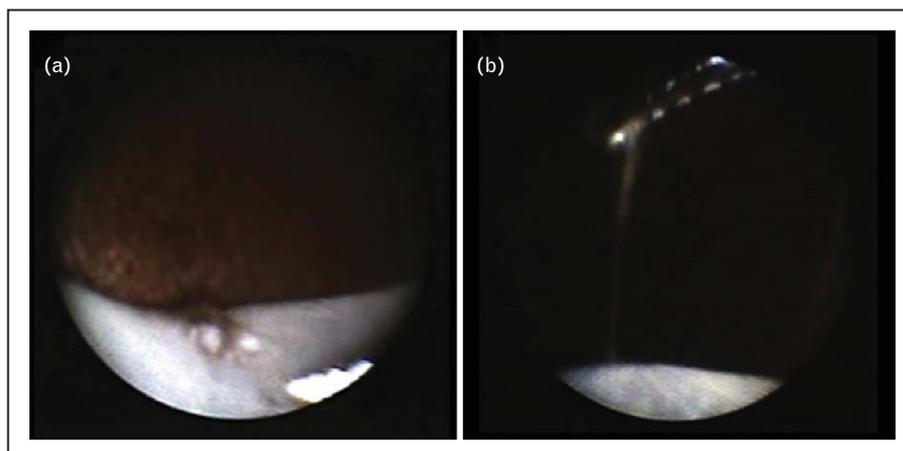
The anterior extent of pediatric TRDs may be adjacent to the lens and pars plana/plicata. There is, thus, a significant risk of lens trauma or iatrogenic retinal break during passage of a sclerotomy blade and vitrectomy. Endoscopy can directly visualize and, thus, improve surgical safety (Fig. 8) [33].



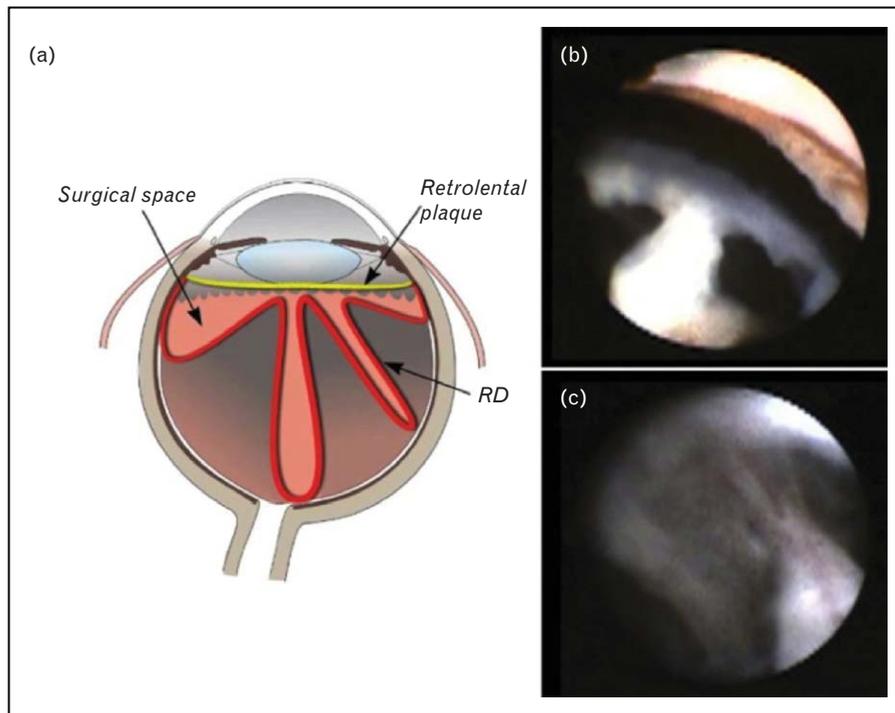
**FIGURE 4.** Intraoperative view with a 19-gauge endoscope. In this case of rhegmatogenous retinal detachment repair, vitreous became incarcerated into the sclerotomy port during perfluorocarbon liquid injection. Vitreous can be seen as 'folds' from the inside of the sclerotomy, extending toward the edge of the image circle in this figure (a). Following release of vitreous incarceration, there was immediate relief of traction and the 'folds' are no longer seen (b). (Image reproduced with permission from [11]).



**FIGURE 5.** Intraoperative view with a 19-gauge endoscope. (a) A case of a subluxed, opacified sutured sulcus intraocular lens (IOL). (b) During intraocular lens removal, the inferior haptic was trapped in a tunnel of fibrosis (white arrow). (c) Close up view of fibrosis with attachment to retina posteriorly as evidenced by retinal vessels (white arrow). This increases the risk for creating a retinal break. The proximity of retina to the IOL haptic could well have been missed by a conventional viewing system due to its very anterior position. (d) The 23 g scissors were used to segment the optic-haptic junction rather than pulling it in one piece. (Image reproduced with permission from [11]).



**FIGURE 6.** Intraoperative view with a 19-gauge endoscope. A case of combined traction-rhegmatogenous retinal detachment with subretinal bands. (a) An underlying subretinal band was engaged posterior to the main arcades, a reasonable distance away from the edge of the limited 3-clock-hour retinectomy. The endoscope enabled the surgeon to track posteriorly along the under-surface of the retina while avoiding the need to extend the retinectomy. Exposed retinal pigment epithelium is seen superiorly. (b) Subretinal band removed with the 23 g serrated forceps. (Image reproduced with permission from [11]).



**FIGURE 7.** Intraoperative view with a 19-gauge endoscope. (a) Illustration of total traction retinal detachment (TRD) in the setting of familial exudative vitreoretinopathy (FEVR) or retinopathy of prematurity showing anteroposterior orientation of the TRD. (b) A case of total TRD from FEVR showing a top-down view of the retrolental plaque; it is difficult to visualize and address the TRD with conventional wide-angle viewing systems. (c) In the same case, a side-on view enabled by the endoscope, bypassing the retrolental plaque. The underlying fibrovascular membranes and extensive tractional retinal detachment can be appreciated. (Image reproduced with permission from [11]).

**OVERCOMING THE LEARNING CURVE: SURGICAL TECHNIQUE, PEARLS, AND PITFALLS**

The learning curve will be addressed in terms of understanding the setup of the endoscope system, followed by some pearls and pitfalls gleaned from our collective experience.

**Setup**

A standard three-port technique is used. The Endo Optiks 23-gauge endoscope is compatible with standard microcannula systems. With the surgeon positioned at the head of the patient, the combined endoscope control unit and LCD monitor are placed next to the side of the bed anywhere along its length at a point that is most comfortably within the surgeon’s line of sight. The surgeon is able to easily access both viewings systems, by switching attention between the LCD screen and microscope through a slight head turn.

**Pearls and pitfalls**

Surgical orientation, image optimization, and tips to more quickly overcome the learning curve have been mentioned.

**Externally leveling the image**

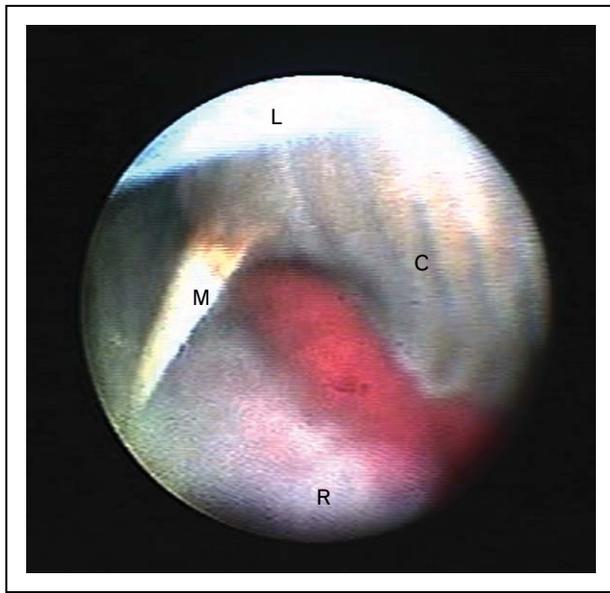
Before advancing the endoscope into the eye, ensure that the image on the LCD screen is leveled, by rotating the proximal (base/control unit) end of the endoscope. The onscreen image is brought into focus by rotating the adjacent black collar.

**Optimizing the intraocular image**

**Orientation**

Staying oriented within the surgical field is one of the main challenges when learning endoscopy. The key to overcoming this is awareness and proactive control of rotation of the probe. This is initially unfamiliar, as rotation of the illumination probe is largely irrelevant with conventional microscope-based viewing systems. By staying oriented at all times, surgical manipulation is optimized and the risk of inadvertent iatrogenic ocular trauma minimized. The authors prefer the straight rather than curved endoscope probe, as the latter adds a further axis of rotation, which can be quite disorientating.

Begin with an extraocular view from the side of the globe, positioning the corneal apex at the top of the LCD screen. Upon entering the vitreous cavity,



**FIGURE 8.** Intraoperative view with a 19-gauge endoscope. This is a case of a neonate with stage 4B retinopathy of prematurity (macular involving TRD). Anterior tractional retinal detachment (TRD) is present. There is a much smaller space than normal for safe sclerotomy placement without lacerating the lens or retina due to an immature pars plana and anterior TRD. C, ciliary processes; L, lens; M, MVR blade (20-gauge); R, retina. (Image reproduced with permission from [33]).

orientate the onscreen view such that the patient's lens is at the top (12 o'clock position), with the iris-lens diaphragm on a horizontal plane. This is useful for maintaining orientation when manipulating anterior retina, lens, and other adjacent structures. On approaching the posterior pole, keep the inferior or superior retina at the top of the screen, depending on surgeon's preference; the former is the view we are accustomed to with conventional viewing systems. Do not hesitate to intermittently re-orientate by seeking out the iris-lens diaphragm, or indeed switch to a conventional microscope-based viewing system.

### **Magnification**

Magnification is a function of the distance of the endoscope from the point of interest. With the high magnification that is achievable, it is possible to fill the entire LCD screen with the image of the tip of a 23-gauge vitrector, that is, a diameter no larger than 0.6 mm. In addition, one could be within 100  $\mu\text{m}$  of the retina, or ciliary body and be lulled into a false sense of security due to the image size. It is important to bear these in mind when manipulating tissue close to the retina or uvea to minimize the risk of iatrogenic ocular trauma such as choroidal hemorrhage or retinal break.

### **Illumination**

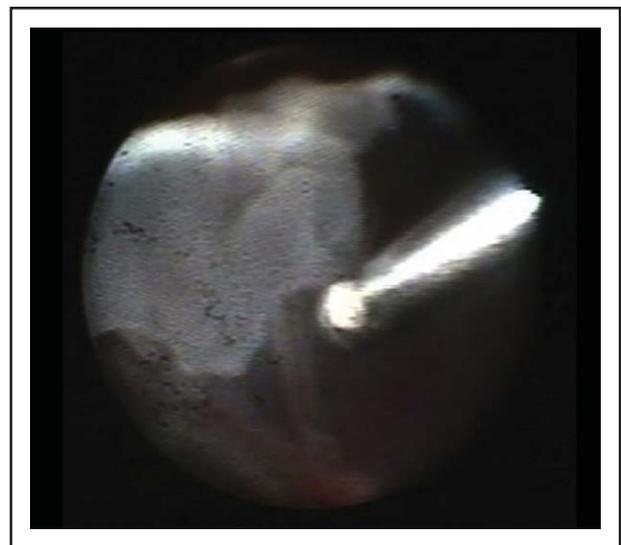
Regular illumination adjustment is required to prevent overexposure and image whiteout. The optimal amount of light required is dependent upon the distance between the point of interest and the endoscope. Illumination intensity is adjustable via a dedicated foot pedal, or at the base unit (assistant required).

### **Safe surgical zone**

The onscreen image has a circular border relating to the shape at the endoscope tip. The center of the image is the safest area for surgical manipulation, as one can fully visualize the surrounding structures along the circumference of the image circle. It is important to maintain the area of interest in the center by making small adjustments to the endoscope position (Fig. 9) [11]. Surgical maneuvers at the edge of the image circle increase the risk of inadvertent iatrogenic trauma at the edge or outside the FOV, which may go unnoticed.

### **Overcoming the learning curve**

The learning curve relates to three principal factors: a lack of stereopsis; dissociation between the surgeon's hand movement and the intraoperative view, as the surgeon is looking at an LCD screen rather than down an operating microscope and directly at the surgical instruments; and maintaining intraocular orientation (see above). In the first 10–20 cases, it is highly recommended to have both the endoscope and a conventional microscope-based



**FIGURE 9.** Vitreous cutter held in the center of the endoscope image circle during retinectomy in a case of complex rhegmatogenous retinal detachment repair. (Image reproduced with permission from [11]).

wide-angle viewing system set up, to enable one to quickly switch to the more familiar surgical perspective to regain orientation and to learn other nonstereoscopic visual clues. It is, thus, preferable that the first cases have clear optical media. Additionally, particularly if starting with cases with media opacity, one should gradually increase surgical movements and actions to facilitate technique adoption. It is also useful to practise in a wet-laboratory-type setup with an artificial eye (to avoid cross-species issues with animal eyes).

## CONCLUSION

Endoscopy is a valuable addition to the modern-day microincision vitreoretinal armamentarium. It is highly complementary to conventional microscope-based viewing systems, exemplified by its distinctive optical properties, namely, the use of reflected (coaxial) rather than transmitted (dissociated) illumination, the ability to bypass media opacities, the vastly different surgeon's perspective, and the ability to visualize and access areas in the eye that may not otherwise be possible with conventional viewing systems.

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## Conflicts of interest

*S.C.W., T.C.L., J.S.H., and A.C.H. are members of the Retinal Scientific Advisory Board at Endo Optiks, Inc. (Little Silver, New Jersey, USA).*

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