15 Endoscopic Surgery in ROP

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In complex intraocular surgery, inadequate visualization can be a major limiting factor to surgical success. The inability to visualize the surgical field effectively prevents any possible surgical intervention. Endoscopy is a valuable tool in complex intraocular surgery [1–3], which provides the vitreoretinal surgeon with a unique perspective and surgical approach. It confers a particular advantage in procedures involving structures in the anterior retina, pars plana, and ciliary body, which conventional top-down viewing systems are unable to adequately visualize. Endoscopy also provides a useful adjunct to modern-day visualization with an operating microscope and wide-angle contact or non-contact viewing systems. Table 15.1 lists the indications where visualization with modern-day microscope viewing has limitations and an endoscopic approach has been studied.

Apart from media opacities, where endoscopic viewing replaces modern-day microscope viewing systems, the endoscope is often a complementary tool to assist in parts of vitrectomy surgery. Therefore, the authors prefer the term endoscope-assisted vitrectomy (EAV) as opposed to endoscopic vitrectomy.

To many vitreoretinal surgeons, EAV remains a black-box and therefore a largely unutilized technique. Due to its learning curve and the fact that it is not commonly learned by training vitreoretinal surgeons in fellowship programs, its use is limited to a few specialized centers. It is most commonly utilized in tertiary centers that manage a large volume of pediatric vitreoretinal cases (such as ROP-RD) or ocular trauma. EAV however may be advantageous in a wide variety of surgical indications (Table 15.1). We hope that this chapter will be of equal value to surgeons who are just starting out in EAV or may only need to use EAV occasionally as opposed to more experienced EAV surgeons. We will cover a broad range of applications, and focus on its use in ROP-RD.

Table 15.1 Indications for Endoscope-assisted vitrectomy (EAV)

Corneal opacities preventing fundal view [4–7] Severe ocular trauma [8, 9] Removal of intraocular foreign body [10] Endophthalmitis [5, 11–14]
ROP-RD [15]
RRD with anterior PVR [16–18]
Removal of cyclitic membranes [17, 19]
Cyclodialysis cleft repair [20]
Prognostication for advanced cases [21]
Haptic visualization for sutured IOLs [22–24]

ROP retinopathy of prematurity, *RRD* rhegmatogenous retinal detachment, *PVR* proliferative vitreoretinopathy, *IOL* intraocular lens

15.1 Advent of EAV

Endoscopes are commonly used in medicine for viewing internal cavities through small incisions. Their basic premise is the capturing of images and their transmission via a conduit to a proximal eyepiece or camera. Although the first endoscope for ophthalmic use was developed almost 90 years ago, [25] endoscopy has been a rarely utilized technique in most centers. This is likely due to numerous factors including advances in microscope viewing systems and microincision vitrectomy surgery, and lack of training and instrumentation for the endoscopic approach. The number of publications relating to EAV, however, has increased steadily over the last few decades, from just two papers in the 1980s to almost 40 in the current decade from 2010. This is due to technological advances in endoscopy and a recognition of its superiority over microscope-based viewing systems in certain situations. There are no randomized trials compar-

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W.-C. Wu, W.-C. Lam (eds.), *A Quick Guide to Pediatric Retina*, https://doi.org/10.1007/978-981-15-6552-6_15

ing EAV with microscope-based viewing; however, these are unlikely to occur due to case-mix, surgeon preference, and experience of one technique over the other.

The integration of the charge-coupled device (CCD) with endoscopy in 1983 [26] allowed electronic transmission of the image to a monitor, a key factor in improving the utility of the endoscope in ophthalmic surgery. Flexible fiber-optics, with its smaller diameter instruments and greater maneuverability has also largely replaced the gradient index lens system (GRIN).

Recently, a hybrid system was described [27] utilizing a combination of standard endoscopy with a 3D heads-up display (NGENUITY 3D® visualization system, Alcon Laboratories, Fort Worth, TX, USA). The purported advantage of this technique was that the images of the two modalities were side by side, and therefore, the surgeon did not need to alternate viewing through a microscope and a screen. A follow-up paper to this technique also reported using a 3D converter for the 2D endoscopic view along with the use of polarized glasses to improve the stereopsis of the image [28].

In the future, it is likely that a true 3D endoscopic view may be achievable, thus making the technique safer and more intuitive. At the present time, the endoscope image resolution is also limited to standard rather than high definition, due to the number and type of fibers the endoscope houses.

15.2 Advantages Over Modern-Day Microscope Viewing

There are two optical properties unique to the endoscope that confers advantages over modern-day microscope viewing in certain surgical scenarios.

Firstly, the unique surgeon's perspective (Fig. 15.1a) with the endoscope is advantageous in viewing structures anterior to the vitreous base, including the ora serrata, pars plicata, pars plana, ciliary body, and posterior iris, as the view is from where the endoscope tip is positioned in the posterior segment, rather than a top-down microscope-based view that relies on the optics of the patient's cornea and lens. This is particularly useful in ROP-RD, where the pars plicata can be visualized, enabling safer sclerotomy formation under direct guidance, avoiding iatrogenic retinal trauma and unnecessary lensectomy. Additionally, there is improved access to anterior PVR and retro-irideal pathology such as cyclitic membranes and intraocular foreign bodies around the ciliary body.

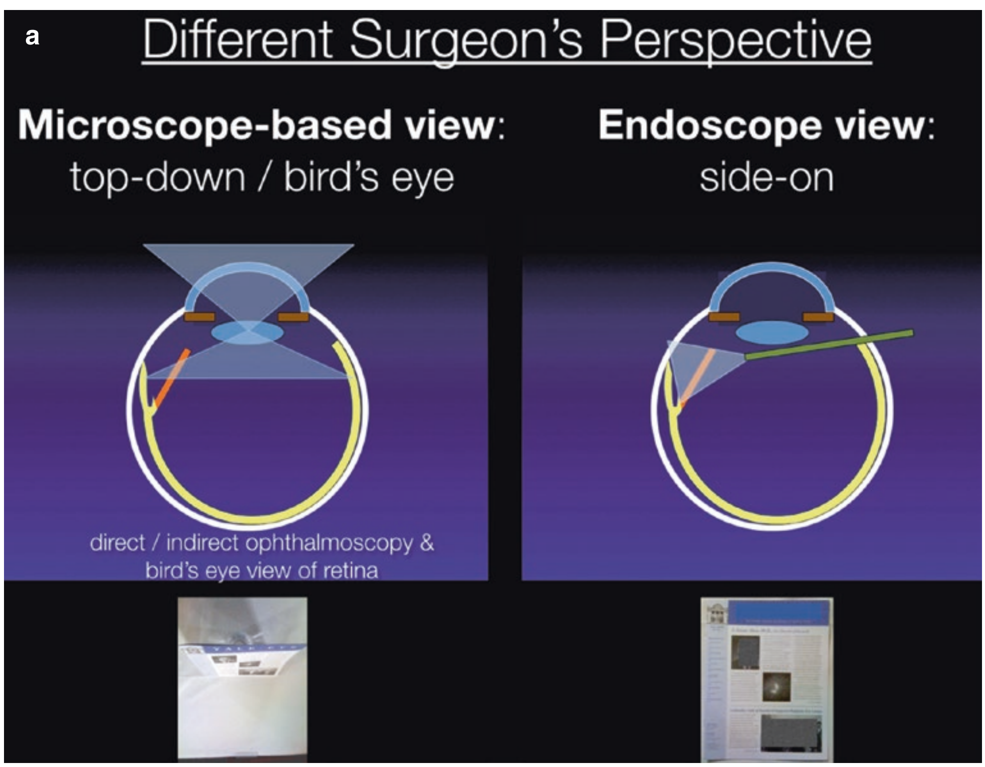
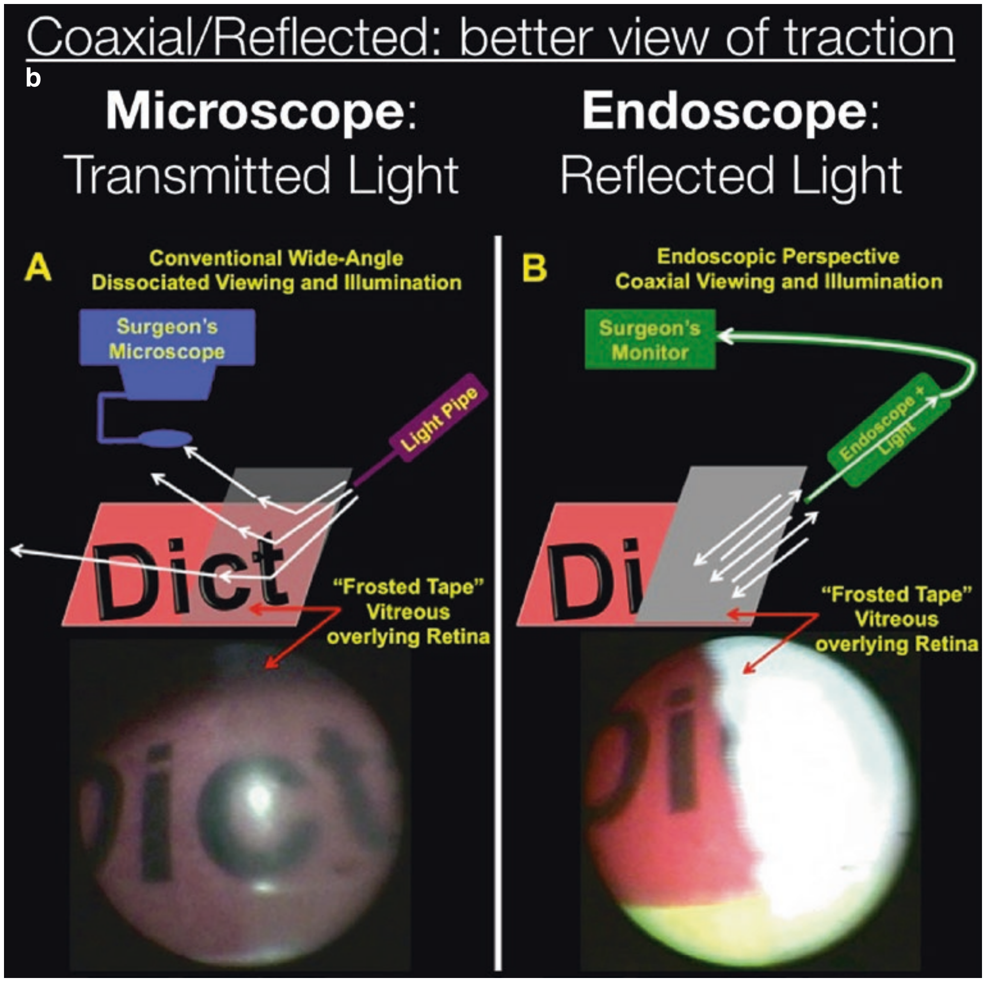


Fig. 15.1 (**a**). This figure illustrates the different perspective which is obtained with the endoscope compared with the microscope-based view. The side-on view of the endoscope allows better visualization of structures that appear almost end-on through the microscope. (**b**). These two photographs of text viewed through frosted tape to simulate vectors of vitreous traction illustrates the ease with which the semi-transparent tape is seen with the endoscopic view compared with the microscope-based view

Fig. 15.1 (continued)



Secondly, visualization of structures that mostly appear transparent with the microscope, such as the anterior hyaloid face, vitreous cortex, and transvitreal traction, is superior with EAV. The reason for this is the effect of direct coaxial illumination, in which the illumination and viewing are performed in the same direction as light emanates from the endoscope tip and is reflected back into it. In traditional microscope viewing of the posterior segment, the endoillumination is directed from an angle, reflects off the retina away from its source, and is transmitted through the patient's anterior segment into the microscope to be viewed by the surgeon. Visualization of semi-transparent structures is superior with direct reflection of light off the structures than with transmission through the structures. This effect is illustrated in Fig. 15.1b. This is advantageous in various conditions such as retinopathy of prematurity associated retinal detachments (ROP-RD) where up to five different vectors of traction contribute to the pathology and surgical success relies on identifying and alleviating these.

EAV has also been utilized in the identification of undetected peripheral retinal breaks [29]. Subretinal surgery to remove fibrotic bands is also feasible without the need for an extensive relieving retinotomy.

15.3 ROP Traction Retinal Detachment

The advantages of EAV is seen particularly in ROP-RD due to the anterior nature of the traction RD that often extends toward the pars plicata and lens, as well as the multiple vectors of traction that are well recognized.

Port placement can be risky in ROP-RD due to a combination of traction RD that can be anteriorly positioned close to the pars plicata paired with a physiologically smaller vitreous compartment and a proportionately larger lens. This leaves a very small area for safe port placement that avoids iatrogenic retinal trauma. A study by El Rayes et al. [30] demonstrated that 57% of patients with Stage 4B ROP having conventional microscope-based vitrectomy required primary lensectomy. This has the downsides of increased amblyopia, visual rehabilitation needs including dependence on aphakic spectacles or contact lenses, and long-term risk

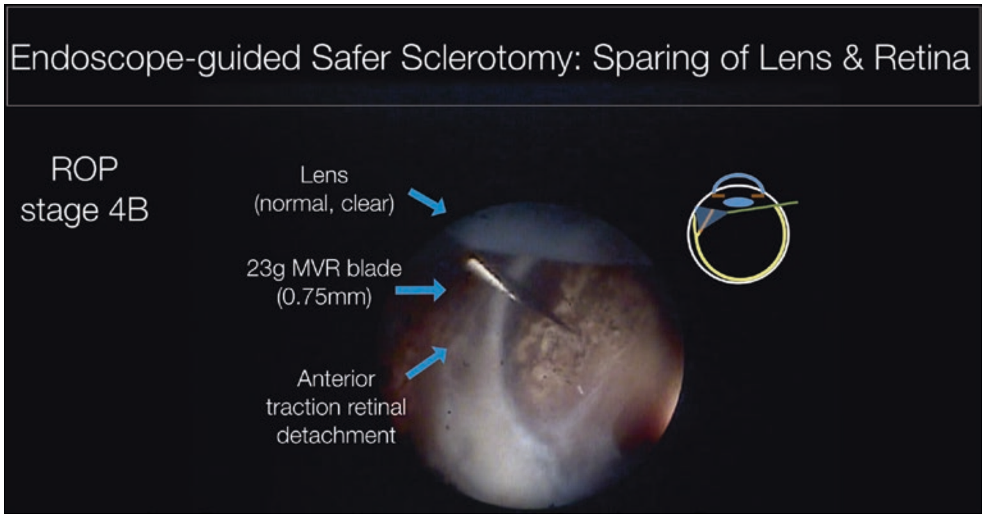


Fig. 15.2 Endoscopic visualization of port insertion allows for safe placement of trocars by avoiding anterior structures such as the lens or anterior tractional retinal detachments

of aphakic glaucoma [31]. A recent nationwide study [15] on endoscopic vitrectomy in the United Kingdom in 51 consecutive patients with Stage 4A and 4B ROP reported 0% of patients requiring primary lensectomy.

Port placement requires careful planning. Firstly, an examination under anesthetic (EUA) with scleral indentation is performed, to identify an area for placement of the endoscope sclerotomy port which is relatively safer, away from areas of traction. Once the endoscope is inserted, subsequent vitrectomy port placement can be directly visualized (Fig. 15.2) to prevent iatrogenic lens or retinal trauma. In cases of ROP-RD, iatrogenic retinal breaks have been found to lead to surgical failure in up to 100% of cases [32]. It is thus vital that all measures are taken to prevent such complications. The authors have found it safer and more controlled to use an MVR blade to make the pars plicata sclerotomy incision under direct endoscopic visualization, rather than a trocar as more force to get through the more elastic sclera is needed than the flatter MVR profile.

In stage 4A or 4B ROP-RD, up to five vectors of traction have been documented [33], ridge-to-ridge (transvitreal), ridge-to-optic disc, ridge-to-lens, ridge-to-vitreous base, and circumferential. Before the advent of EAV, a common approach in management of Stage 4A and 4B ROP was encirclement and more recently vitrectomy alone. Vitrectomy does not reliably relieve all vectors particularly anteroposterior traction from the ridge to the lens or ridge to vitreous base as it is more peripheral and more challenging to visualize. EAV, with the side-on surgeon's perspective as well as the use of coaxial lighting, optimizes visualization of these vectors. Persistent traction can prevent primary retinal reattachment, and increase the long-term risk of re-detachment. It can also contribute to the development or worsening of macular dystopia and dragging which impacts vision.

Table 15.2 Advantages and disadvantages of EAV

Advantages	Disadvantages
Visualize pars plicata and pars plana, enabling direct guidance of sclerotomy formation	Resolution not as good as modern-day microscope-based view
Optimal visualization of transvitreal traction and identification of all vectors of traction, particularly anterior traction	Lack of stereopsis
Reduced possibility of lens trauma	Larger incision required
Allows for safe port placement with reduced iatrogenic breaks	Bimanual surgery not possible

Other tractional retinopathies where EAV has similar benefits include familial exudative vitreoretinopathy and posterior persistent fetal vasculature (PFV). The principles are similar to ROP-RD surgery. A detailed discussion of these conditions is outside the scope of this chapter.

Advantages and disadvantages of EAV compared with modern-day microscope-based vitrectomy are listed in Table 15.2.

15.4 Surgical Tips

15.4.1 Practical Guide to Setup and How to Perform Surgery

A widely utilized platform is the Endo Optiks Ophthalmic Laser Endoscopy system (Beaver Visitec, Waltham, MA). The Endo Optics 19G endoscope integrates high-resolution video imaging, wide-field illumination (175 or 300 watt xenon light source), and a diode laser (810 nm) for retinal or cyclo-photocoagulation. It has a resolution of 17,000 pixels and 140-degree field of view. The 23G probe has a resolution of 10,000 pixels and a field of view of 125 degrees.

Endoscopes are available in various gauges including 19G, 20G, 23G, and recently 25G [34]. The latter two fit through standard valved microcannulas and the two former require a limited peritomy and larger sclerotomy. The drawback of the larger gauges and the need for a larger incision is compensated for by the wider field of view and superior resolution. While a larger 19 g sclerotomy requires suturing, this is normally necessary in ROP surgery anyway even if 25 g or 27 g incisions are used due to the more elastic sclera. Thus, it is the authors' view that the larger incision is a small trade-off for the significant gains in visualization in complex cases, particularly ROP-RD surgery.

In the authors' experience, the 19G endoscope is superior for more complex cases and in cases where there is a greater reliance on the endoscopic view. There is also the choice between a straight tip and an angled tip and a straight probe and a curved probe. The curved probe, while reducing the risk of iatrogenic lens touch, adds an additional degree of complexity in the axis of rotation and therefore is more challenging to use.

Following a EUA and once the optimum position of the endoscope is determined, the surgical setup can be completed. To optimize endoscopic visualization of a particular pathological area of interest, it is best to place the endoscope port within 6 clock hours of it. In ROP-RD surgery, typically, the most relevant area of traction is temporal, causing macular dragging. Therefore, to optimize visualization of the temporal transvitreal traction bands, it is recommended that the surgeon sits temporally, placing the endoscope and vitrectomy ports at about the 11 and 7'o clock positions, respectively (in the scenario where the right eye was being operated on). Thus, the area of temporal traction would be sandwiched between the ports and be most accessible to surgical removal. Figure 15.3 demonstrates a setup where the surgeon is positioned temporally, while in Fig. 15.4 the surgeon is positioned superiorly. The aim is to have the endoscope screen as close to the surgeon's line of sight as possible to ease the alternation between the microscope and endoscope view.

Placement of the ports is carried out in the standard fashion. A peritomy is performed in the desired area and an incision made with a 20G microvitreoretinal (MVR) blade (Fig. 15.5). Depending on the extent and nature of the pathology, a second pars plana incision may occasionally be required on the other side.

Fig. 15.3 Temporal approach EAV, with the scrub assistant at the head of the bed. This approach allows good access to the temporal retina, which is typically involved in ROP-RD. EAV-endoscope-assisted vitrectomy

If the operating microscope is also being utilized for parts of the surgery, illumination can either be provided by a regular endoilluminator or the endoscope. The advantage of using the endoscope as an illuminator is that the surgeon can always alternate between the endoscopic view and the microscope view. Alternating between the microscope and endoscope view is initially challenging and is one of the components of the learning curve. The hand–eye coordination learned during traditional surgical approaches must be modified and re-learned. The orientation is also different as structures are viewed from a side-on perspective as opposed to a top-down perspective.

Fig. 15.4 Superior approach EAV, which is familiar to most vitreoretinal surgeons. The endoscope screen is positioned as close as possible to the line of light of the surgeon

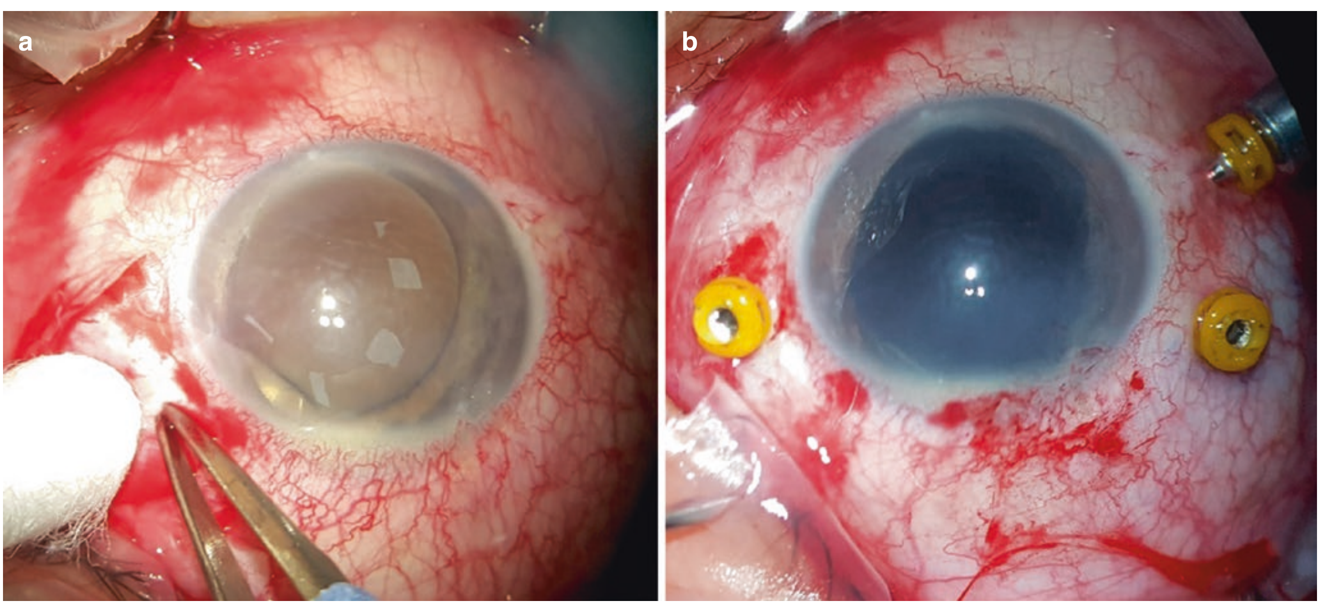


Fig. 15.5 (**a–d**) Steps involved in port placement in EAV (setup shown is 23G vitrectomy with a 19G endoscope in an adult patient). (**a**). A limited peritomy is made in preparation for the endoscope. Surface vessels are cauterised (**b**). Three ports are placed in the standard fashion (**c**). A 20G MVR blade is used to make the incision for endoscope insertion, the opening is slightly enlarged on removal of the blade. (**d**). The endoscope is inserted as shown. If endoscopic guidance is required for port placement, then the other ports are placed after endoscope insertion. MVR—microvitreoretinal

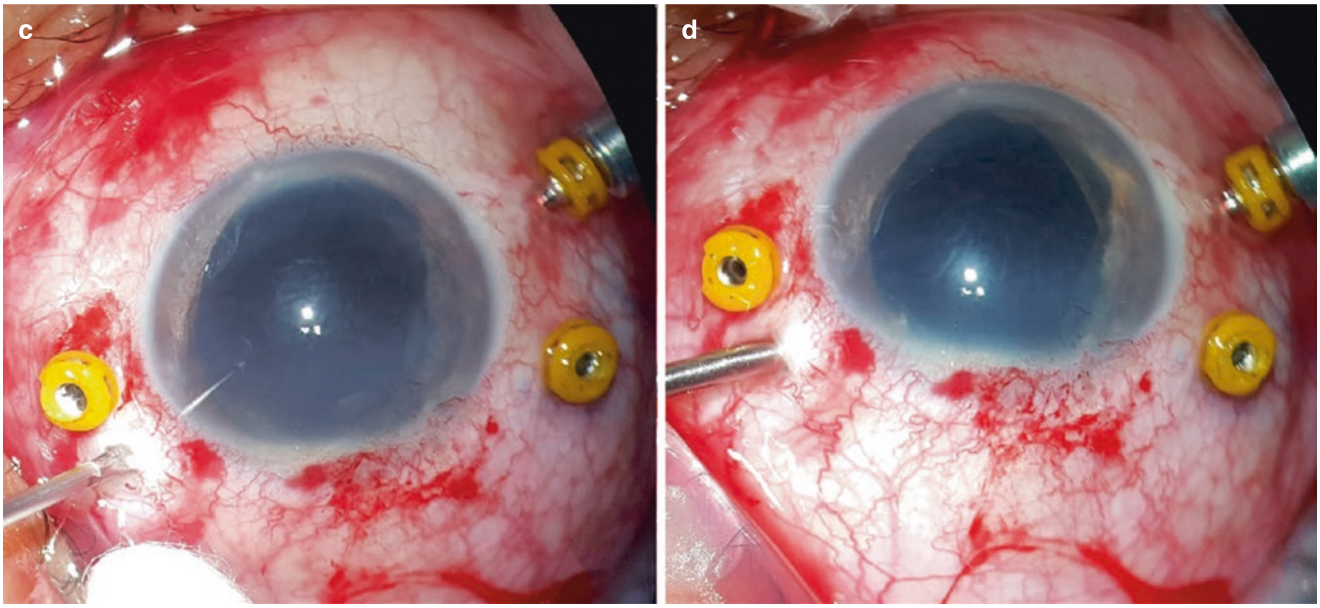


Fig. 15.5 (continued)

15.4.2 Staying Out of Trouble

The endoscopic view can be disorienting in the early stages, due to the extra axis of rotation, potentially narrower field of view, and higher magnification. To maintain orientation, image focusing, and orientation is initially performed with the endoscope outside the eye. Once in the eye, the endoscope should be rotated so that the lens always remains at the top of the image to help maintain orientation, while initially viewing at low magnification (and thus wider field of view). Gauging distance from the retina or other structures is also more difficult due to the lack of stereopsis. Other visual cues, such as shadows and relative size of structures compared with the known gauge of the instruments, need to be employed to maintain a safe working distance. A working distance of 3–4 mm is optimal when trying to view at high magnification, at which a 19 gauge endoscope can resolve detail down to 20 microns. Given that a first-order retinal arteriole is 125 microns, this level of detail is sufficient for fine surgical maneuvers, including the peeling of the internal limiting membrane [35] and fibrovascular membranes.

The narrow field of view necessitates care when moving instruments to avoid iatrogenic retinal or lens touch. The zoom of the image is changed by bringing the endoscope closer or further away. The light intensity also needs to be reduced the closer the endoscope is brought to the area of interest, otherwise a whiteout phenomenon will occur.

During initial insertion of the endoscope into an opaque vitreous cavity, such as in trauma cases or endophthalmitis, a whiteout or blackout view on the monitor may occur. If the anterior segment allows, a core vitrectomy can be performed with a top-down view prior to endoscope insertion to prevent this. If there is no view through the anterior segment, then the cutter needs to be brought into contact with the endoscope tip and a localized clearance performed in order to allow a sufficient view. While this has inherent risks of iatrogenic complications, the risk decreases with surgeon experience. In any case, there is no other way to be able to proceed with surgery and the risks must be balanced against the prospect of not operating.

Due to the significant differences between endoscopic surgery and microscope-based vitrectomy surgery, wet or dry-lab training is recommended to accelerate the process of familiarization and allow relearning of the hand–eye coordination.

15.5 Case Study Example

15.5.1 ROP

This is a case of a baby born at 26 weeks gestational age at 755 g. The child presented at 44 weeks postmenstrual age, with right eye stage 4B (macular involving) ROP and left inoperable stage 5 ROP. Figure 15.6a demonstrates the degree of traction in the right eye, with inferior macular heterotopia. Figure 15.6b demonstrates the first and second attempts at sclerotomy formation with an MVR blade. The first attempt, the tip of the MVR blade can be seen to be in contact with anterior traction RD. Not recognizing this, as would normally be the case with standard non-endoscope trocar insertion, could have led to an iatrogenic retinal break

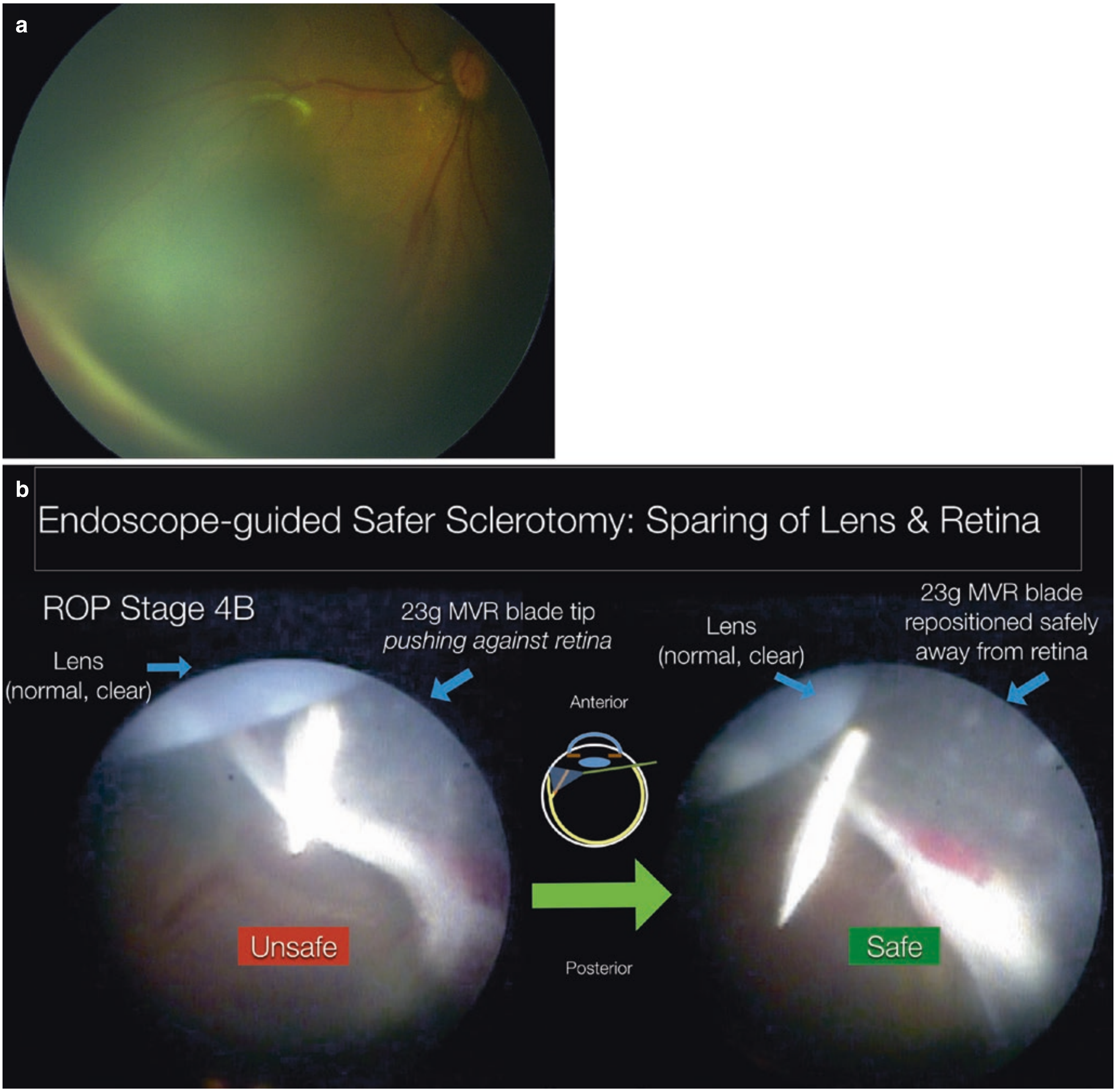


Fig. 15.6 (**a**). Right RetCam fundus photo of premature baby born at 26 weeks with 4B ROP. Note the macular heterotopia. (**b**). Endoscopic guidance of sclerotomy creation with 23G MVR blade, demonstrating the utility of EAV in ensuring safe sclerotomy formation

and surgical failure and blindness in this child's only seeing eye. The endoscope view highlighted this risk, and enabled repositioning of the MVR blade by 1 clock hour and is now seen to have safely entered the eye in a zone free of both lens and retina.

15.6 Conclusions

The endoscopic view during vitrectomy has a range of applications and is a useful adjunct to the modern-day microscope. It is particularly helpful in unique ROP-RD specific pathology, increasing the safety and efficacy of surgery by reducing the risk of iatrogenic lens and retinal trauma.

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