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Indications and Techniques of Endoscope Assisted Vitrectomy

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The popularization of ophthalmic endoscopy has been promoted by recent technological advancements that increase the number of indications for endoscopy. These advancements have improved the endoscope's capabilities in its two fundamental surgical advantages: (1) bypassing anterior segment opacities, and (2) visualizing anteriorly positioned structures such as the ciliary bodies and sub-iris space. In this article, the current state of the ophthalmic endoscope is reviewed alongside its growing number of applications in glaucoma, vitreoretinal, and ocular trauma surgery. We describe the role of endoscopy in endocyclophotocoagulation for glaucoma, cyclitic membrane peeling in hypotony, retinal detachment surgery, intraocular foreign body removal, severe endophthalmitis, and pediatric traumatic vitreoretinal surgery. This review examines both the pearls and limitations of the ophthalmic application of endoscopy. In doing so, we hope to provide guidelines for using the endoscope and also to highlight applications of endoscopy that merit further study.

Keywords: Endoscopy; Vitreoretinal Surgery; Retina; Vitrectomy

INTRODUCTION

Dating back as early as 1934, the ophthalmic application of endoscopy was first described by Thorpe, when he designed an instrument for removal of nonmagnetic intraocular foreign bodies (IOFB).[1] After combining a Galilean telescope and an illumination source within a 6.5 mm diameter shaft, Thorpe attached an eyepiece for direct monocular vision and the device was inserted into the globe through 8 mm scleral incisions.

The ophthalmic endoscope was revisited and improved in 1978 by Norris and Cleasby, who introduced a 1.7 mm diameter (between 13 and 14 gauge) rigid shaft for endoscopic intraocular and orbital surgery.[2-5] The popularization of pars plana vitrectomy soon thereafter complimented this advancement. By 1990, Volkov et al developed flexible endoscopes[6,7] and Eguchi and Arai coupled a flexible 20-gauge videoendoscope with a charged-coupled device (CCD) camera for remote visualization of real time images,[8] similar to modern ophthalmic endoscopes. Laser units were implemented into endoscopy soon thereafter.[9,10]

Since its initial prototypes, the ophthalmic endoscope has been optimized in size, resolution,

and maneuverability. To do so, improvements have been made to the main components of the instrument: the camera, light source, and laser unit. Fiberoptic cables transmit images from the camera and illumination source, which are housed in a base unit, to the hand-piece. Also connected to the base unit are a monitor and image capture system connected through a video output. Today, laser units may be attached through either this base component or through a separate unit. The endoscope currently has two probe designs: straight and curved tips. While straight tips are used in most vitreoretinal surgeries, the curved tip is useful for more anterior instrumentation.

The state of endoscopic technology in the United States today is illustrated by the E2 Laser and Endoscopy System (EndoOptiks, Inc., Little Silver, NJ, USA), which incorporates a variable 300 or 175 Watt xenon light source, a 810 nm diode laser with a 640 nm aiming beam, and thin 0.56 mm (23 gauge) probes. A foot pedal or touch pad controls the light source and aiming beam intensity as well as laser power and pulse width. Through a 200 μm fiberoptic cable, the treatment laser can generate pulses from 0 to 1200 mW in power and 50 to 2000 ms in width, as adjusted by the foot pedal or a digital control unit. A display panel on the on the base unit records the laser counts while a monitor displays real time images obtained by the fiberoptic endoscope and processed by a CCD camera. Recently, the traditional 19.5 gauge endoscope of the E2 system was improved with higher resolution and a wider field of view. While the original 19.5 gauge probe offered 10,000 pixels and a 125˚ field of view, the novel high-resolution camera increased resolution to 17,000 pixels over 140˚ field of view. In 2011, a 23 gauge probe was developed to fit through 23 gauge trocars.[11] This scope delivers 6,000 pixels over a modest 90˚ field of view and requires the 300 Watt xenon light source for appropriate intraocular illumination. These specifications may limit the 23 gauge probe's utility to primarily laser delivery. For additional cost, a gradient index (GRIN) lens system may offer higher resolution with a narrower field of view. The limitation of this add-on, however, is that the camera, which is attached directly to the handpiece, is resultantly not autoclave compatible and thus must be draped during surgery.

Literature on the use of endoscopy in vitreoretinal surgery is relatively limited, but has demonstrated the technique's usefulness in well-conducted case reports and small retrospective studies. Studies have reported indications including penetrating injuries,[12-16] perforating injuries of the globe,[16] intraocular foreign bodies,[14,16] post-traumatic endophthalmitis,[14,17] endogenous, post-cataract and bleb-related endophthalmitis,[14,18] proliferative vitreoretinopathy (PVR),[19,20] and even retinal assessment in forensic cases.[21,22] During these procedures, the endoscope can bypass anterior segment opacities, or serve to enhance visualization while using other wide-angle microscopic viewing systems.

ENDOSCOPY-ASSISTED VITRECTOMY

The endoscopic view provides two fundamental advantages: (1) bypassing anterior segment opacities, and (2) visualizing anterior structures such as the ciliary bodies and sub-iris space. The ability to overcome anterior segment opacities makes endoscopy a particularly valuable technology for eyes with significant corneal edema or scarring. Unique views of anterior structures, not available with standard techniques of microscopic vitrectomy, are made possible by the flexibility and rapid changes in perspective allowed by the endoscopic probe.[23] The modality's wider field of view, ranging from 90˚ to 140˚, and high magnification increase surgical safety and facilitate the identification of subtle findings such as small retinal breaks or holes.

Indication: Anterior Segment Opacities

Eyes with anterior segment opacities present a variety of surgical obstacles. Unlike many other approaches to vitrectomy, endoscopic vitrectomy remains possible despite these opacities. In fact, some small studies suggest a trend toward better visual and anatomical outcomes in eyes treated with endoscopy versus other surgical options.[16]

Corneal opacities that require penetrating keratoplasty or those associated with progressive intraoperative corneal edema significantly limit visualization for vitrectomy. Generally, there are three treatment options in this situation: (1) observation of the posterior segment until corneal opacities clear to allow for uninhibited management, (2) combined surgery consisting of temporary keratoprosthesis implantation to allow for conventional pars plana vitrectomy, followed by permanent keratoplasty at the end of the case, or (3) endoscopy-assisted vitrectomy, which bypasses these anterior segment opacities and may or may not require subsequent keratoplasty. Selection of the appropriate option is determined by the urgency of posterior segment treatment, and the prognosis and obtainability of a corneal graft. While the availability of corneal grafts offers much benefit in the United States, many other nations are not afforded the same convenience.[17]

Temporary keratoprosthesis or endoscopy is appropriate for urgent cases where observation of anterior segment opacities to clear cannot be afforded. Such indications include severe endophthalmitis, intraocular foreign bodies, and acute retinal detachment. The major limitation to temporary keratoprosthesis is the requirement of a corneal graft after the vitrectomy. Grafts are not readily available in many parts of the world. Coordination with corneal surgeons is also required. Ocular conditions that preclude the use of temporary keratoprostheses include acutely injured globes with severely deformed anterior segments, and underlying ocular surface diseases prone to graft failure such as severe autoimmune keratoconjunctivitis.

In addition to being widely applicable, endoscopic vitrectomy has trended toward improved anatomical and visual outcomes in small retrospective studies. One such study performed by Chun, Coyler, and Wroblewski compared eight traumatized eyes treated with vitrectomy aided by a temporary keratoprosthesis to nine eyes that underwent endoscopic vitrectomy.[16] Outcome measures included time to surgery, surgical time, visual outcomes, and qualitative assessments of postoperative developments. While the small sample size limits the study's power, the authors nonetheless reported that endoscopic cases had significantly shorter time to surgery (median 14 vs 38 days; p=0.034) as well as significantly shorter surgical time (median 2.9 vs 8.4 hours; p<0.0005). Eyes treated with the aid of temporary keratoprosthesis were more likely to be observed conservatively, until the decision for vitrectomy was made. Conversely, having endoscopic vitrectomy as part of the armamentarium allows vitreoretinal intervention without hesitation and with less consideration for medical management of the anterior segment opacity.

In the endoscopy group of the above–mentioned study, many occult retinal tears that would have progressed if observed conservatively were discovered and treated. In addition, presumably due to substantially earlier intervention, the endoscopy group developed lower rates of advanced PVR and postoperative retinal detachments. On the other hand, the keratoprosthesis group had higher rates of membrane peeling and perfluorocarbon use, which may be attributed to PVR that developed during the extended time period prior to surgery. A trend towards better visual and anatomic outcomes existed in the endoscopic group, but did not reach statistical significance.

Indication: Unique Visualization Planes

Endoscopy is also an effective method for visualizing and manipulating anterior structures such as the posterior iris surface, ciliary bodies, pars plana, ora serrata and peripheral retina. To this end, variable planes of visualization can facilitate anterior vitrectomy, membrane peeling and sclerotomy placement, and also enhance diagnostic visualization.

The unique endoscopic view of sutured intraocular lenses, sub-iris and ciliary body abscesses, and anterior PVR precludes aggressive scleral depression, which is to be avoided in eyes with recent open globe surgery, unstable intraocular lenses and filtering blebs.[24,25] The endoscope also grants surgeons *in vivo* perspectives of structures, rather than the contorted view via scleral depression. For instance, endoscopy can offer multiple direct

planes of view to reveal exactly how anterior PVR is creating traction instead of the artificially contorted view seen through a microscope with scleral depression. The relatively modest field of view and lack of stereopsis in endoscopy, however, may present challenges not met by a conventional coaxial operating microscope.[23]

Direct visualization of sclerotomy creation allows the maneuver to be performed atraumatically. In aphakic eyes, the endoscope can be initially inserted through a limbal incision, and sclerotomies can be created under transpupillary visualization.[12] The placement of sclerotomies may be complicated by ciliary and choroidal hemorrhage or anterior displacement of the vitreous base and retina; imprecise sclerotomies may result in subciliary, subchoriodal, or subretinal placement of the infusion line.[26] The intraocular view of endoscopy can prevent such complications.

Maneuvers made possible by endoscopy allow for unique tissue removal capabilities. Vitreous removal from sclerotomy sites and from the posterior capsule even in phakic eyes is made possible by the flexibility of the endoscope. Endoscopic view of the subretinal space through retinal breaks allows tasks such as removing migrated subretinal perfluorocarbons or silicone oil, which would be a challenge with traditional vitrectomy. In the same way, subretinal bands can also be visualized and approached. Endoscopic maneuverability is also a powerful tool in preventing retinal slippage while performing fluid/air exchange.[27]

Lastly, the endoscope can also serve diagnostic purposes in cases of severe ocular trauma. When visualization impedes clear assessment of the optic nerve and retinal viability, unique views afforded by the endoscope may shed light on the necessary intervention. In some instances, surgery could be deemed futile and therefore avoided.

APPLICATIONS OF ENDOSCOPY-ASSISTED SURGERY

Ophthalmic endoscopy is a powerful technique for vitreoretinal and glaucoma surgery. While the focus of this review is on vitreoretinal indications, the predominant use of endoscopy today is for endoscopic cyclophotocoagulation (ECP) in patients with glaucoma.

Endoscopic Cyclophotocoagulation

ECP is the photocoagulation of the ciliary bodies through direct visualization with an endoscope in order to decrease aqueous production.[10,28] Historically, such cyclodestructive procedures were used to treat refractory glaucomas,[29] end-stage glaucomas,[23] or in combined surgeries with cataract extraction.[30,31] However, ECP's capability to apply mild laser to areas (like the ciliary processes) difficult to access by other techniques has expanded its indications for endoscopy.

When ECP is applied during cataract surgery, the endoscope probe is introduced transpupillary through the cataract wound assisted by injection of viscoelastic material between the lens and iris. With this approach, the laser can typically treat approximately 8 clock hours of the ciliary processes. In cases where greater than 8 clock hours of laser is necessary, a second limbal wound is required.

Performing pars plana vitrectomy and then introducing the endoscope through the sclerotomy provides nearly full visualization of the ciliary processes and thus allows for more extensive ECP treatment. To achieve 12 clock hours of treatment, however, a second sclerotomy 6 clock hours from the initial port is needed. Observational studies report lower intraocular pressure with no findings of hypotony after 12 clock hours of endoscopic treatment with continuous laser at a power of 0.35 Watts for patients with neovascular glaucoma.[23]

Vapor formation may occur when aqueous is converted to steam. Vapor bubbles can form if a patient has heavy pigmentation, if the laser power is too high, or if the probe is too close to the ciliary processes. Lowering the laser power and increasing the distance between the probe and ciliary processes are typical solutions to this problem.

Panretinal Photocoagulation

The wide field of the endoscope via pars

plana access allows for 360° application of panretinal photocoagulation (PRP) from the equator out to the ora serrata. The ability to easily photocoagulate the far peripheral retina allows optimal endolaser application in severe ischemic retinal vasculopathies. The intensity of the endoscope's 810 nm diode laser may cause significant laser burns. As a result, some surgeons prefer connecting an argon laser to the endoscopic unit to provide familiar argon green wavelength treatment.

Hypotony from Cyclitic Membranes

A popular belief is that hypotonous eyes have few treatment options that can save the eye. For eyes suffering from hypotony due to epiciliary body membranes, however, peeling of the membrane is made possible by the endoscopic view. Previously, conventional microscopic views rendered this technique very difficult, but endoscopy overcomes these challenges encountered by traditional methods. This relatively new methodology is currently an area ripe for clinical research regarding its efficacy and clinical outcomes.

Retinal Detachments

Endoscopy can facilitate safe and effective repair of retinal detachments in appropriate cases.[32-34] Candidates for endoscopic surgery include patients with recent onset detachments with limited or no PVR. The decision to proceed endoscopically is made prior to beginning surgery and the technique offers three benefits: (1) better visualization for safe reattachment in eyes with media or anterior segment opacities[32], (2) improved detection of retinal breaks or tears especially in pseudophakic and aphakic eyes[33] and (3) safe and effective subretinal fluid drainage.[34]

The endoscope's high-magnification is a powerful tool in identifying retinal breaks. While only 2-4% of retinal breaks go undetected in phakic eyes, 5-23% and 7-16% of retinal breaks are unnoticed in pseudophakic and aphakic cases, respectively. Undetected retinal breaks in pseudophakic and aphakic retinal detachments seem to be the underlying reason for the lower success rates of retinal detachment surgery when compared to phakic eyes.[33] In a study on 20 consecutive pseudophakic and aphakic patients with retinal detachment and no detected retinal breaks upon fundus examination using an indirect ophthalmoscope with scleral depression, Kita and Yoshimura identified and successfully treated retinal breaks in 19 employing the endoscope without scleral depression.[33] The study also reported a 100% reattachment rate, which may be related to the endoscope's ability to identify retinal tears.

Open Globe Injuries

The 2.5 million eye injuries that occur each year in the United States are a major cause of visual impairment.[35] Open globe injuries compose 3-4% of major ocular trauma and along with optic nerve injury, are the leading cause of blindness.[36,37] These open globe injuries frequently require subsequent vitreoretinal reconstruction due to their resulting anterior and posterior segment pathologies.

Small studies have shown endoscopy-assisted vitrectomy to be an effective method for treating the sequelae of open globe injuries. For instance, a case report by Kawashima et al described a patient undergoing 20 gauge endoscopy guided vitrectomy for traumatic endophthalmitis that had developed after primary repair of a corneal penetration.[15] Endoscopic vitrectomy was performed to repair the eye because a corneal donor was not available. Not only were the authors able to perform successful vitrectomy, but the endoscopic view made it possible to detect and subsequently remove a peripheral IOFB that was not identifiable by preoperative examination and imaging. The endoscopic surgery reattached the retina using silicone oil tamponade. One year later, anterior segment reconstruction was made possible by the availability of a corneal donor.

A case series by Sabti and Raizada reporting on 50 eyes that underwent endoscopy assisted vitrectomy for severe ocular trauma described the clinical outcomes in 43 (86%) cases with open globe injuries.[14] With a reattachment rate

of 91% and an improvement in vision in 81% of cases, this study demonstrated the efficacy of endoscopic surgery in repairing open globe injuries.

Intraocular Foreign Bodies (IOFBs)

Retained IOFBs are associated with post-traumatic endophthalmitis, therefore early intervention is required in such cases.[38,39] Delayed intervention also increases risk of IOFB encapsulation, which further complicates their excision. If endophthalmitis has already developed in the eye, microscopic view may be obstructed making endoscopy a more attractive option.

Removing IOFBs without appropriate visualization can cause giant retinal tears resulting in disastrous visual outcomes.[17] While the microscopic view typically facilitates safe IOFB removal, endoscopic visualization has become another option for delivery out of the eye.[40] Sabti and Raize reported 11 open globe injuries with retained IOFBs treated with endoscopy. All eyes had retinal tears and vitreous hemorrhage and 6 required lensectomy. Of these, 10 eyes demonstrated improved vision following endoscopic vitrectomy.[14]

Severe Endophthalmitis

The goals of vitrectomy for severe endophthalmitis are the following: to clear the vitreous from microorganisms, to decrease inflammation and toxins, to obtain vitreous cultures, to repair retinal detachment and to remove IOFBs. Conventional methods of vitrectomy may be precluded by concomitant globe injuries and media opacities, but endoscopic vitrectomy is a useful modality for these complex surgeries, especially those involving retinal detachment and IOFB removal. For example, Sabti and Raizada reported treating post-traumatic endophthalmitis in 7 eyes using endoscopic vitrectomy to bypass anterior segment opacities due to edematous corneas from hypopyon/fibrin in the anterior chamber.[14] In addition to overcoming poor visualization, the endoscope granted direct visualization under the iris and over the ciliary body so inflammatory membranes could be removed. Postoperative visual acuity ranged from 20/100 to no light perception.

De Smet et al showed the utility of endoscopic vitrectomy in 15 severe endophthalmitis cases where anterior ocular structures were compromised.[18] Final visual acuities ranged from counting fingers to 20/20, and vitrectomy was performed safely in all patients. Shen and colleagues also reported on 2 patients with posttraumatic endophthalmitis.[17] Corneal grafting was rendered impossible due to dense anterior segment opacities and traumatized corneas. In addition to facilitating the safe performance of complete vitrectomy in the vitreous base and ciliary processes, endoscopic visualization allowed the severe inflammation, retinal detachment and IOFB in both cases to be addressed. Comer et al reported 3 cases of *Fusarium* endophthalmitis treated successfully with endoscopic vitrectomy.[41] Interestingly, multiple abscesses on the ciliary bodies and in the sub-iris space were found in all patients, and were responsible for progressive clinical deterioration despite repeated intravitreal injections of anti-fungal agents.

Pediatric Traumatic Vitreoretinal Surgery

There is currently a lack of published articles describing the role of endoscopy in pediatric vitreoretinal surgery. As one of the most challenging fields of posterior segment surgery, this unexplored niche calls for further research.

Pediatric eyes have a unique anatomy and physiology that often render conservative treatment preferable.[42] Just one iatrogenic retinal tear during vitrectomy in children can cause complete anatomic and functional failure, and thus complete vitrectomy is rarely the goal.[43] The intense inflammatory response of pediatric eyes puts them at higher risk of aggressive and widespread PVR, especially in cases of traumatic retinal detachments and open globe injuries. Endoscopy limits the risk of such devastating outcomes by offering optimal visualization to perform the least possible surgical manipulation with the greatest effect. This proposal, however, must be further substantiated by research.

SURGICAL PEARLS

Substantial differences between endoscopic and conventional microscopic views and instrumentation create a steep learning curve.[44] Initially, operating while viewing a remote monitor may be foreign, however familiarity can be achieved with practice and appropriate bedside positioning of the monitor, which minimizes head turning by the surgeon. In addition to the learning curve, one challenge of endoscopy lies in the loss of binocular stereopsis. Shadowing is also eliminated because the light source and camera are in the same axis. Awareness of instrument location within the globe therefore relies on monocular clues such as the size of landmarks, intensity of illumination and changes in focus.

Another challenge to surgeons accustomed to the bird's eye view of conventional microscopic vitrectomy is the constantly changing perspective of endoscopy. Rotational movements change intraocular orientation; disorientation may be compounded by resolute high magnification. Focusing the endoscope prior to introducing it into the globe can more quickly familiarize the surgeon by controlling the orientation of the intraoperative view, which is crucial for navigating the posterior segment. Exploring the posterior pole is learned more quickly because of its distinct landmarks and intuitive maneuvering, while the reverse orientation while viewing anteriorly may cause disorientation.

LIMITATIONS

In addition to the aforementioned technical challenges, there are three limitations of endoscopy to note. Firstly, instrumentation of the endoscopic unit is still being further developed, but surgeries requiring a bimanual technique should avoid endoscopy, as it does not allow bimanual instrumentation. Secondly, although endoscopy bypasses anterior opacities, postoperative examinations will still be limited by poor visualization in such cases. Identifying postoperative redetachments and endophthalmitis therefore relies on ultrasonography. Lastly, the rehabilitation period is lengthened by the patient's commitment to another reconstructive surgery of the anterior segment if it is performed. Extended rehabilitation time is especially hazardous in pediatric patients in the age range prone to amblyopia.

CONCLUSION

Since its conception nearly 80 years ago, the ophthalmic endoscope has evolved to deliver significant advantages during various surgical procedures. Among these advances include the endoscope's capability to circumvent anterior segment opacities and allow for otherwise difficult vitreoretinal surgery. While endoscopic surgical planes, views and magnification are powerful tools for treatment of complex vitreoretinal conditions, they do not replace conventional vitrectomy but may be the only option in some cases.

Although the literature on endoscopy is currently limited, its widely applied uses pave the way for future studies examining its benefits and indications as a surgical technique. In the future, the field may benefit further from 23-gauge endoscopic probes, which may also prove to be an effective vehicle for retinal vascular cannulation or for delivering cells or therapeutic agents subretinally.

Conflicts of Interest

None.

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