Vitrectomy: when things go wrong

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Pars plana vitrectomy has become an important tool in the treatment of vitreoretinal diseases, with newer applications being considered. This has necessitated an overall improvement in the surgical expertise and the innovative supportive technology driving the machines. Frequent use has also brought about a variety of complications, especially during the learning curve that every surgeon faces. The vitreous cavity being enclosed by the retina and the crystalline lens leave little margin for error. Precise control over instrumentation is required in order to avoid inadvertent mechanical touching of these tissues. Tissue respect is of utmost importance and in this review we discuss all possible complications and ways to avoid them and manage them if they occur.

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History

The idea of vitreous surgery as conceived by Shafer in 1950 and propagated by David Kasner in the form of an open-sky vitrectomy in the 1960s, was rather hazardous, with many complications [1]. A major advancement in the treatment of vitreoretinal diseases was achieved by Machemer and colleagues in 1971 [2] with the introduction of pars plana vitrectomy with a single vitreous infusion suction cutter (VISC) system. The invention of divided system instrumentation by O'Malley gave rise to bimanual vitrectomy. Work carried out by Cibis with intravitreal silicone oil, by Norton with intravitreal sulfur hexafluoride gas and by Chang with heavy liquids has further simplified many steps of the procedure [3]. While present-day vitrectomy has become safer and more reliable, there remains scope for improvement. Newer techniques are being introduced at a rapid pace, bringing with them newer complications.

Relevant surgical anatomy

Any surgical intervention should be based on a sound knowledge of the normal structures and their relations. The vitreous body is a clear gel-like fibrillar meshwork composed of 99% water, with the outer cortex being denser [4]. It contains interpenetrating networks of collagen fibrils and hyaluronic acid [5]. While the anterior hyaloid face is strongly attached to the crystalline lens, the posterior hyaloid face is attached at places to the inner limiting membrane of retina. The strongest attachment is at the vitreous base and relatively weaker attachments exist around the optic disc, at the macula and along retinal vessels [6]. Sclerotomies made through the pars plana region avoid damage to the pars plicata anteriorly and the vitreous base posteriorly.

Instrumentation

Vitrectomy visualization was initially based only on the use of assistant-held irrigating lenses that neutralized the corneal curvature. While these lenses give excellent resolution to the surgeon, his field of view remains restricted. Handling of the peripheral vitreous becomes difficult and may be fraught with complications. Introduction of the stereoscopic diagonal inverter (SDI; Spitznas and Reiver) and the binocular indirect ophthalmomicroscope (BIOM) has popularized the use of contact and noncontact wide-angle viewing systems [7,8]. These offer a simple, effective and quick method for illumination of the ora serrata and anterior vitreous in aphakic and pseudophakic eyes during vitrectomy [9,10]. Self-stabilizing lenses eliminate the need for suturing

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on the sclera or dependence on the assistant to provide placement [11]. Depending on the step of surgery, the lenses can be used interchangeably [12]. Use of a Chandelier illumination system during a four-port vitrectomy has allowed for bimanuality in its true sense, further simplifying many surgical steps that were previously better avoided [13–15]. Even in cases where the media do not allow visualization with the standard microscopic systems, microendoscopy provides an alternative, albeit with a loss of both resolution and the third dimension [16].

Newer cutters that are sharper and have higher cut rates have tried to reduce the complications further [17]. A soft tip extrusion cannula allows for safe removal of fluid, hemorrhage, gas or silicone oil from the subretinal space [18]. Closed vitrectomy is known to cause wide fluctuations in the intraocular pressure (IOP) [19], and present-day machines aim to provide precision and better control over fluidics, reducing the chances of intraoperative hypotony or prolonged raised IOP.

Complications & management

The decision to perform any invasive procedure depends on its benefit:risk ratio. By reducing the complication rate of a procedure we can decrease the risk, making the procedure applicable for additional indications. Patients' general health and the status of the other eye may also influence the final decision.

Conjunctiva-related complications

During peritomy, cutting the conjunctiva close to the limbus allows good exposure, causes less fibrosis and reduces conjunctival shrinkage during resurgeries. Essentially, conjunctival damage has to be minimized by preventing both tearing and button-holing.

Conjunctival closure, as in any ocular surgery, needs to be end to end so as to ensure quicker healing. Absorbable sutures are preferred even though they may produce slightly more tissue reaction in some patients. Fibrin glue and other acrylic adhesives have been advocated for closing conjunctival wounds, especially in elderly patients. They result in good adaptation and are time saving and effective [20,21].

With the advent of sutureless vitrectomy, many conjunctiva- and suture-related complications have been resolved. Conjunctival chemosis, however, is commonly seen with transconjunctival sclerotomies without the placement of cannulas owing to the leakage of perfusion fluid [22]. Also, with an added risk of the conjunctival epithelium being inadvertently introduced into the vitreous cavity, special attention needs to be paid to conjunctival sterilization [23].

Sclerotomy-related complications

Intraoperatively, inadvertent damage may occur to structures adjacent to the site of sclerotomy. Lens damage, ciliary detachment, vitreous base dialysis or retinal tears may occur while making the sclerotomy or during insertion or removal of instruments [24]. The tip of the sclerotomy blade should always be directed toward the midvitreous and it should be ensured that the internal opening of the infusion cannula is well within the vitreous cavity prior to starting the infusion, especially in cases with choroidal thickening. A subretinal cannula infusion, once started, can be a disaster for the surgeon. However, if a choroidal detachment does occur, the infusion should be stopped and the cannula freed from any superficial tissue using a microvitreoretinal blade or a cutter.

Retinal incarceration may occur if an instrument is withdrawn from an eye with raised IOP, resulting in rapid egress of fluid, which pulls the detached retina along with it [25]. Retina may have to be reposited with a blunt instrument followed by fluid–air exchange and cryotherapy.

All sclerotomy wounds heal with an ingrowth of fibrovascular tissue from the eye wall into the vitreous cavity. Fortunately, only in unusual circumstances does this process become exaggerated and result in what clinicians have termed fibrovascular ingrowth (FVIG), with its resultant ocular problems [26]. Postoperatively, FVIG may lead to recurrent vitreous hemorrhage [27]. While episcleral tissue, scleral fibroblasts and ciliary epithelium all contribute, the majority of the fibroproliferative healing of a sclerotomy originates from the uvea of the ciliary body [28]. Incarceration of the vitreous into the wound appears to be the culprit and so care needs to be taken to remove any vitreous from the lips of the wound prior to closure [29]. Ultrasound biomicroscopy (UBM) is useful in detecting fibrovascular proliferation at sclerotomy sites [30]. Episcleral sentinel vessels seen externally entering the wound site should raise our suspicions of FVIG, but they neither confirm it nor does their absence rule it out. They form as a result of a high degree of metabolic activity during the healing and similar vessels are also seen microscopically in the ciliary body [28]. Anterior peripheral retinal cryotherapy combined with cryotherapy of sclerotomy sites might be helpful adjunct procedures in diabetic vitrectomy for the inhibition of FVIG and prevention of recurrent vitreous hemorrhage [31].

Construction of sutureless self-sealing sclerotomies by oblique penetration of the sclera with a 19-G MVR blade has been found to be resistant to stretching and tearing, to rarely need suturing and to be convenient for the passage of instruments [32]. They also reduce the risk of intraoperative hypotony following removal of instruments or the infusion cannula. The technique reduces postoperative inflammation and suture-related problems, including astigmatism, and allows more rapid rehabilitation [33]. In nonphakic eyes, the trauma of making a sclerotomy site may be avoided with the anterior chamber infusion approach by way of a paracentesis [34].

Diathermy should be avoided as far as possible since it can cause undue scarring and, in rare cases, surgically induced necrotizing scleritis (SINS) after repeat surgeries has even been reported [35]. SINS requires prompt and aggressive immunosuppressive treatment.

Cornea-related complications

Corneal complications, mainly in the form of epithelial disturbance, have been found to occur in over 7% of vitrectomy surgeries while, in diabetic patients, the incidence may be as high as 10–50% [36–38]. Use of irrigating lenses has been linked to an increase in the intraoperative corneal edema, necessitating the debridement of corneal epithelium, and this, in turn, seems to be a major contributor for development of corneal complications. Sew-on lenses with a viscoelastic cushion are less damaging, while noncontact lenses may provide the best corneal protection [36,39,40]. The type of viscous surface lubricant used with sew-on lenses may also play a significant role [41]. Corneal complications related to the use of silicone oil will be discussed later.

Use of better instruments [42] and irrigating fluids [43], avoidance of epithelial debridement, and reduction in the time of surgery [40] and the time for which IOP is raised [26] may reduce the incidence of these complications. The degree of surgical invasion that occurs during the procedure also decides the corneal status [37]. Accidental diathermy burns are best avoided by keeping the use of diathermy to a bare minimum. Preservation of anterior lens capsule during pars plana lensectomy has been shown to reduce the risk of corneal endothelial damage, especially when combined with long-acting gas tamponade [44]. Subsequent opacification of the anterior capsule may require Nd:YAG capsulotomy for clearing the visual axis.

Persistent corneal epithelial defects may be treated with ointments, pressure patches or autologous serum eye drops combined with artificial tears and topical antibiotics, and generally respond well within 3 days [45,46]. Defects that fail to heal with conventional therapies may be fitted with an extended-wear gas-permeable scleral lens [47]. Re-epithelialization appears to be aided by a combination of oxygenation, moisture and protection of the fragile epithelium afforded by the scleral lens. However, albumin may be deposited on the contact lens surface and the risk of microbial keratitis cannot be ignored [45,47]. Use of topical steroids is usually avoided; however, topical dexamethasone administered five-times a day may decrease potential stromal scarring without significantly delaying the corneal epithelial healing (BOX 1) [46].

Box 1. Postvitrectomy corneal complications.

Factors that delay corneal epithelial healing

- Pre- and intraoperative topical solutions
- Median operative time
- Presence of diabetes mellitus
- Prior ocular surgeries
- Pseudophakia/aphakia
- Presence of intraocular gas or silicone oil in aphakic patients

Prevention of corneal complications

- Use of better instruments and irrigating fluids
- Avoidance of epithelial debridement
- Preservation of posterior capsule
- Use of viscoelastics in anterior chamber
- Reduced duration of raised intraocular pressure and surgery

Management of corneal complications

- Ointments
- Pressure patches
- Bandage contact lens
- Avoidance of topical steroids

Modified from [46].

Anterior chamber collapse

Anterior chamber collapse has been found in over 3% of aphakic eyes that underwent vitrectomy with gas tamponade. Presence of preoperative shallow anterior chamber, removal of the intraocular lens (IOL) as a part of the procedure, occurrence of intraoperative anterior chamber collapse and use of SF_6 were associated with a higher risk of anterior chamber collapse postoperatively [48].

Iris-related complications

Damage to the iris leading to hemorrhage or iridodialysis may occur occasionally due to an improper technique of making a sclerotomy. Postoperative iritis may be treated with topical steroids.

Postoperative iris and angle neovascularization has been found in 8–15% of eyes undergoing vitrectomy for proliferative diabetic retinopathy (PDR) [49,50]. Preoperative presence of retinal neovascularization and absence of panretinal photocoagulation (PRP) and postoperative retinal detachment (RD) are significant risk factors [50,51]. Recent studies have found a lower incidence of postoperative rubeosis iridis with vitrectomy combined with removal of the lens in these cases of PDR [49,52]. Such rubeosis, however, has been found to be regressive rather than progressive [50].

In nondiabetic patients who undergo vitrectomy for RD, successful reattachment of the retina has been found to be the most important factor in the prevention of iris neovascularization, while PRP has not been found to have any role in such cases [53].

Short-term results have suggested that intravitreal or intracameral injection of anti-VEGFs, such as bevacizumab, results in rapid regression of iris neovascularization secondary to PDR [54–56].

Pupil-related complications

In the past, most surgical dilating procedures for intraoperative miosis involved an incision or excision of iris tissue, which was either inadequate or irreversible [57]. Even though currently used wide-angle lenses allow excellent visualization even in miotic pupils [58], it is always better to ensure proper preoperative dilatation with the use of adjuncts, such as flurbiprofen [59] or ketorolac [60].

Intraoperative miosis can be adequately managed by the use of epinephrine solution without preservatives either intracamerally (0.1 ml of 1:10,000) or in the infusion fluid [61,62], or by the use of flexible nylon iris retractors [63–65] or silicone rings [66]. Sphincterectomy may be used as a final resort [67].Postoperative inflammation may cause pupillary membranes that do not respond to steroids and may be removed with Nd:YAG laser [68].

Lens-related complications

Development of lenticular opacities after vitrectomy is a major complication, often necessitating cataract extraction. The reason for such a change may be related either to the overoxygenation of the lens after removal of the normal vitreous barrier or to diffusion of electrolytes. This is supported by the fact that nuclear sclerosis has not been found to progress even at 5 years after a nonvitrectomizing vitreous surgery [69,70].

Apart from the removal of the vitreous itself, the cataract progression depends on the duration of follow-up, the use of tamponading agent and the age and diabetic status of the patient. Up to 26% of phakic eyes may develop cataract after vitreous surgery for PDR [71]. The cumulative cataract extraction rates at 2 years have been found to be 15% after diabetic vitrectomies and 50–66% after nondiabetic vitrectomies, suggesting a lower rate of cataract formation in diabetics [72]. Patients older than 50 years of age may have an approximately sixfold greater rate of increase in nuclear sclerotic cataracts than patients younger than 50 years of age [73].

Presence of tamponade by intraocular gas has been shown to increase the rate of lenticular opacities to 86–96% [40,76]. Incidence of cataract extraction due to nuclear sclerosis 1 year post-vitrectomy with gas tamponade may be as high as 67%, while in nontamponade vitrectomies it is 18% [73,77]. A transient posterior subcapsular cataract is also seen in gas tamponade cases in the immediate postoperative period, probably due to a disruption of fluid balance [77]. Tamponade with silicone oil causes some degree of cataract in almost 100% cases [74,75], and will be discussed later.

Combined cataract and vitreoretinal surgery with intraocular air or SF_6 gas tamponade also induces severe posterior capsular fibrosis in 50–66% of pseudophakic cases in the early postoperative period, presumably due to accumulation of fibrin and proliferation-stimulating factors in the narrow space between the IOL and air/ SF_6-gas bubble [78].

Extended operating times, constant irrigation of the lens and the type of the irrigating fluid may also be responsible for the lenticular opacities [38]. Various antioxidant, anti-inflammatory and cytostatic agents are being investigated in an attempt to suppress such vitrectomy-induced posterior lens fiber changes [79].

Cataract formation due to direct mechanical trauma is best avoided with careful surgical technique. Damage generally occurs either with the cutter during removal of the anterior vitreous or at times with the light pipe while working in the far periphery. Modified instruments, such as a curved vitrectomy probe, have been designed to facilitate vitreous base excision [80]. A conservative approach may be warranted for minor lens injuries, but if the damage is significant, especially with rupture of the lens capsule, then it is advisable to remove the lens in the same sitting.

Interestingly, the diabetic status of a patient may play a role in deciding whether to remove the lens as diabetic eyes have been found to be less likely to require additional vitreoretinal surgery if they are rendered nonphakic before or during vitrectomy [52].

Glaucoma

Various mechanisms may contribute to a rise in the IOP after vitrectomy. Past studies have reported raised IOP in up to 30% eyes within 2–10 days of vitrectomy for vitreous hemorrhage, mainly due to ghost cell or hemolytic glaucoma [81,82]. Such an obstruction of the trabecular meshwork, either by degenerated red blood cells or by macrophages laden with red blood cell debris, can be prevented by thorough irrigation of the vitreous cavity at the time of vitrectomy, ensuring that no cells or debris are left behind [82]. With the advancement in instrumentation and visualization methods, this incidence has decreased. If the IOP is not controlled with routine antiglaucoma medication, irrigation of hemolytic debris from the anterior chamber, with or without a revitrectomy, may be carried out [83,84].

After vitrectomy with air or gas tamponade, up to 43% of cases may show elevated IOP within 24 h that responds to aqueous suppression by 72 h [86]. At 6 months, follow-up, these raised levels may be maintained in 2–5% eyes [40]. Elevated IOP has been found to be associated with increasing patient age, expansile gas concentrations, use of C_3F_8 and circumferential scleral buckles [86].

Inability to maintain proper prone positioning after vitrectomy with gas tamponade may lead to pupillary block by the buoyant gas bubble, thus pushing the iris diaphragm anteriorly, in turn leading to permanent peripheral anterior synechiae and intractable secondary glaucoma [85]. To prevent such a pupillary block caused by silicone oil in aphakics, Ando has described an inferior peripheral iridectomy to provide an alternate channel for the aqueous to flow into the anterior chamber [87] and this may also be used alongside gas tamponade [88].

Treatment of postvitrectomy glaucoma is initially with standard topical and systemic antiglaucoma medications with YAG peripheral iridotomy or with cyclodestructive procedures such as cyclophotocoagulation, if needed.

Some 5–10% of eyes develop increased IOP secondary to angle neovascularization after vitrectomy in PDR [50,71,82,89]. The presence of lens appears to have a protective role [90] and its removal along with vitrectomy may increase the risk of neovascular glaucoma (NVG) by a factor of more than four. Other factors associated with a significantly increased incidence of postoperative iris neovascularization include severe preoperative retinal neovascularization, absence of preoperative PRP and presence of postoperative RD [51].

Iris neovascularization in nondiabetic cases rarely progresses to NVG and so PRP is not indicated in these patients. Retinal reattachment is the most important factor in the prevention and/or resolution of postoperative iris neovascularization [53].

Intravitreal or intracameral injection of anti-VEGFs, such as bevacizumab, has shown great promise in reducing iris and retinal neovascularizations, thus preventing the onset of NVG

[54–56]. Anterior segment fluorescein angiography may be used to evaluate the response to therapy [91]. Management of NVG is extremely challenging, often requiring multiple filtration surgeries and destructive procedures, such as cyclocryotherapy, which often lead to phthisis bulbi [92]. Combined pars plana vitrectomy and placement of a glaucoma drainage implant is often a successful management option in selected patients with refractory glaucoma, although visual outcome may still be poor [93].

Other causes of raised IOP may be related to the chronic postoperative use of topical steroids and postoperative inflammation.

While an increased risk of open-angle glaucoma (OAG) has been found after vitrectomy, in patients with established OAG, the number of antiglaucoma medications needed may increase after surgery. Oxidative stress has been hypothesized to have a role in the pathogenesis [90].

Vitreous hemorrhage

Vitreous hemorrhage, primary or recurrent, is a common occurrence after diabetic vitrectomy. While the incidence of postvitrectomy diabetic vitreous hemorrhage (PDVH) in cases of PDR ranges from 29 to 75% in earlier reported series [94,95], recent studies have reported a much lower incidence of 13–17% [71,96]. An incidence of 1.5% has been found after vitrectomy for diabetic macular edema [89].

Studies have found a significant correlation of PDVH with iris neovascularization and lower extremity amputations. While presence of the latter indicates a 70% risk of developing PDVH, the risk decreases to 30–40% with the use of antihypertensive agents within 3 months of vitrectomy [97]. PDVH has, however, not shown any correlation with the lens status [52].

PDVH has been linked to the FVIG at the sclerotomy sites, which has been noted in 57–87.5% of all eyes experiencing PDVH [27,98]. UBM has been able to detect FVIG in a high proportion of eyes and its use has been advocated as an aid in planning resurgeries [99].

In diabetic vitrectomy, along with PRP, anterior peripheral retinal cryotherapy (ARC) with cryotherapy of sclerotomy sites has been shown to reduce the incidence of FVIG from 36.5 to 0%, with a corresponding nine-times reduction (from 37.5 to 4.3%) in the incidence of PDVH [98]. These adjunct procedures lead to anatomic stabilization and even visual improvement. ARC is often feasible in cases with media opacity that preclude the use of endolaser or indirect PRP [100]. The use of these adjuncts, however, should not be made routine in all cases of PDR, but should be reserved for cases of recurrent vitreous hemorrhage [101].

Use of either the sew-on or the wide-angle lens systems seems to make no difference to the PDVH occurrence [96].

Fluid–gas exchange and vitreous cavity lavage are popular less-invasive methods of treating this kind of recurrent vitreous hemorrhage [95] and may be needed in up to 12% of cases [27]. The fluid–gas exchange, however, does not offer clear vision immediately after the procedure and has even appeared to exacerbate cataract formation, justifying a period of observation for PDVH [102].

Use of intravitreal injection of 30 µg of tissue plasminogen activator (t-PA) for lysis of postvitrectomy blood clot, administered 4 days prior to the vitreous cavity lavage, has shown an immediate clearing of the vitreous cavity in 80% of eyes [95]. Postvitrectomy tamponade with 10% C_3F_8 may also be a useful adjunct in the reduction of early PDVH [103].

With studies showing marked regression of neovascularization and rapid resolution of vitreous hemorrhage after intravitreal injection of bevacizumab without any side-effects [104–106], this drug has also been used preparatory to diabetic vitrectomy, 1–3 weeks prior to surgery.

Intraoperative bleeding may be prevented by avoiding the vascular component of proliferations while attempting to remove the surrounding traction [107] or by use of prophylactic coagulation [108]. A temporary increase in the infusion pressure or use of endodiathermy usually controls the bleed. Complete removal of posterior vitreous cortex reduces the risk of PDVH by removing the scaffold necessary for proliferation of new vessels and by eliminating vitreous traction on the existing vessels.

Endophthalmitis

Postoperative endophthalmitis is a rare, albeit serious, complication of vitrectomy and with the recent increased use of intravitreal injections, has been noted in these cases as well [109].

Over the years, preoperative and intraoperative measures, such as lid hygiene, appropriate surgical draping, and improved surgical technique, have all decreased the incidence of postoperative endophthalmitis [110]. Prophylaxis with topical povidone–iodine, and possibly antibiotics, has further minimized the risk [109]. Recent studies have found the incidence of postvitrectomy endophthalmitis to be 0.04–0.07% [112–115], which is lower than with postcataract surgery [111].

Studies on vitreous aspirated immediately after sclerotomy and that aspirated before wound closure have shown that bacteria do enter the eye during pars plana vitrectomy but do not necessarily lead to postoperative endophthalmitis [116].

In 80% of cases, it is the patient's own flora that is responsible for endophthalmitis. In two-thirds of cases, bacterial agents are Gram-positive, including *Staphylococcus epidermidis* and *S. aureus*, and in a third of cases they are Gram-negative, including *Pseudomonas*, *Proteus* or *Klebsiella* [113,117].

In one study, while 27% recovered a visual acuity (VA) of 20/50 or better, 61% had less than 5/200 VA. Approximately 50–67% of eyes may end up with vision no better than perception of light [112,113]. Postvitrectomy bacterial endophthalmitis caused by organisms other than coagulase-negative staphylococci has a poor visual prognosis [112,118]. Other predictors of VA include baseline acuity of counting fingers or better, or culture-negative endophthalmitis [118].

Instillation of 5% povidone–iodine just prior to commencement of surgery is a proven method to dramatically reduce the microbial load from the conjunctival sac [119]. Other methods being empirically practiced include the use of preoperative and postoperative topical and intraoperative intracameral, and the subconjunctival antibiotics and use of surgical drapes [120–122].

If endophthalmitis does occur in a vitrectomized eye, a needle may be placed through pars plana to aspirate vitreous fluid for culture and sensitivity [123,124]. Treatment is based on the endophthalmitis vitrectomy study, and consists of intravitreal antibiotics with or without a revitrectomy [110].

Hazard analysis critical control points, a quality assurance system so far used in the food industry to ensure safety, has also been adopted when conventional infection-control measures have failed to reduce the incidence of postoperative endophthalmitis [125]. Hospital cleaning and healthcare-associated infections continue to attract adverse media attention and consumer concern, and so taking this type of approach could provide greater transparency, reduce infection rates and increase consumer confidence [126]. Moreover, the introduction of infection-control policies into clinical practice will make prevention deliberate and more effective [127].

Hypotony

Transient hypotony is common after vitrectomy, observed in up to 15–16% cases [38,128]. With the advent of sutureless vitrectomy, the problem of initial hypotony due to improper sclerotomy is bound to be more common, especially during the learning curve. However, with a tunneled sclerotomy, an airtight closure can be obtained [129]. Chronic hypotony is extremely rare and may be due to leakage through sclerotomy sites or to a cyclodialysis cleft being formed. Steroids may help in relieving any associated inflammation [130].

Retinal complications

Cystoid macular edema

Removal of vitreous has been known not only to cause cystoid macular edema (CME), but also to make it disappear, showing that its pathogenesis is yet to be understood. In vitrectomies for retained lens matter, 29% of eyes with final vision less than 20/40 had CME [131]. The incidence of CME in the presence of a sulcus-fixated posterior chamber IOL implanted at cataract extraction is much lower (8%) compared with eyes with aphakia or an anterior chamber IOL (46%) [132]. CME has been found to develop a mean of 4 months after vitrectomy. The prognosis is guarded and long-term treatment with steroid drops, topical cyclo-oxygenase inhibitor and posterior sub-Tenon's steroid injections may be needed [132].

Vascular occlusion

Prolonged duration of raised IOP during surgery or postoperatively may lead to a loss of central or paracentral vision due to vascular occlusion. Compromise in the choroidal circulation may cause an outer retinal-layer ischemia [133]. Retinal arterial occlusion with resulting visual field loss has been reported 12 days after an uneventful vitrectomy with gas–fluid exchange. Only a rapid resorption of the intraocular gas and timely postoperative examination may reveal such an occlusion since subsequent reperfusion may leave little evidence of the vascular event [134].

Retinal detachment

Iatrogenic retinal breaks leading to postoperative retinal detachment is a serious complication of vitrectomy seen in a varying number of cases (4–8%) [71,89,135,136]. Retinal breaks may occur following direct mechanical trauma or due to vitreous traction during introduction and removal of instruments or due to excessive pull on existing traction bands [137]. Breaks are more common anterior to the equator and the majority of these occur in relation to the sclerotomy site [138].

In patients with PDR, using a wide-angle noncontact lens system has been shown to reduce the incidence of postoperative RD significantly (from 9 to 1%) [96]. Use of an external diaphanoscopic illuminator doubling up as an indenter can help in the removal of peripheral vitreous or incarcerated vitreous from sclerotomies within the pars plana [139].

Traction on the retina should be minimized by using higher cut rates and lower suction, especially near the vitreous base. Removal of posterior hyaloid face when needed has to be performed cautiously starting from the peripapillary region. Standard PRP applied in a complete encircling pattern may prevent macular detachment by restricting the posterior progression of RD due to sclerotomy-related retinal tears that occur after vitrectomy for PDR [140]. At the end of vitrectomy, it is necessary to inspect the peripheral retina carefully with scleral indentation for any missed out or newly created breaks. In up to 71% of eyes, the retina may be successfully reattached with additional surgeries [71].

Microplasmin, a truncated form of the natural human protein plasmin, is currently undergoing a Phase II trial for its use in vitrectomy. Results so far have suggested that microplasmin, when injected 1 week prior to vitrectomy, induces PVD in 50% of patients without the need for either suction or mechanical intervention [301].

The introduction of vital dyes for staining has led to better visibility of the internal limiting membrane (ILM), epiretinal membranes and the posterior hyaloid, potentially making their removal more controllable, easier and safer [141].

Studies on cadaver eyes have shown that of all the marking agents used, triamcinolone acetonide best highlights the vitreous without staining the surrounding ocular structures [142]. Transmission electron microscopy has been used to demonstrate that the posterior vitreous hyaloid remaining on ILM was significantly lower when triamcinolone acetonide was used for its removal [143]. Both triamcinolone acetonide and trypan blue have been found to be useful adjuncts, improving the efficiency and safety of membrane identification and removal [144–146].

Questions concerning the potential toxicity of indocyanine green (ICG) are currently being discussed [141]. ICG has been known to cause pigment epithelial atrophy, disc atrophy, and retinal and choroidal toxicity [147]. However, application of ICG in the air- versus fluid-filled eye, short-time staining, small volume and a lower concentration reduce these possible complications [148–150].

PVR & redetachment

Primary vitrectomy with or without either gas tamponade or without scleral buckle has become a regularly used procedure in complicated rhegmatogenous RDs. Retinal reattachment has been achieved in 64–88% of cases with a single surgery and in 83–96% with one or more operations [76,151,152]. Studies have not found a significant difference in the success rate between eyes that underwent vitrectomy alone and those that received adjunctive scleral buckling [152]. Macular pucker has been noted in 6–11% of cases, CME in 17%, and full-thickness macular holes in 2% [76,151]. Postoperative PVR causing redetachment was found in 6% of cases [76].

Visual field defects

Visual field defects can occur following vitrectomy and gas–fluid exchange for macular hole. Various theories have been proposed to explain this occurrence. A dense and wedge-shaped visual field defect involving the temporal visual field may be due to trauma to the peripapillary retinal vasculature or nerve fiber layer during elevation of the posterior hyaloid or during aspiration at the time of air–fluid exchange, followed by compression and occlusion of the retinal peripapillary vessels during gas tamponade [153]. It has been suggested that the visual field loss after macular surgery may be reduced if peeling of the posterior hyaloid is confined to the area of the macula so that the hyaloid remains attached at the optic nerve head [154].

Nasal and peripheral visual field defects have been seen with ICG-assisted ILM peeling and their incidence appears to depend on the concentration of the ICG solution and/or the exposure time to the retina [155,156].

High infusion flow during air–fluid exchange may result in significant retinal damage, sometimes seen as whitening diagonally opposite to the infusion cannula site. The region of damaged retina may develop a corresponding visual field defect or, occasionally, even a retinal break and detachment [157,158]. New kinds of infusion cannulas with closed tip and side openings have also been devised to prevent this complication [159].

Photic injury

Retinal photic injury may arise from light exposure to the operating microscope or to the fiberoptic endo-illuminator, especially during prolonged surgeries for macular hole. Ultraviolet and short-wavelength visible light are more dangerous than longer wavelength light [160]. While many mild injuries may go unnoticed, fluorescein angiography may demonstrate a previously absent paramacular lesion consistent with a photic injury [161]. It can be reduced by careful planning of vitreous surgery for epimacular membrane removal, using filters, minimizing the length of surgery, keeping the light output low, maintaining maximal light pipe distance from the retina, eccentric orientation of the light pipe, and use of intermittent and variable site illumination techniques [161].

Choroidal complications

Suprachoroidal hemorrhage or a choroidal effusion may be seen in up to 0.1% of eyes during or after vitrectomy in the early postoperative period [162]. In the presence of choroidal detachment or endophthalmitis where the choroid is expected to be thickened, it may be wiser to place a longer infusion cannula, while keeping in mind the risk of damaging the lens in a phakic eye. It is necessary to ensure that the tip is in the vitreous cavity and not infusing into the choroid.

The risk factors for suprachoroidal hemorrhage include old age, high myopia, aphakia or pseudophakia, RD and scleral buckle. Postoperative suprachoroidal hemorrhage has a better prognosis than the intraoperative type [162].

Valsalva maneuver during vitrectomy has been reported to result in massive suprachoroidal hemorrhage and care needs to be taken to prevent prolonged episodes of coughing during surgery [163]. When such a complication does occur, the infusion needs to be stopped and perfluorocarbon liquids used to displace the hemorrhage or fluid through anterior drainage sclerotomies. If the visibility and tone of the eyeball permits, the vitrectomy may be completed. Long-term tamponade with silicone oil is often needed, even at times with the use of heavy liquids for the initial postoperative period up to 7 days [164,165].

Silicone oil-related complications

Intraoperative

The main concern is of overfill of silicone oil leading to rupture of zonules with oil entering the anterior chamber (AC). This can be prevented by lowering the infusion pressure just prior to injecting oil and stopping once oil is seen touching the posterior surface of the lens or refluxing up the infusion line. Silicone oil may, at times, enter the subretinal space through a retinal break [75]. This is best avoided by prior fluid–air exchange and endodrainage of subretinal fluid. However, if it does occur, then air should be replaced with fluid and the oil aspirated through the break or an anterior retinotomy [166].

Refractive changes

In a phakic eye, the silicone oil bubble attains a concave anterior surface and makes the eye hyperopic due to its higher refractive index. Aphakic eyes have a myopic shift due to the convex anterior surface [167]. The degree of myopia increases in the supine position due to separation from the retina and further bulging through the pupil [168].

Intraocular lenses

Silicone oil permanently coats a silicone IOL when the two come in contact, interfering with the surgeon's view of the retina and reducing the patient's VA [169,170]. It has been shown that it is nearly impossible to remove silicone oil from a silicone IOL after short- or long-term contact, while it can be readily removed from an acrylic IOL [171]. Thus, it is recommended to use a soft acrylic or polymethylmethacrylate IOL in patients who may require vitreoretinal procedures with silicone oil tamponade. In addition, if a silicone IOL is encountered during silicone oil injection, it is advisable to explant it or to use an intraocular gas instead if feasible.

Another issue is trying to calculate the IOL power in a silicone oil-filled eye. The change in sound velocity in oil has to be accounted for during axial length measurement. While the calculations may be fairly accurate in eyes with normal axial length, some highly myopic eyes with posterior staphyloma show great deviation. Unsuitable formulae and artifacts may be the cause of errors of deviation of refraction [172]. Various modifications of the standard formulae are advocated to account for the change in refractive index [173]. A conversion factor of 0.71 may be used to correct for the apparent increase in axial length induced by silicone oil with a viscosity of 1300 centistokes [174]. The meniscus style or the planoconvex IOL yield the smallest difference between predicted and actual postoperative refraction even after removal of silicone oil [175].

While some have found sulcus placement of IOL to give a less predictable result than placement in the capsular bag [174], others have found comparable results regardless of the technique of IOL implantation or the type of silicone oil used [172].

In cataract surgery combined with silicone oil removal, an intraoperative biometry after removal of the oil appears to have good predictability for the absolute postoperative refractive error, independent of axial length [176]. Laser interferometry appears to be a feasible and satisfactorily accurate noncontact method to calculate IOL power in such eyes, although it is of lesser value in the presence of advanced cataract [177,178].

Migration of oil

Long-term retention of silicone oil may lead to its migration into adjacent tissues. Subconjunctival migration has been noted in 3% of cases [74]. This may occur through leaking sclerotomies or through shunt tubes placed for glaucoma [179,180]. Migration of silicone oil into the anterior chamber may be seen in 6% of nonphakic eyes [74].

Cases have been reported in which silicone oil in the eye migrated into the cerebral ventricles and the subarachnoid space [181–183], and light microscopy has identified silicone oil bubbles in the optic nerve and the subarachnoidal space of an enucleated eye that had undergone silicone oil injection [184].

Anterior segment complications

Almost all eyes with silicone oil tamponade demonstrate some degree of cataract formation [74,75,185], primarily due to mechanical obstruction to diffusion of nutrients [186]. Removal of oil may delay the process but cannot prevent it completely [187].

Corneal complications have been encountered in up to 27% of cases with severe PVR following vitrectomy with silicone oil injection [188]. Presence of silicone oil in the anterior chamber leads to keratopathy in almost all cases by the end of 6 months [75], the overall incidence being 3–5.5% [74,189].

Prognostic factors for development of corneal complications include preoperative aphakia or pseudophakia, preoperative rubeosis iridis, resurgery, corneal touch by silicone oil and the presence of aqueous cells or aqueous flare [188]. Also, the physicochemical characteristics of the silicone oil injected may be an important variable in long-term complications [74,75].

Corneal problems are best prevented by avoiding overfill of the oil and filling of the AC with air, by performing an inferior iridectomy in aphakics and by a successful surgical repair of RD with a single operation [87,190,191]. If rubeosis iridis or severe aqueous flare is present, preoperative treatment with intense topical and possibly periocular steroids might reduce inflammation and, hence, corneal damage [188].

Routine performance of an inferior iridectomy in all aphakic eyes appears to lower the incidence of emulsification, keratopathy and secondary glaucoma [74]. When lensectomy is being performed in the same sitting, it is advisable to leave the anterior capsule intact to help prevent intraoperative and postoperative complications of silicone oil, simplify future IOL placement and maintain a normal iris appearance [192].

Removal of silicone oil by passive efflux has been shown to cause significant endothelial cell loss and changes in endothelial morphology that, nevertheless, appear to be well tolerated (TABLE 1) [193].

Intraocular pressure

Hypotony is seen in 18% of cases, while raised IOP is seen in 3–11% of cases after intravitreal silicone oil injection [74,75,189,194,195]. Factors prognostic of chronic hypotony include preoperative hypotony, diffuse contraction of the retina anterior to the equator, rubeosis and large retinal breaks [194].

The mechanism of IOP increase could be emulsified oil in the anterior chamber (32–53%), pupillary block with closure of inferior iridectomy (24–30%) or idiopathic angle-closure glaucoma (16–23%) [196,197]. Some patients may also present with OAG without silicone oil in the anterior chamber (21%) [193]. Independent predictive factors for glaucoma include rubeosis iridis, aphakia, diabetes, oil in the AC and unsettled retina [198].

Table 1. Incidence of silicone oil-related complications.

Silicone-oil complications	Incidence (%)
Subconjunctival oil	3
Oil in anterior chamber (nonphakic eyes)	6
Keratopathy	3–5.5
Inferior iridectomy closure	6–14
Glaucoma	3–9
Cataract	100
Silicone oil emulsification	0.7
Subretinal silicone oil	4
Retinal ischemia	13
Epiretinal and subretinal fibrous membranes	15–40
Reretinal detachment	43–45

Modified from [74,75,189].

Postoperative glaucoma due to pupillary block and angle closure in aphakics can be prevented by an inferior iridectomy [87]. Blockage of trabecular meshwork by emulsified oil droplets can be refractory to medical management and even to removal of oil [199].

Control of glaucoma when attempted with medical management, silicone oil removal (SOR), trabeculectomy with mitomycin C, cyclocryotherapy, trans-scleral cyclophotocoagulation and/or anterior chamber shunting, has been shown to succeed in 72% of eyes, while the rest remained refractory [198]. Patients who undergo SOR alone to control IOP are more likely to have persistent elevation of IOP and possibly undergo resurgery for glaucoma, whereas patients who undergo concurrent SOR and glaucoma surgery are more likely to have hypotony [197]. As well as the silicone oil-related causes, all other vitrectomy-related causes should be considered in an eye with raised IOP and silicone oil.

Emulsification

Emulsification is the formation of silicone oil droplets on the surface of ocular tissues or at the interface between oil and intraocular fluids. It facilitates the migration of oil into AC where it causes further complications [200]. Almost all eyes demonstrate some emulsification 1 year after surgery [75]. Fibrin and serum are biologically active emulsifiers. In addition, the lower the viscosity of silicone, the greater is its tendency to emulsify, particularly with viscosities from 1000 to 5000 cSt [201].

Recurrent retinal detachment

Inflammatory membranes occurring at the silicone–fluid interface may lead to macular pucker in 30% of cases and also to recurrent tractional RD [202,203]. Removal of silicone oil in anatomically successful eyes significantly increases the likelihood of improved VA [204] but also carries a risk of redetachment in a quarter of cases. This depends on factors such as the number of previously unsuccessful RD surgeries, VA before silicone oil removal, incomplete removal of vitreous base, absence of an encircling band in eyes with PVR and the indication for pars plana vitrectomy. It is, however, independent of the technique of SOR and duration of silicone oil endotamponade [205]. Incidence rates of complications, such as keratopathy and hypotony, have been found to be lower in eyes with the silicone oil removed [206].

Conventional silicone oil cannot provide inferior tamponade, which is where PVR more often sets in, leading to redetachment. The subsequent use of high-density silicone oil (specific gravity of 1.06 g/ml) to provide support for the inferior retina is being explored as a strategy to reduce the number of reoperations [206,207]. However, an inflammatory response, resembling granulomatous uveitis and not responding to steroids, has been seen in 37% cases after such high-density silicone oil endotamponade. It is likely that this vitreous substitute is an immunogenic agent since after its removal complete resolution of the inflammation has been noted [208].

Expert commentary

Vitrectomy has evolved into a high technology-based surgery. This is a unique example of treating a disease where man and machine go hand-in-hand at every aspect. New surgical techniques are constantly evolving, with the resultant development of new technology and *vice versa*. The technology of cutters and its fluidics, including infusion and suction controls, has provided excellent surgical control and added greater patient safety to the surgery. Adjunct procedures using laser treatments and fragmatomes have also been refined, and are constantly evolving to give improved precision and efficiency to the surgeon.

Over a period of years, several intraoperative surgical complications have been reduced through refined instrumentation and a better understanding of tissue metabolism, infusion fluids and fluidics. The improvement in software technology has enhanced the foot switch control with reduced time lag, also making the surgeon less dependent on support staff. These improvements have drastically reduced the average vitrectomy time, resulting in a delay in the onset of cataract and other metabolic-based sequelae. Personally, we feel that tissue respect is of utmost importance and the way the concepts toward sutureless vitrectomy are evolving, we are heading in the right direction. At the moment, we are in the first generation of sutureless vitrectomy systems, but almost every month new cutters and insertion systems are developing that are sharper and more precise than the previous ones. The next 5 years should see a definite shift towards sutureless vitrectomy procedures with the immense benefits of reducing patient discomfort and early rehabilitation.

Five-year view

Transconjunctival sutureless vitrectomy

Transconjunctival sutureless vitrectomy (TSV) is a recent advancement in vitreoretinal surgical techniques involving the use of smaller gauge instruments through self-sealing sclerotomies. The 25-G TSV is a minimally invasive technique and appears to reduce the convalescence period and the postoperative inflammatory response, while improving patient comfort [209,210]. It has been shown to decrease the operating time by 37% compared with conventional 20-G vitrectomy [211].

In 20-G vitrectomy, repeated introduction and removal of instruments through the sclerotomies results in microtrauma at the pars plana [210,212]. By contrast, the trocar and cannula system used in the 25-G vitrectomy system not only avoids the conjunctival incision and cauterization of the scleral bed, but also facilitates easy entry, with no trauma to the sclera or the pars plana. Additionally, it has been hypothesized that there may be less chance of vitreous and retinal herniation in a sutureless scleral wound compared with one that has been sutured [213]. As the instruments do not come in contact with the sclera or pars plana, prolonged anesthesia is not required. Sutureless vitrectomies have also been carried out under topical anesthesia [214]. In the absence of severe congestion, chemosis or lid swelling, even cosmetically the eye looks much better from the first postoperative day itself.

The success of 25-G vitrectomy has been well described, but its application for more complex vitreoretinal diseases, such as complex RD with PVR, has been limited. While its use has been reported even for tractional RDs in stage 4 and 5 of retinopathy of prematurity, modifications, including conjunctival dissection and suturing of conjunctiva and sclerotomies, need to be used [215].

The main limiting factors of the 25-G system are the relative lack of instrument rigidity, slower vitreous cutting ability and suboptimal fluidics, and even blockage of the cutter tip, all of which are inherent to the reduced caliber of the instrumentation [216,217]. Intraoperatively, problems, such as difficulty in inserting the microcannula leading to deformity and instability of the microcannula, self-disconnection of the infusion tip resulting in lens damage, and the need to convert to 20-G vitrectomy have been noted [128].

Factors such as the unsutured wounds, postoperative hypotony and lower infusion rates may contribute to the reported increased risk of endophthalmitis after 25-G vitrectomy [218–220,302]. An obvious wound leak needs to be sutured. Intravitreal air injection may be used to avoid immediate postoperative hypotony but, despite partial fluid–air exchange, hypotony has been reported in up to 16–25% of cases [128,217]. These concerns are similar to the era of phacoemulsification undergoing a shift toward corneal tunnel incisions. However, we feel that these are concerns of a learning curve and as the surgeon gains experience and selects cases with proper discretion, they will probably not remain major issues.

Some surgeons have suggested that the technique of 20-G sutureless vitrectomy overcomes some of the limitations of 25-G systems, but inconsistencies in the application of this technique have limited its widespread use [216]. Another option is to combine the use of 20-G devices through the main port while keeping the other two sutureless. This may help to expand the indications for the 25-G system. However, postoperative low ocular tension must be addressed by carefully considering surgical indications and prevention measures [221].

The 23-G vitrectomy system has been devised with a view to combining the advantages of decreased surgical trauma and recovery time enjoyed with 25-G sutureless vitrectomy with the sturdier instrumentation and improved fluidics of the 20-G systems [222]. These characteristics make 23-G vitrectomy a promising approach to tackle the complete range of vitreoretinal surgical procedures efficiently and safely with a single system [216].

Pharmacological vitrectomy

Pharmacological vitrectomy refers to the use of enzymes in an effort both to liquefy vitreous and weaken the adhesion of vitreous cortex to the ILM during or before performing vitreous surgery. These vitreolytic enzymes may be of great value in complicated or office-procedure vitreoretinal surgery [223]. Plasmin, dispase and chondroitinase have been used to make the vitreous surgery easier with fewer complications or to avoid vitrectomy. On the other hand, hyaluronidase has been used to facilitate the clearance of vitreous hemorrhage, liquefying vitreous body and developing posterior vitreous detachment [224]. The highest increase of vitreous removal when tested in enucleated pig eyes was found with hyaluronidase and the lowest with chondroitinase. Damage occasionally occurred to the ILM and very rarely to the nerve fiber layer [223]. t-PA, which converts plasminogen present in the vitreous cavity to plasmin, thereby inducing fibrinolysis, has been found to simplify separation of vitreous cortex and pathological membranes without any bleeding [225]. Use of microplasmin for the treatment of diabetic macular edema without the need for vitrectomy is also under trial [301,303].

Every new technique or equipment that is introduced should be well-researched and well-learned before putting it into practice. It is important to follow evidence-based medicine. Complications will occur. They are an integral part of every surgery. We need to realize that our best chance lies not so much in trying to eliminate them, but rather in detecting them early enough and managing them efficiently

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Key issues

- Tissue respect has to be given at every step of vitrectomy.
- The technique used for making sclerotomies has an important bearing on the surgery and its outcome.
- Corneal edema, cataract and glaucoma are commonly observed complications.
- The most significant complications include retinal detachment, choroidal effusion and endophthalmitis.
- The best way to manage a complication is to avoid it.

References

Papers of special note have been highlighted as:
• of interest
•• of considerable interest

1 Kasner D, Miller G, Taylor W, Sever R, Norton E. Surgical treatment of amyloidosis of the vitreous. *Trans. Am. Acad. Ophthalmol. Otolaryngol.* 72, 410–418 (1968).

2 Machemer R, Buettner H, Norton EW, Parel JM. Vitrectomy: a pars plana approach. *Trans. Am. Acad. Ophthalmol. Otolaryngol.* 75, 813–820 (1971).

3 Chang S. Perfluorocarbon liquids in vitreoretinal surgery. *Int. Ophthalmol. Clin.* 32, 153–163 (1992).

4 Peyman GA, Schulman JA. In: *Intravitreal Surgery: Principles and Practice (2nd Edition).* Appleton & Lange, CT, USA 1 (1994).

5 Theocharis AD, Papageorgakopoulou N, Feretis E, Theocharis DA. Occurrence and structural characterization of versican-like proteoglycan in human vitreous. *Biochimie* 84(12), 1237–1243 (2002).

6 Mayne R, Brewton RG, Wright DW *et al.* Morphological and biochemical studies of the structure of the vitreous and the zonular fibres. *Biochem. Soc. Trans.* 19, 868–871 (1991).

7 Spitznas M, Reiver J. A stereoscopic diagonal inverter (SDI) for wide-angle vitreous surgery. *Graefes Arch. Clin. Exp. Ophthalmol.* 225, 9–12 (1987).

8 Spitznas M. A binocular indirect ophthalmomicroscope (BIOM) for wide-angle vitreous surgery. *Graefes Arch. Clin. Exp. Ophthalmol.* 225, 13–15 (1987).

9 Nakata K, Ohji M, Ikuno Y *et al.* Wide-angle viewing lens for vitrectomy. *Am. J. Ophthalmol.* 137(4), 760–762 (2004).

10 Chalam KV, Shah VA. Self-illuminated contact lens for peripheral vitreous surgery. *Ophthalmic Surg. Lasers Imaging* 35(1), 76–77, (2004).

11 Bovey EH, Gonvers M. A new device for noncontact wide-angle viewing of the fundus during vitrectomy. *Arch. Ophthalmol.* 113, 1572–1573 (1995).

12 Chalam KV, Shah VA. Two-piece, dual-purpose comprehensive contact lens for vitreous surgery. *Ophthalmic Res.* 37*(*4), 175–178, (2005).

13 Peyman GA, Canakis C, Livir-Rallatos C, Easley J. A new wide-angle endoillumination probe for use during vitrectomy. *Retina* 22, 242 (2002).

14 Chow DR. Shedding some light on current endoillumination. *Retinal Physician* 2, 37–39 (2005).

15 Oshima Y, Awh CC, Tano Y. Self-retaining 27-gauge transconjunctival chandelier endoillumination for panoramic viewing during vitreous surgery. *Am. J. Ophthalmol.* 143(1), 166–167 (2007).

16 de Smet MD, Mura M. Minimally invasive surgery-endoscopic retinal detachment repair in patients with media opacities. *Eye* (2007) DOI: 10.1038/sj.eye.6702710 (Epub ahead of print).

17 Peyman GA, Livir-Rallatos C, Canakis C, Easley J. A new high-speed pneumatic vitrectomy cutter. *Am. J. Ophthalmol.* 133(4), 568–569 (2002).

18 Flynn HW, Lee WG, Parel JM. Design features and surgical use of a cannulated extrusion needle. *Graefes Arch. Clin. Exp. Ophthalmol.* 227(4), 304–308 (1989).

19 Moorhead LC, Gardner TW, Lambert HM *et al*. Dynamic intraocular pressure measurements during vitrectomy. *Arch. Ophthalmol.* 123(11), 1514–1523 (2005).

20 Krzizok T. Fibrin glue for closing conjunctival wounds in ophthalmic surgery. *Ophthalmologe* 101(10), 1006–1010 (2004).

21 Alio JL, Gomez J, Mulet E, Bujanda MM, Martinez JM, Molina Y. A new acrylic tissue adhesive for conjunctival surgery: experimental study. *Ophthalmic Res.* 35(6), 306–312 (2003).

22 Shimada H, Nakashizuka H, Nakajima M, Mori R, Mizutani Y. Twenty-gauge transconjunctival vitrectomy. *Jpn J. Ophthalmol.* 49(3), 257–260 (2005).

23 Albini TA, Evans M, Lakhanpal RR, Javaheri M, Rao NA, Chong LP. Conjunctival epithelium in pars plana vitrectomy specimens. *Retina* 27(1), 55–58 (2007).

24 Tardif YM, Schepens CL, Tolentino FI. Vitreous surgery. XIV. Complications from sclerotomy in 89 consecutive cases. *Arch. Ophthalmol.* 95(2), 229–234 (1977).

25 Liu W, Huang SY, Zhang P, Tang SB, Li JQ, Zheng HL. Bioptic significance of incarcerated contents at sclerotomy sites during vitrectomy. *Retina* 24(3), 407–411 (2004).

26 Kreiger A, Straatsma B Foos R. Incisional complications in pars plana vitrectomy. *Mod. Prob. Ophthalmol.* 18, 210–233 (1977).

27 West JF, Gregor ZJ. Fibrovascular ingrowth and recurrent haemorrhage following diabetic vitrectomy. *Br. J. Ophthalmol.* 84(8), 822–825 (2000).

28 Kreiger A. The pars plana incision: experimental studies, pathologic observations, and clinical experience. *Trans. Am. Ophthalmol. Soc.* 89, 549–621 (1991).

29 Sabti K, Kapusta M, Mansour M, Overbury O, Chow D. Ultrasound biomicroscopy of sclerotomy sites: the effect of vitreous shaving around sclerotomy sites during pars plana vitrectomy. *Retina* 21(5), 464–468 (2001).

30 Hotta K, Hirakata A, Ohi Y *et al.* Ultrasound biomicroscopy for examination of the sclerotomy site in eyes with proliferative diabetic retinopathy after vitrectomy. *Retina* 20(1), 52–58 (2000).

31 Yeh PT, Yang CM, Yang CH, Huang JS. Cryotherapy of the anterior retina and sclerotomy sites in diabetic vitrectomy to prevent recurrent vitreous hemorrhage: an ultrasound biomicroscopy study. *Ophthalmology* 112(12), 2095–2102 (2005).

32 Yeshurun I, Rock T, Bartov E. Modified sutureless sclerotomies for pars plana vitrectomy. *Am. J. Ophthalmol.* 138(5), 866–867 (2004).

33 Rahman R, Rosen PH, Riddell C, Towler H. Self-sealing sclerotomies for sutureless pars plana vitrectomy. *Ophthalmic Surg. Lasers* 31(6), 462–466 (2000).

34 Schmidt JC, Meyer CH, Mennel S. Pars-plana vitrectomy with anterior chamber infusion via a paracentesis in pseudophakic eyes. *Ophthalmologe* 104(3), 222–225 (2007).

35 Morley AM, Pavesio C. Surgically induced necrotising scleritis following three-port pars plana vitrectomy without scleral buckling: a series of three cases. *Eye* (2007) DOI: 10.1038/sj.eye.6702708 (Epub ahead of print).

36 Chiambo S, Bailez Fidalgo C, Pastor Jimeno JC *et al.* Corneal epithelial complications after vitrectomy: a retrospective study. *Arch. Soc. Esp. Oftalmol.* 79(4), 155–161 (2004).

37 Hiraoka M, Amano S, Oshika T, Kato S, Hori S. Factors contributing to corneal complications after vitrectomy in diabetic patients. *Jpn J. Ophthalmol.* 45(5), 492–495 (2001).

38 Scott IU, Flynn HW Jr, Murray TG, Feuer WJ. Outcomes of surgery for retinal detachment associated with proliferative vitreoretinopathy using perfluoro-n-octane: a multicenter study. *Am. J. Ophthalmol.* 136(3), 454–463 (2003).

39 Friberg TR, Ohji M, Scherer JJ, Tano Y. Frequency of epithelial debridement during diabetic vitrectomy. *Am. J. Ophthalmol.* 135(4), 553–554 (2003).

- **Survey of active vitreoretinal surgeons was carried out to determine how often they intentionally debride the corneal epithelium during vitrectomy surgery for diabetic patients. Irrigating contact lenses were found to increase the need for epithelial debridement the most.**

40 Virata SR, Kylstra JA, Singh HT. Corneal epithelial defects following vitrectomy surgery using hand-held, sew-on, and noncontact viewing lenses. *Retina* 19(4), 287–290 (1999).

41 Garcia-Valenzuela E, Abdelsalam A, Eliott D *et al.* Reduced need for corneal epithelial debridement during vitreo-retinal surgery using two different viscous surface lubricants. *Am. J. Ophthalmol.* 136(6), 1062–1066 (2003).

42 Virata SR, Kylstra JA. Postoperative complications following vitrectomy for proliferative diabetic retinopathy with sew-on and noncontact wide-angle viewing lenses. *Ophthalmic Surg. Lasers* 32(3), 193–197 (2001).

43 Samuel MA, Desai UR, Strassman I, Abusamak M. Intraocular irrigating solutions. A clinical study of BSS Plus and dextrose bicarbonate fortified BSS as an infusate during pars plana vitrectomy. *Indian J. Ophthalmol.* 51(3), 237–242 (2003).

44 Mitamura Y, Yamamoto S, Yamazaki S.

Corneal endothelial cell loss in eyes undergoing lensectomy with and without anterior lens capsule removal combined with pars plana vitrectomy and gas tamponade. *Retina* 20(1), 59–62 (2000).

45 Schrader S, Wedel T, Moll R, Geerling G. Combination of serum eye drops with hydrogel bandage contact lenses in the treatment of persistent epithelial defects. *Graefes Arch. Clin. Exp. Ophthalmol.* 244(10), 1345–1349 (2006).

46 Yulek F, Ozdek S, Gurelik G, Hasanreisoglu B. Effect of topical steroids on corneal epithelial healing after vitreoretinal surgery. *Acta Ophthalmol. Scand.* 84(3), 319–322 (2006).

47 Rosenthal P, Cotter JM, Baum J. Treatment of persistent corneal epithelial defect with extended wear of a fluid-ventilated gas-permeable scleral contact lens. *Am. J. Ophthalmol.* 130(1), 33–41 (2000).

48 Gopal L, Nagpal A, Kabra S, Roy J. Anterior chamber collapse following vitreoretinal surgery with gas tamponade in aphakic eyes: incidence and risk factors. *Retina* 26(9), 1014–1020 (2006).

49 Kadonosono K, Matsumoto S, Uchio E, Sugita M, Akura J, Ohno S. Iris neovascularization after vitrectomy combined with phacoemulsification and intraocular lens implantation for proliferative diabetic retinopathy. *Ophthalmic Surg. Lasers* 32(1), 19–24 (2001).

50 Helbig H, Kellner U, Bornfeld N, Foerster MH. Rubeosis iridis after vitrectomy for diabetic retinopathy. *Graefes Arch. Clin. Exp. Ophthalmol.* 236(10), 730–733 (1998).

51 Rice TA, Michels RG, Maguire MG, Rice EF. The effect of lensectomy on the incidence of iris neovascularization and neovascular glaucoma after vitrectomy for diabetic retinopathy. *Am. J. Ophthalmol.* 95(1), 1–11 (1983).

52 Schiff WM, Barile GR, Hwang JC *et al.* Diabetic vitrectomy: influence of lens status upon anatomic and visual outcomes. *Ophthalmology* 114(3), 544–550 (2007).

53 Comaratta MR, Chang S, Sparrow J. Iris neovascularization in proliferative vitreoretinopathy. *Ophthalmology* 99(6), 898–905 (1992).

54 Avery RL, Pearlman J, Pieramici DJ *et al.* Intravitreal bevacizumab (Avastin) in the treatment of proliferative diabetic retinopathy. *Ophthalmology* 113(10), 1695 (2006).

- **Possible therapeutic effect found in the fellow eye raises concern that systemic side effects may occur in patients receiving intravitreal bevacizumab (1.25 mg). Doses as low as 6.2 µg may achieve a therapeutic result with lesser risk of systemic side effects.**

55 Oshima Y, Sakaguchi H, Gomi F, Tano Y. Regression of iris neovascularization after intravitreal injection of bevacizumab in patients with proliferative diabetic retinopathy. *Am. J. Ophthalmol.* 142(1), 155–158 (2006).

56 Grisanti S, Biester S, Peters S *et al.* Intracameral bevacizumab for iris rubeosis. *Am. J. Ophthalmol.* 142(1), 158–160 (2006).

57 Federman JL, Anand R. Surgical dilation of the pupil during pars plana vitrectomy. *Ophthalmic Surg.* 20(1), 46–48 (1989).

58 Chalam KV, Shah VA. Optics of wide-angle panoramic viewing system-assisted vitreous surgery. *Surv. Ophthalmol.* 49(4), 437–445 (2004).

59 Jackson H, Patel CK, Westcott M, Thompson GM, Mathalone BM. Does topical flurbiprofen affect the pupillary response to acetylcholine? *Eye* 8(3), 329–331 (1994).

60 Stewart R, Grosserode R, Cheetham JK, Rosenthal A. Efficacy and safety profile of ketorolac 0.5% ophthalmic solution in the prevention of surgically induced miosis during cataract surgery. *Clin. Ther.* 21(4), 723–732 (1999).

61 Backstrom G, Behndig A. Redilatation with intracameral mydriatics in phacoemulsification surgery. *Acta Ophthalmol. Scand.* 84(1), 100–104 (2006).

62 Liou SW, Chen CC. Maintenance of mydriasis with one bolus of epinephrine injection during phacoemulsification. *J. Ocul. Pharmacol. Ther.* 17(3), 249–253 (2001).

63 Tognetto D, Agolini G, Grandi G, Ravalico G. Iris alteration using mechanical iris retractors. *J. Cataract Refract. Surg.* 27(10), 1703–1705 (2001).

64 Kadonosono K, Ohno S. New iris retractor for pupil dilatation during anterior vitrectomy: double-hook iris retractor. *Ophthalmic Surg. Lasers* 30(3), 241–243 (1999).

65 Chong LP. A disposable iris retractor for vitrectomy. *Am. J. Ophthalmol.* 112(6), 731–732 (1991).

66 Arpa P. A new device for pupillary dilatation in vitreous surgery. *Retina* 12(Suppl. 3), S87–S89 (1992).

67 Pham DT, Volkmer C, Leder K, Wollensak J. Partial sphincterectomy in cataract surgery. Clinical and patho-histologic results. *Ophthalmologe* 95(9), 635–638 (1998).

68 Kozobolis VP, Pallikaris IG, Tsambarlakis IG, Vlachonikolis IG. Nd:YAG laser removal of pupillary membranes developed after ECCE with PC-IOL implantation. *Acta Ophthalmol. Scand.* 75(6), 711–715 (1997).

69 Sawa M, Saito Y, Hayashi A, Kusaka S, Ohji M, Tano Y. Assessment of nuclear sclerosis after nonvitrectomizing vitreous surgery. *Am. J. Ophthalmol.* 132(3), 356–362 (2001).

70 Sawa M, Ohji M, Kusaka S *et al.* Nonvitrectomizing vitreous surgery for epiretinal membrane long-term follow-up. *Ophthalmology* 112(8), 1402–1408 (2005).

71 Sima P, Zoran T. Long-term results of vitreous surgery for proliferative diabetic retinopathy. *Doc. Ophthalmol.* 87(3), 223–232 (1994).

72 Smiddy WE, Feuer W. Incidence of cataract extraction after diabetic vitrectomy. *Retina* 24(4), 574–581 (2004).

- **Rate of cataract extraction after vitrectomy was found to be lower in diabetics, suggesting a lower rate of cataract formation. Visual loss attributable to cataract maybe overestimated in diabetics undergoing vitrectomy.**

73 Thompson JT. The role of patient age and intraocular gas use in cataract progression after vitrectomy for macular holes and epiretinal membranes. *Am. J. Ophthalmol.* 137(2), 250–257 (2004).

74 Riedel KG, Gabel VP, Neubauer L, Kampik A, Lund OE. Intravitreal silicone oil injection: complications and treatment of 415 consecutive patients. *Graefes Arch. Clin. Exp. Ophthalmol.* 228(1), 19–23 (1990).

75 Federman JL, Schubert HD. Complications associated with the use of silicone oil in 150 eyes after retina-vitreous surgery. *Ophthalmology* 95(7), 870–876 (1988).

76 Heimann H, Bornfeld N, Friedrichs W *et al.* Primary vitrectomy without scleral buckling for rhegmatogenous retinal detachment. *Graefes Arch. Clin. Exp. Ophthalmol.* 234(9), 561–568 (1996).

77 Hsuan JD, Brown NA, Bron AJ, Patel CK, Rosen PH. Posterior subcapsular and nuclear cataract after vitrectomy. *J. Cataract Refract. Surg.* 27(3), 437–444 (2001).

78 Scharwey K, Pavlovic S, Jacobi KW. Early posterior capsule fibrosis after combined cataract and vitreoretinal surgery with intraocular air/SF_6 gas tamponade. *Klin. Monatsbl Augenheilkd.* 212(3), 149–153 (1998).

79 Kuszak JR, Sivak JG, Moran KL *et al.* Suppression of post-vitrectomy lens changes in the rabbit by novel benzopyranyl esters and amides. *Exp. Eye Res.* 75(4), 459–473

(2002).

80 Chalam KV, Shah VA, Tripathi RC. A curved vitrectomy probe. *Ophthalmic Surg. Lasers Imaging* 35(3), 259–260 (2004).

81 Weinberg RS, Peyman GA, Huamonte FU. Elevation of intraocular pressure after pars plana vitrectomy. *Graefes Arch. Klin. Exp. Ophthalmol.* 200, 157–161 (1976).

82 Campbell DG, Simmons RJ, Grant WM. Ghost cells as a cause of glaucoma. *Am. J. Ophthalmol.* 81, 441 (1976).

83 Phelps CD, Watzke RC. Hemolytic glaucoma. *Am. J. Ophthalmol.* 80, 690 (1975).

84 Singh H, Grand MG. Treatment of blood-induced glaucoma by trans pars plana vitrectomy. *Retina* 1(3), 255–257 (1981).

85 Al-Shahwan S, Ghadhfan F, Kalantan H, Al-Torbak AA. Pupillary block glaucoma in phakic perfluoropropane gas filled eye. *Br. J. Ophthalmol.* 90(6), 797–798 (2006).

86 Chen PP, Thompson JT. Risk factors for elevated intraocular pressure after the use of intraocular gases in vitreoretinal surgery. *Ophthalmic Surg. Lasers* 28(1), 37–42 (1997).

87 Ando F. Intraocular hypertension resulting from pupillary block by silicone oil. *Am. J. Ophthalmol.* 99, 87–88 (1985).

88 Kumar A, Kedar S, Garodia VK, Singh RP. Angle closure glaucoma following pupillary block in an aphakic perfluoropropane gas-filled eye. *Indian J. Ophthalmol.* 50, 220–221 (2002).

89 Yamamoto T, Hitani K, Tsukahara I *et al.* Early postoperative retinal thickness changes and complications after vitrectomy for diabetic macular edema. *Am. J. Ophthalmol.* 135(1), 14–19 (2003).

90 Chang S. LXII Edward Jackson lecture: open angle glaucoma after vitrectomy. *Am. J. Ophthalmol.* 141(6), 1033–1043 (2006).

91 Sugiyama W, Ando N. Anterior segment fluorescein angiography for evaluating the effect of vitrectomy for neovascular glaucoma. *Nippon Ganka Gakkai Zasshi.* 109(11), 741–747 (2005).

92 Krupin T, Mitchell KB, Becker B. Cyclocryotherapy in neovascular glaucoma. *Am. J. Ophthalmol.* 86, 24 (1978).

93 Scott IU, Alexandrakis G, Flynn HW Jr *et al.* Combined pars plana vitrectomy and glaucoma drainage implant placement for refractory glaucoma. *Am. J. Ophthalmol.* 129(3), 334–341 (2000).

94 Schachat AP, Oyakawa RT, Michels RG *et al.* Complications of vitreous surgery for diabetic retinopathy. II. Postoperative complications. *Ophthalmology* 90, 522 (1983).

95 Wu WC, Chang SM, Chen JY, Chang CW. Management of postvitrectomy diabetic vitreous hemorrhage with tissue plasminogen activator (t-PA) and volume homeostatic fluid–fluid exchanger. *J. Ocul. Pharmacol. Ther.* 17(4), 363–371 (2001).

96 Virata SR, Kylstra JA. Postoperative complications following vitrectomy for proliferative diabetic retinopathy with sew-on and noncontact wide-angle viewing lenses. *Ophthalmic Surg. Lasers* 32(3), 193–197 (2001).

97 Soto-Pedre E, Hernaez-Ortega MC, Vazquez JA. Risk factors for postoperative hemorrhage after vitrectomy for diabetic retinopathy. *Ophthalmic Epidemiol.* 12(5), 335–341 (2005).

98 Yeh PT, Yang CM, Yang CH, Huang JS. Cryotherapy of the anterior retina and sclerotomy sites in diabetic vitrectomy to prevent recurrent vitreous hemorrhage: an ultrasound biomicroscopy study. *Ophthalmology* 112(12), 2095–2102 (2005).

- **Retrospective analysis that shows a strong correlation between the presence of fibrovascular ingrowth as seen on ultrasound biomicroscopy study to the occurrence of vitreous hemorrhage after diabetic vitrectomy. It also evaluates the role of panretinal photocoagulation, anterior peripheral retinal cryotherapy and cryotherapy to ports in such cases.**

99 Hershberger VS, Augsburger JJ, Hutchins RK, Raymond LA, Krug S. Fibrovascular ingrowth at sclerotomy sites in vitrectomized diabetic eyes with recurrent vitreous hemorrhage: ultrasound biomicroscopy findings. *Ophthalmology* 111(6), 1215–1221 (2004).

100 Neely KA, Scroggs MW, McCuen BW 2nd. Peripheral retinal cryotherapy for postvitrectomy diabetic vitreous hemorrhage in phakic eyes. *Am. J. Ophthalmol.* 126(1), 82–90 (1998).

101 Hajji Z, Rouillot JS, Roth P, Grange JD. Should associated intraoperative and/or postoperative photocoagulation be systematic during or after vitrectomy for proliferative diabetic vitreoretinopathy? *J. Fr. Ophtalmol.* 26(1), 47–53 (2003).

102 Han DP, Murphy ML, Mieler WF, Abrams GW. Outpatient fluid–air exchange for severe postvitrectomy diabetic vitreous hemorrhage. Long-term results and complications. *Retina* 11(3), 309–314 (1991).

103 Yang CM, Yeh PT, Yang CH. Intravitreal long-acting gas in the prevention of early postoperative vitreous hemorrhage in diabetic vitrectomy. *Ophthalmology* 114(4), 710–715 (2007).

104 Jorge R, Costa RA, Calucci D, Cintra LP, Scott IU. Intravitreal bevacizumab (Avastin) for persistent new vessels in diabetic retinopathy (IBEPE study). *Retina* 26(9), 1006–1013 (2006).

105 Spaide RF, Fisher YL. Intravitreal bevacizumab (Avastin) treatment of proliferative diabetic retinopathy complicated by vitreous hemorrhage. *Retina* 26(3), 275–278 (2006).

106 Mason JO 3rd, Nixon PA, White MF. Intravitreal injection of bevacizumab (Avastin) as adjunctive treatment of proliferative diabetic retinopathy. *Am. J. Ophthalmol.* 142(4), 685–688 (2006).

107 Peyman GA, Raichand M, Huamonte FU *et al.* Vitrectomy in 125 eyes with diabetic vitreous hemorrhage. *Br. J. Ophthalmol.* 60, 752 (1976).

108 Peyman GA, Green JL, Carroll CP. A simplified approach to the management of tangential retinal traction bands. *Br. J. Ophthalmol.* 65, 414 (1981).

109 Christopher N. Minimizing the risk of endophthalmitis following intravitreous injections. *Retina* 24(5), 699–705 (2004).

110 Mamalis N, Kearsley L, Brinton E. Postoperative endophthalmitis. *Curr. Opin. Ophthalmol.* 13(1), 14–18 (2002).

111 Somani S, Grinbaum A, Slomovic AR. Postoperative endophthalmitis: incidence, predisposing surgery, clinical course and outcome. *Can. J. Ophthalmol.* 32(5), 303–310 (1997).

112 Cohen SM, Flynn HW Jr, Murray TG, Smiddy WE. Endophthalmitis after pars plana vitrectomy. The Postvitrectomy Endophthalmitis Study Group. *Ophthalmology* 102(5), 705–712 (1995).

113 Eifrig CW, Scott IU, Flynn HW Jr, Smiddy WE, Newton J. Endophthalmitis after pars plana vitrectomy: incidence, causative organisms, and visual acuity outcomes. *Am. J. Ophthalmol.* 138(5), 799–802 (2004).

114 Joondeph BC, Blanc JP, Polkinghorne PJ. Endophthalmitis after pars plana vitrectomy: a New Zealand experience. *Retina* 25(5), 587–589 (2005).

115 Zhang S, Ding X, Hu J, Gao R. Clinical features of endophthalmitis after vitreoretinal surgery. *Yan Ke Xue Bao* 19(1), 39–43 (2003).

116 Egger SF, Scholda C, Haddad R, Vecsei P, Huber-Spitzy V. Contamination of intraocular fluid in pars plana vitrectomy. *Ophthalmologe* 93(2), 126–129 (1996).

117 Zaninetti M, Baglivo E, Safran AB. Morganella morganii endophthalmitis after

vitrectomy: case report and review of the literature. *Klin. Monatsbl Augenheilkd.* 220(3), 207–209 (2003).

118 Wong TY, Chee SP. The epidemiology of acute endophthalmitis after cataract surgery in an Asian population. *Ophthalmology* 111(4), 699–705 (2004).

119 Speaker MG. Prophylaxis of endophthalmitis with topical povidone–iodine. *Ophthalmology* 98, 1769–1774 (1991).

120 Apt L, Isenberg SJ, Yoshimori R *et al.* The effect of povidone-iodine solution applied at the conclusion of ophthalmic surgery. *Am. J. Ophthalmol.* 119, 701–705 (1998).

121 Donnefeld ED, Perry HD. Cataract surgery: five ways to prevent endophthalmitis. *Rev. Ophthalmol.* 3, 67–72 (1996).

122 Liesegang TJ. Use of antimicrobials to prevent postoperative infection in patients with cataracts. *Curr. Opin. Ophthalmol.*12, 68–74 (2001).

123 Donahue SP, Kowalski RP, Jewart BH *et al.* Vitreous cultures in suspected endophthalmitis: biopsy or vitrectomy? *Ophthalmology* 100, 452–455 (1993).

124 Cuilla TA. Update on acute and chronic endophthalmitis. *Ophthalmology* 106, 2237–2238 (1999).

125 Baird DR, Henry M, Liddell KG, Mitchell CM, Sneddon JG. Post-operative endophthalmitis: the application of hazard analysis critical control points (HACCP) to an infection control problem. *J. Hosp. Infect.* 49(1), 14–22 (2001).

126 Griffith C. HACCP and the management of healthcare associated infections: are there lessons to be learnt from other industries? *Int. J. Health Care Qual. Assur. Inc. Leadersh. Health Serv.* 19(4–5), 351–367 (2006).

127 Sohajda Z, Orosi P, Hayfron J, Berta A. The role of infection control in the prevention of postoperative endophthalmitis. *Klin. Monatsbl Augenheilkd.* 223(8), 668–674 (2006).

128 Byeon SH, Chu YK, Lee SC, Koh HJ, Kim SS, Kwon OW. Problems associated with the 25-gauge transconjunctival sutureless vitrectomy system during and after surgery. *Ophthalmologica* 220(4), 259–265 (2006).

129 Rizzo S, Genovesi-Ebert F, Vento A, Miniaci S, Cresti F, Palla M. Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicroscopic study. *Graefes Arch. Clin. Exp. Ophthalmol.* DOI: 10.1007/s00417-006-0533-x (2007) (Epub ahead of print).

130 Brubaker RF, Pederson JE. Ciliochoroidal detachment. *Surv. Ophthalmol.* 27, 281 (1983).

131 Scott IU, Flynn HW Jr, Smiddy WE *et al.* Clinical features and outcomes of pars plana vitrectomy in patients with retained lens fragments. *Ophthalmology* 110(8), 1567–1572 (2003).

132 Cohen SM, Davis A, Cukrowski C. Cystoid macular edema after pars plana vitrectomy for retained lens fragments. *J. Cataract Refract. Surg.* 32(9), 1521–1526 (2006).

133 Gass JDM, Parrish R. Outer retinal ischemic infarction – a newly recognized complication of cataract extraction and closed vitrectomy. Part 1. A case-report. *Ophthalmology* 89, 1467 (1982).

134 Malinowski SM, Pesin SR. Visual field loss caused by retinal vascular occlusion after vitrectomy surgery. *Am. J. Ophthalmol.* 123(5), 707–708 (1997).

135 William SE, Luis G, Rogerio P, William F. Retinal detachment rate after vitrectomy for retained lens material after phacoemulsification. *Am. J. Ophthalmol.* 135(2), 183–187 (2003).

136 Schrey S, Krepler K, Wedrich A. Incidence of rhegmatogenous retinal detachment after vitrectomy in eyes of diabetic patients. *Retina* 26(2), 149–152 (2006).

137 Faulborn J, Conway B, Machemer R. Symposium: complications of modern surgical procedures: surgical complications of pars plana vitreous surgery. *Ophthalmology* 85, 116 (1978).

138 Michels RG. Vitrectomy for complications of diabetic retinopathy. *Arch. Ophthalmol.* 96, 237 (1978).

139 Schmidt JC, Nietgen GW, Hesse L, Kroll P. External diaphanoscopic illuminator: a new device for visualization in pars plana vitrectomy. *Retina* 20(1), 103–106 (2000).

140 Hudson HL, Chong LP, Frambach DA, Valencia M, Green RL, Lopez PF. Encircling panretinal laser photocoagulation may prevent macular detachment after vitrectomy for proliferative diabetic retinopathy. *Int. Ophthalmol.* 18(2), 101–104 (1994).

141 Haritoglou C, Kampik A. Staining techniques in macular surgery. *Ophthalmologe* 103(11), 927–934 (2006).

142 Guo S, Tutela AC, Wagner R, Caputo AR. A comparison of the effectiveness of four biostains in enhancing visualization of the vitreous. *J. Pediatr. Ophthalmol. Strabismus* 43(5), 281–284 (2006).

143 Matsumoto H, Yamanaka I, Hisatomi T *et al.* Triamcinolone acetonide-assisted pars plana vitrectomy improves residual posterior vitreous hyaloid removal: ultrastructural analysis of the inner limiting membrane. *Retina* 27(2), 174–179 (2007).

144 Feron EJ, Veckeneer M, Parys-Van Ginderdeuren R, Van Lommel A, Melles GR, Stalmans P. Trypan blue staining of epiretinal membranes in proliferative vitreoretinopathy. *Arch. Ophthalmol.* 120(2), 141–144 (2002).

145 Da Mata AP, Burk SE, Riemann CD *et al.* Indocyanine green-assisted peeling of the retinal internal limiting membrane during vitrectomy surgery for macular hole repair. *Ophthalmology* 108(7), 1187–1192 (2001).

146 Zheng Y, Sun N, Xiong Q, Wang X, Quan Y. Triamcinolone-assisted pars plana vitrectomy for retinal disease. *Yan Ke Xue Bao* 21(3), 142–146 (2005).

147 Uemoto R, Yamamoto S, Takeuchi S. Changes in retinal pigment epithelium after indocyanine green-assisted internal limiting lamina peeling during macular hole surgery. *Am. J. Ophthalmol.* 140(4), 752–755 (2005).

148 Cheng SN, Yang TC, Ho JD, Hwang JF, Cheng CK. Ocular toxicity of intravitreal indocyanine green. *J. Ocul. Pharmacol. Ther.* 21(1), 85–93 (2005).

149 Schmidt JC, Rodrigues EB, Meyer CH, Hoerle S, Kroll P. A modified technique to stain the internal limiting membrane with indocyanine green. *Ophthalmologica* 218(3), 176–179 (2004).

150 Mennel S, Thumann G, Peter S, Meyer CH, Kroll P. Influence of vital dyes on the function of the outer blood–retinal barrier *in vitro*. *Klin. Monatsbl Augenheilkd.* 223(7), 568–576 (2006).

151 Campo RV, Sipperley JO, Sneed SR *et al.* Pars plana vitrectomy without scleral buckle for pseudophakic retinal detachments. *Ophthalmology* 106(9), 1811–1815 (1996).

152 Hakin KN, Lavin MJ, Leaver PK. Primary vitrectomy for rhegmatogenous retinal detachment. *Graefes Arch. Clin. Exp. Ophthalmol.* 231(6), 344–346 (1993).

153 Boldt HC, Munden PM, Folk JC, Mehaffey MG. Visual field defects after macular hole surgery. *Am. J. Ophthalmol.* 122(3), 371–381 (1996).

154 Cullinane AB, Cleary PE. Prevention of visual field defects after macular hole surgery. *Br. J. Ophthalmol.* 84(4), 372–377 (2000).

155 Kanda S, Uemura A, Yamashita T, Kita H, Yamakiri K, Sakamoto T. Visual field defects after intravitreous administration of indocyanine green in macular hole surgery. *Arch. Ophthalmol.* 122(10), 1447–1451 (2004).

156 Ando F, Sasano K, Ohba N, Hirose H, Yasui O. Anatomic and visual outcomes after indocyanine green-assisted peeling of the

retinal internal limiting membrane in idiopathic macular hole surgery. *Am. J. Ophthalmol.* 137(4), 609–614 (2004).

157 Hirata A, Yonemura N, Hasumura T, Murata Y, Negi A. Effect of infusion air pressure on visual field defects after macular hole surgery. *Am. J. Ophthalmol.* 130(5), 611–616 (2000).

158 Yang SS, McDonald R, Everett AI, Johnson RN, Jumper JM, Fu AD. Retinal damage caused by air–fluid exchange during pars plana vitrectomy. *Retina* 26(3), 334–338 (2006).

159 Hirata A, Yonemura N, Hasumura T, Murata Y, Negi A, Tanihara H. New infusion cannula for prevention of retinal damage by infusion air during vitrectomy. *Retina* 23(5), 682–685 (2003).

160 Azzolini C, Brancato Y, Venturi G, Bandello F, Pece A, Santoro P. Updating on intraoperative light-induced retinal injury. *Int. Ophthalmol.* 269–276 (1994).

161 Kuhn F, Morris R, Massey M. Photic retinal injury from endoillumination during vitrectomy. *Am. J. Ophthalmol.* 111(1), 42–46 (1991).

162 Ghoraba HH, Zayed AI. Suprachoroidal hemorrhage as a complication of vitrectomy. *Ophthalmic Surg. Lasers* 32(4), 281–288 (2001).

163 Pollack AL, McDonald HR, Ai E *et al.* Massive suprachoroidal hemorrhage during pars plana vitrectomy associated with Valsalva maneuver. *Am. J. Ophthalmol.* 132(3), 383–387 (2001).

164 Becquet F, Caputo G, Mashhour B, Chauvaud D, Pouliquen Y. Management of delayed massive suprachoroidal hemorrhage: a clinical retrospective study. *Eur. J. Ophthalmol.* 6(4), 393–397 (1996).

165 Lee SC, Lee I, Koh HJ, Kim SH, Kwon OW. Massive suprachoroidal hemorrhage with retinal and vitreous incarceration; a vitreoretinal surgical approach. *Korean J. Ophthalmol.* 14(1), 41–44 (2000).

166 Peyman GA, Schulman JA. In: *Vitreous Substitutes.* Appleton & Lange, CT, USA 1–52 (1995).

167 Smith RC, Smith GC, Wong D. Refractive changes in silicone filled eyes. *Eye* 4, 230–234 (1990).

168 Dick HB, Schwenn O, Pavlovic S *et al.* Effect of head position on refraction in aphakic and phakic silicone-filled eyes. *Retina* 17, 397–402 (1997).

169 Kusaka S, Kodama T, Ohashi Y. Condensation of silicone oil on the posterior surface of a silicone intraocular lens during vitrectomy. *Am. J. Ophthalmol.* 121, 574–575 (1996).

170 Horgan SE, Cooling RJ. Irreversible silicone oil adhesion. *Ophthalmology* 104, 898–900 (1997).

171 Khawly JA, Lambert RJ, Jaffe GJ. Intraocular lens changes after short- and long-term exposure to intraocular silicone oil. An *in vivo* study. *Ophthalmology* 105(7), 1227–1233 (1998).

172 Ghoraba HH, El-Dorghamy AA, Atia AF, Ismail Yassin Ael A. The problems of biometry in combined silicone oil removal and cataract extraction: a clinical trial. *Retina* 22(5), 589–596 (2002).

173 Takei K, Sekine Y, Okamoto F, Hommura S. Measurement of axial length of eyes with incomplete filling of silicone oil in the vitreous cavity using x ray computed tomography. *Br. J. Ophthalmol.* 86, 47–50 (2002).

174 Murray D, Durrani O, Good P, Benson M, Kirkby G. Biometry of the silicone oil-filled eye: II. *Eye* 16(6), 727–730 (2002).

175 Grinbaum A, Treister G, Moisseiev J. Predicted and actual refraction after intraocular lens implantation in eyes with silicone oil. *J. Cataract Refract. Surg.* 22, 726–729 (1996).

176 el-Baha SM, el-Samadoni A, Idris HF, Rashad KM. Intraoperative biometry for intraocular lens (IOL) power calculation at silicone oil removal. *Eur. J. Ophthalmol.* 13(7), 622–626 (2003).

177 Habibabadi HF, Hashemi H, Jalali KH, Amini A, Esfahani MR. Refractive outcome of silicone oil removal and intraocular lens implantation using laser interferometry. *Retina* 25(2), 162–166 (2005).

178 Nepp J, Krepler K, Jandrasits K *et al.* Biometry and refractive outcome of eyes filled with silicone oil by standardized echography and partial coherence interferometry. *Graefes Arch. Clin. Exp. Ophthalmol.* 243(10), 967–972 (2005).

179 Friberg TR, Fanous MM. Migration of intravitreal silicone oil through a Baerveldt tube into the subconjunctival space. *Semin. Ophthalmol.* 19(3–4), 107–108 (2004).

180 Nazemi PP, Chong LP, Varma R, Burnstine MA. Migration of intraocular silicone oil into the subconjunctival space and orbit through an Ahmed glaucoma valve. *Am. J. Ophthalmol.* 132(6), 929–931 (2001).

181 Fangtian D, Rongping D, Lin Z, Weihong Y. Migration of intraocular silicone into the cerebral ventricles. *Am. J. Ophthalmol.* 140(1), 156–158 (2005).

182 Kuhn F, Kover F, Szabo I, Mester V. Intracranial migration of silicone oil from an eye with optic pit. *Graefes Arch. Clin. Exp. Ophthalmol.* 244(10), 1360–1362 (2006).

183 Yu JT, Apte RS. A case of intravitreal silicone oil migration to the central nervous system. *Retina* 25(6), 791–793 (2005).

184 Papp A, Toth J, Kerenyi T, Jackel M, Suveges I. Silicone oil in the subarachnoidal space – a possible route to the brain? *Pathol. Res. Pract.* 200(3), 247–252 (2004).

185 Moisseiev J, Bartov E, Cahane M *et al.* Cataract extraction in eyes filled with silicone oil. *Arch. Ophthalmol.* 110, 1649–1651 (1992).

186 Lucke K, Laqua H. In: *Silicone Oil in the Treatment of Complicated Retinal Detachments: Techniques, Results and Complications.* Springer-Verlag, NY, USA 21–24 (1990).

187 Franks WA, Leaver PK. Removal of silicone oil: rewards and penalties. *Eye* 5, 333–337 (1991).

188 Abrams GW, Azen SP, Barr CC *et al.* The incidence of corneal abnormalities in the Silicone Study. Silicone Study Report 7. *Arch. Ophthalmol.* 113(6), 764–769 (1995).

- **Probably the first study to document that the incidence rates of corneal abnormalities are equivalent with the use of either oil or gas tamponade. Successful surgical repair of the retinal detachment and prevention of corneal touch by oil were thought to prevent corneal abnormalities.**

189 Karel I, Kalvodova B. Long-term results of pars plana vitrectomy and silicone oil for complications of diabetic retinopathy. *Eur. J. Ophthalmol.* 4(1), 52–58 (1994).

190 Kertes PJ, Peyman GA, Chou F *et al.* The use of tissue plasminogen activator in silicone oil-filled eyes. *Can. J. Ophthalmol.* 33, 28–29 (1998).

191 Madreperla SA, McCuen BW. Rate of closure of surgical inferior peripheral iridectomy and effect on silicone oil position in eyes treated with silicone oil extended tamponade. *Invest. Ophthalmol. Vis. Sci.* 35(Suppl.), 2071 (1994).

192 MacCumber MW, Packo KH, Civantos JM, Greenberg JB. Preservation of anterior capsule during vitrectomy and lensectomy for retinal detachment with proliferative vitreoretinopathy. *Ophthalmology* 109(2), 329–333 (2002).

193 Boscia F, Cardascia N, Sborgia L *et al.* Evaluation of corneal damage by combined phacoemulsification and passive efflux of silicone oil in vitrectomized eyes. *J. Cataract Refract. Surg.* 29(6), 1120–1126 (2003).

194 Barr CC, Lai MY, Lean JS *et al.* Postoperative intraocular pressure abnormalities in the Silicone Study. Silicone Study Report 4. *Ophthalmology* 100, 1629–1635 (1993).

195 Al-Jazzaf AM, Netland PA, Charles S. Incidence and management of elevated intraocular pressure after silicone oil injection. *J. Glaucoma* 14(1), 40–46 (2005).

196 Popovic Suic S, Sikic J, Pokupec R. Intraocular pressure values following vitrectomy with silicone oil tamponade. *Acta Med. Croatica* 59(2), 143–146 (2005).

197 Budenz DL, Taba KE, Feuer WJ *et al.* Surgical management of secondary glaucoma after pars plana vitrectomy and silicone oil injection for complex retinal detachment. *Ophthalmology* 108(9), 1628–1632 (2001).

198 Honavar SG, Goyal M, Majji AB, Sen PK, Naduvilath T, Dandona L. Glaucoma after pars plana vitrectomy and silicone oil injection for complicated retinal detachments. *Ophthalmology* 106(1), 169–176 (1999).

199 Moisseiev J, Barrack A, Manaim T, Treister G. Removal of silicone oil in the management of glaucoma in eyes with emulsified silicone. *Retina* 13, 290–295 (1993).

200 Nakamura K, Refojo MF, Crabtree DV. Factors contributing to the emulsification of intraocular silicone and fluorosilicone oils. *Invest. Ophthalmol. Vis. Sci.* 31, 647–656 (1990).

201 Heidenkummer HP, Kampik A, Theirfelder S. Emulsification of silicone oils with specific physiochemical characteristics. *Graefes Arch. Clin. Exp. Ophthalmol.* 229, 88–94 (1991).

- **Eight different silicone oils in terms of their rate of emulsification with viscosities between 1000 and 10,000 cSt were tested with different emulsifiers. Purified polydimethylsiloxane of high viscosity showed least emulsification.**

202 Charles S. In: *Vitreous Microsurgery (2nd Edition).* Williams & Wilkins, MD, USA 146–147 (1987).

203 Fredman Jl, Schubert HD. Complications associated with the use of silicone oil in 150 eyes after retina–vitreous surgery. *Ophthalmology* 95, 870–876 (1988).

204 Hutton WL, Azen SP, Blumenkranz MS *et al.* The effects of silicone oil removal. Silicone Study Report 6. *Arch. Ophthalmol.* 112, 778–785 (1994).

205 Jonas JB, Knorr HLJ, Rank RM, Budde WM. Retinal redetachment after removal of intraocular silicone oil tamponade. *Br. J. Ophthalmol.* 85, 1203–1207 (2001).

206 Wong D, Cazabon S, Ali H *et al.* Can the sequential use of conventional silicone oil and heavy oil be a strategy for the management of proliferative vitreoretinopathy? *Ann. Acad. Med. Singapore* 35(3), 181–184 (2006).

207 Sandner D, Engelmann K. First experiences with high-density silicone oil (Densiron) as an intraocular tamponade in complex retinal detachment. *Graefes Arch. Clin. Exp. Ophthalmol.* 244(5), 609–619 (2006).

208 Theelen T, Tilanus M, Klevering JB. Intraocular inflammation following endotamponade with high-density silicone oil. *Graefes Arch. Clin. Exp. Ophthalmol.* 242(7), 617–620 (2004).

209 Yanyali A, Celik E, Horozoglu F, Oner S, Nohutcu AF. 25-gauge transconjunctival sutureless pars plana vitrectomy. *Eur. J. Ophthalmol.* 16(1), 141–147 (2006).

210 Fujii GY, De Juan E Jr, Humayun MS *et al.* Initial experience using the tranconjunctival sutureless vitrectomy system for vitreoretinal surgery. *Ophthalmology* 109(10), 1814–1820 (2002).

211 Romero P, Salvat M, Almena M, Baget M, Mendez I. Experience with 25-gauge transconjunctival vitrectomy compared to a 20-gauge system. Analysis of 132 cases. *J. Fr. Ophtalmol.* 29(9), 1025–1032 (2006).

212 Lakhanpal RR, Humayun MS, de Juan E Jr *et al.* Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. *Ophthalmology* 112, 817–824 (2005).

213 Kwok AK, Tham CC, Loo AV, Fan DS, Lam DS. Ultrasound biomicroscopy of conventional and sutureless pars plana sclerotomies: a comparative and longitudinal study. *Am. J. Ophthalmol.* 132(2), 172–177 (2001).

214 Raju B, Raju NSD, Raju AS. 25 gauge vitrectomy under topical anesthesia: a pilot study. *Ind. J. Ophthalmol.* 54(3), 185–188 (2006).

215 Gonzales CR, Boshra J, Schwartz SD. 25-gauge pars plicata vitrectomy for stage 4 and 5 retinopathy of prematurity. *Retina* 26(7), S42–S46 (2006).

216 Bhatnagar P, Fine HF, Van Ho I. Evolutionary and revolutionary trends in vitreoretinal surgery. *Retinal Physician* 2, 37–39 (2005).

217 O'Reilly P, Beatty S. Transconjunctival sutureless vitrectomy: initial experience and surgical tips. *Eye* (2006) (Epub ahead of print).

218 Stewart JM. Wound integrity and the conjunctiva in prevention of endophthalmitis following sutureless 25-gauge vitrectomy. *Eye* 20(12), 1490 (2006).

219 Taban M, Ufret-Vincenty RL, Sears JE. Endophthalmitis after 25-gauge transconjunctival sutureless vitrectomy. *Retina* 26(7), 830–831 (2006).

220 Taylor SR, Aylward GW. Endophthalmitis following 25-gauge vitrectomy. *Eye* 19(11), 1228–1229 (2005).

221 Shimada H, Nakashizuka H, Mori R, Mizutani Y. Expanded indications for 25-gauge transconjunctival vitrectomy. *Jpn J. Ophthalmol.* 49(5), 397–401 (2005).

222 Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. *Retina* 25(2), 208–211 (2005).

223 Staubach F, Nober V, Janknecht P. Enzyme-assisted vitrectomy in enucleated pig eyes: a comparison of hyaluronidase, chondroitinase, and plasmin. *Curr. Eye Res.* 29(4–5), 261–268 (2004).

224 Tanaka M, Qui H. Pharmacological vitrectomy. *Semin. Ophthalmol.* 15(1), 51–61 (2000).

225 Hesse L, Chofflet J, Kroll P. Tissue plasminogen activator as a biochemical adjuvant in vitrectomy for proliferative diabetic vitreoretinopathy. *Ger. J. Ophthalmol.* 4(6), 323–327 (1995).

Websites

301 Thrombogenics www.thrombogenics.com/html/products1eye.html

302 Lynda Charters. Is there more risk with 25-gauge vitrectomy? (As discussed with Kunimoto DY). Ophthalmology Times/Special Report. Mar 1, 2007 www.ophthalmologytimes.com/ophthalmologytimes/article/articledetail.jsp?id=410646.

- **A 12-fold higher incidence of endophthalmitis found after 25-G vitrectomy compared with 20-G vitrectomy in a study of 8601 eyes.**

303 Promising Microplasmin Phase IIa results www.thrombogenics.com/documents/06_tg_12mivi-icapetownfinalen.pdf

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