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The Post Vitrectomy Cataract

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Abstract

To review the recent literature regarding risk factors for cataract formation after vitrectomy, the challenges and management strategies for anterior segment surgeons when facing post-vitrectomy cataract surgery, and the visual outcomes of patients undergoing post-vitrectomy cataract surgery. Cataract surgery after vitrectomy can be safely performed to significantly improve the visual outcome in most post-vitrectomy patients, although final visual acuity is primarily limited by the patient's underlying vitreoretinal pathology.

Overview

With the introduction of small gauge vitrectomy allowing for the treatment of vitreoretinal diseases while minimizing surgical risk, the number of vitrectomies has increased, with over 225,000 being performed each year in the United States for the management of macular holes, vitreous opacities, vitreous hemorrhages, retinal detachments, and epiretinal membranes.[1] As such, the incidence of vitrectomy-associated complications including cataract progression has also been increasing. The rate at which a post-vitrectomy cataract develops has been linked to various risk factors and pathophysiological mechanisms. It is estimated that within one year of vitrectomy, as many as 52% of patients will undergo cataract surgery while 80% of patients will develop a visually significant cataract within two years.[2, 3] Removal of these cataracts is critical for continued monitoring of the posterior segment and full visual rehabilitation; however, these cataracts present unique challenges and increased risks of intraoperative complications for which the anterior segment surgeon should be prepared.

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Pathophysiology and Risk Factors for Cataract Development after Vitrectomies

Cataracts are generally caused by natural aging, nutritional or metabolic disorders, inflammation, or trauma. Nuclear sclerotic cataracts are the most common form of cataracts encountered after vitrectomies, especially in patients over 50 years of age. [4] The exact pathogenesis for cataract development after vitrectomy has not been fully elucidated and is often multifactorial. Prior research has identified factors including oxidation of lens proteins, length of operative time, light toxicity, and use of intraocular gas.[5–7] More recent studies have suggested that vitrectomy leads to increased oxygen tension in the eye, allowing for cataract progression due to oxidation of the lens fibers.[8, 9] Additionally, certain cytokines can accumulate in the anterior chambers of post-vitrectomized eyes, changing the micro-environment and facilitating cataract development.[10] DNA methylation has also been shown to play a role in this process, where the hypermethylation of the aA-crystallin gene in the CpG islands reduces its expression, promoting the formation of cataracts.[11] Perhaps most importantly, direct trauma to the peripheral or posterior lens capsule by surgical instruments is a prominent cause of post-vitrectomy cataracts. Accidental contact can rupture the posterior capsule allowing for hydration of the cortex and result in rapid progression to a near-white opacified cataracts.[4] Some vitreoretinal surgeons have considered leaving the anterior hyaloid during a vitrectomy in order to minimize direct or indirect trauma to the lens after a vitrectomy. The gauge of vitrectomy does not appear to affect the rate of cataract formation.[15, 16]

The use of tamponade agents such as intraocular gas or silicone oil have also been associated with an increased risk of post-vitrectomy lens opacification.[12, 13] Of the two, intraocular gas tamponade may contribute to transient feathering of the lens while silicone oil can cause subcapsular opacification.[12] Lens feathering can occur within 24 hours and typically resolves within 4–6 weeks. It has been hypothesized that increased gas tension or decreased humidity may affect the Na+/K+ ATPase pumps that deturgese the lens, resulting in excess intra- and extracellular fluid overload in the posterior lens fibers.[14] In contrast, subcapsular opacities typically occur after 10 weeks and tend to persist over time.[14] If young patients develop cataracts, they tend to be posterior subcapsular cataracts while patients over 50 are more likely to develop or experience worsening of their preexisting nuclear sclerotic cataracts.[14]

While diabetics tend to develop cataracts earlier, perhaps counterintuitively, the presence of diabetes has been reported to be protective against post-vitrectomy cataract formation due to the lower ocular oxygen tension in these eyes. These changes in ocular physiology often take place due to the altered viscosity in the vitreous cavity post-vitrectomy, which causes oxygen to diffuse more rapidly down a gradient from the anterior to the posterior segment. A similar trend is seen with the concentration of ascorbate in the vitreous cavity, which is reduced along the same gradient in the vitrectomized patient. This physiologic change can result in a slower progression of post-vitrectomy cataracts in diabetic patients.[17–19]

Prevention of Post-Vitrectomy Cataracts

As oxidative damage is known to play a major role in the development of cataract, multiple studies have investigated the use of antioxidants to prevent age-related cataract and post-vitrectomy cataracts. One such study investigated the use of N-acetylcysteine eyedrops dosed at 20 mM–40 mM, which significantly reduced hyperoxia-induced cortical lens opacification in a rabbit model.[20] On the other hand, results of daily supplementation with 500mg oral vitamin C did not prevent age-related cataract changes—although mechanistically, post-vitrectomy eyes may be predicted to demonstrate a greater effect, no formal controlled studies have been completed in this specific patient population to date. [21]

Other methods to reduce post-vitrectomy cataracts include a novel irrigation solution containing benzopyranyl esters and amides, which in a rabbit animal model prevented abnormal post-vitrectomy posterior lens fiber changes.[22] Lastly, maintaining "face-down" positioning to reduce direct contact of the gas and the lens post-surgery has been shown to reduce post-vitrectomy cataract formation after gas tamponade.[23]

Challenges to Anterior Segment Surgeon

Preoperative Counseling

The first challenge the anterior segment surgeon faces when performing cataract surgery on post-vitrectomy patients is management of the patient's expectations. It is critical that patients are educated on the higher risk of intraoperative complications, possible need for additional procedures, and fully understand their final visual acuity may be limited by their posterior segment pathology. Detailed and complete counseling regarding expectations for visual gains by the anterior segment surgeon is critical. With appropriate expectations, cataract surgery is often both recommended and required as the next step for visual rehabilitation and continued monitoring of the posterior segment. Communication with the vitreoretinal surgeon in these cases is key, as some decisions affect surgical planning, such as long-term use of silicone oil.

Biometry and IOL Selection

The second challenge is intraocular (IOL) lens selection. In patients with posterior pathology where contrast sensitivity may already be reduced due to retinal dysfunction, selecting a monofocal lens is almost universally the best option to maximize visual potential. Additional considerations include difficultly obtaining reliable biometry and the higher rate of late in-the-bag dislocation in post-vitrectomized eyes, all which argue against multifocal lens placement where even minor decentration can be visually significant.[3] As the vast majority of multifocal lenses are one-piece IOLs, they are also less amenable to typical rescue techniques such as Yamane scleral-fixation, limiting rescue options to lasso techniques.[24] Furthermore, as the retinal surgeon's view is correlated to the type of intraocular lens, diffractive IOLs may interfere with the intraoperative view should the need for further posterior segment surgery arise.[25]

In patients with highly myopic or staphylomatous eyes, optical biometry has proven to be more precise and repeatable than applanation ultrasound biometry. In other words, patients with altered parameters such as longer axial lengths, increased anterior chamber depths, poor preoperative visual acuities, and preoperative foveal detachments tended to have more consistent measurements with optical biometry than ultrasound biometry due to myopic shifts. It is recommended, therefore, that IOL calculations be done with an optical biometry whenever possible and a careful lens selection is done in these groups, as their postoperative refraction can be difficult to predict.[26, 27]

Intraocular tamponades may affect predicted IOL outcomes. Replacement of the vitreous with balanced salt solution can induce a refractive change of −0.13 to −0.50 diopters.[31] Silicone oil has a higher refractive index than aqueous fluid and can induce −6.7 to −7.4 diopters of myopia in aphakic eyes, +3 to +3.85 diopters of hyperopia in pseudophakic eyes, and +5.25 to +5.57 diopters in phakic eyes.[32] This difference can be explained by the fact that with equiconvex lenses, the front and back surfaces each provide half of the total lens power. In the standard biconvex IOL, the refractive index is around 1.47 (close to that of silicone oil's 1.41), so the back part of the lens does not provide that additional refractive power, resulting in a substantial loss of effective lens power.

Studies such as by Tan et al concluded that silicone-oil filled eyes also made obtaining lens calculations more challenging due to the optical and sound attenuation properties of silicone oil. Fortunately, analyses have shown that the use of optical biometers with newer fourth generation formulas resulted in no difference in the predictive error or difference between the postoperative and formula-predicted spherical equivalent in eyes that previously had silicone oil tamponade.[28] However, not all eyes are amenable to optical biometry and ultrasound biometry sometimes must be used, usually in the context of very dense lenses or in the presence of vitreous opacities. The axial length (AL) can be separately measured for each ocular segment, with subsequent velocity conversions as have been previously published.[29] Another approach is that if ultrasound biometry is performed with a silicone oil-filled eye (1300 centistokes), the measured axial length can be multiplied by 0.71 to obtain the true axial length (or by 0.64 for 1000 centistokes silicone oil).[30]

Prior to undergoing cataract surgery, a discussion should be made with the vitreoretinal surgeon to determine whether the oil will likely be retained or removed in the future. For those with planned long-term oil, the intraocular lens used would preferably not be made of silicone or be hydrophilic. Silicone oil droplets can adhere to the surface of silicone lenses.[35] Scanning electron microscopy have also demonstrated that calcium phosphate crystallites and silicone oil can deposit on the surface or within hydrophilic lenses.[33, 34] For the reasons mentioned above, it is ideal to choose a convex-plano lens to avoid the loss of power of the part of the lens in contact with the oil, and then use formulas to further adjust for the refractive index of the oil. As described by Meldrum et al, and further expanded on by Dr. Warren Hill, this would typically require adding between +3.0 to +3.5 D to the power of the lens.[36, 37] If using a biconvex lens, then increasing power adjustments would be necessary, but a rule of thumb is to aim for about 4-diopters more myopic than intended.

In cases of good visual potential with a desire for spectacle independence, evaluation for monovision can be considered. Patients who undergo a gradual myopic shift after vitrectomy may be ideal candidates for monovision as the longer interval between pars plana vitrectomy

(PPV) and cataract surgery may favor adaptation to monovision, or at least serve as a monovision trial. [38, 39]

Intraoperative Complications

The anterior segment surgeon should be prepared for an increased risk of intraoperative complications. Without the support provided by the vitreous face, the posterior capsule and zonules can be excessively mobile with increased anterior-posterior movement, sometimes referred to as trampolining,[3, 40] which can also make the posterior capsule be more prone to rupture. Various rates of posterior capsular rupture (PCR) have been reported, ranging from 13.3% in a small series of 6 eyes, to a non-statistically significant 1.49% in a large series of 2261 eyes by Soliman et al.[13, 41] However, the rate of post-vitrectomy zonular dialysis (1.3% in PPV group vs 0.6% in control) and dropped nuclear fragments (0.6% in PPV group vs 0.2% in control, $P<0.0001$) were both clinically significant in the Soliman series.[13] This difference underscores that without the increased viscosity or buoyancy of the vitreous, even with a similar rate of PCR, there may still be a greater risk of dropped nuclear fragments in post-vitrectomized eyes since nuclear fragments can proceed rapidly to the posterior cavity before scaffold maneuvers or viscoelastic can be used to levitate them back into the anterior segment for phacoemulsification.

In eyes that may already be myopic with deep anterior chambers, the addition of zonular weakness can lead to large shifts in the anterior chamber depth (ACD). When dramatic, this may also cause zonular traction and even zonular trauma, compounding overall capsular instability.[42] The surgeon can lower the infusion pressure to minimize retropulsion of the lens and excess force on the zonules.[41, 43] In contrast, AC instability can also lead to posterior bowing of the zonular fibers and lens, potentially causing lens-iris diaphragm retropulsion syndrome (LIDRS). This condition can be prevented by increasing vitreous volume through the use of an intravitreal injection through the pars plana with a small needle using a standard technique.[44]

In patients with prior silicone oil tamponades, severe anterior capsule rigidity may be encountered, so the use of anterior capsular staining is recommended. Various techniques have been described using retinal scissors, vannas scissors, or vitrectors to puncture this rigid capsule and create a rhexis.[3, 45] This may lead some to consider Femtosecond Laser-Assisted Cataract Surgery, or FLACS. In the case series of 24 eyes by Wang et al, it was noted that all capsulorrhexis were completed without tags or tears, though there was no discussion regarding the choice of FLACS specifically to manage anterior capsular rigidity.[46, 47] If the patient has previously had a gas or silicone oil tamponade, or if there are any posterior capsular defects, then FLACS will need to be performed with an increased posterior safety margin to protect the posterior capsule.[48] Of note, the presence of silicone oil in the anterior chamber can alert the surgeon of potential zonular weakness, and the media opacity may lead to an incomplete anterior capsulotomy with the use of FLACS.[49] In this same manner, oil may obstruct the view during cataract surgery if it has migrated anteriorly, so the judicious use of viscoelastic is recommended. Small anterior chamber silicone oil bubbles can be removed by irrigating the anterior chamber with balanced salt solution and allowing the oil to egress through a superior paracentesis. Finally, the posterior pressure of the silicone oil can generate issues, especially after the nucleus has been removed from the capsular bag, so extra care must be used towards the end of surgery for cortical removal.

As post-vitrectomy eyes have a higher incidence of possible preexisting posterior capsule defects from accidental intraoperative lens touch, gentle hydrodissection and hydrodelineation should be performed with careful attention to capsular distention. Even aggressive hydrodelination can extend a preexisting defect and lead to dropped nuclear fragments.

As nuclear disassembly proceeds, maneuvers that push the lens or increase zonular tension should be avoided during surgery. Recommended techniques include "phaco chop", "quick-chop", and "horizontal chop." Studies suggest that the "phaco chop" technique is more suitable for vitrectomized eyes as the movements are farther from the zonules, reducing the chances of broken zonules and subsequently potential bag subluxation or PC rent due to excess stress in the absence of vitreous support.[50, 51] If extensive zonular damage is suspected, and it is determined that nuclear disassembly would be unsafe with conventional chopping techniques or use of the miLOOP device (Carl Zeiss Inc. Dublin, CA), then manual small incision cataract surgery (MSICS) may be the preferred technique. Studies on MSICS in post-vitrectomized eyes are limited but demonstrate success in preventing nuclear drop.[52, 53] In a head-to-head comparison of 116 vitrectomized eyes that underwent cataract extraction via nuclear expression versus phacoemulsification, there was no significant difference in intraoperative complications or visual acuity gains.[54]

In addition to rigid anterior capsules, rigid posterior plates can also be frequently encountered, propagating an anterior crack through this fibrous posterior plate can become quite difficult.[13, 55, 56] Even femtosecond laser-assisted lens fragmentation often does not fully segment through the dense plate due to the posterior safety margin. Efforts to break residual connecting fibers between nuclear segments require larger mechanical forces and risk zonular dialysis in eyes that may already have underlying zonular damage. One option to assure bisection of a leathery posterior plate is the use of the miLOOP device, a flexible retractable nitinol loop that centripetally (out-to-in or back-to-front) rather than centrifugally divides the nucleus, minimizing capsular stress.[57] A variant on the standard technique termed "piggyback miLOOP" was reported for use in hypermature cataracts, whereby the nucleus is prolapsed anteriorly through the capsulorhexis, an IOL scaffold is placed below the nucleus, and then the miLOOP is brought into the anterior chamber to segment the nucleus. The reported advantage of the piggyback technique is that it still assures segmentation of the leathery posterior plate while avoiding the risks of guiding the device behind a dense lens with minimal protective epinuclear shell or poor view for proper alignment of the loop.[58]

Lastly, removal of cortical material can be difficult due to the lack of countertraction on the posterior capsule. [3] The use of bimanual irrigation/aspiration (I/A), which separates the cortical lens material after phacoemulsification, can help with this issue.[59]

Prior to intraocular lens placement, a thorough evaluation of the capsular support is needed. Even with an intact capsular bag for an in-the-bag placement or an intact anterior capsule sufficient for sulcus lens placement and optic capture, if significant zonulopathy is observed or suspected, then zonular support or secondary intraocular lens (IOL) options should be considered, as late in-the-bag dislocation is more common in post-vitrectomized eyes and has been reported up to 8.5 years later.[3] This longer latency period suggests that the damage caused to the zonular apparatus is not stationary and can progress for years until the capsular support finally fails in the form of "spontaneous" IOL dislocation. Rates of IOL decentration after vitrectomy ranges in the literature from 2.0% to 2.9%.[56, 60, 61] Some preventative options may include sutured or in-the-bag capsular tension segments and capsular tension rings, sulcus-sutured, scleral fixated, or anterior chamber IOLs when significant phacodonesis is observed or expected. Placement of a capsular tension ring (CTR) may assist in planning rescue fixation procedures should a late in-the-bag dislocation occur, even when using single piece IOLs, and therefore surgeons are recommended to have a low threshold to place a CTR if zonulopathy is observed. These advanced techniques should be considered in the appropriate patient, but many times, it can be difficult to predict preoperatively, so the surgeon must have the ability and tools available to manage any unexpected complications.[3]

Visual Outcomes

In the largest study of phacoemulsification in vitrectomized versus non-vitrectomized eyes (n =2,221 vs 135,533), results showed that despite vitrectomized patients having a larger visual gains with 66.5% gaining more than 0.3 logMAR units or ~3 Snellen lines, they still had overall worse average visual outcomes (on average 0.48 logMAR or roughly 20/60) due to the limitations of preexisting vitreoretinal pathology and a lower overall baseline vision.[13] In comparison, only 59.6% of non-vitrectomized eyes gained more than 0.3 logMAR units, but their final visual acuity was on average 0.22 logMAR (approximately 20/30).

Similarly, large visual gains after phacoemulsification in vitrectomized patients were also seen in a smaller study of 87 patients, with Rey et al reporting that 91% of vitrectomized eyes gained two or more lines. However, in their study, even 95% achieved visual acuity ≥ 20/40. In terms of perioperative complications, the study found no cases of nuclear fragmentation or zonular dehiscence.[62]

Certain postoperative complications are more common among post-vitrectomy patients. These include cystoid macular edema, posterior capsular opacification (PCO), recurrent retinal detachment, and IOL decentration.[56, 60, 63] In a retrospective study of 149 previously vitrectomized eyes, Chiras et al reported a 4% rate of macular edema as compared to just 1.5% in the non-vitrectomized reference group. With regards to PCO requiring YAG laser capsulotomy, rates varied from 6% to 33%.[56, 63] The higher rate has been attributed to increased postoperative inflammation and loss of vitreous compression of the posterior capsule.[63] Retinal re-detachment rates varied from 0% to 5.2% and have been attributed to development of new anterior breaks which were hypothesized to occur due to stress on the vitreous base from large fluctuations in AC depth from an unstable iris lens-diaphragm and increased risk of posterior capsular ruptures.[60, 64]

The Special Case of Combined Surgery

Given the high concordance and eventual need for cataract surgery, a combined cataract surgery with a vitrectomy (phacovitrectomy) is becoming increasingly popular, especially in centers with limited operating room availability. According to U.K. national database searches, 23% of patients undergoing membrane peels for vitreomacular traction had concurrent cataract surgery and 11.7% of phakic eyes undergoing PPV for a retinal detachment (RD) underwent a combined procedure.[2]

A recent meta-analysis of combined versus sequential cataract surgery and vitrectomy identified no significant differences in the visual results when choosing either approach. Even though the overall complication rates were similar, the sequential group had a higher proportion of posterior capsular tears and the combined group had higher rates of synechia and fibrin formation.[65] In terms of refractive outcomes, there was a trend towards postoperative myopia,[66] especially for high myopes and those with macula-involving retinal detachments. This trend was seen with both ultrasound and optical biometry. Alternatively, sequential surgery has the benefit of allowing surgeons to account for a change in axial length after vitreoretinal surgeries and adjust the IOL power to provide more predictable results.

For toric IOLs, several studies have demonstrated improved visual results and long-term stability of toric lenses in patients undergoing phacovitrectomies, with 85% being within 5 degrees of target, 95% within 15 degrees, and 57% experiencing astigmatism-reducing effect compared to 65% with cataract surgery alone.[67, 68] However, these studies were limited by small sample sizes. Combined phacovitrectomies with a toric IOL may be a reasonable option, but larger reports on the predictability of final outcomes are lacking.

Discussion

After PPV, patients are at higher risk for cataract progression and the majority will likely require phacoemulsification within the next 2 years. This paper reviewed recent literature to summarize risk factors for cataract formation after surgery (such as preexisting nuclear sclerosis, older age, and type of tamponade agents) and challenges and strategies that surgeons face in this clinical scenario (like use of regional anesthesia, FLACS, maintenance of anterior chamber stability, techniques to perform capsulorhexis, proper lens selection, and lens power calculations). In the determination of IOL selection after vitrectomy, the main considerations are for zonular stability and the presence of silicone oil.

Preoperatively, regional block anesthesia should be considered for post-vitrectomy cataracts given the higher rate of potential lens drop and other complications that may require immediate posterior segment intervention. Whenever possible, cases should be booked such that a vitreoretinal surgeon can be available in a timely manner in case intraoperative complications are encountered. An optical biometry for in-the-bag, sulcus, anterior chamber, and scleral fixated IOLs should be readily available in the room in preparation for case complexities. If an ultrasound biometry is required, an immersion technique is recommended, with speed adjustments for the silicone oil to determine the true axial length.

The authors strongly advocate for the use of a 3-piece IOL if zonular weakness is seen or suspected as these tend to be more forgiving in the event of decentration and are amenable to scleral or iris fixation in the future without the need for an IOL exchange. The intraocular lens used would preferably not be made of silicone or be hydrophilic due to the risk of lens opacification in the presence of silicone oil of gas. For lens power calculations, axial length appropriate modern generation formulas should be used, with attention to post-refractive adjustment in patients with prior refractive surgery. If silicone oil is to remain in the posterior segment, it is ideal to choose a convex-plano lens to avoid the loss of effective power of the posterior lens surface, in addition to adjustments for the refractive index of the oil. If using a biconvex lens, then increasing power adjustments are necessary, but a good rule of thumb is to aim about 4-diopters more myopic than intended.

Intraoperatively, viscoelastic tamponade may prevent silicone oil bubbles from migrating into the anterior chamber and blocking the surgeon's view. Continuous irrigation with lower infusion pressures can help maintain anterior chamber stability, and if this is not sufficient, increasing vitreous cavity pressure with balanced salt solution through a pars plana injection may help. The capsulorhexis may be done safely using FLACS or with the help of capsular stains, but sometimes scissors are needed to safely complete this step. Careful hydration maneuvers in these eyes with potential preexisting capsular rents are recommended. Nuclear disassembly with chopping techniques and/or the MiLoop device can aid in the safe removal of the nuclear material; the latter is especially useful when encountering a hard "leathery" posterior plate. The surgeon should have a low threshold to implant a CTR. Finally, the use of bimanual I/A devices can help overcome the difficulties encountered in cortical removal when zonular countertraction is compromised.

Cataract surgery after a pars plana vitrectomy can be safely performed to significantly improve the visual outcomes in most post-vitrectomy patients, even though final visual acuities may be limited by the patients' underlying vitreoretinal pathologies. Certain maneuvers and techniques can be implemented to minimize the risks and ensure the best possible visual outcomes for the patients.

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