Relaxing Retinotomy/Retinectomy in Advanced Proliferative Vitreoretinopathy: Concept, Principles and Management Techniques

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ABSTRACT

Proliferative vitreoretinopathy (PVR) is a cellular migration and proliferation following rhegmatogenous retinal detachment (RD) and is the major cause of failure of RD surgery. Vitreoretinal surgery is the mainstay for management of PVR as there is no proven pharmacologic approach for the prevention or treatment of PVR. In advanced anterior PVR, the retina remains stiff and does not lend itself to reattachment intraoperatively in spite of meticulous dissection of preretinal membranes. In these cases, there is intraretinal fibrosis leading to shortening of the detached retina and the only option remaining is to perform a retinotomy/retinectomy (R/R) in order to relax the retina. Relaxing retinotomy entails incision of the foreshortened and stiffened retina using vertical scissor, whereas retinectomy involves removal of the retina using the vitrectomy probe. Circumferential relaxing R/R is performed parallel to the ora serrata and reduces the radial tractions on the retina. On the othe hand, radial relaxing R/R alone or in combination with circumferential R/R may potentially relieve both the radial and tangential retinal tractions. Relaxing R/Rs have generally been reserved as a salvage attempt for complex RDs with advanced PVR when other procedures, including membrane peeling and/or scleral buckling are ineffective. The need for performing relaxing R/R had been usually associated with limited visual prognosis. However, most recent studies have provided evidence supporting better functional outcomes. Advanced PVR-related RD repair is a complex vitreoretinal procedure. There are multiple intraoperative and postoperative complications following retinectomy surgery leading to a disappointing functional and anatomical results.

Keywords: Proliferative vitreoretinopathy, Retinal detachment, Retinectomy, Retinotomy, Silicone oil.

INTRODUCTION

Rhegmatogenous retinal detachment (RD) is the most common type of retinal detachment. It occurs in about 1 in 10,000 people per year, most commonly in the fourth decade of life or later.[1,2] The main predisposing factors of RD are myopia and previous cataract surgery.[2] Improvements to instrumentation and techniques for vitrectomy have resulted in greatly improved outcomes of RD surgery. However, despite these advances, RD repair can be very challenging when the condition is complicated by proliferative vitreoretinopathy (PVR). Proliferative vitreoretinopathy is a cellular migration and proliferation producing periretinal membranes, followed by contraction of the membranes and traction on the retina. It complicates about 5% to 10% of the repairs of primary RD, accounting for approximately 75% of all primary surgical failures.[3-5] In general, PVR occurs following RD surgery; however, it can occasionally occur in the setting of chronic primary RDs or those related to trauma.[6,7]

Pathogenesis

Proliferative vitreoretinopathy is a complex disease entity that is not still completely understood. Is thought to be comparable to the abnormal wound repair process leading to a keloid growth in the skin.[8] Proliferative vitreoretinopathy has been described as a process of cellular reaction characterized by migration and proliferation of retinal pigment epithelial cells into the vitreous cavity and retinal surface and activation of glial cells and macrophages with release of pro-inflammatory mediators inducing the development of vitreoretinal tractional membranes.[9-11] Contraction and atrophy of intrinsic retinal

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structures causing retinal rigidity and shortening are more important, leading to anteroposterior or circumferential traction on the retina, most notably around the vitreous base.[12,13] This traction, causing opening of successfully treated retinal breaks or creating new retinal breaks results in redetachment (Figure 1). Most of the proliferative mediators settle in the inferior retina because of gravity, so this region is most severely affected by PVR formation.[14]

Clinical Risk Factors

Multiple factors have been associated with high risk for developing PVR in RD cases. Preoperative ocular trauma, uveitis, giant retinal tear, multiple breaks, retinal detachment in more than two quadrants, vitreous hemorrhage, choroidal detachment and multiple previous surgical procedures exacerbate the risk of PVR formation.[15] Intraocular bleeding during or after surgery, excessive diathermy, photocoagulation or cryotherapy, also lead to higher rates of PVR.[16,17]

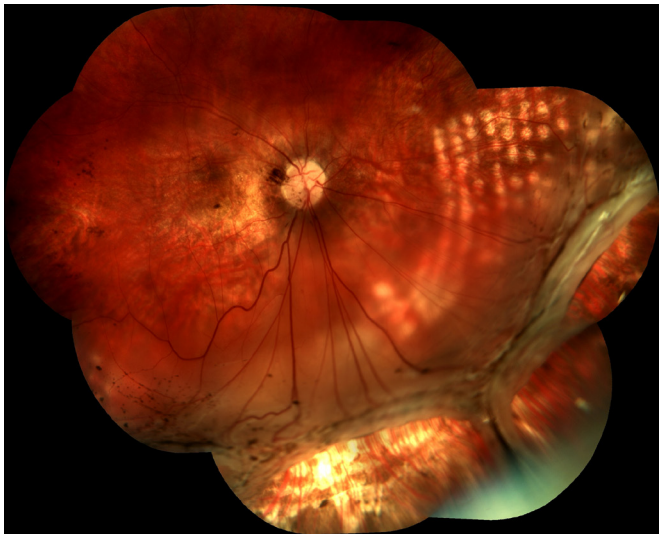

Figure 1: *Three-month postoperative fundus photograph of a 12-year-old boy who underwent pars plana vitrectomy for macula-off rhegmatogenous retinal detachment due to 270º giant retinal tear. Proliferation of scar tissue, contraction of posterior edge of giant retinal tear, inferior retinal shortening and detachment under silicone oil is observed. The macula remains attached. A wide band of laser was performed intraoperatively to reduce the likelihood of recurrence.*

Grading of Proliferative Vitreoretinopathy

The current classification divided PVR into three stages, A, B and C (Table). Grade A PVR is defined by the presence of vitreous haze and pigment clumps. Grade B is recognized by the presence of rolled or irregular edges of a tear or wrinkling of inner retinal surface. Grade C indicates the formation of preretinal or subretinal membranes.

General Principles in the Management of Retinal Detachment Complicated with Proliferative Vitreoretinopathy

Despite increasing knowledge of PVR pathophysiology and the latest developments in vitreoretinal surgery, management of RDs complicated by advanced PVR remains a surgical challenge. Meticulous vitrectomy with peripheral 360° shaving of the vitreous base, membrane peeling with or without additional relaxing retinotomy/retinectomy (R/R) in order to relieve anterior traction, cryo or laser retinopexy, and endotamponade or external tamponade (scleral buckle) remain as the standard procedures to achieve a successful retinal reattachment in such complex cases.[18,19] Relaxing retinotomies/retinectomies (R/R) have generally been reserved as a salvage attempt for complex RDs with advanced PVR when other procedures, including membrane peeling and/or scleral buckling are ineffective.[20]

Definition of Relaxing Retinotomy/Retinectomy in Proliferative Vitreoretinopathy

Machemer was the first to describe retinotomy for relaxing the retina in PVR.[21] In many cases of PVR, the retina remains foreshortened preventing an intraoperative reattachment in spite of extensive dissection of preretinal and subretina of membranes.[22] In these cases, there seems

Table: *Retina society updated classification of retinal detachment with proliferative vitreoretinopathy.*

GRADE	FEATURES
A	Vitreous haze; vitreous pigment clumps; pigment clusters on inferior retina
B	Wrinkling of inner retinal surface; retinal stiffness; vessel tortuosity; rolled and irregular edge of retinal break; decreased mobility of vitreous
C p 1-12	**Posterior to equator:** focal, diffuse, or circumferential full-thickness folds*; subretinal strands*
C a 1-12	**Anterior to equator:** focal, diffuse, or circumferential full-thickness folds*; subretinal strands*; anterior displacement*; condensed vitreous with strands

*Expressed in the number of clock hours involved. (Reproduced from Machemer R, Aaberg TM, Freeman HM, et al. An updated classification of retinal detachment with proliferative vitreoretinopathy. Am J Ophthalmol. 1991;112:159-65.)

to be some intraretinal fibrosis causing shortening of the chronically detached retina and if there are no visible membranes to be removed, the only option remaining is to perform a R/R in order to relax the retina.[23] Relaxing retinotomy entails incision of the foreshortened and stiffened retina, whereas retinectomy involves removal of the retina. Retinotomy/retinectomy could be performed in a radial fashion, but most commonly it is done circumferentially, parallel to the ora serrata.[24]

Instrumentation

Both contact and non-contact wide angle viewing systems are ideal for visualization of the retina during complex retinal detachment surgery. Chandelier illuminating systems should be used in retinectomy to enhance endoillumination and, at the same time, allow a bimanual approach. In recent years there has been a general trend toward smaller gauge vitrectomy instrumentation. Most surgeons have now switched from using 20-gauge vitrectomy systems to 23- or 25-gauge systems. The smaller gauge systems facilitate less postoperative inflammation and faster recovery. At the same time, the smaller-gauge vitreous cutter can be placed closer to the retinal surface when cutting near mobile retina or dissecting membranes. Higher cut-rates allow greater fluidic stability around the vitrectomy port and reduce unwanted traction and mobility of the retina.

Principles of Relaxing Retinotomy/Retinectomy Surgery

Following the core vitrectomy (in primary cases), partial or complete removal of the posterior hyaloid should be performed, if not already present. Induction of posterior vitreous detachment can be attempted by active aspiration with a vitreous cutter just anterior to the peripapillary retina. In cases with a thickened posterior hyaloid membrane, if posterior vitreous detachment could not be induced by this procedure, an end-gripping membrane forceps should be used to separate the posterior hyaloid from the retinal surface. Extensive removal of the vitreous body and cortex with trimming of vitreous base over 360° has become a widely accepted surgical approach to reduce the risk of postoperative PVR formation. Performing scleral indentation is critical for a successful shaving of the vitreous base. In cases with PVR-associated recurrent RD underneath the silicone oil (SO), the SO should be removed first. Effort should be made to eliminate all traction by careful and gentle dissection of the preretinal membranes. Intraoperative application of trypan blue and triamcinolone acetonide help to visualize the preretinal and vitreous membranes. Wide range of different surgical instruments, including scissors, forceps, spatulas, and picks are available for segmentation and delamination of the membranes. The vitrectomy probe can also be used to dissect and/or trim the fibrous tissue in areas of dense adhesions. Usually, membranes in posterior PVR can be removed surgically and the need for a posterior relaxing R/R rarely arises.[17] On the other hand, peripheral membrane removal in anterior PVR is often more complicated and anteroposterior, circumferential, and perpendicular tractional forces cannot be adequately relieved. After membrane removal had been considered insufficient to relieve the retinal traction, a circumferential relaxing R/R should be created. Circumferential relaxing R/R should be applied along the posterior border of the vitreous base, as anteriorly as possible in order to preserve the functional retina (peripheral relaxing retinotomy).[23] The R/R incision also can be placed slightly anterior to the equatorial retina (equatorial relaxing retinotomy), depending on the individual pathologic characteristics. To control hemorrhage during R/R, the area to be incised should be cauterized with endodiathermy (Figure 2). If endodiathermy is not effective (the retina does not become white), then vitreous is left and residual vitreous should be removed with the vitreous cutter.[23] The R/R should be extended circumferentially to the extent of anterior PVR into the uninvolved retina usually for a clock hour from either side.[25] The retinotomy is performed with the vitreous cutter using a low cut rate or vertical scissors (Figure 3). Complete haemostasis of the retinotomy edge is required to minimize the possibility of further inflammation and recurrent PVR formation.[23] As much as possible of the peripheral anterior retinal flap should be removed (anterior retinectomy) to minimize ischemia and its complications. Then subretinal membranes, if any, are peeled. If, despite all these procedures, the intrinsic retinal rigidity (circumferential retinal shortening) not allow

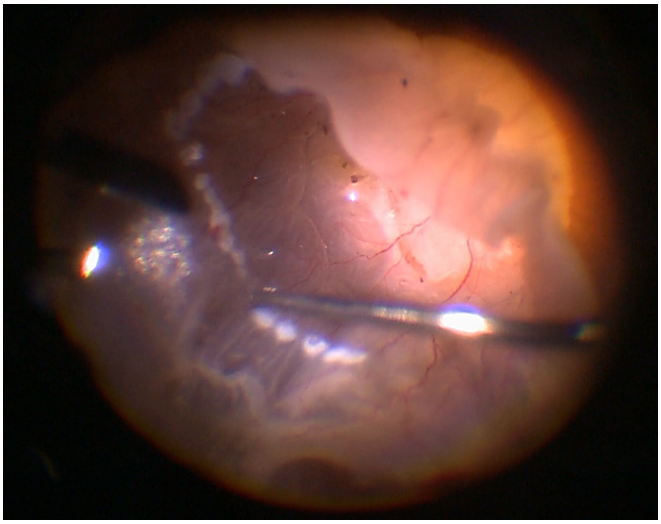

Figure 2: *Intraoperative image showing a row of diathermy before retinotomy/retinectomy.*

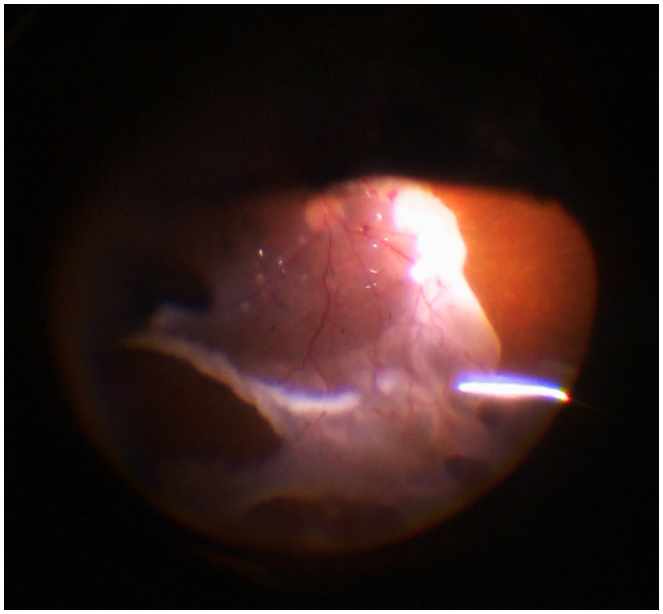

Figure 3: *Intraoperative image showing a retinectomy anterior to the row of endodiathermy.*

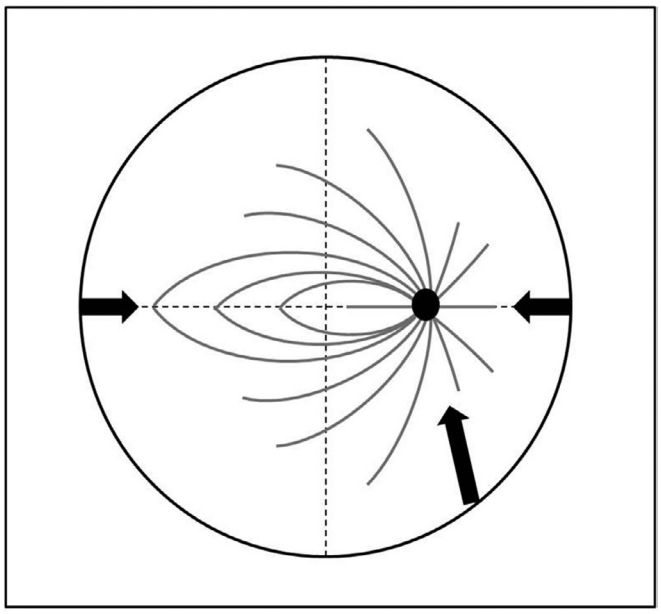

Figure 4: *Drawing showing the distribution of retinal nerve fiber layer. Radial retinectomy needs to be performed in the direction indicated by the arrows. This approach will minimize the amount of the nerve fibers cut during the retinectomy, thereby reducing visual feld defect. Adapted with permission from Grabowska.*[28]

retinal reattachment, radial R/R is required. It has been noted that a circumferential R/R relieves anteroposterior retinal shortening, but is not efective in the management of circumferential shortening commonly found in more advanced stages of PVR.[26] The combination of both circumferential and radial R/R relieves circumferential shortening more efectively and is a good option when residual circumferential shortening cannot be completely eliminated. Radial R/R is performed mostly in the nasal and inferonasal quadrants from the circumferential retinectomy edge to 1 disc diameter from the optic disc margin or in the temporal quadrant. This approach avoids the major retinal vessels and avoids cutting across too many retinal nerve fibres (Figure 4).[27,28]

Timing and Extent of Retinotomy/Retinectomy

It is generally accepted that the PVR process should be in a quiescent state before R/R. An early retinectomy procedure in a case with active PVR process can stimulate extensive PVR formation.[29,30] Most commonly, relaxing retinectomies are performed at the a pathologic site of the retina. The extent and location of retinectomy is dictated by the severity of retinal shortening and individual pathologic features. The retinectomy should be extended circumferentially as far as necessary to relieve all retinal traction. It may require a limited peripheral relaxing retinectomy or even a large circumferential or radial retinectomy. In sircumferential relaxing retinectomies the peripheral retina is cut parallel to the ora serrata (from 90° to 360°). It is believed that a 180° retinectomy, preferably performed at the inferior quadrant, is more effective for the relief of traction than limited retinectomies.[31] For a variety of reasons, many surgeons performe a nearly 180° retinectomy even in the presence of focal anterior PVR. On the other hand, it has been proposed that the angular extent of retinectomy reflect on the severity of the PVR process.[20] We have recently demonstrated that relief of the anterior traction could be achieved effectively in cases with lesser extension of grade C PVR by performing R/R with a limited extent. In our series, 56% of the eyes had limited (<180°) extent of the relaxing R/R.[7]

Adjunctive Scleral Buckling

The addition of scleral buckling to the vitrectomy in cases of advanced PVR is a common source of discussion, especially when retinectomy is performed.[31] It has been proposed that the use of an encircling scleral buckle in combination with retinectomy shows some benefit in preventing retinal redetachment and most of the earlier series on retinectomy surgery have included eyes treated with a scleral buckle.[32-34] On the other hand, Tsui and Schubert have found that buckles support the edges of the retinectomy above the horizontal meridian but are less useful inferiorly.[22] Due to the recently reported encouraging results, it seems that there is an increasing trend toward primary retinectomy without adjuvant scleral buckling.[7,10,20,22,35] If there is still residual traction after complete vitrectomy, retinectomy as a primary procedure may have a similar or better effect

than using a scleral buckle for relaxing the retina, while at the same time avoiding the risks of the scleral buckle.[35]

Management of Lens

Wide-angle viewing system is enabling complete anterior dissection. However, the lens can be sacrificed when extensive anterior traction is noted preoperatively. Some studies provide evidence on the effect of lensectomy (either pars plana lensectomy or phacoemulsification) in the management of RD complicated by anterior PVR. It has been reported that eyes undergoing lensectomy and 180° inferior retinectomy had significantly higher rates of anatomical success than those that did not (74% and 38%).[32] Combined lens removal with or without IOL implantation and inferior R/R is not performed as a routine procedure in our practice, but only if the lens is found to obscure intraoperative visualization or impede adequate dissection of the anterior PVR.[7,36]

Retinopexy

Retinopexy is achieved usually using endolaser photocoagulation. Laser photocoagulation allows long-term stabilisation of the reattached retina. Laser photocoagulation should be preferred over cryotherapy as cryo leads to more infammation, cellular proliferation and risk of recurrent PVR formation. Before performing laser photocoagulation, R/R edges should be completely attached under perfluorocarbon liquid (PFCL). All retinal breaks and R/R margin should be surrounded by at least 3-4 rows of laser burns (Figure 5). Laser is usually applied 360° around the peripheral retina overlying the vitreous base. In case an extensive R/R has been performed, laser should be extended posteriorly almost to the vascular arcades. The duration should be longer and laser power should be higher than used for in offce setting, however excessive laser power should be avoided as this may result in choroidal hemorrhage and rupture of Bruch's membrane. High-power laser burns induce an immediate retinal adhesion.[17,27]

Intraocular Tamponade

The type of tamponade is another factor that is important in determining the likelihood of successful outcomes from surgery. A randomized clinical trial reported no significant difference in reattachment rates for SO and gas tamponade in eyes with severe PVR.[37] On the other hand, retrospective studies reported better reattachment rates in patients with SO tamponade than those with gas tamponade for RD repaired with retinectomy.[32,34,38] We never use a gas temponade in an eye with R/R (Figure 6). Silicone oil injection may be performed using two techniques; PFCL-air-SO exchange and direct PFCL-SO exchange. It is known that the standard intraocular tamponades are not efficient enough to provide an adequate tamponade effect on the inferior retina. Therefore, efforts to enhance the tamponade efficiency to the inferior retina have led to the development of heavy SO. However, no significant differences in reattachment rates between heavy and standard SOs were observed in eyes with inferior PVR.[39] In practice, most surgeons prefer standard, less viscous form of 1000 centistokes SO because of its relative ease of removal. The majority of recent retinectomy studies have reported removal of SO in

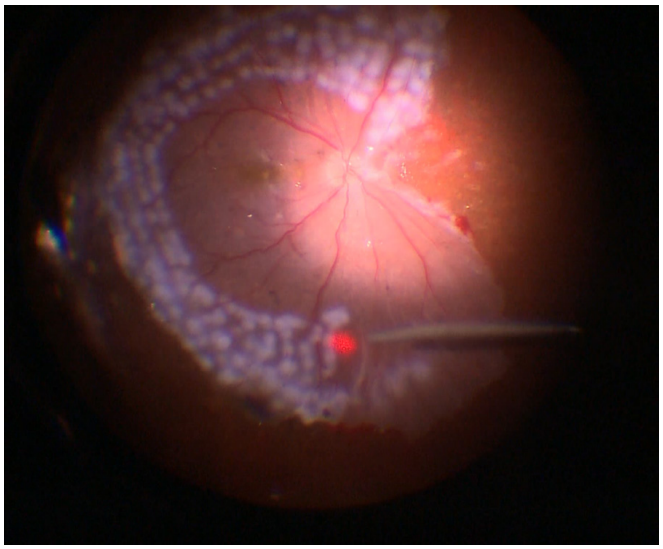

Figure 5: *Intraoperative image showing the margins of the retinectomy being treated extensively with endolaser photocoagulation.*

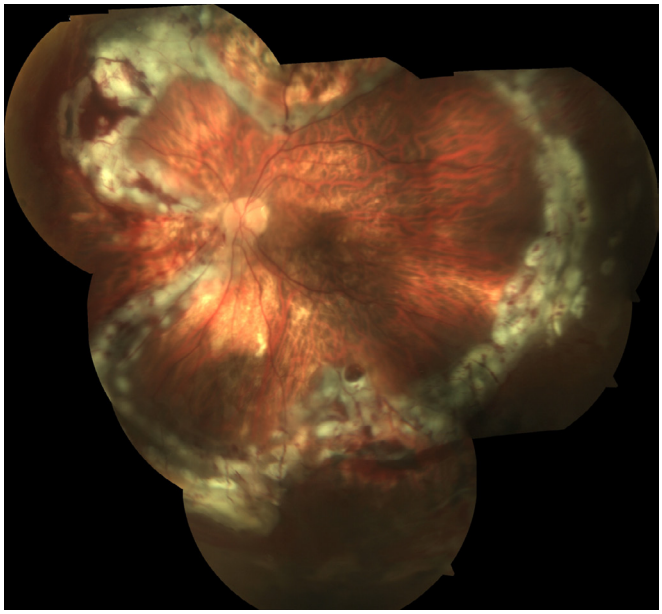

Figure 6: *Postoperative photograph showing a well attached retina under silicone oil tamponade, after relaxing peripheral 360-degree retinectomy and radial retinectomy for proliferative vitreoretinopathy.*

20%-96% of eyes and several recent studies have reported a long-term duration of SO tamponade, ranging from 24 to 67 weeks.[22,32,38,40,41] The redetachment rate after SO removal has been reported to be 4%- 28%.[20,22,32,41,42] The duration of SO in our case series was only 11 weeks. It was removed from 98% of the eyes and only 5% had detachment after SO removal following primary R/R or revisional surgery.[7] In our experience, removal of SO as early as possible with effective control of fluid dynamics seems to reduce the incidence of SO-related complications without increasing the risk of redetachment.[7,36]

COMPLICATIONS

Intraoperative Complications

Bleeding is the most common major intraoperative complication. Intraoperative hemorrhage can occur after dissection of epiretinal membranes and when the retinectomy is extended into normal retina. Endodiathermy may be used to prevent bleeding and delineate the retinectomy edge. Intraoperative hemorrhage can be easily controlled by raising the infusion pressure temporarily and, if necessary, by placement of endodiathermy.[30]

In cases with large retinectomies (>180°), slippage (posterior displacement of fluid underneath the retina) can occur during fluid-air or PFCL-air exchange. To avoid slippage, performing an intense laser treatment which creates immediate retinal adhesion and a meticulous aspiration of fluid at the R/R edges are important. Very slow controlled fluid-air exchange with complete aspiration of fluid amount over PFCL before removal of PFCL itself is recommended. If the R/R is too short and R/R edges are not attached under PFCL or air (if contracted retina remains), then the R/R has to be enlarged. It is otherwise possible that the retina will detach under SO. Another aproach preventing retinal slippage during SO injection is direct PFCL-SO exchange. In this technique the fluid over PFCL should be aspirated completely.[23,25]

Postoperative Complications

The most severe late complication of surgery for PVR is formation of preretinal membranes, resulting in retinal detachment and tractional retinal tears. The rate of redetachment due to reproliferation has improved significantly with the advent of better instrumentation and surgical techniques. Reproliferation of membranes at the posterior edge of the R/R incision leading to redetachment has been recently reported in 13% of eyes with inferior retinectomy and in 23% of eyes with combined radial retinotomy and circumferential retinectomy.[7,36]

Formation of epiretinal macular membrane in 20% of eyes with inferior retinectomy and in 23% of eyes with combined radial retinotomy and circumferential retinectomy has been recently reported.[7,36] Membrane peeling may be considered if there is significant visual loss and/or metamorphopsia.

Hypotony is another frequent complication of retinectomy. It has been proposed that the retina serves as a barrier between aqueous and choroid. A retinectomy remove this barrier partially and the IOP sinks.[23] Interestingly, earlier studies have reported a high risk of hypotony, ranging from 11% to 39% after retinectomy.[20,34,40] More recent studies have revealed lower rates of hypotony, ranging from 2% to 8%.[7,20,32,36,38,42] It has been proposed that anterior surface proliferation, referred to as proliferative vitreociliopathy may gradually interfere with the ciliary body secretory function and lead to hypotony.[30] According to recent research findings, the most probable explanation of lower rates of hypotony is the extensive surgical procedures, including adequate trimming of the vitreous base, meticulous removal removal of the anterior retinal flap and anterior hyaloid, eliminating factors leading to ciliary body contraction and traction.[38,42]

It should be stressed that, in case of permanent damage to the ciliary body, the SO provides a short-term positive effect on hypotony. However, it is likely that this effect is usually transient.[43] Taking into account the possibility of SO-related complications in long-term, using SO for maintenance of IOP needs reconsideration, and better alternative treatment options are required.[7,36] Several complications have been associated with SO endotamponade. A major problem with use of SO as a long-acting tamponade is emulsification. It is time dependent and induces inflammation, PVR formation, optic nerve damage, secondary glaucoma, and keratopathy. Prompt SO removal seems to reduce the incidence of SO-related complications.[7,36,44]

Anatomical Outcomes

Recent series on circumferential relaxing retinectomy surgery have reported final anatomical success rates ranging from 84% to 96%. [7,20,32,34,38,42] Interestingly, association between anatomical success and the extent of R/R was not reported.[7,20,33,34,38,42] At the same time, retrospective case series on combined radial retinotomy and circumferential retinectomy surgery reported final anatomical success rates ranging from 78% to 93%.[36,45]

Visual Outcomes

The need for performing relaxing R/R had been usually associated with limited visual prognosis. However, most recent studies have provided evidence supporting better functional outcomes. Final visual acuity (VA) of 20/200 or better has been reported in 57%-59% of cases in recent series.[32,38] There is a real potential of better visual outcomes

following R/R. In our case series, final vision of 20/200 or better was recorded in 80% of the patients.[7] These results might be related to the high anatomical success rate, lesser extent of RD, less extensive R/R, short-term SO tamponade, lower rate of the SO left in situ, as well as lower rates of significant lenticular opacity, aphakia, glaucomatous damage, corneal damage, and hypotony at the final follow-up.

Our analysis for predictability showed that good visual outcome was correlated positively with preoperative VA, previous vitrectomy with gas tamponade, and was negatively correlated with number of previous RD operations, larger extent of RD and more extensive R/R.[7] It has been proposed that these factors are indirect indicators of less advanced grade C PVR.[33] On the basis of the above findings, it has been speculated that early surgical intervention can contribute to improved prognosis and vitreoretinal surgeons should consider performing relaxing retinectomy at an earlier stage in the process of anterior grade C PVR development.[33,42]

Radial retinotomies have been reported to be associated with a worse visual outcome than circumferential retinotomies. For example, in our study patients, only 25% of the eyes had VA of 20/200 or better after combined 360 degree retinotomy and radial retinotomy for management of advanced PVR.[36]

CONCLUSION

The retinotomy and retinectomy are surgical techniques to attach foreshortened retina resulting from severe intraretinal PVR formation. The R/R should be performed as the final step when the retinal contracture prevented successful retinal reattachment. Retinotomy/retinectomy should be always extend into the healthy retina. Performing a large circumferential R/R is always better than a small and unstable retinotomy. This is a condition resulting in elevation of the retinotomy edge and possibly redetachment. In our opinion, R/R works very well under SO and retinectomy as a primary procedure may have a similar effect than using a scleral buckle for relaxing the retina. Performing a well timed retinectomy in less advanced grade C PVR cases seems to be associated with better visual outcomes. Prompt SO removal seems to reduce the incidence of SO-related complications without increasing the risk of redetachment. Main complications included redetachment due to reproliferation and hypotony. It is likely that silicone oil provides a transient positive effect on hypotony. Taking into account the long-term risks of SO-related complications, using SO for maintenance of intraocular pressure requires better alternative treatment options. More efforts should be directed toward the biochemical inhibition and early prevention of cellular proliferation in PVR.

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