Ocular Hypotension and Epiretinal Membrane as Risk Factors for Visual Deterioration Following Glaucoma Filtering Surgery

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Precis: Postsurgical hypotension at 1 week and the presence of an epiretinal membrane (ERM) were significant risk factors for the deterioration of postsurgical visual acuity (VA) at 3 and 12 months, respectively.

Purpose: The purpose of this study was to assess the effects of an ERM and postsurgical hypotension <6 mm Hg at 1 week on postsurgical VA loss.

Patients and Methods: A total of 69 patients (69 eyes) who underwent trabeculectomy with adjunctive mitomycin C (MMC) between 2017 and 2019 (mean follow-up period: 22.8 mo) were enrolled, and 14 parameters that could be associated with the deterioration of VA at 3 and 12 months were studied.

Results: There was a significant association between VA loss at 3 months and postsurgical intraocular pressure at 1 week (P = 0.006 by multiple regression) and hypotony maculopathy (P = 0.024 by Fisher exact test). However, this association was lost at 12 months. Instead of postsurgical hypotension, the presence of an ERM was significantly associated with VA loss at 12 months (P = 0.035 by Fisher exact test, and P = 0.023 by logistic regression).

Conclusions: Postsurgical hypotension at 1 week was significantly associated with mid-term, but not long-term, postsurgical VA loss. The presence of an ERM, which was not a risk factor for mid-term acuity loss, was a significant risk factor for VA loss at 12 months.

Key Words: epiretinal membrane, filtering surgery, hypotony maculopathy, optical coherence tomography, visual acuity (J Glaucoma 2021;30:515–525)

Deterioration of visual acuity (VA) by postsurgical hypotony is not uncommon after filtering surgery. VA loss of 4 or more lines was found in 14.6% of patients who underwent trabeculectomy with adjunctive mitomycin C (MMC), and postsurgical hypotension and hypotony maculopathy were found in 42.3% and 8.9% of patients, respectively, after filtering surgery.1 This kind of VA loss may be found 3 years after the tube (P ≤ 0.001) and trabeculectomy surgeries (P = 0.002).2 In another study, 43.9% of patients experienced VA impairment after trabeculectomy wherein, the visual disturbance was reversible in 15.4% and not reversible in 28.3%.3 Potential causes of visual disturbance after filtering surgery include hypotensive corneal striae and edema, cataracts, deformation of the globe by external forces, astigmatism, choroidal effusion, hypotony maculopathy, ocular ischemic syndrome, retinal detachment, uveitis, decompensation retinopathy, and optic nerve damage.4 Delayed normalization of intraocular pressure (IOP) may result in permanent structural and functional damage. Hypotony-associated choroidal folds and pigment epithelial changes have been well-studied. However, microscopic changes in retinal structure have not been well-studied. Hypotony maculopathy is more common in young patients, the male sex, myopia, primary filtering surgery, and the use of MMC.5,6 and is associated with duration of hypotony and hypotony score.7 Thickening of the perifoveal sclera wall and choroid leads to fold formation8 and may provide a space for fluid accumulation beneath the retina, leading to retinal pigment epithelial atrophy.4 There is no doubt that hypotony maculopathy is a risk factor for postsurgical visual dysfunction after filtering surgery. However, many patients suffer from VA loss without signs of macroscopic hypotony maculopathy. One study found that 36% of patients had low vision (between 3/60 and 20/60) when their mean postsurgical IOP was <6 mm Hg.3 In case of severe hypotension after filtering surgery, disruption of the hydrostatic and oncotic pressure gradient across the blood-aqueous barrier leads to the accumulation of serum transudate from the choroidal vessels into the choroidal space and subretinal space, leading to retinal edema. Lima et al9 reported an increase in the central retinal thickness of 40 μm in hypotensive eyes. This increase in central retinal thickness may lead to traction on the Müller cell cone (MCC) and VA loss. Subclinical macular abnormalities are detected using Fourier-domain optical coherence tomography (OCT) in over half of the eyes with postoperative hypotony.9 Other than the retinal edema, other factors, such as epiretinal membrane (ERM) may enhance traction on the MCC. In this study, we assessed the effects of an ERM and postsurgical hypotony on postsurgical VA loss after filtering surgery.

PATIENTS AND METHODS

This study was a retrospective, interventional case series. The inclusion criteria were patients who underwent trabeculectomy combined with deep sclerectomy (removal of the inner scleral flap) and adjunctive MMC between 2017 and 2019; the VA of enrolled patients needed to be better than 20/40 before surgery, and eyes must have been examined by OCT before surgery, 3 and 12 months postsurgery. The exclusion criteria included: retinal vascular diseases, combined cataract, and glaucoma surgery; active iridocyclitis at the time of surgery; and incomplete data. If the postsurgical IOP exceeded 21 mm Hg or glaucoma surgery

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was performed within 12 months, the patient was excluded from the current study. The study design was approved by the Internal Review Board of the Sensho-Kai Eye Institute. Informed consent for this retrospective study was obtained at the time of the surgery. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

We recruited 1 eye each from 182 patients. If patients underwent surgery in both eyes, the first eye was selected for analysis. Fifty-one eyes with poor VA <20/40, 58 eyes who underwent combined cataract surgery and trabeculectomy, and 4 eyes with postsurgical hypertension exceeding 21 mm Hg, were excluded.

Finally, 69 eyes of 69 patients who underwent filtering surgery alone were enrolled in this study. Six patients dropped out after 6 months of follow-up, and the data for these eyes at 12 months were treated as missing statistical data.

Age, sex, type of glaucoma, side of the eye treated, best-corrected visual acuity (BCVA), refractive error, hypotony maculopathy, and central corneal thickness were recorded.

### Surgical Procedures

After sub-Tenon injection of 2% lidocaine, subconjunctival 0.02% MMC was applied at the superotemporal meridian without washout of the MMC; 1 radial conjunctival incision was made at 10 o’clock, and a 2-clock hour fornix-based peritomy was created. A 6-0 nylon traction suture was placed at the tendon of the superior rectus muscle, a 5×4 mm parabolic area was marked on the sclera, and a one third full-thickness scleral flap was created and extended 1 mm into the clear cornea. Beneath the first scleral flap, a second scleral flap with a size of 4×3.5 mm and one half scleral thickness was created, extended to the limbus, and removed by excising at the limbus. The anterior chamber was entered at the surgical limbus, and peripheral iridectomy was performed. A small amount of viscoelastic material was injected from the side-port paracentesis site at 9 o’clock into the anterior chamber, and the first flap was repositioned and secured using three 10-0 nylon sutures. The conjunctival wound was closed using absorbable 10-0 polyglactin sutures. After the surgery, 0.8 mg of dexamethasone ointment. Topical gatifloxacin and betamethasone eye drops were administered for 1 month. Postoperative laser suture lysis was performed according to the decision made by the attending doctors.

The IOP, lowest postsurgical IOP, number of medications, and BCVA at 1 week and 1, 3, 6, and 12 months after surgery were recorded. Visual deterioration at 3 and 12 months, and postsurgical interventions, such as laser suture lysis and gonipuncture, were recorded. The postsurgical complications studied included hypotony maculopathy, cataract, shallow chamber, iridocyclitis, cystoid macular edema, decomposition retinopathy, serous choroidal detachment, macular degeneration, hyphaema, presence of bleb, bleb leaks, and malignant glaucoma. The progression of lens opacity was assessed using the Emery-Little classification.

The macular retina was studied using spectral-domain OCT (AngioVue XR; Optovue, Fremont, CA). Details of the device and our technique of image acquisition have been reported previously.10,11 The vertical and horizontal section images and ganglion cell complex data were recorded before and after surgery, and detailed images were analyzed using cross line and retinal map images of the device. Hypotony maculopathy in this study was defined as eyes with low IOP, presence of ophthalmoscopic retinal and choroidal folds, venous tortuosity, optic disc edema, and/or presence of choroidal folds by OCT. The presence of an ERM within a 3 mm circle of the fovea was assessed every 3 times we acquired OCT images. Hypotension in this study was defined as a low IOP <6 mm Hg.

### Statistical Analysis

Multiple regression analysis, logistic regression analysis, Fisher exact test, Wilcoxon signed-rank test, and Pearson correlation coefficient analysis were performed using BellCurve for Excel (Social Survey Research Information Co. Ltd, Tokyo, Japan).

### RESULTS

The demographic and follow-up data are shown in Table 1. The number of patients who lost >0.1 or >0.2 logarithm of the minimum angle of resolution (logMAR) BCVA were greater than the number of patients with hypotony maculopathy. The results of the Pearson correlation coefficient matrix are shown in Table 2. The VA loss at 3 months after surgery was significantly correlated with presurgical IOP (r = 0.237, P = 0.0498) and postsurgical IOP at 1 week (r = -0.328, P = 0.006).

In Table 2, we see some confounding correlations between the parameters.

Patient age was significantly correlated with presurgical visual field loss (r = -0.351, P = 0.004) and VA (r = 0.527, P < 0.001). There was a positive association between patient age and postsurgical IOP at 1 week (r = 0.260, P = 0.031). This suggests that older patients have a lower risk of postsurgical intraocular hypotension.

Other significant confounding associations were between presurgical visual field MD and presurgical logMAR BCVA (r = -0.389, P = 0.001), presurgical MD and thin cornea (r = 0.328, P = 0.039), poor presurgical logMAR BCVA and high presurgical IOP (r = 0.274, P = 0.023), and between postsurgical IOP at 1 week and presurgical IOP (r = 0.259, P = 0.032), and the lowest postsurgical IOP (r = 0.720, P < 0.001).

Significant associations between VA loss at 3 months and presurgical IOP (P = 0.0498) and 1 week postsurgical IOP (P = 0.006) were lost at 12 months. The Pearson correlation coefficient between logMAR BCVA loss at 12 months and all 7 parameters, such as age (r = -0.128, P = 0.32), presurgical MD by the Humphrey visual field analyzer (r = 0.016, P = 0.902), presurgical logMAR BCVA (r = 0.079, P = 0.54), presurgical mean IOP on 3 consecutive occasions (r = -0.107, P = 0.41), number of presurgical medications (r = 0.033, P = 0.80), CCT (r = -0.167, P = 0.32), and lowest IOP recorded (r = -0.109, P = 0.40) were not significant. The association between IOP 1 week after surgery and VA loss at 12 months (r = -0.219, P = 0.084) was marginal, but not statistically significant.

For the multiple regression analysis, the numerical logMAR BCVA loss at 3 months against presurgical BCVA was set as a dependent variable, and numerical variables such as age, presurgical MD, number of presurgical medications, and postsurgical IOP at 1 week were set as
explanatory variables. Postsurgical IOP at 1 week ($P=0.006$) and presurgical MD ($P=0.030$) were significant risk factors for VA loss at 3 months (Table 3). Presurgical logMAR BCVA ($P=0.057$) and mean presurgical IOP on 3 consecutive occasions ($P=0.057$) were marginal risk factors for visual loss at 3 months (Table 3).

However, when the logMAR BCVA loss at 12 months was set as the dependent variable, none of the 6 parameters listed above were found to be significant risk factors for VA loss at 3 months (Table 3).

This finding suggests that the effects of low IOP at 1 week on VA loss were temporal and not long-lasting.

The Fisher exact test showed that hypotony maculopathy was a significant risk factor for a logMAR BCVA loss of 0.2 at 3 months ($P=0.024$). However, this was not the case for VA loss at 12 months ($P=0.34$). This finding confirms the previous Pearson correlation coefficient and multiple regression analysis results that postsurgical short-term hypotension affected VA at 3 months, but not at 12 months.

In contrast, the effects of an ERM at the macula contrasted with these results. The Fisher exact test revealed that the presence of an ERM within a 3 mm circle of the foveola was not a significant risk factor for VA loss of 0.2 but was a significant risk factor at 12 months postsurgery ($P=0.0352$). Choroidal effusion alone was not a risk factor for VA loss at either 3, or 12 months postoperatively (Table 5).

To perform the binary logistic regression analysis, the dependent variable was set as yes or no in 0.1 logMAR BCVA loss at 3 and 12 months, confounding factors such as presurgical IOP, central corneal thickness, and other parameters were included. The results showed that hypotony maculopathy and ERM were significant risk factors for VA loss at 3 months, but not at 12 months.
| TABLE 2. Pearson Correlation Coefficient $P$-value and $r$-value Matrix Table of the Presurgical and Postsurgical Parameters at 3 Months ($N = 69$) |
|---------------------------------------------|----------------|----------------|----------------|----------------|-----------------------------|----------------|----------------|----------------|
| LogMAR Visual Acuity Loss at 3 mo          | Age            | Presurgical MD | Presurgical LogMAR | Presurgical Mean IOP on 3 Occasions | Presurgical Number of Medications | CCT            | IOP 1 wk After Surgery | Lowest IOP Recorded |
| LogMAR visual acuity loss at 3 mo          | $P = 0.90$     | $P = 0.52$    | $P = 0.0498^*$      | $P = 0.47$                  | $P = 0.63$                     | $P = 0.006^{**}$ | $P = 0.017^*$ |                  |
| Age                                        | $r = -0.016$   | $r = 0.078$   | $r = -0.237$        | $r = -0.088$                | $r = -0.078$                   | $r = -0.328$    | $r = -0.287$   | $P < 0.05$.     |
| Presurgical MD                             | $P = 0.004^{**}$ | $P = 0.50$   | $P = 0.54$           | $P = 0.55$                  | $P = 0.031^*$                  | $P = 0.037^*$  | $P = 0.252$    |                  |
| $r = -0.351$                               | $r = 0.083$    | $r = -0.076$  | $r = 0.098$          | $r = 0.260$                 | $r = 0.252$                    |                |                | $P < 0.01$.     |
| Presurgical logMAR                         | $P = 0.001^{**}$ | $P = 0.92$   | $P = 0.96$           | $P = 0.039^*$               | $P = 0.42$                     | $P = 0.79$     |                |                  |
| $r = -0.389$                               | $r = 0.012$    | $r = 0.006$   | $r = 0.328$          | $r = 0.101$                 | $r = 0.034$                    |                |                |                  |
| Presurgical mean IOP on 3 occasions        | $P = 0.023^*$  | $P = 0.93$    | $P = 0.42$           | $P = 0.21$                  | $P = 0.31$                     | $P = 0.124$    |                |                  |
| $r = 0.274$                                | $r = -0.011$   | $r = -0.130$  | $r = 0.153$          | $r = 0.124$                 | $r = 0.124$                    |                |                |                  |
| Presurgical number of medications          | $P = 0.68$     | $P = 0.58$    | $P = 0.032^*$        | $P = 0.20$                  | $P = 0.155$                    |                |                |                  |
| $r = -0.050$                               | $r = 0.089$    | $r = 0.299$   | $r = 0.155$          | $r = 0.155$                 | $r = 0.155$                    |                |                |                  |
| CCT                                        | $P = 0.32$     | $P = 0.97$    | $P = 0.77$           | $P = 0.006^{**}$            | $P = 0.101$                    | $P = 0.101$    |                |                  |
| $r = 0.161$                                | $r = 0.004$    | $r = -0.036$  | $r = 0.133$          | $r = 0.035$                 | $r = 0.720$                    |                |                |                  |
| IOP 1 wk after surgery                     | $P = 0.41$     | $P = 0.83$    | $P < 0.001^{**}$     | $P < 0.001^{**}$            | $P = 0.720$                    |                |                |                  |
| Lowest IOP recorded                        | $P = 1.000$    |                |                |                | $P = 1.000$                    |                |                |                  |

*CCT indicates central corneal thickness; IOP, intraocular pressure; logMAR, logarithm of the minimum angle of resolution; MD, mean deviation.*
thickness, and the lowest IOP recorded were excluded based on the results of the multiple regression analysis, and the risk of 10 explanatory variables was studied.

In the logistic regression analysis, none of the 10 parameters studied were found to be statistically significant risk factors for the reduction of logMAR BCVA by 0.1 at 3 months. However, a low IOP 1 week after surgery (P=0.076) was a marginally significant risk factor (Table 6). In contrast, the presence of an ERM (P=0.023) was a significant risk factor for VA loss at 12 months. The odds ratio of an ERM was as high as 10.6 (Table 7). No parameter was a significant risk factor if the dependent variable was Yes/No in 0.2 logMAR BCVA loss.

In this study, 41 of 69 eyes were pseudophakic, and cataract progression was noted in 7 of 28 phakic eyes. The deterioration of logMAR in these 7 eyes was 0.076±0.061 at 3 months and 0.086±0.113 at 12 months. Cataracts could potentially affect postsurgical VA. However, the number of phakic eyes was small in this study, and the P-value for visual deterioration at 3 and 12 months was P=0.68 and 0.65, respectively (Tables 6, 7). This was not significant in logistic regression analysis.

In this study, several types of macular changes were observed in the eyes with ERM. Fourteen events occurred in 10 eyes with ERM. Changes in the outer retinal structure were noted in 4 eyes (Figs. 1, 3). We did not experience the development of a new ERM; however, elongation of the ERM was noted in 2 eyes (Fig. 2). While steepening and flattening of the foveolar pit (Figs. 3B, C), and disturbance of the ellipsoid zone (EZ) (Fig. 1E) were observed in 6, and 2 eyes, respectively. In 5 eyes, no postsurgical changes in macular structure were detected. In Table 8, VA changes in 15 eyes with ERM were compared between eyes with postsurgical macular structural changes (10 eyes) and those without macular structural changes (5 eyes). VA loss was significant in eyes with macular structural changes at 3 months (P=0.012) and 12 months (P=0.028, Wilcoxon signed-rank test). However, VA loss was not significant in eyes without macular changes. Postsurgical IOP was marginally lower (P=0.086) in eyes with macular structural changes (Table 8).

An example of the macular structural changes observed is shown in Figures 1–3.

Figure 1 is an OCT image of a 67-year-old man with primary open-angle glaucoma (POAG) and high myopia (−12.5 D). His left VA, MD, and IOP before surgery were 20/15, −9.15 dB (decibels), and 21 mm Hg, respectively, and he was taking 2 medications (prostaglandin and beta-blocker). His MD slope was −1.46 dB per year, and he underwent trabeculectomy with an adjunctive MMC in August 2017. Before surgery, he had an ERM in his left eye (Fig. 1A) but did not have metamorphopsia.

| Variables                                      | Partial Regression Coefficient | Lower Limit | Upper Limit | P  |
|------------------------------------------------|--------------------------------|-------------|-------------|----|
| Age                                            | 0.0004                         | −0.0030     | 0.0039      | 0.79|
| Presurgical MD                                  | 0.0052                         | 0.0005      | 0.0098      | 0.030*|
| Presurgical logMAR                              | 0.2726                         | −0.0089     | 0.5541      | 0.057|
| Presurgical mean IOP on 3 occasions             | −0.0040                        | −0.0082     | 0.0001      | 0.057|
| Presurgical number of medications               | −0.0155                        | −0.0520     | 0.0209      | 0.40|
| IOP at 1 wk after surgery                       | −0.0072                        | −0.0122     | −0.0021     | 0.006**|
| Constant                                       | 0.3431                         | 0.0304      | 0.6558      | 0.032*|

IOP indicates intraocular pressure; logMAR, logarithm of the minimum angle of resolution; MD, mean deviation.

**P<0.05.  
*P<0.01.

TABLE 4. Multiple Regression Analysis Results of the Associations Between the Deterioration of Visual Acuity at 12 Months and 6 Parameters

| Variables                                      | Partial Regression Coefficient | Lower Limit | Upper Limit | P  |
|------------------------------------------------|--------------------------------|-------------|-------------|----|
| Age                                            | −0.0017                        | −0.0048     | 0.0014      | 0.28|
| Presurgical MD                                  | 0.0011                         | −0.0031     | 0.0053      | 0.61|
| Presurgical logMAR                              | 0.1773                         | −0.0779     | 0.4324      | 0.17|
| Presurgical mean IOP on 3 occasions             | −0.0018                        | −0.0067     | 0.0031      | 0.47|
| Presurgical number of medications               | 0.0036                         | −0.0296     | 0.0368      | 0.83|
| IOP at 1 wk after surgery                       | −0.0033                        | −0.0083     | 0.0017      | 0.19|
| Constant                                       | 0.2399                         | −0.0541     | 0.5339      | 0.11|

IOP indicates intraocular pressure; logMAR, logarithm of the minimum angle of resolution; MD, mean deviation.

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### TABLE 5. Fisher Exact Test Results of the Risk Factors for LogMAR Visual Acuity Loss of 0.2 at 3 and 12 Months

| Variables | Deterioration of LogMAR > 0.2 at 3 mo | Deterioration of LogMAR ≤ 0.2 at 3 mo | Deterioration of LogMAR > 0.2 at 12 mo | Deterioration of LogMAR ≤ 0.2 at 12 mo |
|-----------|-------------------------------|---------------------------------|--------------------------------|-------------------------------|
|           | Yes                           | No                             | Yes                          | No                             |
| Presurgical ERM within a 3 mm circle of the foveola | 5                             | 10                             | 5                             | 10                             |
| Hypotony maculopathy | 0.28                          | 5                              | 0.035*                       | 0.34                           |
| CD         | Yes                           | 3                              | 0.024*                       | 0.21                           |
|           | No                            | 9                              | 50                            | 8                              |

*P-value: Both-sided *P-value by Fisher exact test.
*P < 0.05.

CD indicates choroidal detachment; ERM, epiretinal membrane; logMAR, logarithm of the minimum angle of resolution.

### TABLE 6. Binary Logistic Regression Results of the Risk Factors for Visual Acuity Loss at 3 Months

| Variables                          | Partial Regression Coefficient | Lower Limit | Upper Limit | Odds Ratio | P |
|-----------------------------------|--------------------------------|-------------|-------------|------------|---|
| Hypotony maculopathy (yes/no)     | 1.0901                         | −0.6555     | 2.8357      | 2.97       | 0.22|
| Shallow chamber (yes/no)          | 0.0286                         | −1.6463     | 1.7034      | 1.03       | 0.97|
| Presence of ERM (yes/no)          | 0.3510                         | −1.1418     | 1.8437      | 1.42       | 0.64|
| Postsurgical IOP at 1 wk          | −0.1259                        | −0.2651     | 0.0132      | 0.88       | 0.076|
| Presurgical MD                    | 0.0586                         | −0.0139     | 0.1311      | 1.06       | 0.11|
| Age                               | 0.0302                         | −0.0284     | 0.0888      | 1.03       | 0.31|
| Presurgical medications           | −0.2537                        | −0.8894     | 0.3819      | 0.78       | 0.43|
| DM (yes/no)                       | −0.5161                        | −3.2547     | 2.2224      | 0.60       | 0.71|
| Myopia <−6 D (yes/no)             | 0.7977                         | −1.0819     | 2.6773      | 2.22       | 0.41|
| Progression of Cat (yes/no)       | −0.5728                        | −3.3134     | 2.1678      | 0.56       | 0.68|
| Constant                          | −0.7258                        | −5.3786     | 3.9270      | 0.48       | 0.76|

*P < 0.05.

Cat indicates cataract; DM, diabetes mellitus; ERM, epiretinal membrane; IOP, intraocular pressure; MD, mean deviation.

### TABLE 7. Binary Logistic Regression Results of the Risk Factors for Visual Acuity Loss at 12 Months

| Variables                          | Partial Regression Coefficient | Lower Limit | Upper Limit | Odds Ratio | P |
|-----------------------------------|--------------------------------|-------------|-------------|------------|---|
| Hypotony maculopathy (yes/no)     | 0.0934                         | −2.5300     | 2.7169      | 1.10       | 0.94|
| Shallow chamber (yes/no)          | 0.1855                         | −1.8258     | 2.2167      | 1.20       | 0.86|
| Presence of ERM (yes/no)          | 2.3562                         | 0.3202      | 4.3922      | 10.55      | 0.023*|
| Postsurgical IOP at 1 wk          | −0.9027                        | −0.2567     | 0.0712      | 0.91       | 0.27|
| Presurgical MD                    | −0.0449                        | −0.1364     | 0.0466      | 0.96       | 0.34|
| Age                               | 0.0306                         | −0.0448     | 0.1059      | 1.03       | 0.43|
| Presurgical medications           | 0.0175                         | −0.7817     | 0.8168      | 1.02       | 0.97|
| DM (yes/no)                       | 0.2122                         | −2.7017     | 2.2774      | 0.81       | 0.87|
| Myopia <−6 D (yes/no)             | 0.7048                         | −1.2012     | 2.6108      | 2.02       | 0.47|
| Progression of Cat (yes/no)       | 0.4719                         | −1.5748     | 2.5185      | 1.60       | 0.65|
| Constant                          | −3.7406                        | −9.8614     | 2.3802      | 0.02       | 0.23|

*P < 0.05.

Cat indicates cataract; DM, diabetes mellitus; ERM, epiretinal membrane; IOP, intraocular pressure; MD, mean deviation.
One week after surgery, his IOP was 3 mm Hg, the anterior chamber was shallow, hypotony maculopathy had developed, and VA decreased to 20/300.

One month after surgery (Fig. 1B), his IOP was 11 mm Hg without medication, and his VA was 20/60. At that time, the central foveal thickness (CFT) was 282 μm, and hypotony maculopathy was diminishing. However, mild choroidal folding was persisting. A small gap was noted between the neural retina and the ERM, which is suggestive of the ERM contraction. The EZ became blurred and fluffy material (hyperreflective foci: arrow) appeared in the outer retina at the fovea, which is a so-called “vitelliform lesion.”

Three months after surgery, the separation between the ERM and neural retina became more evident, and the vitelliform lesion (arrow) was found in front of the regenerated EZ at the fovea. At that time, his VA had deteriorated to 20/100, and his IOP and CFT were 17 mm Hg and 281 μm, respectively. One year after surgery, regeneration of the EZ was evident, and the intraretinal vitelliform lesion while fading, persisted (arrow). The neural retina was stretched out, and the gap between the ERM and neural retina had decreased. The CFT, left best-corrected visual acuity (BCVA), and Humphrey visual field analyzer mean deviation were 289 μm, 20/60, and −8.04 dB, respectively. Two years after the surgery, the size of the hyperreflective foci at the fovea had further decreased (arrow). However, parafoveal disruption of EZ persisted, the recovery of his BCVA was poor and stayed at 20/30. The CFT and IOP were 283 μm and 17 mm Hg, respectively. He claimed persistent metamorphopsia.

FIGURE 1. Optical coherence tomography (OCT) image of an eye with epiretinal membrane (ERM) and development of vitelliform lesion after trabeculectomy. A, OCT findings before surgery (vertical section image). The patient had ERM on his left eye but did not have metamorphopsia. The ellipsoid zone (EZ) was intact, and his left visual acuity (VA) and intraocular pressure (IOP) were 20/15 and 21 mm Hg, respectively. B, OCT image 1 month after surgery. His IOP without medications, VA, and central foveal thickness (CFT) were 11 mm Hg, 20/60, and 282 μm, respectively. Hypotony maculopathy was subsiding; however, mild choroidal folding was persisting. A small gap was noted between the neural retina and the ERM, which is suggestive of the ERM contraction. The EZ became blurred and fluffy material (hyperreflective foci: arrow) appeared in the outer retina at the fovea, which is a so-called “vitelliform lesion.”

C. Three months after surgery, the separation between the ERM and neural retina became more evident, and the vitelliform lesion (arrow) was found in front of the regenerated EZ at the fovea. At that time, his VA had deteriorated to 20/100, and his IOP and CFT were 17 mm Hg and 281 μm, respectively. D, One year after surgery, regeneration of the EZ was evident, and the intraretinal vitelliform lesion while fading, persisted (arrow). The neural retina was stretched out, and the gap between the ERM and neural retina had decreased. The CFT, left best-corrected visual acuity (BCVA), and Humphrey visual field analyzer mean deviation were 289 μm, 20/60, and −8.04 dB, respectively. E, Two years after the surgery, the size of the hyperreflective foci at the fovea had further decreased (arrow). However, parafoveal disruption of EZ persisted, the recovery of his BCVA was poor and stayed at 20/30. The CFT and IOP were 283 μm and 17 mm Hg, respectively. He claimed persistent metamorphopsia.
blurred and fluffy material (hyperreflective foci, arrow) appeared at the fovea, characteristic of a "vitelliform lesion." Three months after surgery (Fig. 1C), choroidal folds were not found, the separation between the ERM and neural retina became more evident, and the vitelliform lesion (arrow) became more evident. At that time, the patient claimed metamorphopsia, and his VA, IOP, and CFT were 20/100, 17 mm Hg, and 281 μm, respectively. Maximal CFT was recorded 8 months after surgery (292 μm).

One year after surgery (Fig. 1D), the intraretinal vitelliform lesion (arrow) was fading but persisted, the neural retina was stretched out, and the gap between the ERM and neural retina had decreased. His BCVA was 20/60.

FIGURE 2. Optical coherence tomography image of an eye with postsurgical elongation of the epiretinal membrane (ERM). A, This is an 84-year-old woman with secondary open-angle glaucoma. She has a history of retinal detachment surgery done 28 years ago. Before trabeculectomy her BCVA, axial length, spherical equivalent refractive error, central corneal thickness, intraocular pressure (IOP), and visual field mean deviation by Humphrey visual field analyzer were 20/25, 23.75 mm, −2.375 D, 556 μm, 34 mm Hg, and −29.14 dB, respectively. Her postoperative IOP at 1, 2, and 4 weeks after surgery was 0, 3, and 11 mm Hg, respectively. Three months after surgery, her best-corrected visual acuity (BCVA) and IOP were 20/30 and 11 mm Hg, respectively. At that time, the ERM bridged the fovea centralis, and the margin of the ERM was indicated by the arrow. B, Twelve months after surgery, her BCVA and IOP was 20/25 and 10 mm Hg. The edge of the ERM extended to the arrowed area.

Two years after surgery (Fig. 1E), the IOP was 17 mm Hg, and the size of the hyperreflective foci (arrow) at the fovea had further decreased. However, the EZ was still disrupted, the recovery of his BCVA was poor and was 20/30 at 2 years. The BCVA and IOP at 3 years were 20/30 and 17 mm Hg, respectively.

Figure 2 shows an OCT image of 84 years old woman who showed ERM elongation after trabeculectomy. Before the filtering surgery, her BCVA and IOP were 20/25 and 34 mm Hg, respectively. The lowest IOP recorded was 0 mm Hg at 1 week. Elongation of ERM was confirmed at 12 months by comparing the edge of the ERM at 3 and 12 months (arrows, Figs. 2A, B).
Figure 3 shows OCT images of 70 years old woman with pseudophakic open-angle glaucoma. Her presurgical IOP was 29 mm Hg. She had ERM and a deformed foveal pit but had a BCVA of 20/20 before surgery (Fig. 3A). Three months after surgery, her IOP was 2 mm Hg, foveal pit flattened, and foveal detachment appeared (Fig. 3B). One year after surgery, the IOP recovered to 7 mm Hg, and foveal detachment disappeared. However, the wall of the foveal pit was steep, and BCVA only partially recovered to 20/40 (Fig. 3C).

**DISCUSSION**

Several factors may affect VA after filtering surgery. Cataract can potentially cause postsurgical visual deterioration and were indeed found to cause deterioration of VA in this study. However, the vast majority of eyes in this study were pseudophakic, and mild cataract progression was noted in only 7 of 69 eyes and was not found to be a risk factor for visual deterioration by logistic regression (Tables 6, 7). Therefore, it is clear that other factors affected the VA loss in this study.

Hypotony maculopathy is another parameter that can potentially explain VA loss after filtering surgery. Choroidal and retinal folds, as well as effusion, can cause metamorphopsia and loss of VA. Hypotony maculopathy was found in 10 of 69 eyes (14%) and was a significant risk factor for VA loss at 3 months (Table 5; \( P = 0.024 \)), but not at 12 months (\( P = 0.34 \)). Therefore, hypotony maculopathy leads to mid-term VA loss at 3 months. However, this factor is insufficient to explain long-term VA loss after filtering surgery. Furthermore, deterioration of BCVA > 0.1 logMAR was found in 19 and 14 eyes at 3 and 12 months, respectively (Table 1); the number exceeded that of hypotony maculopathy (10 of 69 eyes). Thus, macroscopic hypotony maculopathy cannot explain all VA loss after trabeculectomy.

Post surgical short-term hypotension itself may be recognized as another risk factor for VA deterioration after filtering surgery. In this report, deterioration of VA at 3 months was significantly associated with low IOP at 1 week (Tables 2, 3). The association between postsurgical hypotension and the deterioration of VA may be explained by tractional abnormalities of the central foveal bouquet, which are detected exclusively by OCT. There is an MCC that connects the inner segment of the photoreceptor and the internal limiting membrane at the fovea, which transmits mechanical stress of the internal limiting membrane to the photoreceptors. If the postsurgical IOP is < 6 mm Hg, the retinal thickness increases because of subretinal effusion and retinal edema. A consequence of retinal edema, the elevation of the internal limiting membrane occurs, which leads to the pull-up of the MCC. It has been reported that the MCC is rigid, and the tractional power is transmitted to the photoreceptors, leading to abnormalities of the central foveal bouquet. In cases of simple ERM, 3 clinical features, such as the cotton ball sign, foveolar detachment, and acquired vitelliform lesions, develop and lead to the deterioration of VA. If the effusion does not persist long and the EZ is intact, good VA recovery within a few months may be expected.

A statistically significant association between the deterioration of VA and IOP at 1 week was apparent at 3 months (\( r = -0.328, \ P = 0.006 \); Table 2), but not at 12 months (\( r = -0.2193, \ P = 0.084 \)). The fact that there was no association between VA loss at 12 months and low IOP...
at 1 week ($P = 0.29$) and hypotony maculopathy ($P = 0.94$ by logistic regression; Table 6) suggests that the repair of mid-term visual deterioration was mostly completed within 12 months and other factors affected VA at 12 months.

In this study, ERM was one of the factors that explained VA loss at 12 months. According to the Fisher exact test, ERM was not associated with visual deterioration at 3 months ($P = 0.28$; Table 5) but was significantly associated with visual deterioration at 12 months ($P = 0.035$, Table 5). When the ERM combines with postsurgical hypotension, the ERM squeezes the folded retina, and a strong traction force is transmitted to the outer retina, which may lead to abnormalities in the central foveal bouquet. In the patient shown in Figure 1, a vitelliform lesion appeared and evolved in the retina at 1 to 3 months, which may indicate that the EZ had been destroyed and retinal pigment epithelium-derived materials such as lipofuscin granules and others had accumulated in the retina (Fig. 1). In Figure 3, a combination of ERM and ocular hypotension lead to structural changes in the foveal pit and tractional detachment of photoreceptors. Govetto et al reported that an acquired vitelliform lesion and foveal detachment are significantly associated with VA loss. Once the ERM squeezes the folded retina, the ERM hampers the repositioning and reconstruction of the neural retina (Figs. 1, 3). Here, deformed retinas, such as deformation of the foveal pit (Figs. 3B, C), traction to the MCC, or damage to the EZ (Fig. 1E), may persist longer, resulting in long-lasting visual deterioration.

It is our opinion that if postoperative intraocular hypotension <6 mm Hg does not occur, contraction of an elastic ERM or lift-up of the neural retina does not occur. Structural changes of the retina tend to occur in eyes with severe postoperative hypotension and lead to significant VA loss at 3 and 12 months (Table 8). It was reported that intraretinal changes in normal retina eyes caused by the ERM are significantly correlated with BCVA. Govetto’s theory may be useful to understand why hypotension and ERM-associated changes in the inner retina leads to the deterioration of VA at 3 and 12 months. A previous concept stated that hypotony-associated deformation of the inner retina may not affect the final VA; however, unlike recovery from mid-term visual deterioration, the presence of an ERM may lead to long-term tension of the MCC and photoreceptors, leading to long-term VA impairment after glaucoma surgery.

ERM was found in 5 of 11 secondary glaucoma eyes (45.5%) and 6 of 26 eyes with POAG (20.7%; Table 1). In the current study, the difference in the prevalence of ERM between POAG and secondary glaucoma was not significant ($P = 0.1573$, Fisher exact test). However, this difference may become significant with larger sample size. The prevalence of ERM in an epidemic study was around 6%, with a higher prevalence in older patients. It is not clear whether the prevalence of ERM is high in patients with POAG. However, the prevalence of ERM has been found to increase after trabeculectomy. After filtering surgery, elongation of the ERM may occur, and further VA deterioration may result. This finding is contrasting with stable ERM in eyes without surgical intervention. If candidates of glaucoma filtering surgery have ERM, it may be better to inform patients that glaucoma surgery may trigger ERM-associated changes of the retina and VA loss. If peeling of ERM precedes glaucoma surgery, conjunctival scarring may hamper bleb formation, and the retinal nerve fiber layer may be injured by surgery. If glaucoma surgery alone is planned, minimally invasive glaucoma surgery or tube surgery, in which postsurgical IOP is higher than that after trabeculectomy, may be an option.

The CFT is an important parameter that can assess postvitrectomy visual function in nonglaucoma eyes. The CFT increases in cases with traction by the ERM, while it may be thin in eyes with glaucomatous retinal atrophy. Therefore, the configuration of the fovea rather than the CFT may be a better indicator for understanding the damage to visual function in cases of combined ERM and glaucoma. This study had several limitations; it was retrospective in design and had a small sample size. The effects of corneal damage, such as astigmatism, striae, and opacity, were not studied. Therefore, further studies should be conducted.

In conclusion, VA loss at 3 months was associated with postsurgical hypotension at 1 week and was mostly self-limiting. Intraocular hypotension, combined with presurgical ERM, was associated with a higher risk of visual deterioration at 12 months.

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