Changes in Retinochoroidal Thickness After Vitrectomy for Proliferative Diabetic Retinopathy

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PURPOSE. To evaluate the changes in the peripheral retinochoroidal thickness after pars plana vitrectomy (PPV) with scatter photocoagulation for proliferative diabetic retinopathy (PDR).

METHODS. Small gauge PPV was performed on 22 eyes with PDR with scatter photocoagulation, and on 32 eyes with an epiretinal membrane (ERM) without photocoagulation as control. The peripheral retinochoroidal thickness was measured at 5 mm from the limbus in the four quadrants using anterior segment optical coherence tomography preoperatively, and 3 days and 1 and 2 weeks after the surgery. In eyes with a peripheral choroidal detachment, the retinochoroidal thickness and the height of choroidal detachment were measured separately. The total peripheral thickness was defined as the sum of retinochoroidal thickness and the height of choroidal detachment.

RESULTS. A significant larger number of eyes developed a choroidal detachment in the PDR group than in the ERM group 3 days after surgery (P < 0.001). The total peripheral choroidal thickness 3 days after surgery was significantly thinner than that before surgery in the PDR group (P = 0.009). The increase in the total peripheral thickness in the PDR group was significantly greater than that in the ERM group at 3 days after surgery (P = 0.007). The number of photocoagulation burns was significantly and positively correlated with the total peripheral thickness (r = 0.57, P = 0.006).

CONCLUSIONS. We conclude that the transient thickening of the total peripheral thickness in early postoperative stage for PDR was due to the intraoperative scatter photocoagulation.

Keywords: anterior segment optical coherence tomography, choroidal detachment, intraocular pressure, scatter photocoagulation, proliferative diabetic retinopathy, retinochoroidal thickness, total peripheral thickness, vitrectomy

Panretinal laser photocoagulation (PRP) is an effective treatment for proliferative diabetic retinopathy (PDR), and it will reduce the risk of severe visual loss.1-3 In eyes with PDR, a dissection of the vitreous base with complete intraoperative laser photocoagulation is required for anatomic and functional success. Therefore, it has been recommended that if laser photocoagulation had not been completed before vitrectomy in eyes with PDR cases, PRP should be completed during the vitrectomy. However, PRP can also lead to complications such as massive choroidal detachment, angle closure glaucoma, and IOP elevation.4 Another complication that Chen et al.5 reported was that retinochoroidal detachments occurred frequently after PPV with PRP and also after PRP alone.

A silicone oil tamponade has been shown to be helpful in treating eyes with severe PDR.6 However, it has been reported that PRP in conjunction with silicone oil tamponade for PDR has the highest risk for an elevation of the IOP.7 Thus, information about the factors causing the postoperative IOP elevation in PDR cases is critical for appropriate patient care.

The purpose of this study was to evaluate the changes in the peripheral retinochoroidal thickness after pars plana vitrectomy (PPV) with intraoperative scatter photocoagulation, resulting in a complete PRP for the treatment of proliferative diabetic retinopathy (PDR).

METHODS

Ethics Statement

This study was conducted in adherence with the tenets of the Declaration of Helsinki. This was a retrospective, observational comparative, single-center study, and the procedures were approved by the institutional review board and the Ethics Committee of the Nagoya University Graduate School of Medicine (Nagoya, Japan).

Subjects

We reviewed the medical records of all patients who had undergone 23- or 25-G PPV for PDR at the Nagoya University Hospital from June 2012 to June 2013. Patients who had undergone PPV for an epiretinal membrane (ERM) were studied as controls. All of the patients signed an informed consent form before surgery.

All patients underwent a comprehensive ophthalmic examination including the measurements of IOP and axial length, slit-lamp examination, fundus examination, and optical coherence tomography (OCT) preoperatively, and 3 days, and 1 and 2 weeks after the surgery.

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Peripheral Retinochoroidal Thickness

Measurements Using Swept Source Anterior Segment Optical Coherence Tomography (AS-OCT)

The peripheral retinochoroidal thickness was measured in the images obtained by a swept source AS-OCT (CASIA SS-1000; Tomey Corporation, Nagoya, Japan; Figs. 1, 2). The vertical retinochoroidal thickness was manually measured from the vitreoretinal interface to the outer surface of the choroid at 5000 μm from the limbus in the four quadrants in the AS-OCT images (C–F). We measured both the retinochoroid thickness and the distance from outer surface of choroid to the inner surface of sclera as the height of choroidal detachment thickness separately in eyes with a retinochoroidal detachment. The white arrowheads indicate the total peripheral thickness consisting of the retinochoroid thickness (white arrow) plus the height of choroidal detachment 3 days after surgery (D). The retinochoroid thickness was decrease and the choroidal detachment disappeared 1 (E) and 2 weeks (F) after surgery. AC, anterior chamber.

Surgical Technique

Standard 3-port PPV was performed with either 23- or 25-G instruments after retrobulbar anesthesia with 2.5 mL of 2%...
lidocaine and 2.5 mL of 0.5% bupivacaine. None of the patients had concurrent scleral buckling surgery. In eyes with a cataract, cataract surgery was performed as described below. To begin, a 3.0-mm wide self-sealing superior sclerocorneal tunnel was created at 12 o’clock, and a continuous curvilinear capsulorhexis was performed. The lens nucleus was removed and the residual cortex was aspirated with an irrigation/aspiration (I/A) tip. Next, a foldable acrylic IOL was implanted into the bag.

A trocar was inserted at an angle of approximately 30° parallel to the limbus with the bevel-side up. Once the trocar past the trocar sleeve, the angle was changed to be perpendicular to the surface. After making the three ports, vitrectomy was performed using the Constellation system (Alcon Laboratories, Inc., Fort Worth, TX, USA). Intraoperative scatter photocoagulation was applied singly to the retina, resulting in a complete PRP in the PDR group. We tried to make the same laser photocoagulation spot size by placing the laser probe the same distance from the retina. The power and the duration of the photocoagulation were 150 mW and 150 ms, respectively. Air, 20% sulfur hexafluoride (SF6), or silicone oil was injected into the vitreous at the completion of the vitrectomy if needed. We injected 0.3 to 0.5 cc lesser amount of silicone oil than the vitreous volume to avoid postoperative hypertension. After the IOP was adjusted to a normal tension, the cannulas were withdrawn. The sclera was pressed and massaged with an indenter to close the wound.

At the end of surgery, gentamicin and betamethasone were injected subconjunctivally. Anti-inflammatory drops and antibacterial drops were administered four times/d for 3 months.

**Figure 2.** Representative AS-OCT images of eyes with an ERM. An AS-OCT image was taken at the temporal area (A). The structure was described on an image taken by AS-OCT (B). The retinochoroidal thickness was measured in eyes with ERM before (C) and after (D–F) surgery. Most of eyes in the ERM group did not have a choroidal detachment after surgery 3 days (D), 1 week (E), and 2 weeks (F) after surgery.
Exclusion Criteria
In the PDR group, eyes that had fewer than 500 burns, burns limited to a quadrant, or eyes injected with subtenon triamcinolone during surgery, were excluded. In the ERM group, none of the patients was not taking any medication for diabetes, and none had diabetic retinopathy. Eyes that had any focal photocoagulation for peripheral lattice degeneration, atrophic retinal hole, or old branch retinal vein occlusion were excluded. Thus, all ERM eyes had no previous or intraoperative photocoagulation.

Statistical Analyses
Chi-square tests were used to compare the categorical data, and independent t-tests were used to compare normally distributed data. Repeated ANOVA with post hoc Bonferroni corrections was used to evaluate changes in the IOPs and the retinochoroidal thicknesses. Pearson’s correlation coefficient tests and Kruskal-Wallis one-way ANOVA were used to determine the variables significantly associated with the retinochoroidal thickness. Multiple linear regression analysis was used to evaluate the correlation between the total peripheral thickness at 3 days after surgery and independent surgical type, and sex. A value less than 0.05 was considered statistically significant.

RESULTS
Demographics and Surgical Characteristics of Patients
The demographics and the surgical characteristics of all of the patients are shown in Table 1. There were 22 eyes of 21 consecutive PDR patients and 32 eyes of 32 consecutive ERM patients. The differences in the age, sex, and axial length were not significant in the two groups. On the other hand, the peripheral retinochoroid in the PDR group was significantly thicker than that in the ERM group before surgery ($P < 0.001$; Fig. 3). There were significant differences in the surgical procedures ($P = 0.015$), and operation time ($P < 0.001$) between the two groups.

Changes in Peripheral Retinochoroidal Thickness
In the PDR group, the mean peripheral retinochoroidal thickness was $203 \pm 45 \mu m$ before surgery, $391 \pm 175 \mu m$ at 3 days, $234 \pm 66 \mu m$ at 1 week, and $210 \pm 45 \mu m$ at 2 weeks after surgery (Fig. 3). The mean peripheral retinochoroidal thickness 3 days after surgery was significantly thicker than that before surgery ($P < 0.001$). The mean total peripheral thickness was $203 \pm 45 \mu m$ before surgery, $548 \pm 331 \mu m$ at 3 days, $267 \pm 158 \mu m$ at 1 week, and $223 \pm 68 \mu m$ at 2 weeks after surgery. The total peripheral thickness 3 days after surgery was significantly thicker than that before surgery ($P < 0.001$).

In the ERM group, the mean peripheral retinochoroidal thickness was $149 \pm 26 \mu m$ before surgery, $235 \pm 10 \mu m$ at 3 days, $220 \pm 71 \mu m$ at 1 week, and $172 \pm 30 \mu m$ at 2 weeks after surgery. The mean peripheral retinochoroidal thickness 3 days after surgery was significantly thicker than that before surgery ($P < 0.001$). The mean total peripheral thickness was $149 \pm 26 \mu m$ before surgery, $281 \pm 186 \mu m$ at 3 days, $225 \pm 127 \mu m$ at 1 week, and $173 \pm 30 \mu m$ at 2 weeks after surgery. The mean total peripheral thickness 3 days after surgery was significantly thicker than that before surgery ($P = 0.001$; Fig. 3).

The mean increase of the total peripheral thickness 3 days after surgery was $351 \pm 316 \mu m$ in the PDR group and $132 \pm 179 \mu m$ in the ERM group (Fig. 3). The increase in the thickness in the PDR group was significantly greater than that in the ERM group ($P = 0.007$). However, there was no significant difference in the increase of the total peripheral thickness between the groups at 1 and 2 weeks after surgery.

Choroidal detachments were present in the 14 of 22 eyes (63.6%) in the PDR group, which was significantly greater than the 6 of 32 eyes (18.7%) in the ERM group 3 days after surgery ($P < 0.001$; Table 2). The choroidal detachment disappeared with time and without treatment, but persisted in four eyes in the PDR group even at 2 weeks after surgery.

![Figure 3. Changes in the mean total peripheral thickness. There was a significant difference in the retinochoroid thickness between the two groups preoperatively ($P < 0.001$) and 3 days after surgery ($P = 0.002$). The total peripheral thickness 3 days after surgery is significantly thicker than that preoperatively in the both groups ($P = 0.009$, $P = 0.014$, respectively).](image-url)
The total peripheral thickness of the inferior peripheral quadrant was thicker than the other quadrants, but the differences among the quadrants in each group were not significant (Fig. 4A). The height of the choroidal detachment also had similar differences, but none of the differences were significant at any time point after surgery in each group as well (Fig. 4B).

**Correlation Between Changes of Total Peripheral Thickness and Number of Photocoagulation Burns**

The results of the multiple linear regression analysis for the total peripheral thickness at 3 days after surgery are shown in Table 3. Only the number of laser photocoagulation burns was significantly correlated with the total peripheral thickness at 3 days after surgery \( (P = 0.004) \). The increase of the total peripheral thickness at 3 days after surgery was not significantly correlated with the other variables. The number of photocoagulation burns was significantly and positively correlated with the total peripheral thickness \( (r = 0.57, P = 0.006; \text{Fig. } 5A) \) and also with the increase of the total peripheral thickness at 3 days after surgery \( (r = 0.54, P = 0.009; \text{Fig. } 5B) \). The total peripheral thickness in the nasal, inferior, and temporal quadrants were significantly correlated with the number of laser photocoagulation burns \( (r = 0.46, 0.53, 0.60, P = 0.030, 0.004, 0.001, \text{respectively}) \).

**Change of IOP**

In the PDR group, the mean IOP was 14.3 ± 3.3 mm Hg preoperatively, and 13.3 ± 2.3 mm Hg at 3 days, 12.7 ± 3.1 mm Hg at 1 week, and 13.2 ± 3.5 mm Hg at 2 weeks after the surgery. In the ERM group, the mean IOP was 14.1 ± 2.5 mm Hg preoperatively, and 12.5 ± 4.5 mm Hg at 3 days, 13.0 ± 4.2 μm at 1 week, and 12.5 ± 3.2 mm Hg at 2 weeks after the surgery. There was no significant change in the IOPs before and at any time after surgery in both groups.

**DISCUSSION**

Our results showed that the total peripheral thickness, which was the sum of retinochoroidal thickness and the height of choroidal detachment, was significantly increased in the PDR group compared with that before surgery only at 3 days after surgery. The increase of the total peripheral thickness was also significantly greater in the PDR group than that in the ERM group only at 3 days after surgery (Fig. 3). To the best of our knowledge, this is the first report quantifying the degree of change of the retinochoroidal thickness and the total peripheral thickness after surgery.

A local choroidal detachment is one of the major complications of vitrectomy.9 A choroidal detachment was detected in 6 of 32 eyes (19%), and the mean total peripheral thickness was significantly greater at 3 days after surgery than before surgery. This was also true for the ERM group even though these eyes did not receive any photocoagulation. The AS-OCT images in our study were taken at 12-, 3-, 6-, and 9-o’clock, which did not correspond with the sclerotomy sites. This is in accordance with the findings of Guthoff et al.10 who reported that a choroidal detachment developed not only at the sites of the ports for the surgical instruments but also at other sites such as at 6-o’clock after PPV (8 of 39 eyes). In comparison, our results showed that 14 of 22 eyes (64%) developed choroidal detachment 3 days after the vitrectomy in the PDR group. In addition, there was a significant difference in the percentage of eyes with a choroidal detachment between the PDR and the ERM group 3 days after surgery. This is in agreement with the findings of Chen et al.5 who reported that a ciliochoroidal detachment was observed by ultrasound biomicroscopy in 64% of eyes with extensive intraoperative retinal photocoagulation after PPV for the treatment of PDR. These findings suggest that the choroidal detachment in the PDR group was not caused by the sclerotomies, but more likely from other surgical procedures such as the intraoperative scatter photocoagulation.

**Table 2. The Proportion of Postoperative Choroidal Detachment**

<table>
<thead>
<tr>
<th>Postoperative Choroidal Detachment</th>
<th>PDR (n = 22)</th>
<th>ERM (n = 32)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 3</td>
<td>14 (65.6%)</td>
<td>6 (18.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week 1</td>
<td>2 (9.1%)</td>
<td>4 (12.5%)</td>
<td>0.718</td>
</tr>
<tr>
<td>Week 2</td>
<td>4 (18.2%)</td>
<td>0 (0%)</td>
<td>0.017</td>
</tr>
</tbody>
</table>

![Figure 4](image_url)

**Figure 4.** Changes in the mean total peripheral thickness in each quadrant. In the PDR group, the total peripheral thickness at the inferior site is relatively thicker than the other sites but the differences were not significant (A). The height of the choroidal detachment had similar differences but none of the differences was significant in both groups (B).
Different tamponade agents were used in this study, which may have affected the postoperative values of the retinochoroidal thickness. However, multiple linear regression analysis of the PDR group showed that only the number of laser photocoagulation burns was significantly correlated with the total peripheral thickness at 3 days after surgery. In addition, the total peripheral thickness in the PDR group at 3 days after surgery was significantly and positively correlated with the number of laser photocoagulation burns. Thus, our results indicate that a larger number of intraoperative laser burns could cause a greater increase in the overall total peripheral thickness and temporarily reduce the volume of the vitreous cavity. Gentile et al.\(^1\) used ultrasound biomicroscopy and reported that choroidal effusion developed frequently after PRP. They found a greater number of laser burns was associated with an increasing likelihood for the development of a choroidal effusion. One possible explanation is that retinal photocoagulation affected not only the retina but also the choroidal capillary network\(^,\)\(^1\) which can then cause choroidal inflammation, stasis of choroidal blood flow, and choroidal detachment with subchoroidal effusion\(^,\)\(^1\)\(^3\)\(^4\).

Kim et al.\(^1\) reported that the subfoveal choroidal thickness was correlated with the severity of PDR and suggested that an increased production of VEGF or other cytokines caused choroidal vasodilation and an increase in the choroidal blood flow. These changes then resulted in an increase in the subfoveal choroidal thickness. The peripheral retinochoroidal in the PDR group was significantly thicker than that in the ERM group before surgery, although we were not able to calculate the subfoveal choroidal thickness because of vitreous hemorrhage in the PDR group. One possible explanation is that the peripheral retinochoroidal thickness was thicker in the PDR group before surgery because of VEGF or other cytokines, which would cause choroidal vasodilation and an increase of choroidal blood flow.

It has been previously reported that PRP with silicone oil tamponade for PDR led to a high risk for early and late IOP elevations.\(^7\) We found a thickening of the total peripheral thickness 3 days after vitrectomy combined with scatter photocoagulation for the treatment of PDR. In addition, photocoagulation can cause massive choroidal detachment and transient retinal edema at the photocoagulation spot.\(^6\) Therefore, it seems to be more likely that this reduction in the volume of the vitreous cavity is due to these reasons, and a reduced compressibility of silicone oil tamponade would be able to cause IOP elevation as an early postoperative complication. These findings indicated that the hypotensive IOP medications would have difficulty in controlling the IOP in eyes filled with silicone oil especially in the early postoperative stage after vitrectomy with scatter photocoagulation. However, in the present study, the IOP did not significantly increase after surgery in both of two eyes with silicone oil tamponade. This could have been because 0.3 to 0.5 cc lesser amount of silicone oil than the vitreous volume was injected to avoid hypertensive IOP after surgery.

There was no significant difference in the total retinochoroidal thickness between before and after day 7 postoperatively. This is in agreement with the findings of Yuki et al.\(^5\) who reported that a ciliary detachment had disappeared spontaneously 7 days after photocoagulation.\(^1\) This indicates that we should pay attention and treat the IOP elevation for at least 1 week after vitrectomy in eyes with PDR treated with scatter photocoagulation, especially in eyes with silicone oil tamponade.

Our findings showed that the total peripheral thickness in the inferior quadrant was thicker than the other quadrants in the PDR group 3 days after surgery. This indicated that the retinochoroidal detachment after surgery was not uniform in all quadrants, and could move inferiorly with gravity and pooling in the inferior quadrant. We measured the retinochoroidal thickness at 5-mm posterior from the limbus where we could identify the peripheral retinochoroidal thickness and the height of choroidal detachment separately. Usually, choroidal detachments spread from the ora serrata to the equatorial line.\(^1\)\(^8\) The detachment thickness might be thicker at the more posterior site, but it was difficult to determine the thickness there because the eyelid prevented the measurements by AS-OCT.

**Table 3.** Results of Multiple Regression Analysis of Factors Independently Contributing to the Total Peripheral Thickness in the PDR Group (Day 3)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Coefficients</th>
<th>t Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser photocoagulation burns</td>
<td>0.616</td>
<td>3.317</td>
<td>0.004</td>
</tr>
<tr>
<td>Preoperative RCT, μm</td>
<td>0.274</td>
<td>1.320</td>
<td>0.204</td>
</tr>
<tr>
<td>Axial length, mm</td>
<td>−0.187</td>
<td>−0.975</td>
<td>0.345</td>
</tr>
<tr>
<td>Tamponade (none/air or SF6/Silicone oil)</td>
<td>0.169</td>
<td>0.869</td>
<td>0.397</td>
</tr>
<tr>
<td>Operation time, min</td>
<td>0.099</td>
<td>0.508</td>
<td>0.618</td>
</tr>
<tr>
<td>IOP (Day 3), mm Hg</td>
<td>0.091</td>
<td>0.465</td>
<td>0.649</td>
</tr>
<tr>
<td>Gauge, 23/25</td>
<td>0.007</td>
<td>0.033</td>
<td>0.694</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.083</td>
<td>−0.376</td>
<td>0.712</td>
</tr>
<tr>
<td>Surgical type (PPV/PPV+C0)</td>
<td>0.064</td>
<td>0.336</td>
<td>0.741</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>0.077</td>
<td>0.400</td>
<td>0.974</td>
</tr>
</tbody>
</table>

**Figure 5.** Scatterplot of the total peripheral thickness versus the number of laser photocoagulation burns. The total peripheral thickness (A) and the increase of the total peripheral thickness (B) was significantly and positively correlated with the number of laser photocoagulation burns ($r = 0.57, P = 0.006$; $r = 0.54, P = 0.009$, respectively).
Our study has limitations such as it being retrospective with a small sample size and not having patient with diabetes or any comparable disease process to proliferative diabetic retinopathy. In addition, the surgical procedures (e.g., operation time and types of surgery performed) were different between the two groups, which would have influenced the thickness.

Further prospective studies on a greater number of cases including diabetic patients with no retinopathy, simple retinopathy, or preproliferative retinopathy with similar operation times and surgical procedures will be necessary to determine the cause of the increased retinochoroidal thickness and IOP elevation after surgery.

We conclude that the large number of intraoperative scatter photocoagulation caused the thickening of the total peripheral thickness, which resulted in the reduction of volume of the vitreous cavity. This would then cause an elevation of the IOP in the early postoperative stage in PDR cases.

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