

Peripapillary changes after vitrectomy and silicone oil tamponade for rhegmatogenous retinal detachment

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Purpose: To evaluate the peripapillary changes after vitrectomy and silicone oil (SO) tamponade in eyes with rhegmatogenous retinal detachment (RRD). **Methods:** In this study, 25-gauge vitrectomy with SO tamponade was performed in 22 eyes with RRD. The radial peripapillary capillary (RPC) vessel density (VD) and retinal nerve fiber layer thickness (RNFLT) were assessed by optical coherence tomography angiography at 2, 4, 8, and 12 weeks postoperatively. The values of healthy fellow eyes were used as controls. **Results:** The global RPC VDs were significantly lower in the eyes with RRD than in fellow healthy eyes at 2 weeks ($P < 0.001$), and increased at 4 weeks, then decreased over time after surgery ($F = 1.046$, $P = 0.377$). The RPC VDs in the superior-hemifield were lower than those in the inferior-hemifield at 12 weeks postoperatively ($t = -2.844$, $P = 0.010$). The global RNFLTs decreased gradually after vitrectomy in the eyes with RRD ($F = 1.312$, $P = 0.276$). The RNFLTs in the superior-hemifield were thinner than those in the inferior-hemifield at 12 weeks postoperatively ($t = -2.222$, $P = 0.037$). The global, superior, and inferior RNFLTs were correlated with corresponding RPC VDs in the eyes with RRD at all time-points postoperatively ($P < 0.05$). **Conclusion:** RRD resulted in the decrease of RPC VDs. The RPC VDs recovered in the early postoperative period but were still lower than the normal level. Long-term application of SO tamponade resulted in the reduction of peripapillary VDs secondary to loss of RNFLTs.

Key words: Optical coherence tomography angiography, radial peripapillary capillary, rhegmatogenous retinal detachment, silicone oil, vitrectomy

Patients with rhegmatogenous retinal detachment (RRD) may have suboptimal visual recovery for various reasons, especially those treated successfully with pars plana vitrectomy (PPV) and silicone oil (SO) tamponade.^[1,2] Currently, most studies have focused on the effect of SO on macular microstructure and vessel density (VD) in eyes with RRD after surgery.^[3-13] However, few studies have been conducted on the effect of SO on the optic disc. In the past, it was difficult to detect the blood flow density around the optic disc due to a lack of related technology.

Optical coherence tomography angiography (OCTA) is a noninvasive, real-time method that has been used to measure relative peripapillary VD and retinal nerve fiber layer thickness (RNFLT). Recently, peripapillary VD has been applied in the study of optic nerve-related diseases.^[14-17] We found only one study that examined the effect of SO on peripapillary VD in eyes with RRD.^[18]

This study aimed to evaluate the changes in peripapillary VD and RNFLT in PPV-treated with SO tamponade in eyes with RRD.

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Methods

Ethical approval

This retrospective study was approved by the Ethics Committee and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants before surgery.

Experimental design

All 22 participants with unilateral RRD who successfully underwent a 25 G PPV with SO tamponade at Taiyuan Aier Eye Hospital from June 2019 to June 2020 were reviewed. Their fellow healthy eyes were used as controls.

The exclusion criteria were as follows: (1) had undergone prior ocular surgery; (2) optic disc abnormalities (e.g. glaucoma, anterior ischemic optic neuropathy, optic disc atrophy, or uveitis in either eye); (3) postoperative complications (e.g. vitreous hemorrhage, proliferative vitreoretinopathy, endophthalmitis); (4) any medical condition that could affect the hemodynamics of the eye (e.g. hypertension, diabetes,

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arrhythmia, or vascular diseases); (5) axial length ≥ 26.5 mm, or axial length difference of >0.3 mm between bilateral eyes; and (6) poor image quality.

Standard 25 G PPV was performed after retrobulbar anesthesia by a single experienced retinal surgeon (J.J.) using the Alcon Constellation system (Alcon Laboratories, Inc., Fort Worth, TX, USA). After complete vitreous removal, subretinal fluid drainage, and endophotocoagulation, the same brand of SO (Oxane 5700; Bausch and Lomb, Inc., NY) was injected into the vitreous cavity. All 22 participants remained in a face-down position for 2 weeks after surgery. The follow-up time was at least 3 months after surgery, and the retinal attachment was confirmed in the eyes by a comprehensive ophthalmic examination. All 22 participants underwent comprehensive ophthalmic standard examinations 2, 4, 8, and 12 weeks postoperatively from June 2019 to October 2020, which included BCVA, IOP, slit-lamp biomicroscopy examination, fundus examination, and OCTA.

We quantitatively assessed the radial peripapillary capillary (RPC) VD and RNFLT from OCTA images obtained from RTVue XR Avanti AngioVue (Optovue Inc., Fremont, CA, USA). The software AngioVue AngioAnalytics (version 2018.1.0.43) generated the images on a 4.5 mm \times 4.5 mm optic disc scan using an 840-nm diode laser source via dilated pupil in the eyes with RRD and fellow healthy eyes. The relative information was obtained using a split-spectrum amplitude-decorrelation angiography algorithm. A three-dimensional projection artifact removal technique was applied to make the information more accurate. The peripapillary area was defined as the area between the 2 mm and 4 mm diameter annular contour lines around the disc margin by the software. The RPC VD in a 1.00-mm-wide elliptical annulus extends from the internal limiting membrane to the nerve fiber layer. Based on Garway-Heath's map, the RPC VD and RNFLT of the global 360° area, superior-hemifield, and inferior-hemifield were automatically generated [Fig. 1]. Healthy fellow eyes were used as controls.

Statistical analyses

SPSS 25.0 (SPSS, Inc., Chicago, IL, USA) was used to perform all statistical analyses. One-way ANOVA was used to evaluate changes in RPC VD and RNFLT parameters postoperatively. Paired *t*-tests were used to compare global values between the eyes with RRD and their fellow healthy eyes, and values between superior-hemifield and inferior-hemifield in the eyes with RRD and their fellow healthy eyes at specific time-points. Pearson test was used to evaluate the correlation between RPC VD and RNFLT at different postoperative time-points. $P < 0.05$ was considered statistically significant.

Results

The demographics and ocular characteristics are shown in Table 1.

Twenty-two eyes of 22 patients with RRD underwent PPV with SO tamponade in our hospital from June 2019 to June 2020. Transient increased IOP occurred in four eyes (18.2%) within 1 month postoperatively and was controlled by the administration of topical antiglaucoma medication. The retina was successfully reattached before SO removal surgery (at least 3 months interval).

Table 1: Demographics and baseline characteristics of the patients in the study ($n=22$)

Variable	Study eyes
Age, mean (range) (years)	42.86 \pm 17.15 (14-68)
Sex (male/female)	11/11
RRD eye (right/left)	14/8
Duration of detachment (range) (days)	14.7 \pm 13.6 (2-60)
Axial length (range) (mm)	25.64 \pm 0.75 (23.68-26.48)
Duration of SO tamponade (range) (months)	4.7 \pm 1.7 (3.0-9.0)
Operation time (range) (min)	58.2 \pm 14.6 (30-90)

RRD - rhegmatogenous retinal detachment, SO - silicone oil

The global RPC VDs were lower in the eyes with RRD than in fellow healthy eyes at 2 weeks postoperatively ($t = -4.851$, $P < 0.001$). The global RPC VDs increased at 4 weeks and then decreased postoperatively ($F = 1.046$, $P = 0.377$) [Fig. 2]. There was no statistical difference in global RPC VD in the RRD eyes between 4 weeks and 12 weeks postoperatively ($P = 0.082$). There were no statistical differences in the global RPC VDs in the fellow healthy eyes at different time-points postoperatively ($F = 0.025$, $P = 0.995$).

The RPC VD changes in the superior-hemifield and inferior-hemifield were consistent with the global RPC VDs [Fig. 2]. The RPC VDs in the superior-hemifield were lower than those in the inferior-hemifield postoperatively and decreased more obviously after 4 weeks postoperatively. The statistical difference occurred at 12 weeks postoperatively ($t = -2.844$, $P = 0.010$). However, there was no statistical significance in the RPC VDs between the superior-hemifield and inferior-hemifield in the fellow healthy eyes at all time-points postoperatively (all $P > 0.05$).

The global RNFLTs in the eyes with RRD were thicker than in the fellow healthy eyes at 2 weeks postoperatively ($t = 1.819$, $P = 0.083$) and decreased over time until 12 weeks postoperatively ($F = 1.312$, $P = 0.276$). The RNFLTs in the superior-hemifield were thinner than those in the inferior-hemifield in the eyes with RRD after 4 weeks postoperatively ($t = -1.338$, $P = 0.195$, 8 weeks; $t = -2.222$, $P = 0.037$, 12 weeks) [Fig. 3]. There was no statistical significance in the global RNFLTs ($F = 0.029$, $P = 0.993$), and the RNFLTs between the superior-hemifield and inferior-hemifield in the fellow healthy eyes at all time-points postoperatively (all $P > 0.05$).

The global, superior, and inferior RNFLTs were correlated with corresponding RPC VDs in the eyes with RRD at all time-points postoperatively (all $P < 0.05$).

Discussion

Recently, Wang *et al.*^[18] demonstrated that there was a mild increase in RPC VD in eyes with RRD after SO removal using OCTA, which suggested that SO tamponade might have adverse effects on RPC VD. The result was based on the assumption that RPC VD, which decreases in the eyes with RRD due to SO tamponade, will recover after SO removal. However, another ignored assumption was that SO removal surgery could affect RPC VD. Until now, the process by which RPC

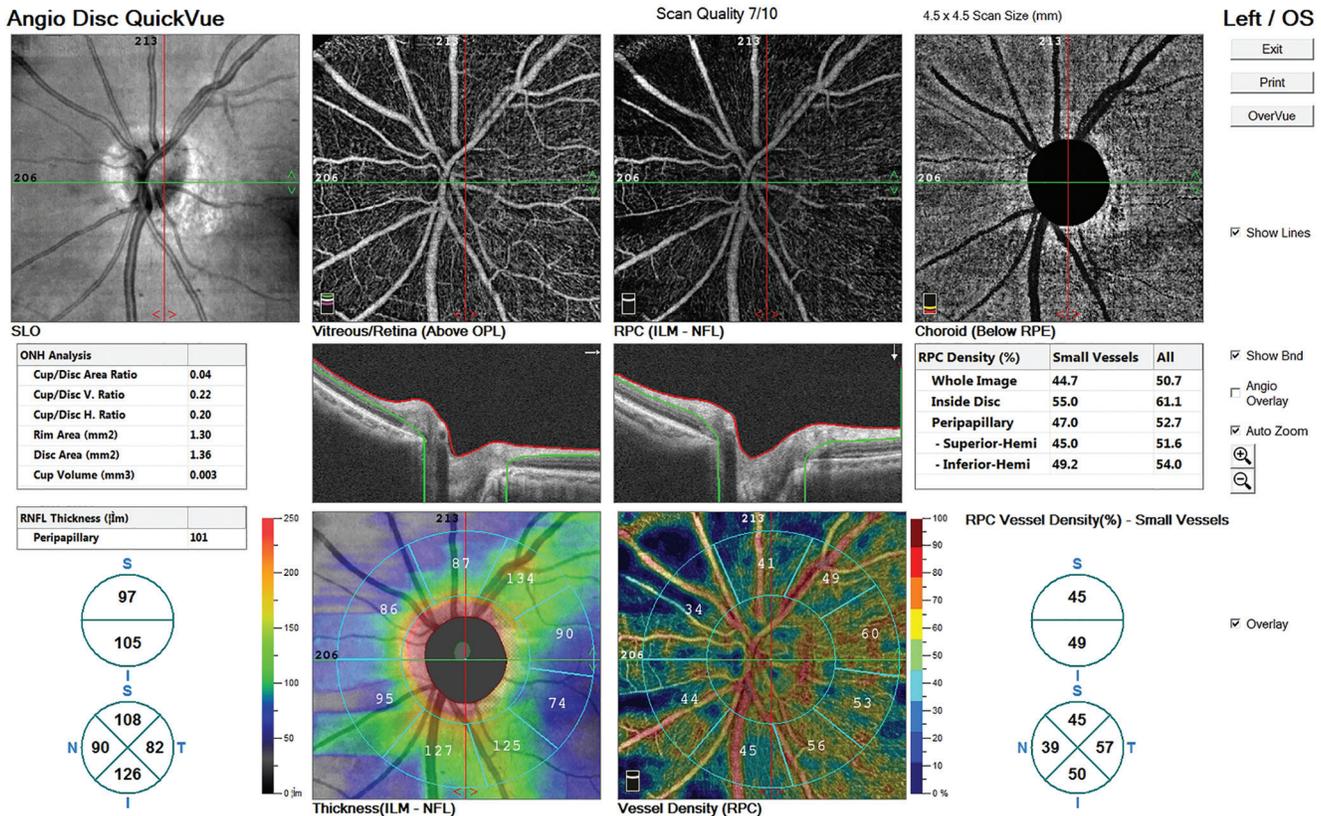


Figure 1: Optical coherence tomography angiography (OCTA) images of a 60-year-old male patient with macula-off rhegmatogenous retinal detachment (RRD) eye at week 4 postoperatively. The small vessels of radical peripapillary capillary (RPC) density shown on the right side of the figure was defined as RPC vessel density (VD). The retinal nerve fiber layer thickness (RNFLT) is shown on the left side of the figure. The corresponding values in the superior-hemifield and inferior-hemifield were below the RPC VD and RNFLT.

VD changes in eyes with RRD after surgery remains unclear, especially the intraocular SO tamponade.

Our study showed that the RPC VDs decreased in the early period of PPV-treated eyes with RRD and then increased within 4 weeks postoperatively using OCTA. The increase in RPC VD was consistent with macular VD change in eyes with RRD in the early period after surgery.^[19] Iwase *et al.*^[20] showed that the retinal blood flow was reduced in eyes with RRD preoperatively and could recover after vitrectomy using the laser speckle flowgraph. Therefore, we thought that RRD resulted in the decrease of RPC VDs and RPC VDs recovered over time in the early postoperative period, consistent with macular VD.

Lee *et al.*^[12] found that the duration of SO tamponade was significantly correlated with the enlargement of the FAZ area and reduction in the macular VD in DCP. In our previous study, the macular VD in eyes with RRD after PPV-treated with SO tamponade recovered over time but decreased at 16 weeks postoperatively. Therefore, we suspected that SO tamponade might result in a decrease of RPC VD at a specific time-point postoperatively, consistent with macular VD. In the present study, RPC VD decreased after 4 weeks postoperatively, although the differences between all time-points were not statistically significant. Surprisingly, the time-point for the decline in RPC VD was earlier than that of the macular VD in our previous study. Another study demonstrated that a

decrease in RPC VD was earlier than the macular VD occurred in patients with diabetes mellitus (DM) without DR.^[17] This may be because the peripapillary plexus is composed of capillaries with long straight paths and rare anastomotic connections, which is different from the macular vascular plexus. Another reason might be that ONH is more vulnerable to the mechanical stress of SO because of the anatomic conformation that ONH protrudes from the surface of the fundus.

In the present study, peripapillary RNFLT became thinner with increasing time postoperatively. This is consistent with foveal macular thickness in eyes with RRD after PPV with SO tamponade in our previous study. Previous studies have shown that SO tamponade resulted in retinal thinning in macula-on eyes with RRD on OCT, which was not seen in eyes treated with gas.^[21] The precise mechanism by which SO causes significant retinal thinning remains unclear. Several causes may be involved in this phenomenon, including mechanical stress,^[22] toxicity of emulsified silicone oil on the retina,^[23] and retinal ionic environmental changes,^[24]. Our study showed that the superior RNFLT became thinner than the inferior RNFLT with increasing time after surgery. The difference became statistically significant until 12 weeks postoperatively. Therefore, we suspected that mechanical stress by SO to the retina mainly resulted in a decrease in RNFLT and the difference in RNFLT between superior-hemifield and inferior-hemifield at the later stage postoperatively.

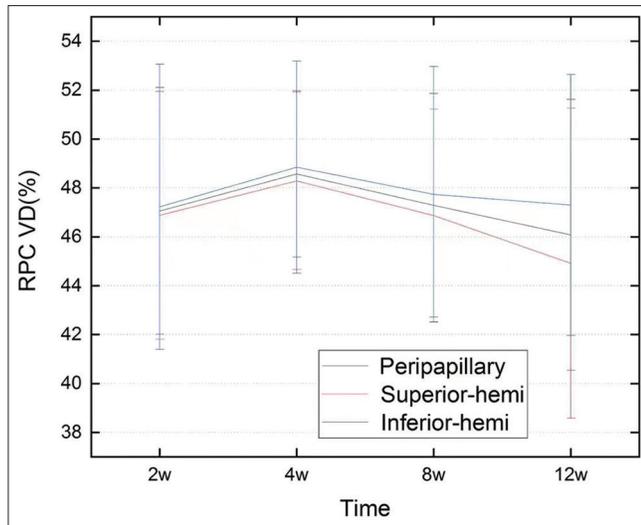


Figure 2: The curve of mean RPC VDs in eyes with RRD after surgery. The global, superior, and inferior RPC VDs increased within 4 weeks postoperatively and then decreased until 12 weeks postoperatively. The difference in RPC VDs between superior-hemifield and inferior-hemifield was significant at week 12 postoperatively.

In the present study, statistical analysis showed that RPC VDs were correlated with RNFLTs in all counterparts at all time-points (all $P < 0.05$). The innermost layer of RPC runs parallel to the peripapillary nerve fiber layer and has a function to nourish the peripapillary nerve fiber layer. However, the exact relationship between RPC VD and RNFLT remains unclear. Vujosevic *et al.*^[17] showed that there are early changes in RPC VD in patients with DM without DR that correlated with RNFLT. Jo *et al.*^[25] demonstrated that a decrease in circumpapillary vasculature was accompanied by loss of RNFLT in POAG. However, the correlation between peripapillary VD and RNFLT was complicated in primary angle-closure glaucoma (PACG). Zhang *et al.*^[15] found that peripapillary VD was positively correlated with RNFLT in acute PACG eyes with controlled IOP for years. In contrast to a previous study, the deterioration of peripapillary VD may occur earlier than the reduction of the RNFLT after an acute attack in acute primary angle-closure eyes.^[26] Rao *et al.*^[27] found that the change in peripapillary VD and RNFLT occurred in the different stages of PACG, and the change of peripapillary RNFLT was earlier than that of peripapillary VD. Whether RPC VD loss is the cause or a consequence of the neural structure loss remains unclear in ocular diseases, including eyes with RRD with PPV-treated and SO tamponade. In the present study, the reduction of RNFLT occurred earlier than the decrease in the RPC VD, which is consistent with the results of a study by Rao *et al.* We suspected that long-term SO tamponade resulted in the reduction of RPC VD secondary to the loss of RNFLT.

This study has several limitations. First, different ways were employed to detect retinal blood flow in previous studies. In the present study, OCTA differences in the parameters measured may have caused the difference. The changes in retinal vessel diameter might be affected by oxygen concentration instead of blood flow velocity using OCTA. Second, a single hospital and a relatively small sample size were not sufficient to make strong conclusions. Third, the OCTA findings in this present study are possibly due to RRD or surgical factors that could

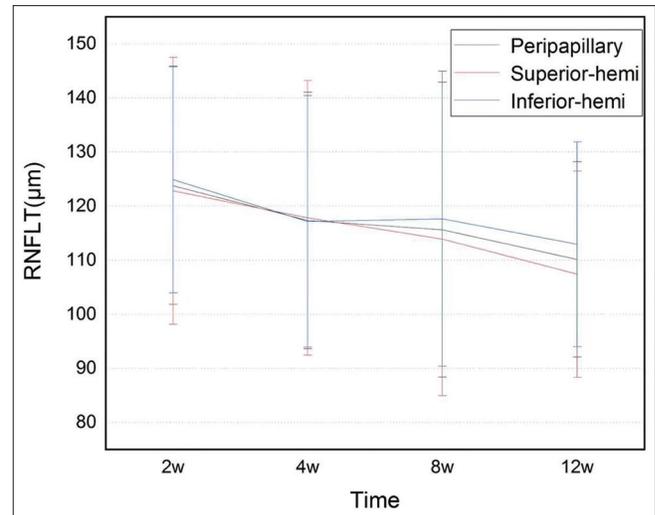


Figure 3: The curve of mean RNFLTs in eyes with RRD after surgery. The global, superior, and inferior RNFLTs decreased over time postoperatively. The difference in RNFLTs between superior-hemifield and inferior-hemifield was significant at week 12 postoperatively.

not be excluded. Finally, retinal reattachment was defined in the state of SO tamponade.

Conclusion

In conclusion, our study showed that RRD resulted in decreased RPC VDs. RPC VDs gradually increased but were still lower than the normal level. Long-term SO tamponade could cause a decrease in RPC VD and RNFLT, especially in the superior-hemifield. The negative effect of SO on RPC VD and RNFLT was relatively mild within 12 weeks postoperatively.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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