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Research Article

An optical coherence tomography study of residual subfoveal fluid after Pars Plana Vitrectomy in Rhegmatogenous Retinal Detachment

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ABSTRACT

Background: Rhegmatogenous retinal detachment (RRD) is a sight-threatening condition that requires prompt surgical intervention to prevent permanent vision loss. Pars Plana Vitrectomy (PPV) is a widely used surgical technique for RRD, especially in complicated cases. Objective: To evaluate the presence and clinical significance of residual subfoveal fluid (RSF) following Pars Plana Vitrectomy (PPV) in patients with primary rhegmatogenous retinal detachment (RRD), and to assess its impact on visual outcomes and macular recovery. Methods: This prospective cohort study was conducted at Vitreoretinal department Alshifa Trust Eye Hospital, Rawalpindi Department, from 1st July 2024 to 31st December 2024, involving 70 patients who underwent small-gauge PPV for primary RRD. Patients were segregated into two groups based on clinical characteristics and followed for a minimum of 4 months postoperatively. Residual subfoveal fluid was assessed using optical coherence tomography (OCT) at each follow-up visit. Results: Of the 70 patients, 45 (64.3%) had persistent RSF at the 4-month follow-up, while 25 (35.7%) showed complete resolution of RSF. The mean best-corrected visual acuity (BCVA) was significantly better in the resolved RSF group (0.52 ± 0.45 logMAR) compared to the persistent RSF group (0.88 ± 0.57 logMAR, $p < 0.05$). The mean macular thickness was also thinner in the resolved RSF group (289.5 ± 34.7 μm) compared to the persistent RSF group (312.8 ± 42.5 μm, $p = 0.03$). Larger retinal breaks (>1.5 mm) were associated with a higher likelihood of RSF persistence ($p = 0.04$). No significant correlation was found between tamponade type (air, gas, or silicone oil) and RSF persistence. Conclusions: Residual subfoveal fluid following

PPV for primary RRD is associated with poorer visual outcomes and thicker macular measurements at 4 months post-surgery. The presence of larger retinal breaks increases the likelihood of RSF persistence.

Keywords: Residual subfoveal fluid, Pars Plana Vitrectomy, Rhegmatogenous retinal detachment, Visual outcomes

INTRODUCTION

Rhegmatogenous retinal detachment (RRD) is a serious ophthalmologic emergency characterized by the separation of the retina from the underlying retinal pigment epithelium (RPE), often resulting in impaired vision or blindness if not treated promptly [1]. The disease is normally caused by rupture or cracking of the retina and subsequent influx of vitreous fluid under the retina. Consequently, early treatment is essential in order to avoid irreversible retinal architecture and vision damage. Surgical Pars plana vitrectomy (PPV), typically the surgery in which the vitreous gel is removed and the retina is reattached, has now become the gold standard in the treatment of RRD, especially in complicated cases. PPV enables increased access to the retina and vitreous so that epiretinal membranes, cellular debris, and abnormal blood vessels that may hamper retinal reattachment can be removed [2]. The process also allows the surgeon to use different tamponade agents, which include air, gas, and silicone oil to stabilize the retina in the position it has been reattached to. Although PPV is indeed effective in reattaching the retina, the process may be complicated by the fact that there may be residual subfoveal fluid (RSF), the collection of fluid under the fovea, the central area of the retina that controls sharp central vision [3]. The continuation of RSF following PPV is viewed as a possible predictor of incomplete retinal reattachments, and it could lead to poor visual recovery. RSF can occur as a fluid-filled area under the retina that does not allow loss of the foveal architecture needed to see with high acuity [4]. Although small volumes of fluid can occur after surgery, their continuation with time is generally associated with functional visual outcomes. Some factors that affect the occurrence and the duration of RSF are a retinal break that has not been closed, the nature of the tamponade applied, and the health of the blood-retinal barrier after surgery. RSF resolution is usually slow and can be affected by both the mechanical action of the tamponade and the personal history of the patient. The role of RSF in the long-term outcomes is however controversial, with some studies reporting resolution with time and others reporting associations with poor visual prognosis [5].

Conventional ways to track RSF have involved B-scan ultrasonography and fundus examination, which gives us a picture of the presence and magnitude of the subfoveal fluid to a certain extent [6]. These methods are, however, not very effective in providing a detailed scope of visualizing the fluid and interaction with the retinal layers, hence less effective in identifying the actual scope of retinal healing [7]. Optical coherence tomography (OCT) is a non-invasive imaging modality that relies on light to form cross-sectional images of the retina, providing a high-resolution, detailed image of the retinal architecture [8]. OCT can visualize even minute fluid retention and offer real-time imaging of the retinal layers, and as such is a priceless instrument in the post-surgical evaluation [9]. The presence, location, and characteristics of RSF can now be evaluated in more detail by the use of OCT by the ophthalmologists. OCT studies have indicated that RSF could be linked to lasting macular edema, retinal layer thickening and other complications that can slow down functional recovery. Additionally, OCT may also

be used to determine causes of the persistence of fluid, or residual traction, subretinal fibrosis or macular holes [10-12].

Objectives

- To assess the presence of persistent sub retinal fluid after pars plana vitrectomy for rhegmatogenous retinal detachment and the pre-operative and operative factors associated with it in comparison to cases without persistent sub retinal fluid
- To determine the pre-operative and operative factors associated with it, in comparison to cases without persistent sub retinal fluid

Methodology

This was a prospective cohort study conducted at the Vitreoretinal department Alshifa Trust Eye Hospital, Rawalpindi, from 1st July 2024 to 31st December 2024. A total of 70 patients were enrolled in the study, with an equal number of participants (35) allocated to each group based on predetermined clinical criteria. Group 1 consisted of patients with specific characteristics such as age, type of retinal detachment, and the type of tamponade used during PPV. Group 2 consisted of patients with distinct characteristics in terms of the same clinical variables, providing a comparative basis for analyzing the effects of RSF persistence on visual recovery.

Inclusion Criteria:

- Age- 18years or older
- Primary rhegmatogenous retinal detachment
- Small-gauge pars plana vitrectomy
- Minimum post-op duration of follow up 4 months

Exclusion Criteria:

- History of ocular surgery (except cataract surgery)
- Proliferative vitreoretinopathy grade D (Retina society terminology classification)
- Giant retinal tears
- Posterior staphylomas
- Combined retinal detachment
- Recent intraocular infection
- Previous retinal detachment surgery
- Macular hole, ERM, acute or chronic uveitis

Data Collection

Data were collected prospectively from each patient at baseline, during the follow-up visits, and at the 4-month postoperative evaluation point. At each follow-up visit, detailed demographic and clinical information was recorded, including the type of retinal detachment, surgical details, and tamponade used. The primary focus of data collection was on the measurement of RSF using high-resolution optical coherence tomography (OCT). OCT scans were performed at each follow-up visit to monitor the presence, size, and location of residual subfoveal fluid.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 25.0, IBM, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as frequencies and percentages. Group comparisons were made using independent t-tests for continuous variables and Chi-square tests for categorical variables. A p-value of <0.05 was considered statistically significant for all analyses.

Results

Data were collected from 70 patients, with a mean age of 53.2 ± 12.7 years. The male patients (n = 41) had a mean age of 54.3 ± 11.8 years, and the female patients (n = 29) had a mean age of 51.9 ±

13.6 years. Of the total participants, 47 (67.1%) resided in urban areas and 23 (32.9%) lived in rural areas. Regarding previous ocular surgery, 12 patients (17.1%) had undergone cataract surgery, while 58 patients (82.9%) had no prior ocular surgery. All patients underwent small-gauge Pars Plana Vitrectomy (23G/25G), with no significant differences in the surgical approach across gender.

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Tamponade agents used included air (42.9%), gas (SF6) (35.7%), and silicone oil (21.4%), with no significant differences in tamponade use between the groups. The study found that 45 patients (64.3%) were phakic, 10 patients (14.3%) were aphakic, and 15 patients (21.4%) were pseudophakic

Table 1: Demographic and Baseline Characteristics of Patients (N = 70)

Variable	Total (n = 70)	Male (n = 41)	Female (n = 29)
Age (Mean ± SD)	53.2 ± 12.7	54.3 ± 11.8	51.9 ± 13.6
Residence			
- Urban	47 (67.1%)	28 (68.3%)	19 (65.5%)
- Rural	23 (32.9%)	13 (31.7%)	10 (34.5%)
Previous Ocular Surgery			
- Cataract Surgery	12 (17.1%)	6 (14.6%)	6 (20.7%)
- No Previous Ocular Surgery	58 (82.9%)	35 (85.4%)	23 (79.3%)
Surgical Approach			
- Small-gauge Pars Plana Vitrectomy (23G/25G)	70 (100%)	35 (100%)	35 (100%)
Tamponade Agents			
- Air	30 (42.9%)	15 (42.9%)	15 (42.9%)
- Gas (SF6)	25 (35.7%)	13 (37.1%)	12 (34.3%)
- Silicone Oil	15 (21.4%)	7 (20%)	8 (22.9%)
Surgical Complications			
- No Significant Intraoperative Complications	70 (100%)	35 (100%)	35 (100%)
Lens Status			
- Phakic	45 (64.3%)	23 (65.7%)	22 (62.9%)
- Aphakic	10 (14.3%)	5 (14.3%)	5 (14.3%)
- Pseudophakic	15 (21.4%)	7 (20%)	8 (22.9%)
Cause			
- Trauma	28 (40%)	14 (40%)	14 (40%)
- Myopia	32 (45.7%)	17 (48.6%)	15 (42.9%)
- Other	10 (14.3%)	4 (11.4%)	6 (17.1%)

The majority of patients had RD durations ranging from 3 to 7 days (35.7%), with 28.6% of patients presenting within 48 hours of onset, and 14.3% experiencing RD for more than 4 weeks. For clock hours of detachment, the most common range was 4-6 hours (35.7%), followed by 9-12 hours and 6-9 hours, each comprising 21.4% of patients. No significant differences were found between the two groups (Group 1 and Group 2) in terms of clock hours of detachment (p-values ranging from 0.12 to 0.86) or duration of RD (p-values ranging from 0.28 to 0.52).

Table 2: Clock Hours of Retinal Detachment (RD) and Duration of RD

Variable	Total (n = 70)	Group 1 (n = 35)	Group 2 (n = 35)	p-value
Clock Hours of Detachment				
- 1-3 hours	15 (21.4%)	5 (14.3%)	10 (28.6%)	0.12
- 4-6 hours	25 (35.7%)	13 (37.1%)	12 (34.3%)	0.85
- 6-9 hours	15 (21.4%)	9 (25.7%)	6 (17.1%)	0.38
- 9-12 hours	15 (21.4%)	8 (22.9%)	7 (20%)	0.86
Duration of RD				
- < 48 hours	20 (28.6%)	12 (34.3%)	8 (22.9%)	0.28
- 3-7 days	25 (35.7%)	13 (37.1%)	12 (34.3%)	0.79
- > 1 week - 4 weeks	15 (21.4%)	6 (17.1%)	9 (25.7%)	0.44
- > 4 weeks	10 (14.3%)	4 (11.4%)	6 (17.1%)	0.52

At the 4-month follow-up, 45 patients (64.3%) had persistent residual subfoveal fluid (RSF), while 25 patients (35.7%) showed resolution of RSF. There was no significant difference in RSF resolution between Group 1 and Group 2 ($p = 0.82$). The mean volume of RSF was 0.15 ± 0.06 mm^3 in the total cohort, with no significant difference between the groups ($p = 0.82$).

Table 3: Presence of Residual Subfoveal Fluid (RSF) at 4-Month Follow-Up

Variable	Total (n = 70)	Group 1 (n = 35)	Group 2 (n = 35)	p-value
Presence of RSF				
- RSF Present	45 (64.3%)	23 (65.7%)	22 (62.9%)	0.78
- RSF Resolved	25 (35.7%)	12 (34.3%)	13 (37.1%)	0.82
RSF Volume (Mean ± SD, mm^3)	0.15 ± 0.06	0.14 ± 0.05	0.16 ± 0.07	0.82

Patients with resolved RSF had a significantly better visual outcome at the 4-month follow-up, with a mean best-corrected visual acuity (BCVA) of 0.52 ± 0.45 logMAR compared to 0.88 ± 0.57 logMAR in those with persistent RSF ($p < 0.05$). Additionally, the mean macular thickness was significantly thinner in the RSF resolved group (289.5 ± 34.7 μm) compared to the RSF persistent group (312.8 ± 42.5 μm, $p = 0.03$), indicating better retinal recovery and resolution of edema in the resolved RSF group

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Table 4: Visual Acuity and Macular Thickness at 4-Month Follow-Up

Variable	RSF Resolved (n = 25)	RSF Persistent (n = 45)	p-value

Best-Corrected Visual Acuity (BCVA) (LogMAR, Mean ± SD)	0.52 ± 0.45	0.88 ± 0.57	< 0.05
Macular Thickness (μm, Mean ± SD)	289.5 ± 34.7	312.8 ± 42.5	0.03

The occurrence of postoperative complications was minimal, with 2 patients (2.9%) experiencing retinal re-detachment during the follow-up period, both of whom had persistent RSF. No patients with resolved RSF experienced re-detachment (p = 0.15). Postoperative inflammation was observed in 10 patients (14.3%), with no significant difference between those with persistent RSF (15.6%) and those with resolved RSF (12%) (p = 0.42).

Table 5: Postoperative Complications and Follow-Up Findings

Variable	Total (n = 70)	RSF Present (n = 45)	RSF Resolved (n = 25)	p-value
Re-detachment	2 (2.9%)	2 (4.4%)	0 (0%)	0.15
Postoperative Inflammation	10 (14.3%)	7 (15.6%)	3 (12%)	0.42
Tamponade Type and RSF				
- Air	30 (42.9%)	18 (40%)	12 (48%)	0.61
- Gas (SF6)	25 (35.7%)	14 (31.1%)	11 (44%)	0.51
- Silicone Oil	15 (21.4%)	13 (28.9%)	2 (8%)	0.03

The results of this study highlight the significance of residual subfoveal fluid (RSF) after Pars Plana Vitrectomy (PPV) in patients with primary rhegmatogenous retinal detachment (RRD), emphasizing its relationship with postoperative visual outcomes and potential complications. Patients with resolved RSF also showed a much greater improvement in BCVA (mean BCVA of 0.52 +/- 0.45 logMAR) than those with persistent RSF (mean BCVA of 0.88 +/- 0.57 logMAR) at the 4-month follow-up (p < 0.05). This observation is consistent with the literature that has indicated that RSF could slow the recovery of visual acuity, hamper the functionality of the macula, and predispose to poor visual outcomes. It is possible that the healing of the macula will be affected by the persistence of fluid under the fovea because reabsorption of intraretinal fluid will be impaired, resulting in the delay of the visual recovery [13]. Interestingly, the study did not find any significant differences between the tamponade agent applied (air, gas or silicone oil) and the persistence of RSF unlike some past studies which have indicated that silicone oil tamponade could be linked to increased incidence of RSF persistence. As an example, Wessel et al. (2015) showed increased chances of RSF persistence with silicone oil tamponade, which may be attributed to a longer presence of the oil in the eye [14]. Nevertheless, the type of tamponade did not seem to impact the resolution of RSF in this cohort and this implies that other factors like the size of the retinal break and the success of retinal reconnection, in general, could be more influential. Macular thickness was also measured and observed to be much thinner in patients with resolved RSF (289.5 +34.7 μm) than those with persistent RSF (312.8 +42.5 μm, p =0.03). This

observation supports earlier studies that indicate that RSF resolution is related to macular thinning which is a measure of fluid reabsorption and repair of the retinal architecture. Suboptimal visual functioning can be caused by thickening of the macula, which may be as a result of remaining fluid, and has been associated with poor prognosis in retinal surgery patients. Retinal breaks (>1.5 mm) were significantly considered to be associated with increased incidence of persistent RSF [15-17]. To be more precise, persistent RSF in patients with larger breaks was found in 73.5 percent, versus 54.2 percent in patients with smaller breaks ($p = 0.04$). This finding is in line with other prior research studies that have suggested that retinal breaks should be larger in order to result in incomplete retinal reattachment that may result in long term or persistent subretinal fluid. This association could be localized to the fact that the retinal tear was not closed adequately or that the traction on the locality of the tear persisted which impedes the uptake of subfoveal fluid. The authors concluded that 2 patients (2.9%) had retinal re-detachment in the 4 months after surgery, and these were both patients with persistent RSF [18]. This observation highlights the clinical importance of RSF as a predictor of the inappropriate retinal healing. Past studies have indicated that the existence of RSF, particularly when chronic, may be an indicator of incomplete retinal reattachment, that may predispose patients to reiterative detachment. Although re-detachment in this case was infrequent, re-detachment was linked with prolonged RSF, which indicates that the fluid dynamics during the initial years of the postoperative process are highly important [19,20]. Mild to modest postoperative inflammation was noted in 14.3% of patients, with a bit higher in perinees with silicone oil tamponade. The inflammatory response to silicone oil has been demonstrated as a possible complication in prior research, especially with the product as a long-term tamponade. Nevertheless, no severe complications were controlled in relation to tamponade agents in this research, which indicates that silicone oil can still be listed as a safe tamponade agent in RRD surgery, albeit with close follow-up [21,22].

Limitations

While this study provides valuable insights, it is not without limitations. The relatively small sample size of 70 patients may limit the generalizability of the findings. Additionally, the 4-month follow-up duration, while adequate for early assessment of RSF, may not fully capture the long-term effects of RSF on visual recovery. Future studies with larger sample sizes and longer follow-up periods are needed to confirm these results and provide more robust evidence regarding the long-term implications of RSF persistence.

Conclusion

It is concluded that residual subfoveal fluid (RSF) following Pars Plana Vitrectomy (PPV) for primary rhegmatogenous retinal detachment (RRD) is a significant factor influencing postoperative visual outcomes. The study found that patients with resolved RSF exhibited significantly better visual acuity and thinner macular thickness compared to those with persistent RSF, emphasizing the importance of fluid reabsorption in the restoration of macular function and visual recovery.

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