

Subfoveal Choroidal Thickness After Successful Retinal Detachment Repair with Persistent Subretinal Fluid at the Macula

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Objective: To explore the relationship between subfoveal choroidal thickness (SFCT) and persistent subretinal fluid (pSRF) at the macula after successful rhegmatogenous retinal detachment (RRD) surgery.

Methods: This is a retrospective multicenter comparative study of Caucasian subjects with successful RRD repair. SFCT was measured in 2 groups: Group 1 with persistent subretinal fluid (pSRF) 1 month after repair, and Group 2 with absence of pSRF. SFCT was measured by a masked observer based on ImageJ. Multiple regression analyses were implemented to control for age, refraction, and gender.

Results: Surgery type was as follows: Group 1 (24 scleral buckle SB, 23 pars plana vitrectomy PPV, 9 SB+PPV, and 5 pneumoretinopexy), and Group 2 (68 PPV). Adjusted mean 1-month SFCT was thicker in Group 1 than in Group 2 by 41.0 μm ($p = 0.049$). Within Group 1, PPV subgroup tended to have thinner SFCT than the other subgroups by: SB (117.4 μm), SB-PPV (9.3) and pneumoretinopexy (1.2 μm) (all $p > 0.05$). SFCT at 1-month was not different between pSRF (237.5 \pm 77.2 μm) and no pSRF (213.7 \pm 72.1 μm) in PPV groups ($p = 0.2$).

Conclusion: SFCT post PPV appeared similar in eyes with or without pSRF. In eyes with pSRF, SFCT tended to be thicker following SB compared to PPV.

Plain Language Summary:

What was known before:

- Persistent subretinal fluid one month after successful retinal detachment surgery is associated with a thicker choroid and pachychoroid.

What this study adds:

- Persisting subretinal fluid one month after successful retinal detachment repair by pars plana vitrectomy is not influenced by the subfoveal choroidal thickness.
- Scleral buckle leads to increased subfoveal choroidal thickness due to compression of the choroid.

Keywords: choroid, choroidal thickness, optical coherence tomography, pars plana vitrectomy, persistent subretinal fluid, pneumoretinopexy, rhegmatogenous retinal detachment, scleral buckling, subfoveal choroidal thickness

Introduction

Visual recovery is often incomplete after a successful repair of macula-off rhegmatogenous retinal detachment (RRD) from persistent subretinal fluid (pSRF) at the macula.¹ Long duration of pSRF in any retinal location appears multifactorial: high viscosity of SRF, long-standing RRD, protracted breakdown of the blood-retinal barrier from surgical trauma to the retinal pigment epithelium. In most cases, pSRF disappears spontaneously within 1 year. However, delayed absorption of SRF at the macula may not occur in some cases resulting in photoreceptor damage with visual loss. Little is known why some cases have pSRF at the fovea, and this may relate to a disturbed RPE function.¹ The highly vascularized choroid plays an important role in ocular metabolism with some ocular disorders being associated with choroidal thickening or hyperpermeability. Chantarasorn et al¹ demonstrated an intriguing link between pSRF and increased subfoveal choroidal thickness (SFCT) (one biomarker of choroidal thickening), suggesting pachychoroidopathy as a cause of delayed resorption of pSRF. Our goal was to assess SFCT in a cohort of surgical eyes with pSRF and to compare it with a surgical group without pSRF.

Materials and Methods

This was a retrospective multicenter comparative case series consisting of 2 groups: Group 1 included cases of pSRF 1 month after a straightforward, successful primary RRD repair (pars plana vitrectomy PPV, scleral buckle SB, combined PPV-SB, or pneumoretinopexy); Group 2 included consecutive cases from the same contributing centers and same time frame and exam schedule (between 10 am and 2 pm) but with absence of pSRF documented 1 month after successful PPV for RRD repair. Anatomical success was defined as the complete resolution of RRD as observed with binocular indirect ophthalmoscopy. This retrospective cross-sectional study followed the tenets of the Declaration of Helsinki. The study was approved by the Ethics Committee of Rafik Hariri University Hospital. A waiver of patient consent was granted to review medical records per Ethics Committee approval as this research involved very minimal risk to subjects. Patient data confidentiality was maintained by making sure that only authorized persons collected data and that data was accessible and stored through secure storage outlets for research data.

Criteria for inclusion included: persistence of SRF at the 1 month after RRD surgery (mostly PPV and/or SB) confirmed by OCT and successful RRD surgery (PPV) controls without pSRF; high-quality OCT horizontal foveal scan that delineates the whole choroidal contour; Caucasian race; age 16 years and above; OCT machines were restricted to Spectralis^R using 815nm (Heidelberg Engineering, Heidelberg, Germany), Triton^R using 1,050nm wavelength (Topcon, Tokyo, Japan) and Cirrus 600^R using 840nm (Zeiss, Oberkochen, Germany). Criteria for exclusion included: previous retinal surgery; need for subsequent retina surgery; presence of a giant retinal tear; presence of tractional rhegmatogenous retinal detachment or silicone oil use; presence of proliferative vitreoretinopathy, glaucoma or ocular hypertension; history of ocular trauma; preexisting ocular diseases such as high myopia (<-8 diopters) or high hyperopia (>+6 diopters), uveitis, cystoid macular edema, retinal vascular disorder, optic disc pit or coloboma, macular degeneration, retinal pigment epithelial detachment, central serous retinopathy (CSR),^{2,3} pachychoroid, vitreomacular traction, macular hole (lamellar or full-thickness); and presence of systemic illness (diabetes mellitus, Alzheimer's disease, cirrhosis, kidney disease, and uncontrolled systemic hypertension).

Choroidal Imaging

SFCT was defined as the height from the Bruch's membrane to the choroid-scleral interface based on the best horizontal foveal cut. OCT images of the three groups were imported into Image J (Bethesda, Maryland, USA). Measurements of the choroidal thickness were done in a masked fashion with no knowledge of clinical information. Each image was measured two times independently by a single rater (SHU) with the mean being recorded for final analysis. SFCT was further adjusted for the OCT machine used based on established algorithms: (1) SFCT values are quite equivalent

between Spectralis and Cirrus;⁴ (2) SFCT values using Spectralis SD-OCT were 7.31 μm thinner than that obtained with the DRI SS-OCT.⁵

Statistical Analysis

Continuous data were presented as means \pm standard deviations. Statistical analyses were performed using one-way analysis of variance (ANOVA). Pearson correlation coefficient was used to measure the covariance between variables. Multiple regression analysis was carried out using SPSS 22 (IBM SPSS, Armonk, New York, USA) to control for age, gender, and spherical equivalence to SFCT.⁶⁻⁸ The measures of association were expressed as odds ratios (OR) with 95% confidence intervals (CI). *P* values of less than 0.05 were considered statistically significant.

Results

Ocular exam and history for Group 1 are detailed in Table 1. Group 1 included 24 eyes that underwent SB (with SRF drainage), 23 that had PPV, 9 that had combined SB+PPV, and 5 that had pneumoretinopexy (SF6 or C3F8 gas without SRF drainage). In that group, 56 eyes had macula-off RRD, while 5 had macula-on RRD. Group 2 included 68 eyes that underwent successful PPV for RRD with no pSRF. Data on gender, age, race, refractive error (automated refractometer) and OCT machine used for the 2 groups are presented in Table 2. Adjusted mean SFCT was thicker in Group 1 than in Group 2 by 41.0 microns ($p=0.049$) (Table 3) by multiple regression analysis. Within group 1, PPV subgroup had SFCT

Table 1 Clinical Data of Group 1

	Mean	Median	Minimum	Maximum	SD
Pseudophakia vs phakia (number of eyes)	7 vs 54				
Duration of RRD (days)	31	7	1	700	95
Macula Off vs On	56 vs 5				
Number of retinal tears	1.5	1	1	6	0.9
Number of clock hours of RRD	5.3	5	3	12	1.7
Superior (S) vs Inferior (I) vs Temporal (T) vs Nasal (N) tears	35 S 19 I 7N 44T				
RRD quadrant S,I,N,T	33 S 23 I 10 N 47 T				
Type of surgery (pars plana vitrectomy PPV, scleral buckle SB, pneumoretinopexy (Gas))	23 PPV 9 SB+PPV 24 SB 5 Gas				
Transscleral Subretinal fluid drainage number (%)	14 (23.0%)				
Internal subretinal fluid drainage number (%)	10 (16.4%)				
Height of pSRF at 1 month post surgery (microns)	92.8	95.0	0 (juxtafoveal SRF)	480.0	76.1
Initial vision in logMAR (Snellen equivalent)	1.11 (20/258)	1.00 (20/200)	0 (20/20)	3.0 (20/20,000)	0.84
1-year vision in logMAR (Snellen equivalent)	0.24 (20/35)	0.18 (20/30)	0 (20/20)	1 (20/200)	0.23
Time of resolution of macular pSRF (months)	10.8	10.0	3	39	6.3

Abbreviations: RRD, rhegmatogenous retinal; detachment; pSRF, persistent subretinal fluid at the macula.

Table 2 Demographics of groups 1 and 2. Adjusted subfoveal choroidal thickness SFCT= corrected for differences in optical coherence tomography OCT machines.

	Caucasian	Age (years)	% Male	Spherical Equivalence (Diopter)	OCT Machine	Adjusted Subfoveal Choroidal Thickness (Microns)
Group 1 (61 eyes)	100%		45.9%		17 Triton 4 Cirrus 40 Spectralis	
Mean±SD		54.0±14.8		-2.3±2.6		253.0±69.6
Median (range)		57 (19–80)		-2.0 (-8.0 to +6.0)		253 (110–396)
GROUP 2 (68 eyes)	100%		56.9%		18 Triton 47 Spectralis	
Mean±SD		61.0±12.3		-1.5±3.2		213.7±72.1
Median (range)		61 (22–86)		-0.5 (-8.0 to +2.6)		209 (90–443)

Table 3 Comparison of Subfoveal Choroidal Thickness (SFCT) Between the Group 1 and 2 (Top) and Subgroups of Group 1 After Adjusting for Age, Gender and Spherical Equivalence

SFCT (Micron)	Mean Difference	Standard Error	p-value	Lower Bound 95% CI	Upper Bound 95% CI
Group 1 minus Group 2	41.0	16.6	0.049	0.1	81.9
Group 1					
PPV minus SB	-117.4	77.8	0.52	-341.6	106.8
PPV minus (SB+PPV)	-9.3	104.9	1.00	-311.4	292.8
PPV minus pneumoretinopexy	-1.2	131.6	1.00	-380.4	378.0

Abbreviations: PPV, pars plana vitrectomy; SB, scleral buckle; CI, confidence interval.

thinner than the other subgroups by: SB (117.4 microns) ($p=0.52$), SB-PPV (9.3 microns) ($p=1.0$) and pneumoretinopexy (1.2 microns) ($p=1.0$) after controlling for gender, age, and spherical equivalent (Tables 3 and 4).

SFCT was larger in eyes with SB and pSRF ($273.6\pm 53.2\ \mu\text{m}$) versus control PPV without pSRF ($213.7\pm 72.1\ \mu\text{m}$) ($p=0.04$ by univariate analysis; $p=0.011$ after controlling for age, gender and spherical equivalence). SFCT in eyes with

Table 4 Demographics of the 4 Subgroups with Persistent Subretinal Fluid at Macula pSRF (SFCT=Subfoveal Choroidal Thickness; RRD=Rhegmatogenous Retinal Detachment; M=Male; F=Female). PPV Subgroup Had SFCT Thinner Than the Other Subgroups By: SB (117.4 Microns) ($p=0.52$), SB-PPV (9.3 Microns) ($p=1.0$) and Pneumoretinopexy (1.2 Microns) ($p=1.0$) After Controlling for Gender, Age, and Spherical Equivalent

	PPV	SB	SB+PPV	Gas
Number of eyes	23	24	9	5
SFCT mean± SD (range) in μm	237.5±77.2 (117–396)	273.6±53.2 (181–380)	245.9±80.7 (129–380)	237.8±79.7 (190–371)
Age (years)	58.3±14.1 (33–80)	46.2±15.4 (19–78)	61.4±10.1 (39–76)	59.2±1.3 (57–60)
Gender M:F	14M:9F	7M:17F	4M:5F	3M:2F

(Continued)

Table 4 (Continued).

	PPV	SB	SB+PPV	Gas
Spherical equivalent (diopter)	-2.1±2.6 (0.3 to -7)	-2.8±2.9 (6 to -8)	-2.6±2.3 (0.3 to -7)	-1.2±0.9 (0 to -2)
Subretinal fluid height (SRFH) mean±SD (range) in µm	58.3±49.7 (33–80)	46.2±97.4 (19–78)	61.4±45.2 (39–76)	59.2±53.1 (57–60)
Number of Macula off RRD (%)	21 (91.3%)	21 (87.5%)	9 (100%)	5 (100%)
Number of SRF drainage (%)	7 (30.4%)	14 (41.7%)	3 (33.3%)	0 (0%)
Number of clock hours of RRD mean±SD (range)	4.7±1.2 (3–9)	5.8±1.2 (4–9)	5±1.4 (3–7)	6±3.5 (3–12)

PPV and pSRF was not different from control PPV ($p=0.067$) before and $p=0.098$ after controlling for age, gender and spherical equivalence. There was a positive correlation between subretinal fluid height (SRFH) and SFCT with Pearson correlation $r=0.26$ ($p=0.046$). Of note, the interclass correlation coefficient (ICC) between the 2 SFCT measures (per eye) was 0.988 (95% CI 0.984 to 0.991).

Discussion

The current paper evaluated some of the possible associations of pSRF after successful repair of RRD.^{9–31} SFCT was thicker (by 117.4 µm) in SB eyes with pSRF vs PPV eyes with pSRF, but the difference was not significant. Also, PPV eyes with pSRF had equivalent choroidal thickness to control PPV eyes. SFCT was significantly larger in eyes with SB and pSRF versus control PPV eyes without pSRF (by 59.9 µm). From these findings, it appears that SB has a direct effect on the choroidal circulation unlike PPV. Odrobina et al¹⁹ found a long-lasting thickening of the choroid after an encircling buckle (up to a mean of 22 months), while there was a transient choroidal thickening (lasting a few weeks) after a radial buckle^{18,20} and no thickening after PPV (Table 5).^{22,24,25} Encircling SB (considering that the width and size of materials) have long-lasting effect on SFCT vs segmental SB or PPV.¹⁹ Besides, cryopexy that accompanies SB leads to inflammation and choroidal thickening but this effect only lasts a few weeks.²¹ SB is thought to be more associated with residual SRF for several reasons: incomplete drainage of subretinal fluid, use of cryopexy which disrupts the blood retinal barrier, and compression of vortex veins. On the other hand, PPV in most studies does not alter SFCT.

Table 5 Literature review^{1,10,11,17–23,25–31} of One-month (1m) Subfoveal Choroidal Thickness (SFCT) or Other Biomarkers (Choriocapillaris Flow Density (CCFD) or Choroidal Vascularity Index (CVI) or Choroidal Blood Flow Ratio (ChBF Ratio) After Successful RRD Repair Comparing Pars Plana Vitrectomy (PPV), Scleral Buckle (SB) or Combination to Fellow Non-Operated Eye (F) or Control Eye (C)). (CCFD=choriocapillaris Flow Density Within 3×3 mm Macular Fovea; Choroidal Vascularity Index (CVI)=luminal Area Divided by Choroidal Area. ChBF ratio= ChBF of Surgical Eye/ChBF of the Fellow Control Eye; SEM=Standard Error of the Mean)

Author (Publication Year)	Number of Eyes	Kind of Surgery	1m SFCT vs Control (C) or Fellow (F)	Country	pSRF
Scleral buckle SB					
Sugawara 2006 ²⁸	11	SB	ChBF ratio (SEM) 0.67 (0.12)* compared to 1(0.20) baseline $p<0.05$	Japan	No
Miura 2012 ³⁰	11	Segmental SB	1m: 267± 64 vs F 276±71 ($P>0.05$)	Japan	No

(Continued)

Table 5 (Continued).

Author (Publication Year)	Number of Eyes	Kind of Surgery	Im SFCT vs Control (C) or Fellow (F)	Country	pSRF
Kimura 2012 ¹⁸	21	Segmental SB	1m: 251±96 vs preop 239±91 p=1.0	Japan	No
Odrobina 2013 ¹⁹	48	Encircling SB	22m: 261±46 vs F 218±37 (p<0.001)	Poland	No
Iwase 2017 ²⁰	46	Segmental SB	1m: 240±70 vs F 242±74 (p>0.05)	Japan	No
Bernabei 2021 ²⁷	30	SB	26m: 272±78 vs F 239±83 p=0.001 CVI** 66.4±3.6 vs 65.9±3.2, p=0.49	Italy	No
Yoshida 1992 ³¹	24	Segmental SB	6m: Ophthalmic perfusion pressure OPP 29±11 mm Hg vs F 42.0±5.6 mmHg p=0.001		No
Pars plana vitrectomy PPV					
Muslubas 2016 ²²	22	PPV	1m: 261±47 vs F 257±46 p=0.087	Turkey	No
Gama 2017 ²⁵	15	PPV	>6m: 155±35 vs F 157.27. P=0.69 Vs SB+PPV p=0.019	Portugal	No
Giacuzzo 2020 ²³	14	PPV	1m: 208±58 vs F 173±42 p>0.05	Switzerland	No
Giacuzzo 2020 ²³	14	PPV	1m: 205 ±69 vs F 231±81 p>0.05	Switzerland	No
Giacuzzo 2020 ²³	26	PPV	1m: 201±71 vs F 235±70 p>0.05	Switzerland	No
Trivizki 2022 ¹⁷	93	PPV	3m: attached n=81, 232±79 vs redetached n= 12, 281±57 p=0.02	Israel	No
Lim 2024 ²¹	63	PPV	>6m: 210±83 vs F 223±80 p=0.18 CVI: 68.8±4.1 vs 66.1±8.8 p=0.028	Korea	No
Combined PPV+SB					
Montezuma 2016 ²⁹	23	11 SB and 12 SB+PPV	>3m: 198±73 vs C 200±81 p>0.05	US	No
Gama 2017 ²⁵	15	PPV+SB	>6m: 234±94 vs F 195±78 P=0.001 Vs PPV p=0.019	Portugal	No
Baeg 2023 ²⁶	15 vs. 18	Encircling SB+PPV vs Encircling SB	6m: 226±75 vs 261±78 (p<0.05)	Korea	No
With persistent subretinal fluid pSRF					
Chantarasorn 2019 ¹	76	14 pSRF (2SB, 12 PPV) vs 62 (7SB, 55 PPV) no pSRF	>3m: 305±61 vs 200±70 p<0.001	US	Yes
Long 2021 ¹¹	63	SB	3m: values not cited (n=35 without pSRF vs n=28 pSRF) p=0.75 CCFD* 0.66±0.04% vs 0.63±0.05% p=0.046	China	Yes
Albanese 2023 ¹⁰	100 (21 pSRF)	56 SB (16 pSRF) 44 PPV (5 pSRF)	1m: 189±76 pSRF vs 237±79 no pSRF p=0.018	Italy	Yes

At 1-month post-surgery, pSRF can impact at least the time course of visual recovery and suggested causes include incomplete SRF drainage (not using perfluorocarbon), poor retinal pigment epithelium (RPE) pump (membrane pumps, endocytosis, passive diffusion, hydrostatic pressure, and oncotic pressure), long duration of RRD (high protein content of SRF), macula-off RRD, advanced age (age-related hydrophobic barrier formed by accumulated sub-RPE lipoproteins),

persistent choroidal inflammation or ocular hypotony and type of surgery.^{9–16} The choroid plays an important role in ocular metabolism with thickening involved in the pathophysiology of various ocular diseases.¹⁷ The inclusion criteria in the current study excluded cases of CSR, pachychoroid, high hyperopia and high myopia in all the 2 groups. Thereafter, there was no difference in SFCT comparing PPV with pSRF vs PPV without pSRF. The literature gives controversial results about choroidal thickness in pSRF due to differences in timing of the OCT after surgery, combining SB with PPV, and inclusion of cases with diabetes mellitus, CSR or high ametropia.^{1,9–11}

SFCT may not be the best biomarker of choroidal health. There is considerable interindividual variation in SFCT in healthy individuals,³² Also there is diurnal variation and can also be influenced by intake of caffeine. Higher SFCT correlated with younger age,⁶ hyperopia⁷ and male gender,⁸ hence we did multiple regression to account for these variables.

The main limitations of this study are its retrospective nature, the inclusion of patients from different centers and use of different OCT protocols, the wide variations in surgical techniques, non-inclusion of fellow eyes measurements, and not accounting for other potential risk factors such as systemic hypertension, dyslipidemia and caffeine intake. Another drawback is the absence of measurements related to the choriocapillaris flow density of the macular fovea or to the choroidal vascular index. The study is limited to the 1-month post-surgery values not studying serial changes view the dynamic nature of SFCT changes following an ongoing choroidal remodeling. Another limitation is the choice to compare eyes operated using a variety of techniques (PPV with or without SB, SB alone, pneumoretinopexy in Group 1) versus eyes operated with only PPV (in Group 2). This decision was made because OCT was readily available in this group. However, because this is a retrospective, multicenter series, there were no predetermined criteria for which patients received which surgical modalities. It is possible that eyes operated with PPV were somehow different from eyes operated with other techniques, which may have introduced bias into the results.

In conclusion, based on current findings, SFCT was not different between eyes with PPV and pSRF vs PPV without pSRF but was higher after SB than PPV. Omitting eyes having either CSR or pachychoroid, increased choroidal thickness was not associated with pSRF in PPV eyes.

Abbreviations

BCVA, best-corrected visual acuity; log MAR, logarithm of the minimum angle of resolution; SRF, subretinal fluid; RRD, rhegmatogenous retinal detachment.

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