Visual acuity and contrast sensitivity outcomes based on photoreceptor layer after retinal reattachment surgery

by Dr Habibah Muhiddin

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Visual acuity and contrast sensitivity outcomes based on photoreceptor layer after retinal reattachment surgery

Andi Muhammad Ichsan, Andi Suryanita Tajuddin,
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ABSTRACT

Aims: To evaluate correlation between photoreceptor layer thickness with visual acuity and contrast sensitivity in primary retinal reattachment after vitrectomy. Methods: Twenty-seven eyes of 27 patients (mean age 45.6±12.7 years) with successfully retinal reattached were analyzed. Snellen chart visual acuity (VA) to evaluate best-corrected visual acuity (BCVA) converted to the logarithm of the minimum angle of resolution scale (logMAR) and contrast sensitivity in photopic and mesopic illumination using Lea Symbol Flip Chart, funduscopy examination and High Definition Optical Coherence Tomography (HD-OCT) were used to measure retinal condition and photoreceptor layer thickness. Results: Nineteen (70.4%) cases of total 27 cases were reported with macular-on RRD. The thickness of the photoreceptor layer was 43.8±10.8 µm which was significantly correlated with BCVA (logMAR 0.3-2.4, mean 1.0) with p <0.005 and also with contrast sensitivity in mesopic with p 0.033 (p ≤ 0.05). Contrast sensitivity in photopic was better than in mesopic. Foveal anatomic abnormalities were detected in six eyes (22.2%), that was disruption of inner segment (IS)/outer segment (OS) junction and also disruption of external limiting membrane (ELM). Duration of detachment also significantly correlated with BCVA with mean 36±29 days. The macular status before surgery determines the quality of vision, whereas the macular-on rhegmatogen retinal detachment gives visual acuity, contrast sensitivity, that is better in both photopic and mesopic, than macular-off. Conclusion: Photoreceptor layer thickness significantly correlated with visual acuity and contrast sensitivity in mesopic illumination, whereas thicker the photoreceptor, better the visual acuity and mesopic contrast sensitivity.

Keywords: Contrast sensitivity, Inner segment (IS)/outer segment (OS) junction, Rhegmatogenous retinal detachment

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INTRODUCTION

Recently, surgical techniques and equipment for retinal reattachment allow higher success rate of retinal detachment management resulting better visual outcomes even in cases of macular-on or macular-off rhegmatogenous retinal detachments (RRD) [1–4]. However, some cases showed poor anatomical results that include epiretinal membranes, pigment migration, cystoid macular edema, and retinal folds [5–7].

In these cases, subtle changes in the foveal structure, which may cause visual disturbances, can hardly be identified during standard clinical examinations such as slit-lamp biomicroscopy or binocular indirect ophthalmoscopy.

The introduction of optical coherence tomography (OCT) provides a new way to obtain objective data of clinically hidden retinal structures. OCT has led to many new findings in studies of retinal abnormalities, especially of macular disorders [8–10]. Sometimes, the retina had already anatomically reattached as confirmed with indirect ophthalmolscopy [11–13]. Even after successful retinal reattachment and normal OCT findings, however, postoperative vision may be unsatisfactory in some cases despite good visual acuity [14]. Such patients may report poor visual function that cannot be detected by visual acuity tests. Contrast sensitivity is an index capable of assessing visual function more sensitively than visual acuity [15]. It was known that the longer the duration of macular detachment, the smaller the increase in contrast sensitivity in patients after RRD surgery [16]. However, no reports have addressed contrast sensitivity in patients with primary retinal reattachment in mesopic and photopic illumination. The purpose of this study was to assess the correlation between photoreceptor layer thickness with visual acuity and contrast sensitivity photopic and mesopic in primary retinal reattachment after vitrectomy.

MATERIALS AND METHODS

The present study was an analytic observational study with cross-sectional design conducted in Hasanuddin University Hospital and Celebes Eye Centre, Makassar, Indonesia. The subjects who met the inclusion criteria were patients with primary retinal reattachment after vitrectomy pars plana. Any additional ocular diseases affecting central visual function including severe macular degeneration, history of past retinal surgery and ocular trauma were considered in exclusion criteria.

Data collection

All patients who met the inclusion criteria were informed about the study procedure and if they agreed then they were asked to sign the consent application. Twenty seven patients were included in our study. Preoperative data were age, sex, preoperative best-corrected visual acuity (BCVA) using Snellen chart converted to the logarithm of the minimal angle of resolution (logMAR), time from the onset of symptoms to surgery, lens status, macular status, vitreous substitutes. Patients had a complete ophthalmologic examination including measurement of BCVA, contrast sensitivity, intraocular pressure using Goldmann applanation tonometry, slit-lamp examination, and dilated fundus ophthalmoscopy.

Contrast sensitivity

Contrast sensitivity was measured using LEA numbers flip chart with three meters distance in two conditions, photopic with illumination level 85 cd/m² (85 lux) and mesopic with illumination level 3 cd/m² (3 lux). Illumination level was determined using luxmeter. Chart presents numbers at the following contrast levels: black, 25%, 10%, 5%, 2.5%, and 1.25%. Each level consists of five numbers. The result was based on the number of patients who could see.

HD-OCT imaging

The entire macular area was scanned with an HD-OCT instrument (Cirrus OCT; Carl Zeiss Meditec) with scan lengths of 9 mm for horizontal scans and 6 mm for vertical scans. High-quality images were obtained by using the five-line raster mode and en face analysis for IS-OS junctions. The distance between the inner border of the ELM and the ellipsoid zone (EZ) which had previously been called as the photoreceptor IS and OS junction line, was taken to be the IS thickness, and the distance between the EZ and the inner border of the retinal pigment epithelium (RPE) was taken to be the OS thickness. Photoreceptor thickness was taken from IS and OS thickness and measured in three locations : at foveola, 1000 μm nasal foveola (perifovea 1), and 1000 μm temporal foveola (perifovea 2). Central foveal thickness is distance from ILM to RPE thickness that was made on the OCT images passing through the fovea. This was made with the software of the system (Figure 1). Scans with a signal strength of >7/10 were considered appropriate, and a representative image was selected for the measurements.

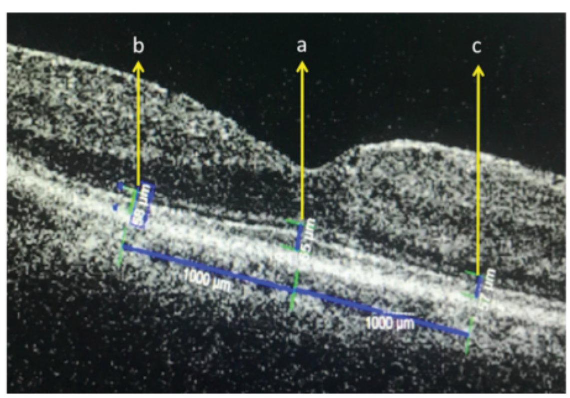

Figure 1: Photoreceptor thickness in three locations: a. at foveola, b. 1000 μm nasal foveola (perifovea 1), and c. 1000 μm temporal foveola (perifovea 2).

Data analysis

All data obtained was recorded and data analysis was performed using Statistical Package for Social Science (SPSS) version 22. The analysis method used was descriptive and analytic (statistical test). For statistical tests, Spearman rho correlation coefficient and comparative Mann Whitney U test were used. The test results were considered significant if the p value was <0.05.

RESULTS

Twenty seven eyes from 27 patients were included in the study. There are 12 men and 15 women with 18 samples in right eye and 9 samples in left eye. Of 27 patients, 19 patients had macular-on RRD, and 8 patients had macular-off RRD. Based on lens status only 3 patients had phakic eyes and remaining were pseudophakic. All patients underwent vitrectomy pars plana surgery to attach the retina with silicon oil as vitreous substitutes and only one patient with gas C3F8.

Characteristics of patients are shown in Table 1. Mean age was 45.59±12.71 years with duration of detachment 36.07±28.99 days. Best corrected visual acuity (BCVA) preoperative had logMAR mean 1.59±0.64 (range : 0.7-2.7) and post-operative with logMAR mean 1.00±0.61 (range : 0.3-2.4). Central foveal thickness was 114–418 µm with mean photoreceptor thickness at foveola was 43.85±10.81µm.

Table 2 reveals there was negative significant correlation between photoreceptor thickness with visual acuity (p value < 0.05) which means the thicker photoreceptor layer gives better visual acuity in logMAR (Figure 2), where best BCVA have lowest logMAR. In Figure 3, similarly with contrast sensitivity in mesopic illumination had positive significant correlation with photoreceptor layer with p value 0.033 (p< 0.05). In contrast, there was insignificant correlation photoreceptor layer with CS in photopic illumination.

Table 3 consists of comparison visual acuity and contrast sensitivity in mesopic and photopic based on macular status. There was significant difference between BCVA, CS in photopic and mesopic compared between macular-on and macular-off RRD with p value 0.000.

Table 1: Characteristics of patients

Variable	Mean	SD
Age (years)	45.59	12.71
IOP (mmHg)	15.89	3.04
Detachment duration (days)	36.07	28.99
Reattachment duration (days)	393.33	200.37
Central foveal thickness (µm)	269.15	65.47
Photoreceptor thickness (µm)		
Foveola	43.85	10.81
Perifovea 1	47.41	9.91
Perifovea 2	46.96	10.15
Mean perifovea	47.18	9.54
Contrast sensitivity		
Photopic	5.15	4.17
Mesopic	4.74	4.02
BCVA (logMar)		
Pre operative	1.59	0.64
Post operative	1.00	0.61

Table 2: Correlation of photoreceptor thickness with visual acuity and contrast sensitivity

Variable	Statistic	Post-operative BCVA	Contrast Sensitivity	
			Photopic	Mesopic
Central foveal thickness	Correlation coefficient	-0.132	-0.019	0.016
	P	0.510	0.925	0.938
	N	27	27	27
Photoreceptor thickness (foveola)	Correlation coefficient	-0.526	0.365	0.412
	P	0.005	0.061	0.033
	N	27	27	27
Mean photorecep-tor thickness (perifovea)	Correlation coefficient		0.308	0.353
	p		0.118	0.071
	n		27	27

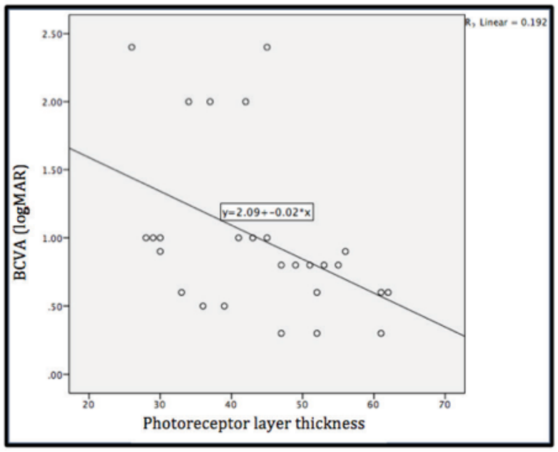

Figure 2: Correlation photoreceptor thickness with BCVA in logMAR.

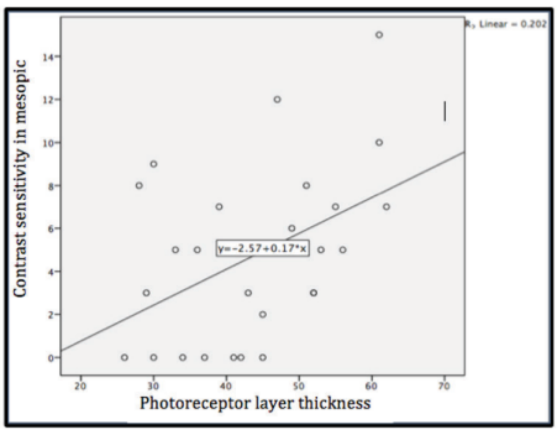

Figure 3: Correlation photoreceptor thickness with contrast sensitivity in mesopic illumination.

Mean visual acuity post-operative in macular-on was 1.73±0.62, while in macular-off was 0.69±0.23. Contrast sensitivity post-operative in photopic illumination had mean 6.90 and 1.00, in macular-on and macular-off RRD, respectively.

Foveal anatomic abnormalities were detected in six eyes (22.2%), five eyes were in the group macular off RRD, including disruption of the junction between the photoreceptor inner and outer segments (IS/OS) in four eyes, two patients also had a disrupted external limiting membrane (ELM) as shown in Figure 4. One patient with macular on RRD had subretinal fluid who was not detected by indirect ophthalmoscopy, but was detected by the OCT (Figure 5).

DISCUSSION

In our study, there was negative significant correlation between photoreceptor thickness with visual acuity (p value < 0.05) which means the thicker photoreceptor layer gives better visual acuity in logMAR shown in Figure 2, where best BCVA had lowest logMAR. Long term duration of detachment can cause photoreceptor apoptosis, and further it causes neurosensory thinning and dystrophy. The relatively thicker neurosensory of the foveal had a better BCVA compared to the thinner one. Hence, we might conclude that the thinner fovea with macular atrophy had a poor VA, while the thicker one had a better VA. The group with thicker fovea had better VA than the thinner one. Foveal thickness turned thin after retina recovery, it might be due to the cone/rod cell apoptosis. These changes were also detected by OCT.

According to recent studies, a discontinued IS/OS junction was the most frequent lesion, found in 40% to 82% of patients within the photoreceptor layer, and was described as a marker of poor prognosis for visual recovery [17–19]. Lai and associates reported that the presence

Table 3: Comparison visual acuity and contrast sensitivity in mesopic and photopic based on macular status

Macular status	Variable	Mean ± SD	p
Macular-on	**BCVA***		
	• Pre Op	1.28 ± 0.44	0.000
	• Post Op	0.69 ± 0.23	0.000
	CS post op		
	• Photopic	6.90 ± 3.67	0.000
	• Mesopic	6.47 ± 3.47	0.000
	N	19	
Macular-off	**BCVA***		
	• Pre Op	2.31 ± 0.39	0.000
	• Post Op	1.73 ± 0.62	0.000
	CS post op		
	• Photopic	1.00 ± 1.41	0.000
	• Mesopic	0.62 ± 1.18	0.000
	N	8	

*Mann-Whitney U- Test
* BCVA- best-corrected visual acuity

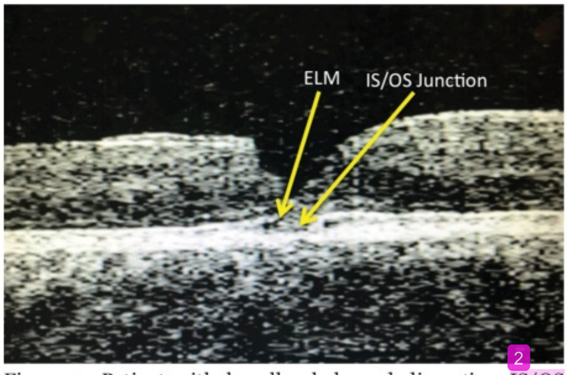

Figure 4: Patient with lamellar hole and disruption IS/OS junction and external limiting membrane (ELM) with BCVA 2.4 logMAR.

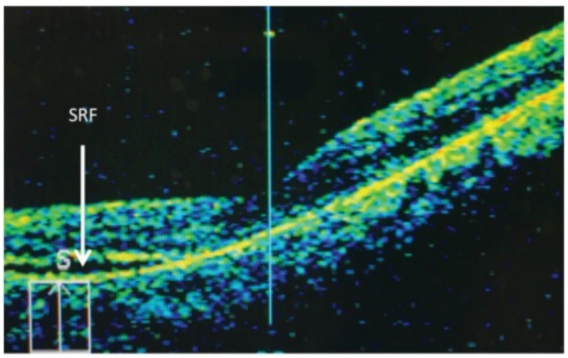

Figure 5: Persistent subretinal fluid (SRF) in the fovea area (arrow) in history of macular-on RRD with best-corrected visual acuity (BCVA) 0.5 logMAR.

of one or more abnormalities among the ELM, the IS/OS junction, or the Verhoeff membrane was correlated to poor postoperative BCVA [20]. In our study, IS/OS lesions were detected in five subjects eyes. Wakabayashi and his associates noted a disrupted IS/OS junction in 43% of 51 macula-off eyes and found that the integrity of both the ELM and the IS/OS junction was significantly associated with better visual outcome [19]. Final visual acuity in our study, did not differ between patients with simultaneous IS/OS and ELM disruptions and patients with IS/OS disruption and intact ELM. Terauchi et al also demonstrated that photoreceptor abnormalities persisted a long time after surgery. Twenty of 30 eyes (66.7%) had photoreceptor damage that was extended from the outer segments to the outer nuclear layer through the IS/OS [21].

Terauchi findings clearly showed that the IS and OS thicknesses increased in parallel with the improvement of the BCVA after successful retinal reattachment. The results showed that the IS and OS thickness were thin soon after the retina was reattached, and there was an increase in the thickness with increasing time [21].

Visual acuity and contrast sensitivity in photopic and mesopic condition with macular on history of RRD better than macular off with p value 0.00 in this study. Okamoto et al. demonstrated that CS decreased significantly after surgery for macular-on RRD without postoperative complications and abnormal OCT findings. Collectively, these findings indicate that surgical stress could cause a reduction in postoperative CS [22]. However, in our study, the difference in CS was between the macular-on and the macular-off group, possibly suggesting that reduced CS is due rather to foveal detachment than to surgical stress.

Ozgur et al. investigated macular function in eyes with successfully repaired macular-off RRD. They found that CS was lower in the operated eyes than in the fellow eyes. Since their studies included patients with lower postoperative BCVA, they concluded the low CS may have been caused by diminished visual acuity [16]. However, in our study CS was reduced even in eyes with visual acuity of logMAR 0.3 after PPV for RRD. Best corrected visual acuity measurement is the most common test used to evaluate visual function. However, a recent improvement in outcomes of RRD surgery requires a more precise method of visual function testing than BCVA measurement. Although central visual function can be evaluated by several tests including CS measurement, electroretinogram, and central visual field analysis, CS measurement is one of the least invasive, safest, and minimal time consuming. Taken together, the data indicate that CS can be a useful examination for multidimensional evaluation of postoperative visual function [16].

Microscopic changes after successful retinal reattachment with the regeneration process analyzed using animal model and resulted that the length of the outer photoreceptor segments gradually increases depending on the duration of retinal detachment and time since reattachment. The strongest regeneration was observed in eyes with the shortest detachment period and the longest interval between the reattachment and the morphological examination. Cone and rod regeneration processes differ, in cone regeneration, greater variability of outer segment length and generally lower regeneration potential was observed [23].

The topographic variability of changes in reflectivity patterns observed in our study may be associated with the differences between the cone and rod regenerative processes. The processes leading to increased reflectivity of the IS/OS start within the peripheral macula, where rods predominate, and gradually shift towards the center. At the same time, hyper reflective areas begin to appear within the central fovea, where only cones are present. These areas are initially small and tend to progress toward the peripheral macula [23]. Based on the established theory, that should be photopic contrast sensitivity had significant correlation with photoreceptor layer thickness, as cone plays important role in photopic illumination. In contrast, our study revealed that contrast sensitivity in mesopic illumination had positive significant correlation with photoreceptor layer thickness, presumably that pupil more dilated in mesopic condition, and rod predominates in peripheral macula.

This study had some limitations that included different instrument or chart from previously report, therefore it was difficult to compare this study results with other studies. The sample size was small. The method was cross sectional, that could only measure in once follow up. A future larger study with normal control and longer follow up is needed to confirm these findings and to better understand the morphologic and functional changes associated with RRD and subsequent recovery.

CONCLUSION

In conclusion, photoreceptor layer thickness significantly correlated with visual acuity and contrast sensitivity in mesopic illumination. The thicker the photoreceptor, the better visual acuity and mesopic contrast sensitivity was observed.

Henceforth, we strongly recommend OCT for patients whose retina had anatomic reattachment successfully, but achieved VA was not so good. Applying OCT makes it possible to find out the reason of poor VA, even long period of time after operation. This study may provide useful guidelines for the clinical management of retinal detachment as well as for assessing the potential possibilities of visual recovery of patients after successful vitrectomy pars plana.

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Author Contributions

Andi Muhammad Ichsan – Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Andi Suryanita Tajuddin – Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Habibah Setyawati Muhiddin – Design of the work, Interpretation of data, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Budu – Design of the work, Interpretation of data, Drafting the work, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Batari Todja Umar – Design of the work, Interpretation of data, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Noro Waspodo – Design of the work, Interpretation of data, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Guarantor of Submission

The corresponding author is the guarantor of submission.

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Consent Statement

Written informed consent was obtained from the patient for publication of this article.

Conflict of Interest

Authors declare no conflict of interest.

Data Availability

All relevant data are within the paper and its Supporting Information files.

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