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RESEARCH

Pattern electroretinography in patients with unilateral acute central serous chorioretinopathy

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Background: To evaluate the pattern electroretinography (PERG) in patients with acute central serous chorioretinopathy (CSCR) at baseline and after spontaneous resolution.
Methods: A total of 32 patients (mean ± SD age: 38.8 ± 8.2 years, 71.9 per cent female) with unilateral acute CSCR and spontaneous resolution during follow-up period were included. The unaffected eyes of the study patients comprised the control group. The best-corrected visual acuity, PERG and optical coherence tomography findings were recorded both at baseline and following spontaneous resolution at two to four months.
Results: The P50 and N95 amplitudes of the affected eyes were significantly lower than the control group both at baseline and after CSCR resolution ($p < 0.001$ for each). A significant increase was noted in both P50 and N95 amplitudes of the affected eyes from baseline to post-resolution ($p < 0.001$ for each). Subfoveal choroidal thickness was significantly higher in the affected eyes as compared with control eyes both at the baseline and after CSCR resolution along with a significant decrease in the affected eyes from baseline to post-resolution ($p < 0.001$ for each). The central retinal thickness was higher in the affected eyes as compared with the control eyes at baseline ($p = 0.009$), along with a significant decrease in the affected eyes from baseline to post-resolution ($p < 0.001$). Between the baseline P50 amplitude and the visual acuities of the affected eyes, a strong correlation was noted at baseline ($r = –0.691$, $p < 0.001$) and a moderate correlation was noted after CSCR resolution ($r = –0.422$, $p = 0.031$).
Conclusions: In conclusion, our findings revealed an association of CSCR with impaired P50 and N95 amplitudes and a significant improvement but not a complete recovery in both parameters after CSCR resolution. Our findings emphasise potential utility of PERG in the electrophysiological evaluation of functional impairment in CSCR patients and the likelihood of P50 amplitude to have a prognostic value in CSCR.

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Central serous chorioretinopathy (CSCR) is an idiopathic disease associated with the detachment of the neurosensorial retina frequently in the posterior pole and pigmented epithelium detachment (PED) at one or multiple foci in a range from five per cent to 63 per cent.[1,2]

CSCR is among the most common vision-threatening retinopathies including loss of visual acuity and contrast sensitivity accompanied by the development of central scotoma and metamorphopsia.[3] Acute CSCR is more common among males and at 20 to 50 years of age.[1,2] Since spontaneous recovery can be observed in 80–90 per cent of patients within one to four months, the first-line treatment is usually observation, while the recurrence rate varies between 35 per cent and 50 per cent.[1,2]

In patients with persistent serous retinal detachment or severe vision loss, several treatment options are available including photocoagulation by direct argon, micropulse laser, half-dose or half-fluence verteporfin photodynamic therapy or oral treatment by mineralocorticoid-receptor antagonists.[3]

The pathogenesis of CSCR includes local serous detachment of the neurosensorial retina as well as increased hyperpermeability and dysfunction in retinal pigment epithelium.[3] The introduction of optical coherence tomography (OCT) to the ophthalmology practice has provided high-resolution images helping to collect detailed data on quantitative assessment of several parameters in CSCR patients, such as the presence and extent of subretinal fluid, presence of the PED, the thickness of the central fovea and the choroid, and the presence of hyperreflective dots.[4]

Pattern electroretinography (PERG) is an ocular electrophysiological technique to evaluate the central retinal response to isoluminant stimuli in the form of a black and white reversing checkerboard. PERG allows an objective evaluation of the macular and retinal ganglion cell functions. Three wave landmarks are observed in a normal PERG response. The first small negative wave, N35, is generated approximately in the 35th millisecond after the checkerboard pattern reversal. The second wave, P50, is a large but positive one and is generated in 45–60 milliseconds. The third wave, N95, is a large negative wave generated in the 90–100th milliseconds.[5] While the positive P50 wave predominantly corresponds to the macular

photoreceptor function, N95 mostly reflects the retinal ganglion cell function.[6]

Given that CSCR is a disease primarily affecting the macula, PERG may provide invaluable information on this disease.[7,8] However, only limited data are available in the literature on PERG parameters in patients with CSCR[8] and no study to date has addressed the PERG findings in relation to visual acuity among patients with CSCR.

The present study was therefore designed to evaluate the PERG and OCT findings in acute CSCR patients at baseline and after spontaneous recovery and in relation to visual acuity.

Methods

Study population

A total of 32 patients (mean ± SD age: 38.8 ± 8.2 years, 71.9 per cent female) diagnosed with unilateral acute CSCR at the Ulucanlar Eye Training and Research Hospital between January 2016 and February 2018 were included in the study. Inclusion criteria included having a diagnosis of unilateral acute CSCR with symptom duration for less than six weeks, visual acuity of better than 6/60 and showing a spontaneous recovery at two to four months of the follow-up period. Patients with history of CSCR diagnosed or suggested in the fellow eye by any history of decreased vision, central scotoma, or central distortion and those with concomitant retinal (age-related macular degeneration, diabetic retinopathy, retinal vein occlusion) or other ocular pathologies (intraocular inflammation, cataract, amblyopia, glaucoma, optic atrophy, corneal opacities), any systemic disease such as diabetes and hypertension and history of intraocular surgery or steroid use and active smokers were excluded from the study. The unaffected contralateral eyes of the study patients comprised the control group. The diagnosis of CSCR was based on the findings obtained by OCT and fundus fluorescence angiography.

Written informed consent was obtained from each subject following a detailed explanation of the objectives and protocol of the study which was conducted in accordance with the ethical principles stated in the Declaration of Helsinki and approved by the Ethics Committee of Numune Training and Research Hospital.

Assessments

At baseline and follow-up visits, all patients underwent a thorough ocular examination of both eyes, including measurements of best-corrected visual acuity (BCVA) with a standard Snellen chart (converted to the logarithm of the minimum angle of resolution for statistical analysis) and intraocular pressure (via a non-contact tonometer) along with slitlamp biomicroscopy, spectral domain OCT (SD-OCT), enhanced depth-imaging OCT (EDI-OCT), fundus fluorescence angiography and PERG assessments.

As the measurement of the choroidal thickness is subject to diurnal variations, SD-OCT was performed at the same time interval (between 15:00–17:00 hours) in all study patients.

Central retinal thickness (CRT) and subfoveal choroidal thickness (SCT) measurements were performed by SD-OCT and EDI-OCT, respectively. The acquisition protocol for SD-OCT (Spectralis, HRA Heidelberg, Germany) included 49 horizontal raster dense linear B-scans centred on the fovea and a 30° EDI-OCT horizontal scan through the fovea the 'automatic real time' averaging set at the maximal value of 100 images. The quality of the scans was assessed before the analysis, and only images that scored higher than 25 (range 0–40; 0, poor quality; 40, excellent quality) were analysed. The follow-up function of the Heidelberg OCT was turned on for progression checking. Being measured manually based on a minimal distance from the foveal pit, CRT was defined as the distance between the internal surface of the retina and the external surface of the photoreceptor layer. SCT was defined as the distance between the hyperreflective line of Bruchs membrane and the border separating the choroid and sclera. The repeatability and reproducibility of CRT and SCT measurements were assessed by the co-efficient of variation (CoV) and intraclass correlation co-efficient (ICC) for five participants who underwent three consecutive measurements by two different masked examiners. The analysis revealed CoV and ICC values to be 2.90 per cent and 0.81 for CRT and to be 2.83 per cent and 0.85 for SCT, respectively. A resolution of CSCR was defined as the complete resorption of subretinal fluid and the serous detachment on SD-OCT images acquired.

PERG was performed twice (at the time of diagnosis and after spontaneous resolution) in each patient using a Metrovision MonPack One model electrophysiological device (MonPack One, Metrovision, France). For the recordings, subjects were refracted as needed for best corrected vision outcome. The tests were performed by the same technician using HK loop electrodes and in compliance with the International Society for Clinical Electrophysiology of Vision (ISCEV) standards.[5] To eliminate the luminance artefact of standard liquid crystal monitors, the stimulator liquid crystal monitors with feedback model were used in the Metrovision MonPack One

	Affected eyes, mean ± SD (min-max)	Control eyes, mean ± SD (min-max)	p-value†
P50 amplitude (μv)			
Baseline	2.96 ± 0.51 (1.9–5.3)	3.47 ± 0.64 (2.1–7.9)	**< 0.001**
After CSCR resolution	3.41 ± 0.62 (2.1–5.6)	3.59 ± 0.60 (2.3–8.1)	**< 0.001**
p-value‡	**< 0.001**	0.132	–
N95 amplitude (μv)			
Baseline	4.81 ± 0.78 (2.5–7.4)	5.56 ± 0.75 (4.0–8.8)	**< 0.001**
After CSCR resolution	5.36 ± 0.67 (3.9–7.2)	5.63 ± 0.87 (3.7–8.6)	**< 0.001**
p-value‡	**< 0.001**	0.324	–
P50 implicit time (ms)			
Baseline	48.41 ± 4.14	50.13 ± 4.04	0.56
After CSCR resolution	50.34 ± 3.23	49.62 ± 4.24	0.71
p-value‡	0.32	0.23	–

CSCR: central serous chorioretinopathy.
†Between-eye comparison.
‡Between-visit comparison (Wilcoxon signed rank test).

Table 1. Pattern electroretinography findings in the affected and control eyes (n = 32)

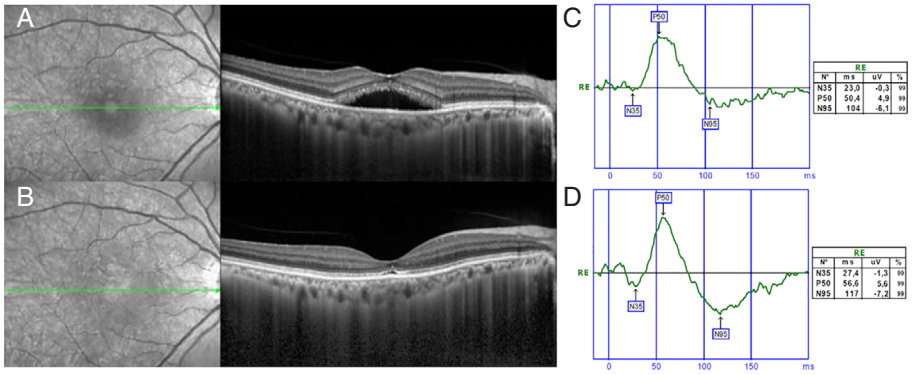

Figure 1. Spectral domain optical coherence tomography (SD-OCT) and pattern electroretinography (PERG) images of a patient with central serous chorioretinopathy (CSCR). A: SD-OCT image of the patient at baseline with subfoveal retinal fluid. B: SD-OCT image of the patient after spontaneous resolution. C: PERG output of the patient at baseline. D: PERG output of the patient after spontaneous resolution. Visual acuity was 0.4 logMAR at baseline and 0.2 logMAR after spontaneous resolution.

	Affected eyes, mean ± SD (min-max)	Control eyes, mean ± SD (min-max)	p-value†
SD-OCT SCT (μm)			
Baseline	443.6 ± 31.2 (379–489)	403.4 ± 22.9 (376–459)	**< 0.001**
After CSCR resolution	418.1 ± 25.6 (364–462)	398.7 ± 24.7 (375–456)	**< 0.001**
p-value‡	**< 0.001**	0.119	–
SD-OCT CRT (μm)			
Baseline	194.2 ± 12.5 (186–233)	190.3 ± 13.7 (179–224)	**0.009**
After CSCR resolution	189.6 ± 10.9 (179–239)	191.2 ± 12.9 (176–228)	0.334
p-value‡	**< 0.001**	0.312	–

CRT: central retinal thickness, CSCR: central serous chorioretinopathy, SCT: subfoveal choroidal thickness, SD-OCT: spectral domain optical coherence tomography.

†Between-eye comparison.

‡Between-visit comparison (Wilcoxon signed rank test).

Table 2. SD-OCT findings in the affected and control eyes (n = 32)

electrophysiological device. In accordance with the ISCEV standards,[5] the stimulus for the PERG was a black and white reversing checkerboard with a 0.8° check size. A photopic luminance greater than 80 cd/m^2 was used for the white areas. The contrast between black and white squares was maximal (close to 100 per cent) with a reversal rate of 4.0 ± 0.8 reversals per second. PERG recording was done binocularly after placing the head of the patient 30 cm to the fixation mark in the centre of the screen with appropriate optical correction for the test distance and without dilation of the pupils to maximise retinal image quality. During the test, patients were monitored whether they kept their eyes open or complied with the requirements of the test. The patient was asked to blink after every 10 seconds to avoid blurring of image due to tearing.

Statistical analysis

Sample size calculation was performed using computer software Power and Sample Size version 11 (PASS 2008; NCSS, Kaysville, UT, USA) and revealed that at least 30 eyes were required based on a confidence level of > 95 per cent and statistical power of 80 per cent. Overall, 32 eyes were included in the study and the power of our study was calculated to be 88.2 per cent.

Statistical analysis was made using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). The conformity of the quantitative variables to normal distribution was evaluated by visual (histograms and probability graphics) and analytical methods (Shapiro–Wilk test). Wilcoxon signed rank test was used to analyse parametric variables, while correlation analysis was performed using Spearman's correlation analysis. The correlation was assessed to be 'weak', 'moderate', 'strong' or 'very strong' according to the correlation co-efficients between 0–0.25, 0.26–0.50, 0.51–0.75, and 0.76–1.00, respectively.[9] Data were expressed as mean ± SD (standard deviation) and percentages where appropriate. P < 0.05 was considered statistically significant.

Results

Baseline characteristics

A total of 32 patients (23 male and nine female) with acute CSCR were included in the study. The mean age of the patients was 38.8 ± 8.2 years (range 28–59 years), while mean ± SD recovery time was 3 ± 0.4 months (range two to four months). Acute CSCR was left-sided in 19 (59.4 per cent) patients and right-sided in 13 (40.6 per cent) patients. SD-OCT revealed PED in 10 (31.3 per cent) patients. Mean ± SD intraocular pressure (IOP) of affected eyes was 14.6 ± 1.5 mmHg at baseline and 15.1 ± 1.7 mmHg after CSCR resolution. In the control eyes, corresponding values for IOP were 13.6 ± 1.9 and 14.2 ± 0.9 mmHg, respectively. No abnormality was observed in baseline and post-resolution slitlamp biomicroscopy assessment in both affected and control eyes.

BCVA

Mean ± SD BCVA values were significantly improved from diagnosis to resolution in the affected eye (0.35 ± 0.14 logMAR [range 0.1–0.5] versus 0.10 ± 0.06 logMAR [range 0.0–0.3], p < 0.001). No significant difference was noted in mean ± SD BCVA from diagnosis to post-resolution in the control eyes (0.01 ± 0.02 logMAR [range 0.0–0.1] versus 0.01 ± 0.04 logMAR [range 0.0–0.2], p = 0.8).

PERG parameters in the affected and control eyes

The P50 and N95 amplitudes of the affected eyes were significantly lower than the control group both at baseline and after CSCR resolution (p < 0.001 for each) (Table 1). A significant increase was noted in both P50 and N95

	Visual acuity	
	Baseline	**After CSCR resolution**
Baseline		
P50 amplitude		
r	−0.691	−0.422
p	**< 0.001**	**0.031**
N95 amplitude		
r	−0.234	−0.255
p	0.319	0.228
SD-OCT SCT		
r	−0.169	−0.107
p	0.432	0.643
SD-OCT CRT		
r	0.199	0.302
p	0.388	0.183
After CSCR resolution		
P50 amplitude		
r	−0.323	−0.521
p	0.129	**0.012**
N95 amplitude		
r	−0.365	−0.312
p	0.087	0.121
SD-OCT SCT		
r	0.021	−0.059
p	0.927	0.802
SD-OCT-CRT		
r	0.173	0.311
p	0.374	0.186

CRT: central retinal thickness, CSCR: central serous chorioretinopathy, r: Spearman correlation co-efficient, SCT: subfoveal choroidal thickness, SD-OCT: spectral domain optical coherence tomography.

Table 3. Correlation of visual acuity with pattern electroretinography and SD-OCT findings in the affected eyes (n = 16)

amplitudes of the affected eyes from baseline to post-resolution ($p < 0.001$ for each) (Table 1, Figure 1). No significant change was noted in P50 or N95 amplitudes from baseline to post-resolution in the control eyes (Table 1).

P50 implicit time was similar between control and affected eyes and from baseline to post-resolution in each group (Table 1).

SD-OCT findings in the affected and control eyes

SCT was significantly higher in the affected eyes as compared with control eyes both at the baseline and after CSCR resolution ($p < 0.001$ for each). A significant decrease was noted in SCT values from baseline to post-resolution in the affected eyes ($p < 0.001$) (Table 2, Figure 1).

CRT values were higher in the affected eyes as compared with the control eyes at baseline ($p = 0.009$), while no significant difference was noted between affected and control eyes in terms of CRT values measured after CSCR resolution. A significant decrease was noted in CRT values from baseline to post-resolution in the affected eyes ($p < 0.001$) (Table 2).

No significant change was noted in SCT and CRT values from baseline to post-resolution in the control eyes (Table 2).

Correlation of visual acuity with PERG and SD-OCT findings in the affected eyes

Baseline P50 amplitude was negatively correlated with baseline ($r = -0.691$, $p < 0.001$) and post-resolution ($r = -0.422$, $p = 0.031$) visual acuity values, while post-resolution P50 amplitude was also negatively correlated with post-resolution visual acuity ($r = -0.521$, $p = 0.012$) (Table 3).

No significant correlation of visual acuity values was noted with SD-OCT findings at baseline or after CSCR resolution (Table 3, Figure 2).

Discussion

Our findings in a cohort of acute unilateral CSCR patients with spontaneous resolution within two to four months revealed the significant deterioration in OCT and PERG parameters in affected versus control eyes at the time of diagnosis to be improved significantly after CSCR resolution along with a negative correlation of baseline P50 amplitude with post-resolution visual acuity in the affected eyes.

Demographic profile of our patients seems in agreement with the age range (36.7 to 47 years) and a male predominance of the disease reported in past case series.[10,11]

The BCVA values recorded at the time of diagnosis in affected eyes (range 0.1–0.5 logMAR) revealed a favourable visual acuity, being consistent with BCVA range (0.1–0.4 logMAR) reported in past studies with CSCR patients.[1,12] In addition, significant improvement in BCVA from baseline to post-resolution in our patients seems to be in line with data from a study by Gilbert et al. among patients with CSCR which indicated spontaneous resolution in 80–90 per cent alongside a significant increase in visual acuity at two to six months.[1] Hence, our findings seem to support the consideration that visual acuity is often affected at a mild to moderate extent in CSCR patients, while the likelihood of an impaired quality of vision has also been suggested despite a slight reduction in the visual acuity.[13]

The PERG assessment in our patients revealed significantly lower P50 amplitude both at the baseline and after CSCR resolution in the affected eyes as compared with the control eyes, whereas there was significant increase in the P50 amplitude of the affected eyes from baseline to post-resolution. Furthermore, the correlation of P50 amplitude with visual acuity was noted both at baseline and after CSCR resolution, indicating strongly and moderately negative associations, respectively.

To the best of our knowledge, there are only two studies in the literature addressing PERG parameters in CSCR patients. Eckstein et al. were the first reporting a significant decrease in the P50 values of CSCR patients.[7] Moreover, similar to our findings, Goyal et al. demonstrated that while P50

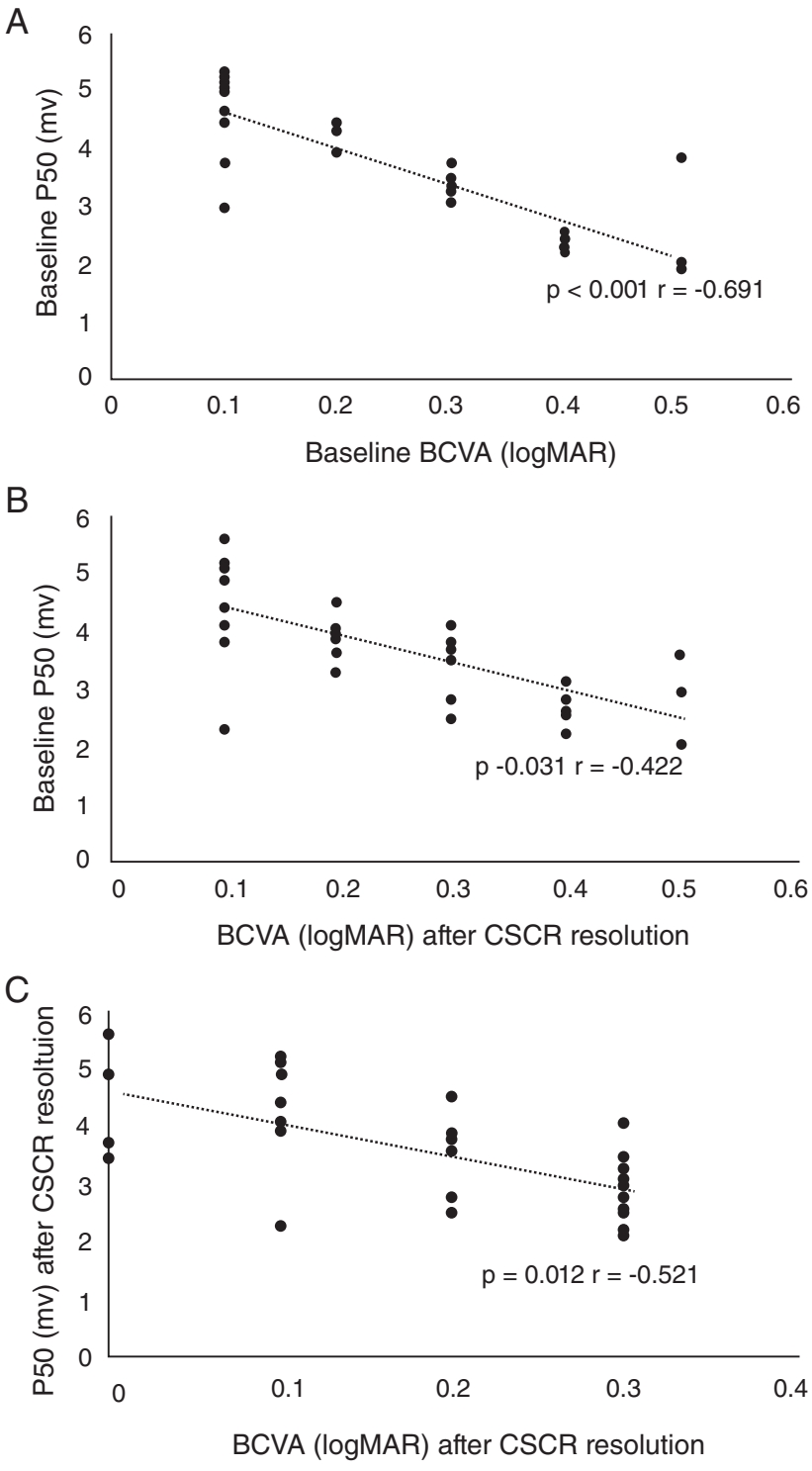

Figure 2. A: Scatter plot for the correlation between baseline P50 amplitude and baseline best-corrected visual acuity (BCVA) (logMAR). B: Scatter plot for the correlation between baseline P50 amplitude and BCVA (logMAR) after central serous chorioretinopathy (CSCR) resolution. C: Scatter plot for the correlation between P50 amplitude after CSCR resolution and BCVA (logMAR) after CSCR resolution.

amplitudes increased significantly in CSCR patients after CSCR resolution, they remained significantly lower compared to the control eyes.[8]

In fact, the studies evaluating the multifocal electroretinography (mfERG) findings in the CSCR patients also reported significantly affected wave amplitudes and latencies primarily reflecting the function of the cone receptors and demonstrated a significant correlation of these parameters with visual acuity.[14,15] In a study by Huang et al., mfERG findings associated with CSCR were reported to include a decrease in the N1, P1 average response densities of the first and second annuli and a delay in the N1, P1 latencies of first to third rings.[16]

Moreover, several electrophysiologic studies have demonstrated that the macula is involved functionally in CSCR patients.[8,14,17,18] The impaired visual function involving reduced contrast sensitivity, decreased adaptation to dark, and impaired colour vision has also been reported even in CSCR patients with good visual acuity.[8,14,17–19] However, no studies to date have addressed the PERG findings in relation to visual acuity among patients with CSCR. Our findings support the utility of PERG in the electrophysiological evaluation of CSCR patients, given that it provides data on residual deficit even after anatomical resolution of CSCR and attaining normal visual acuity.[8] In this regard, along with the findings on negative correlation between baseline P50 amplitude and post-resolution visual acuity in our cohort, we may suggest that the function of the macular photoreceptors are primarily impaired in CSCR and P50 amplitude may have a prognostic value in CSCR.

Another finding related to PERG assessment in our study was significantly lower N95 amplitude both at the baseline and after CSCR resolution in the affected versus control eyes along with a significant increase in the N95 amplitude of the affected eyes from baseline to post-resolution. Given that N95 amplitude is a PERG parameter mostly derived from the retinal ganglion cells, these findings may indicate the likelihood of functional impairment in ganglion cell layers in CSCR patients, besides significant involvement of the photoreceptors. Similar findings related to N95 amplitudes in patients with CSCR were also reported by Goyal et al.,[8] while Demirok et al.[20] demonstrated thinning of the ganglion cell layer in both the acute and chronic CSCR patients. In addition, in a PERG-based study among CSCR patients by Miyake et al.,[21] both b-waves and

a-waves along with oscillatory potentials were reported to be impaired in the affected areas, indicating that the functions of the inner retinal layers were also impaired along with the photoreceptors in CSCR. Nonetheless, it should be noted that N95 amplitude was impaired at a lesser extent (by ~38 per cent) than P50 amplitude in our study, and the decrease in the P50 wave amplitude may precede and mediate the changes observed in the N95 amplitude.

Our findings revealed that CRT values were higher in the affected eyes than in the control eyes at baseline but not after CSCR resolution, along with significant reduction in CRT values from baseline to post-resolution in the affected eyes. Similarly, Iida et al.[22] reported association of acute CSCR with increased thickness of neurosensorial retina in a study among 23 patients, while retinal thickening and microcystic changes (particularly in the Henle layer) were also demonstrated in an autopsy study by Ikui et al.[23] involving the autopsies of five patients with serous macular detachments due to CSCR. Moreover, association of spontaneous resolution with improved CRT as compared to acute period of CSCR has also been reported by Iida et al.[22] In other studies with CSCR patients, authors noted not only a decreased CRT (especially in the outer nuclear layer) after spontaneous resolution but also its correlation with reduced visual acuity, suggesting the likelihood of degeneration and loss in the photoreceptor layer following subfoveal retinal detachment.[24–28]

However, in accordance with our findings, no significant correlation between CRT and visual acuity was reported in other studies with acute CSCR patients.[4,22] Lack of a correlation between CRT and visual acuity in our study was evident both at diagnosis and after CSCR resolution. In fact, duration of the subfoveal retinal detachment was reported to be associated with likelihood of degeneration and loss of the photoreceptors, as well as with reductions in the thickness of the outer nuclear layer and central retina.[28] Accordingly, it should be noted that alongside a small sample size, the potential variation in the duration of subfoveal retinal detachment during baseline CRT measurement might have also influenced our findings.

Higher baseline SCT values in affected versus control eyes in our study supports the consideration of increased choroid thickness to have an important role in the pathophysiology of CSCR.[29,30] Similarly, findings from a meta-analysis of studies among CSCR patients revealed SCT values to range from 414 $\pm$ 109.0 to 61.4 $\pm$ 101.4 μm in the affected eyes and from 350.9 $\pm$ 116 to 387 $\pm$ 94 μm in the control eyes.[31] In our study, there was no significant correlation between SCT and visual acuity either at baseline or following spontaneous resolution. Similarly, in a study by Yalcinbayir et al.,[4] the authors reported no significant association between SCT and visual acuity in patients with CSCR and emphasised the likelihood of choroidal thickness not to be among the primary determinants of visual acuity, despite its important role in the pathophysiology of CSCR.[4]

Lack of data on in-depth analysis of overall SD-OCT parameters involving the outer retinal thickness, the thicknesses of the inner and outer segments of the photoreceptors, and the impairments in the ellipsoid zone seem to be the major limitations of the current study. Nevertheless, the current study is one with the highest number of patients among the past studies on PERG in CSCR patients which has also demonstrated for the first time in the literature, the significant correlation between the P50 amplitude and visual acuity in patients with CSCR.

In conclusion, our findings revealed a significant decrease in P50 and N95 amplitudes of the affected eyes at the time of CSCR diagnosis, and a significant improvement but not a complete recovery in both parameters after CSCR resolution. Our findings indicate that the function of the macular photoreceptors is primarily impaired in CSCR and emphasise the utility of PERG in the electrophysiological evaluation of functional impairment in CSCR patients, providing data on residual deficit even after anatomical resolution of CSCR and attaining normal visual acuity. In addition, the negative correlation of baseline P50 amplitude with post-resolution visual acuity in affected eyes seems to emphasise the likelihood of P50 amplitude to be a PERG parameter with a potential prognostic value in CSCR.

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