Original Article

Electroretinogram changes before and after silicone oil removal in eyes with macula-off rhegmatogenous retinal detachment

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ABSTRACT

Background: Pars plana vitrectomy (PPV) with silicone oil (SO) injection for rhegmatogenous retinal detachment (RRD) repair may adversely affect electroretinographic responses. This study was aimed at assessing retinal function using electrodiagnostic testing after successful PPV with SO tamponade in the eyes with macula-off RRD.

Methods: In this interventional comparative study, eligible participants were recruited prospectively over 1 year. We included the eyes that underwent a single successful three-port PPV with SO tamponade for the primary repair of macula-off RRD. Full-field electroretinogram (ffERG) and multifocal electroretinogram (mfERG) were recorded 1 day before and 3 days after SO removal. The amplitude and implicit time of the a- and b-waves for ffERG and P1 and N1 waves for mfERG were evaluated. The unaffected fellow eyes of the patients were selected as controls.

Results: We included the ten eyes of ten patients (seven men and three women) with a mean (standard deviation) age of 58.8 (6.2) years. The mean (SD) interval between the diagnoses of macula-off RRD and PPV was 11.7 (3.6) days. The mean (SD) duration of SO tamponade was 147.8 (34.9) days. Using ffERG, significantly lower a- and b-wave amplitudes were found in the eyes before and after SO removal or compared to the unaffected fellow eyes (all $P < 0.05$). Using the mfERG, treated eyes had significantly lower P1 amplitudes in the central R1+R2+R3 rings and in the R4 and-R5 peripheral rings of the macular area in the eyes before and after SO removal or compared to the unaffected fellow eyes (all $P < 0.05$). The wave implicit time in ffERG and mfERG did not differ significantly in the eyes before and after SO removal or compared to the unaffected fellow eyes (all $P > 0.05$).

Conclusions: The electrical retinal response density in ERG waveforms increased following SO removal, indicating amelioration of the electrical activity of the retina and macula. These results indicate that the adverse effects of SO tamponade on electroretinography responses may be reversible with removal. In addition, ffERG and mfERG can be used to monitor retinal function in the eyes with macula-off RRD and SO tamponade. Further clinical trials are required to verify the preliminary findings of this study.

KEYWORDS

multifocal ERG, electroretinogram, electroretinography, retinal detachments, silicone oil, vitrectomies, vitrectomy, macula luteas

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INTRODUCTION

Silicone oil (SO) is extensively used as a retinal tamponade medium to manage complicated vitreoretinal conditions [1]. Its use is typically limited to complex cases, including proliferative vitreoretinopathy (PVR), giant retinal tears, and trauma [2-4]. Longstanding intravitreal SO may lead to visual impairment due to anterior segment complications, such as secondary glaucoma, keratopathy, and cataract formation. It may adversely affect retinal function [5-8].

Electroretinography (ERG) has been extensively used to assess retinal function [9-14]. Full-field electroretinography (ffERG) evaluates the electrophysiological activity of the entire retina [15], whereas multifocal electroretinography (mfERG) is better suited to evaluate the macular area [16]. Electrophysiological examination of the retina may determine the functional status of this tissue in cases of suspected pathology and unexplained visual loss after intraocular surgery [6-8].

Only a few studies have evaluated electroretinographic changes following retinal detachment repair with temporary SO tamponade for any vitreoretinal pathology [17-20], although with contradictory theories explaining their results. According to this limited body of evidence, pars plana vitrectomy (PPV) with SO injection may adversely affect electroretinographically determined responses of the retina [17-19]. A hypothesis states that SO itself may cause retinal dysfunction characterized by a decline in electrophysiological responses [17-20]. Other explanations regarding reduced electroretinographic responses include insulating properties of the SO itself, surgical intervention per se, or potential for retinal degeneration [17-20]. To date, no study has investigated the effects of SO on electrical retinal response density using ffERG or mfERG exclusively in the eyes with macula-off rhegmatogenous retinal detachment (RRD) that underwent a single successful three-port PPV with SO tamponade.

The present study was aimed at evaluating the retinal function in the eyes that underwent PPV with SO tamponade for macula-off RRD. ffERG and mfERG responses were recorded before and after SO removal and compared with those of the unaffected fellow eyes and between the eyes before and after SO removal.

METHODS

This prospective, interventional, comparative study was conducted at the University Hospital of Ioannina, Greece, from September 2017 to October 2018, and approved by the Institutional Ethics Committee of the University of Ioannina. This study adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Patients who underwent three-port PPV with SO tamponade for macula-off RRD were recruited. For inclusion, patients should have undergone a single successful three-port PPV with SO tamponade for primary macula-off RRD. The eyes with a history of trauma or previous ocular surgery other than phacoemulsification, RRD duration > 3 months, coexistent macular and vitreoretinal pathologies, or current medications that can affect retinal function, such as phenothiazine, quinine sulfate, clofazimine, chlorpromazine, desferrioxamine, and chloroquine, were excluded. Furthermore, we excluded eyes with postoperative complications, such as SO emulsification, secondary glaucoma, epiretinal membrane, macular hole, cystoid macular edema, and retinal re-detachment, or low-quality electrophysiological test recordings. We considered the operated eyes as cases and unaffected fellow eyes as controls.

The indication for the SO injection was macula-off RRD with multiple giant breaks or proliferative vitreoretinopathy (PVR). Surgical procedures were performed by a single experienced vitreoretinal surgeon using the 23-gauge PPV Alcon Constellation Vision System (Alcon Laboratories Inc., Fort Worth, TX, USA). After core vitrectomy, peripheral vitreous removal with a 360° scleral indentation was performed. Vitreous traction was released from the retinal tear, and almost all PVR membranes were peeled from the retinal surface. Perfluorocarbon liquid (PFCL) was used to flatten the retina. After flattening, the retinal endolaser was applied, followed by direct PFCL / SO (1,300 centistokes) exchange. The SO was removed within 4 – 6 months after the initial surgery.

All participants underwent a comprehensive eye examination preoperatively and postoperatively. The examination included best-corrected distance visual acuity measurement using a Snellen chart (auto chart projector CP 670; Nidek Co., Ltd, Gamagori, Japan), intraocular pressure measurement using the Goldmann applanation tonometer (AT900, Haag-Streit, Koeniz, Switzerland), detailed anterior segment assessment with slit-lamp biomicroscopy (Photo-Slit Lamp BX 900; Haag-Streit, Koeniz, Switzerland), and dilated fundus examination using a 78 D non-contact fundus lens (Volk Optical Inc., Mentor, OH, USA) which is used with the slit-lamp. Patients were followed-up regularly for at least 12 months after SO removal. No recurrence or other complications were observed.

ffERG and mfERG were conducted 1 day before and 3 days after SO removal in both treated and unaffected fellow eyes of all participants, based on the following protocols. ffERGs and mfERGs were recorded using an EP-1000 PRO electrophysiology system (TOMEY, Nagoya, Japan). The principal structure of this system and recording conditions conform to the general concepts of electrophysiology diagnostic procedures and the International Society for Clinical Electrophysiology of Vision (ISCEV) standards [21, 22].

The ISCEV standards were followed for ffERG recordings [22]. The recorded parameters in ffERG included the a- and b-wave of the dark-adapted 0.01, dark-adapted 3.0, and light-adapted 3.0 ERG amplitudes and implicit times [22]. The pupils were fully dilated with tropicamide 0.5% (Tropixal, DEMO SA Pharmaceuticals, Kryoneri, Greece) and phenylephrine 5% (phenylephrine, Cooper AE, Greece) before the test. Scotopic (dark-adapted 0.01) ERGs were recorded after the patient was dark-adapted for 20 min. Dark-adapted 3.0 (combined rod and cone system responses) ERGs were recorded directly after dark-adapted 0.01 ERG. Photopic (light-adapted 3.0) ERG was recorded after the patient was light-adapted for 10 min.

The ISCEV standards were followed for the mfERG recording [21]. The mfERG produces visually evoked signals with spatial differentiation, and its stimuli, composed of 241 elements that subtended 1.7° [23], were separately determined for the appropriate reaction signal. The stimulus field consisted of a hexagonal array with a fixation point at the center. During the recording, the patient's visual field from each eye was stimulated using a 22″ thin-film transistor monitor at a distance of 30 cm. In our examination, the field contained 103 hexagons within a field diameter of 40 – 50° (20 – 25° radius from the fixation point to the edge of the display) and included the blind spot. The main waveform of mfERG was a biphasic wave consisting of an initial negative deflection (N1) followed by a positive peak (P1) [21]. The through-to-peak (P1) amplitude was measured and expressed in nano volts per square degree of visual field (nV/deg^2). The P1 implicit time was measured and expressed in milliseconds (ms). As available from the machine software, the N1 implicit time was also recorded and expressed in ms.

The patient concentrated on a fixation point throughout the measurement procedure with a continuous reaction signal without fluctuations or interruptions. The patients were under ordinary room illumination before the test, and the pupils were fully dilated [21] with tropicamide 0.5% and phenylephrine 5%. Refractive correction for near vision was provided such that the patients could clearly see the small fixation spot at the center of the stimulus matrix. The 'Rings' analysis was used to interpret circular changes in reaction signals from the inside outwards.

Response densities of mfERG were analyzed by grouping 103 responses into six concentric rings. Wave amplitudes were evaluated in all rings of the macular region, and trace arrays were assessed in each ring. At the center, the approximate mfERG stimulus locations and corresponding anatomic areas were as follows: ring 1, < 2° field, corresponding to the fovea; ring 2, 2° – 7° field, corresponding to the parafoveal region; and ring 3, 7° – 13° field, corresponding to the perifoveal region. In the periphery, the respective stimulus locations and corresponding anatomic areas were as follows: ring 4, 13° – 20° field; ring 5, 20° – 31° field; and ring 6, 31° – 44° field.

Data were analyzed using a statistical software package (IBM SPSS Statistics for Windows, version 22.0, IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed with the Shapiro – Wilk test. Continuous data are expressed as mean (standard deviation [SD]). The paired *t*-test or non-parametric Wilcoxon signed-rank test was used to compare the a- and b-wave amplitudes and implicit times for ERG waveforms, amplitude and implicit time of P1, and implicit time of N1 for mfERG waveforms between the eyes before and after SO removal and treated and unaffected fellow eyes. Categorical data are expressed as count (percentage). The *P*-values obtained were two-tailed and were determined to be significant at 0.05.

RESULTS

The ten eyes of ten patients (seven men and three women) with a mean (SD) age of 58.8 (6.2) years were included. Table 1 shows the baseline characteristics of the participants. The retina remained attached after SO removal in all eyes.

The a- and b-wave amplitudes and implicit times for the ffERG waveforms were evaluated. The amplitudes of the a- and b-waves after SO removal were significantly higher than those before SO removal (both $P < 0.05$) (Table 2). Moreover, the eyes treated before SO removal had significantly lower a- and b-wave amplitudes than the unaffected fellow eyes (both $P < 0.05$) (Table 2). After SO removal, differences in the a- and b-wave amplitudes compared with the unaffected fellow eyes were smaller, with the b-wave amplitude remaining significantly different ($P < 0.05$) but the a-wave amplitude becoming comparable ($P > 0.05$) (Table 2, Figure 1).

Table 1. Baseline characteristics of the study participants

Variable		Value
Sex (Male / Female), n (%)		7 (70) / 3 (30)
Age (y), Mean ± SD, Median (Range)		58.8 ± 6.2, 59.5 (47 to 67)
Macula-off RRD duration (d), Mean± SD, Median (Range)		11.7 ± 3.6, 12.0 (7 to 18)
Duration of SO tamponade (d), Mean ± SD, Median (Range)		147.8 ± 34.9, 148.5 (97 to 205)
Vitreoretinal pathology	**Multiple retinal breaks, n (%)**	4 (40)
	Giant retinal breaks, n (%)	4 (40)
	Stage 3 PVR, n (%)	2 (20)

Abbreviations: n, number; %, percentage; y; years; SD, standard deviation; RRD, rhegmatogenous retinal detachment; d, days; SO, silicone oil; PVR, proliferative vitreoretinopathy.

Table 2. Changes in a- and b-wave amplitudes of ffERG waveforms

Variable	Before SOR – After SOR	*P*	Before SOR – Fellow eye	*P*	After SOR – Fellow eye	*P*
a-wave (μV), Mean difference ± SD	- 58.3 ± 46.9	**0.003**	- 90.1 ± 46.8	**< 0.001**	- 31.9 ± 46.6	0.059
b-wave (μV), Mean difference ± SD	- 107.6 ± 76.7	**0.002**	- 173.4 ± 83.6	**0.005**	- 65.8 ± 74.8	**0.037**

Abbreviations: ffERG, full-field electroretinography; μV, microvolt; SD, standard deviation; SOR, silicone oil removal. *P*, *P*-values < 0.05 are shown in bold.

Table 3. Changes in the P1 amplitude of mfERG waveforms

Ring	Before SOR – After SOR	*P*	Before SOR – Fellow eye	*P*	After SOR – Fellow eye	*P*
R1 (nV/deg^2), Mean difference ± SD	- 37.5 ± 68.3	0.116	- 107.5 ± 132.0	**0.005**	- 70.00 ± 118.1	0.059
R2 (nV/deg^2), Mean difference ± SD	- 15.9 ± 35.7	0.192	- 12.2 ± 41.6	0.378	3.7 ± 39.1	0.772
R3 (nV/deg^2), Mean difference ± SD	- 4.6 ± 23.5	0.552	- 22.7 ± 19.9	**0.017**	- 18.1 ± 21.9	**0.037**
R4 (nV/deg^2), Mean difference ± SD	- 8.1 ± 9.4	**0.023**	- 15.6 ± 8.4	**0.001**	- 7.5 ± 8.6	**0.023**
R5 (nV/deg^2), Mean difference ± SD	- 7.8 ± 10.4	**0.042**	- 9.30 ± 5.7	**0.001**	- 1.5 ± 8.4	0.587
R6 (nV/deg^2), Mean difference ± SD	- 6.1 ± 10.2	**0.039**	- 9.4 ± 6.0	**0.012**	- 2.8 ± 13.6	0.400
R1+R2+R3 (nV/deg^2), Mean difference ± SD	- 19.3 ± 22.2	**0.022**	- 47.5 ± 43.7	**0.005**	- 28.1 ± 44.7	0.093

Abbreviations: mfERG, multifocal electroretinography; nV/deg^2, nano volts per square degree of the visual field; SD, standard deviation; SOR, silicone oil removal. *P*, *P*-values < 0.05 are shown in bold. Note: Ring 1, < 2° field, corresponding to the fovea; Ring 2, 2° – 7° field, corresponding to the parafoveal region; Ring 3, 7° – 13° field, corresponding to the perifoveal region. In the periphery, the respective stimulus locations and corresponding anatomic areas were as follows: Ring 4, 13° – 20° field; Ring 5, 20° – 31° field; and Ring 6, 31° – 44° field.

The mean (SD) a-wave (before SO removal: 23.9 [3.3] ms; after SO removal: 24.0 [3.4] ms; unaffected fellow eyes: 21.5 [4.7] ms) and b-wave (before SO removal: 53.3 [7.0] ms; after SO removal: 54.1 [6.8] ms; unaffected fellow eyes: 51.3 [6.3] ms) implicit times did not differ significantly before SO removal from that after SO removal ($P = 0.974$ for a-wave and $P = 0.426$ for b-wave) or compared to the unaffected fellow eyes before ($P = 0.014$ for a-wave and $P = 0.677$ for b-wave) and after ($P = 0.209$ for a-wave and $P = 0.305$ for b-wave) SO removal.

The P1 amplitude and implicit time and N1 implicit time for the mfERG waveforms were evaluated. The P1 amplitudes after SO removal were significantly higher than those before SO removal in the R4, R5, and R6 rings (all $P < 0.05$) (Table 3, Figure 2). After SO removal, the P1 amplitudes increased in the R1, R2, and R3 central rings, although without statistical significance (all $P > 0.05$) (Table 3). However, evaluating the macular area as a whole by analyzing the mean P1 amplitude derived from the three central rings (R1, R2, and R3) before and after SO removal revealed a significant increase in the P1 amplitude after SO removal ($P < 0.05$) (Table 3).

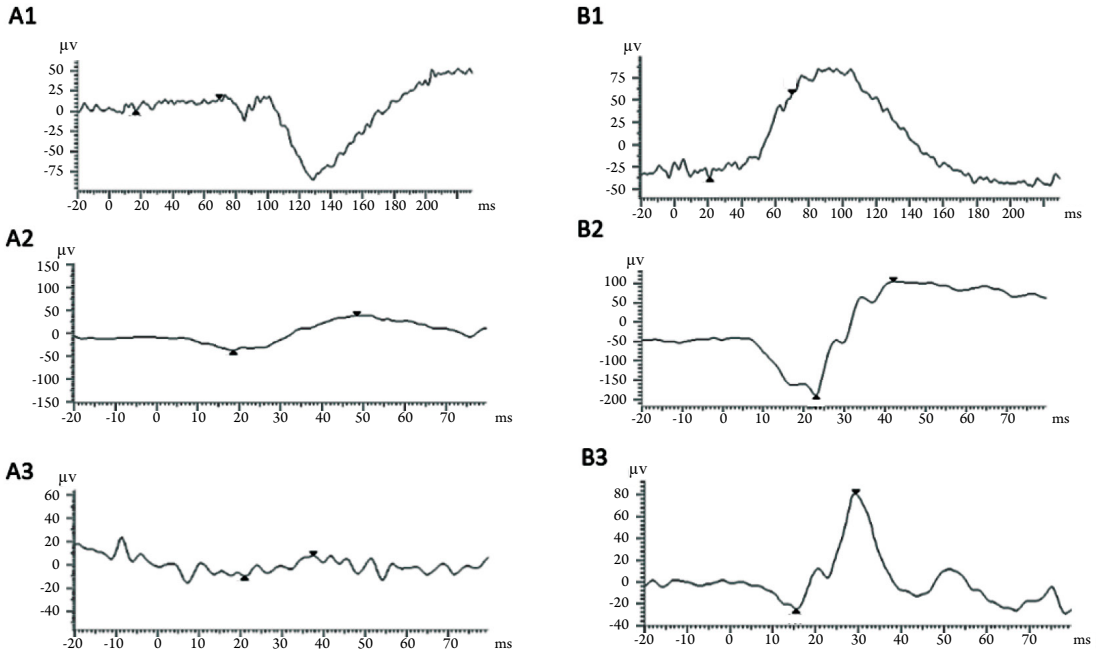

Figure 1. Full-field electroretinography (ffERG) a- and b-wave amplitudes (vertical axis in μv and horizontal axis in ms) recordings from the treated eyes for macula-off rhegmatogenous retinal detachment (A) before silicone oil (SO) removal and (B) after SO removal. (A1) ffERG waveform amplitude recordings before SO removal of rod responses (scotopic), (A2) combined rod and cone responses (mesopic), and (A3) cone responses (photopic) are barely detectable. (B1) ffERG waveform amplitude recordings after SO removal of rod responses (scotopic), (B2) combined rod and cone responses (mesopic), and (B3) cone responses (photopic) are close to normal.

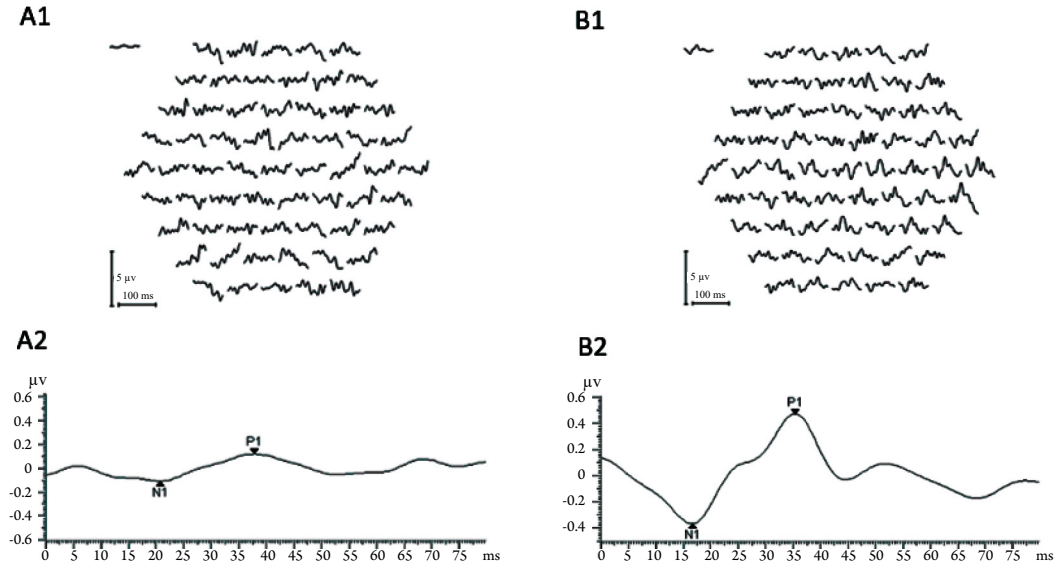

Figure 2. Multifocal electroretinography (mfERG) waveform amplitude (vertical axis in μv and horizontal axis in ms) recordings from the treated eyes for macula-off rhegmatogenous retinal detachment (A) before SO removal and (B) after SO removal. (A1) mfERG waveform amplitude recordings before SO removal in all 60 sectors and (A2) the summation response are decreased. (B1) mfERG waveform amplitude recordings after SO removal in all 60 sectors and (B2) the summation response are close to normal.

Moreover, the treated eyes before SO removal had significantly lower P1 amplitudes compared to the unaffected fellow eyes in five of the six rings (all $P < 0.05$), except R2 ($P > 0.05$) (Table 3). However, after SO removal, these differences in P1 amplitudes between the treated and unaffected fellow eyes became smaller in all rings and were not significant for most rings ($P > 0.05$, for R1, R2, R5, and R6), except for R3 and R4 (both $P < 0.05$) (Table 3).

The mean (SD) N1 implicit time before SO removal (24.8 [10.0] ms), after SO removal (20.1 [7.7] ms), and in the unaffected fellow eyes (17.4 [3.7] ms), and the mean (SD) P1 implicit time before SO removal (50.91 [11.0] ms), after SO removal (52.9 [10.9] ms), and in the unaffected fellow eyes (50.1 [10.6] ms) were recorded. The P1 or N1 implicit time before SO removal did not differ significantly from that after SO removal ($P = 0.257$ for N1; $P = 0.579$ for P1) or in comparison with the unaffected fellow eyes before ($P = 0.045$ for N1; $P = 0.519$ for P1) and after ($P = 1.000$ for N1; $P = 0.671$ for P1) SO removal.

DISCUSSION

This study revealed an increased retinal response density in electroretinographic recordings following the removal of intravitreal SO from the eyes operated for macula-off RRD. This outcome suggests an amelioration of the electrical activity of the retina and macular area.

Unexplained visual impairment after uncomplicated RRD repair with temporary SO tamponade has been associated with structural [24-26] and functional [27-30] retinal deteriorations. Electrophysiological responses in the SO-filled eyes have been evaluated [17-20, 31, 32]. Several studies have analyzed electroretinographic recordings of the eyes with intravitreal SO under different vitreoretinal conditions, such as primary, recurrent, or posttraumatic RRD, myopic degeneration, and endophthalmitis [19, 33, 34]. To the best of our knowledge, this is the first study focusing exclusively on the eyes with macula-off RRD repaired successfully with a single surgical procedure accompanied by intravitreal SO tamponade using both ffERG and mfERG recordings.

A few studies have demonstrated early deterioration with a lasting effect on ERG amplitude after SO injection [17, 20, 35]. A study suggested retinal degeneration or a nerve impulse insulating effect due to the presence of intravitreal SO [20]. In contrast, ERG measurements showed a comparable decline in the vitrectomized eyes irrespective of SO implantation. This decline was followed by a recovery to normal recordings over 20 months [33]. These symmetrically affected amplitudes in the early postoperative period suggest that surgical intervention in the vitreous cavity may be responsible for electroretinographic changes. An experimental study revealed no difference with the scotopic b-wave of the ERG waveform in the SO-filled eyes injected with ganciclovir [35]. We observed an improvement in the electrical function of the retina after SO removal. The explanation for these ERG changes remains unclear and requires evaluation in large-scale clinical trials.

The explanations regarding electrophysiologic findings following vitreoretinal surgery with SO tamponade are conflicting [18, 19, 32, 34]. Previous studies mainly referred to the impact of intravitreal SO on the characteristics of ffERG waveforms [27, 28, 30, 32, 35], with limited reference to mfERG [33]. After retinal reattachment surgery, ERG responses tended to improve, although they did not reach normal values. The latter indicates a potentially incomplete functional recovery of the retina [36, 19]. ERG waveforms can be recorded even in the presence of a non-conductive agent [34]. Some studies have suggested that ffERG responses are diminished or even unrecordable in the SO-filled eyes compared to the healthy eyes [19, 37]. Some authors have suspected deteriorative effects of SO on the retina and suggested that the reduction in ERG waveform amplitudes results from impaired retinal function caused by intravitreal SO [38, 20]. Nevertheless, conclusive evidence for purported SO-related retinal dysfunction has not been reported. However, the evidence provided by our study may indicate that the impaired electrical retinal response density is reversible after SO removal.

Considering the findings of the aforementioned studies, the decline in the ERG waveform parameters may be a consequence of the nerve-conduction insulating effect [37, 39]. An increase in the waveform amplitude after SO removal has been reported [19, 37, 40], similar to the present study. This finding may support the hypothesis that the retina tolerates intraocular SO well [19, 37, 40].

Ozaki et al. [34] reported that ERG waveforms before and after SO removal were significantly and positively correlated. Therefore, they proposed that the wave amplitude in the SO-filled eyes could be used to predict the amplitude and, in turn, retinal function after SO removal. In the present study, the amplitudes of the a- and b-waves in ffERG of the SO-filled eyes decreased but returned to near-normal limits after SO removal. Nonetheless, whether the decline in ERG values in the SO-filled eyes is related to SO itself, the surgical procedure, or both remains unclear [19, 20, 36, 38]. However, ERG values improved shortly after SO removal from the vitreous cavity, possibly reflecting its conduction-impeding effect [37]. Consistent with other published reports, our data imply a nonconductive effect of SO on the retina.

ffERG assesses the entire retinal electrical function and may not detect damage to the macula. In contrast, mfERG assesses electrophysiological activity predominantly in the macula [41]. Functional mapping of the macula may be described in detail using mfERG [16]. Macular responses in the SO-filled eyes have not been studied extensively. Kumawat et al. [33] evaluated the effect of SO on mfERG after RRD repair. Their results indicate that the wave amplitude in the SO-filled eyes may be reduced, although it recovers shortly after SO

removal and remains stable during a 4-week follow-up period [33]. The conduction-insulating effect of SO may interfere with the density of electric potentials from the retina, thus explaining the wave amplitude improvement after SO removal from the vitreous cavity [33, 37].

The data presented in our study show that mfERG can detect functional defects in the SO-filled eyes after macula-off RRD surgery, followed by a subsequent improvement in retinal response density in all regions after SO removal. The retinal response density decreased at the center and to a lesser degree in the peripheral region of the macular area, reflecting the functional decline of photoreceptors. The central part of the fovea is more densely populated by cone photoreceptors than the peripheral part [42]; thus, the central area may be more severely affected. We evaluated the N1 amplitude in each macular ring and found a lower P1 amplitude 1 day before SO removal compared to 3 days after SO removal or in comparison with the unaffected fellow eyes. We considered the sum of the central R1+R2+R3 rings corresponding to the foveal, parafoveal, and perifoveal areas. The mfERG waveform amplitude of the central rings of the macula significantly decreased after macula-off RRD repair with SO use. The P1 amplitude in the R1, R2, and R3 central rings before SO removal did not differ significantly from the respective amplitudes after SO removal. In contrast, the P1 amplitudes in the R4, R5, and R6 peripheral rings before SO removal were significantly lower than the respective amplitudes after SO removal. A hypothesis states that, in our patients, the fovea, parafovea, and perifovea were more affected than the eccentric regions of the macula. Consistent with previous studies [33, 37, 39], we suggest a substantial functional alteration of the macula underlying the SO, assuming that the observed increase in macular response density after its removal may be attributed to an insulating effect [37, 39].

The wave implicit time was previously evaluated in ffERG and mfERG studies. A prolonged wave implicit time may be attributed to vitreoretinal pathology or the surgical procedure [37, 44]. The insulating effect of SO may not affect synaptic transmission within the retina, leading to implicit time stability after SO removal from the vitreous cavity. Based on this hypothesis, Kumawat et al. [33] recently suggested that implicit time is a predictive factor for retinal function in the eyes with intravitreal SO after surgical repair. In the present study, the wave implicit time in ffERG and mfERG did not differ between the eyes before and after SO removal. Additionally, we hypothesized that the implicit time measurement could be inaccurate because of the low ERG waveform amplitude before SO removal. This hypothesis should be verified through correlational studies [44, 45].

Alterations in retinal oxygen saturation may occur 9 months after SO tamponade [46]. ERG responses may gradually decrease if SO remains in the vitreous cavity for a long time [46]. We should consider that photoreceptor recovery after retinal reattachment requires approximately 4 weeks [17, 47-49]. In our series, the SO tamponade duration was shorter than 9 months but significantly longer than 4 weeks (mean [SD]: 147.8 [34.9] days). Thus, ERG responses were unaffected by retinal saturation changes or photoreceptor recovery.

Unlike previous studies that analyzed electroretinographic findings in the SO-filled eyes for diverse vitreoretinal conditions, we included only macula-off RRD cases that successfully underwent PPV. This can be considered as a strength of our study. Some limitations of the present study should be considered. First, the unaffected fellow eye of each patient was used as the control. The eyes that underwent vitrectomy without SO tamponade would be a better group for comparison. However, the control group consisted of the eyes of different patients, possibly with significant (and unaccounted for) physiological differences. The normal eyes were used as controls in previous clinical studies [50]. Second, the sample size was relatively small. Nonetheless, even this small sample size enabled the detection of significant differences, at least in waveform amplitudes. More statistically significant differences could be found using a larger sample. Finally, our patients were examined shortly after SO removal. Therefore, our results may not accurately reflect the long-term ERG characteristics of these eyes. Additional prospective longitudinal studies are warranted to validate our findings and address the limitations and gaps in the present and previous studies.

CONCLUSIONS

The data of our study indicate an increase in the electrical retinal response density after SO removal, which in turn may imply amelioration of the electrical activity of the retina and macular area. ffERG and mfERG can be used to assess retinal function after vitrectomy in the eyes treated for macula-off RRD with SO tamponade. Our preliminary outcomes should be verified in large-scale clinical trials to establish real-life practice guidelines for electrophysiological test applications in retinal detachment surgeries.

ETHICAL DECLARATIONS

Ethical approval: The study was conducted at the University Hospital of Ioannina, Greece, and approved by the Institutional Ethics Committee of the University of Ioannina. This study adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Conflict of interest: None.

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