Unveiling the visual system in migraine: Electrophysiological evidence from electroretinogram and visual evoked potential

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Abstract

Background

Since there is evidence that the bioelectrical activity in migraineurs' visual cortex varies significantly throughout the migraine cycle and that the retina, according to embryology, is an extension of the cortex, and has similar angiogenesis configurations and regulatory mechanisms, so the aim of this study was to investigate the cortical activity, functional and electrophysiological retinal changes in migraine patients using different modalities of electroretinogram (flash full field, multifocal and pattern) during interictal period.

Methods

Fifty-six migraine patients according to the international headache society, third edition and fifty-six healthy subjects age and sex matched as control group all were subjected to assessment of cortical activity, functional and electrophysiological retinal changes using visual evoked potential and electroretinogram (flash full field, multifocal and pattern).

Results

In terms of flash full field ERG findings, there was a statistically significant delayed latencies of both photopic and scotopic a and b wave and lower amplitudes of scotopic a and b waves among patients compared to controls ($P < 0.001$). Multifocal ERG showed that there were significantly lower amplitudes of N1 wave of zones 1 and 5 ($P < 0.001$) and P1 wave amplitudes in zones 2, 4 and 5 among patients compared to control ($P = 0.039, < 0.001, < 0.001$) respectively. As regards pattern ERG and visual evoked potential P50 and P100 latencies and amplitudes showed no statistically significant difference between patients compared to controls.

Conclusion

These findings suggest that migraine patients had functional retinal changes, even during headache-free periods that could be related to selective neuronal and/ or vascular alterations.

Introduction

Migraine is a public chronic disorder characterized by an episodic headache accompanied by several neurological, gastrointestinal and/or autonomic disturbances, up to 21% of women and 6% of men had migraine attacks associated with activity impairment and disability. Clinically there are two main subtypes: migraine without aura and migraine with aura **(1).** Debilitating headache, nausea, vomiting, photophobia, phonophobia, and occasionally visual or sensory abnormalities are its hallmarks **(2).**

Numerous studies have shown that the bioelectrical activity in migraineurs' visual cortex varies significantly throughout the migraine cycle. Visual evoked potential (VEP) recordings have demonstrated an interictal deficit of habituation during stimulus repetition in the brains of migraineurs with and without aura **(3).**

The exact etiology of migraines is still unknown, however neurovascular alterations associated with activation of the trigeminovascular system are linked to the onset of migraine headaches. It causes disturbances in the circulation of the brain and retina **(4)**. These alterations may cause harm to the brain, or retina or optic nerve **(5)**.

The aim of this study was to investigate the cortical activity, functional and electrophysiological retinal changes in migraine patients using different modalities of ERG (flash full field, multifocal and pattern) during interictal period.

Methods

This case control study was carried out at tertiary care center recruited over one and half years.

One hundred and ten subjects were included and divided into two groups:

Patients Group: included fifty-six migraine patients further divided into migraine with and without aura.

Control Group: fifty-six healthy subjects age and sex matched.

Informed oral and written consents were taken from patients prior to participation to ensure complete satisfaction. The study was approved by the ethical committee (code: MD-229-2021)

Inclusion Criteria:

Patients diagnosed with migraine with or without aura according to the international classification of headache disorders, third edition, 2018

Age from 20 – 55 years old.

Both sexes are included.

Exclusion Criteria:

Any ophthalmological pathology other than refractive errors,

Any lifetime history of intake of hallucinogenic drugs, or any other drugs that can cause visual hallucinations as psychotropic drugs or dopamine agonists.

Patients with MRI brain show structural lesions like infarcts, intracerebral hemorrhage, subdural hematoma, tumors, encephalitis, or hydrocephalus.

Methods:

All patients recruited during the interictal periods and controls will be submitted to the following:

1-Clinical assessment:

Complete general, neurological assessment (history and examination) and ophthalmological assessment.

Detailed Headache history

2-Neurophysiological tests were carried out using metrovision scan version 8000F (Metrovision, Francais) in the Clinical Neurophysiology Unit, Kasr Al-Ainy Hospitals.

a) **Visual evoked potential (VEP):**

The VEP stimuli technique and measurements conformed to the International Society For Clinical Electrophysiology of Vision (ISCEV) standards for clinical VEP recording 2016 (**6**) The non-viewing eye was occluded with a tight-fitting opaque patch

b) Electroretinogram (ERG)

- Flash full field ERG: according to ISCEV 2022 **(7).**

-Multifocal electroretinogram (mfERG) technique:

The recording using HK Loop electrodes after 10 minutes of light adaptation and pupil dilation with tropicamide (that is why Pattern ERG (PERG) was done first) and a few drops of topical anesthesia.

A gold cup electrode served as a reference and a ground electrode was connected to the forehead. The fellow eye was occluded with light pressure to prevent blinking and the electrical artifacts it can introduce.

The stimulus consisted of sixty-one hexagons, covering 25-30° of visual field to either side of fixation. The monopack stimulator is made of an liquid crystal display panel with light emitting diode backlight.

Signals were amplified with a gain of 100.000 and filtered with a band- pass filter (5–300 Hz). The surface electrode impedance was less than 10 kohm. According to ISCEV 2021 (**8)**

Each session lasted 6 minutes and they were broken into 45- second segments, and eight trials were recorded in total.

These maps allowed displaying a map of amplitudes or implicit times of N1, P1, N2 and P2wave peaks. Measurements that correspond to each stimulation area were displayed in rectangles of orange color. Values are provided in nV/deg2 (nano volt per unit surface area in square degrees). The 3D color map

was obtained by direct interpolation between the measuring points. The responses and their measurements are plotted at corresponding retinal locations rather than in visual field orientation

mfERG evaluates the local retinal functions from the fovea to the peripheral 30 degrees by dividing this area into up to five retinal zones (central hexagon and four rings). These analyses provide the characteristics of the average responses over a group of these zones as follows:

- Central hexagon (fovea) ” Z1”: from 0 to 2 degrees of eccentricity relative to the fixation.
- R1"Z2": from 2 to 5 degrees
- R2"Z3": from 5 to 10 degrees.
- R3"Z4": from 10 to 15 degrees.
- R4"Z5": over 15 degrees

For each hexagon, the amplitude of P1 (defined as the difference between N1 trough and P1 peak) was calculated, and the implicit time of the P1 component determined from the onset of the stimulus till the peak of the P1 wave.

- Pattern ERG: The amplitude and peak time of P50 and N95 waves were analyzed. The P50 amplitude is measured from the trough of N35 to the peak of P50. The N95 amplitude is measured from the peak of P50 to the trough of N95 according to ISCEV standard 2024 (**9**)

3- Neuroimaging:

Brain MRI was performed for patients and control group on a 1.5TGE Signa (General Electric, Milwaukee, WI, USA) closed-configuration whole body scanner using a standard quadrature head coil. Each MRI examination included Sagittal 3D T1 weighted spoiled gradient utilizing the following parameters: A repetition time of 7.2 msec, an echo time of 120 msec, a slice thickness of 1.2 mm, FOV= 256 x 256 mm, preparation time 500ms, FOV 256x256mm.phase FOV1.0,slice thickness 1.2mm,number of slices 160,slice spacing 0,matrix192x192,flip angle 10 degrees, frequency 16 kHz, frequency direction S/I,NEX 1.0,shim auto, Phased Array Uniformity Enhancement on, Surface Coil Intensity Correction off.

4- Statistical analysis

Statistical analysis was conducted using SPSS 22nd edition, categorical variables were presented in count and percentage and compared using Chi2 test. Quantitative variables were presented in mean, standard deviation, min and max, and compared between studied groups using the Mann Whitney U test. All tests were two sided with a level of significance 0.05.

Results

Clinical characteristics:

In the patients' group, the age ranged from 20 to 44 years with a mean age of 30.1 ± 6.01 years. In the control group, the age ranged from 30 to 54 years with a mean age of 32.6 ± 10.6 years. There was no statistically significant difference between the two groups (ρ value = 0.874).

Among the migraine patients, forty-five patients (80.4%) were females, and eleven patients (19.6%) were males. While forty subjects (71.4%) of the control group were females and sixteen subjects (28.6%) were males showing no statistically significant difference.

The duration of migraines among patients ranged from 2 to 144 months with a mean of 38.1± 37 months.

Fifty-three (94.6%) patients had episodic migraine and only three patients (5.4%) had chronic migraine**.**

Forty-six patients (82.1%) had episodic migraine without aura, and all the chronic migraine patients (3 patients, 5.4%) had no aura while seven patients (12.5%) had episodic migraine with aura, 5 of them had visual aura and 2 had sensory aura.

Comparative results:

1- Comparison between both groups as regards Visual Evoked Potential (VEP):

Comparison between patients and controls showed no statistically significant difference in p100 amplitude and latency with p value >0.05 (table 1)

Table (1): Comparison between both groups as regard VEP

	patients		**Controls**		
	Mean± SD	range	Mean± SD	range	P value
P100 Latency (ms)	101.5±12.6	84.6-167.5	100.1±8.1	84-117	0.773
P100 Amplitude (µV)	11.9±4.9	4.1-22.7	10.8±3.6	5.2-18.5	0.325
***Significant at P<0.05**					

Comparison between both groups as regards electroretinogram (flash full field, multifocal and pattern)

a. Flash full field electroretinogram.

There was a statistically significant difference between studied groups in terms of flash ERG findings, both photopic and scotopic a and b wave latencies were significantly delayed among patients in comparison to controls whereas regarding amplitudes there was no statistically significant difference in photopic a and b waves between both groups while amplitudes of scotopic a and b waves were

significantly lower in patients compared to controls with p values <0.001, illustrated in table (2) and figure (1).

Table (2): Comparison of Flash full field ERG between migraine patients and control group

	patients	**Control**	
	Mean ±SD	Mean ±SD	P value
Photopic a wave Latency (ms)	18.9±4.04	15.35±2.4	<0.001*
Photopic a wave Amplitude (µV)	15.97±6.4	16.47±6.22	0.676
Photopic b wave Latency (ms)	40.5±13.6	35.6±11.1	0.039*
Photopic b wave Amplitude (µV)	55.5±21.5	54.5±23.9	0.819
Scotopic a wave Latency (ms)	25.3±10.6	18.1±3.07	<0.001*
Scotopic a wave Amplitude (µV)	55.37±18.2	70.8±34.3	0.004*
Scotopic b wave Latency (ms)	67.8±30.8	39.5±4.2	<0.001*
Scotopic b wave Amplitude (µV)	128.8±31.7	151.36±60	0.015*
***Significant at P<0.05**			

b. Multifocal Electroretinogram

- **N1 wave:**

Multifocal ERG showed that the amplitude of N1 of zones 1 and 5 was significantly lower among patients compared to control with p value <0.001, while implicit time did not show significant difference between both groups as shown in table (3), figure (2,3,4)

Table (3): Comparison of multifocal ERG N1 wave amplitude and implicit time between migraine and control groups.

	Groups	Z1	Z2	Z3	Z4	Z5
N1 Amplitude (µV)	**patients**	431.1±214.2	214.1±73.4	201.4±96.9	176.3±68.8	172.5±70.5
	Controls	568.8±171.7	226.5±62	215.6±91.3	209.4±110.6	222.9±99.6
	p value	<0.001*	0.456	0.308	0.054	0.001*
N1 Implicit time (ms)	**patients**	41.1±55.2	34.7±35.9	31.4±22.3	31.4±24.3	31.8±21.3
	Controls	29.7±3.6	28.7±5.1	27.9±4	27.9±2.8	29.4±4
	p value	0.530	0.202	0.793	0.084	0.085
***Significant at P<0.05**						

- **P1 wave:**

P1 wave amplitude was significantly lower among patients in zones 2, 4 and 5 with p values 0.039, <0.001 and <0.001, respectively, while implicit time was not significantly different between both groups as shown in table (4) figure (2,3,4).

Table (4): Comparison of multifocal ERG P1 wave amplitude and implicit time in both eyes between migraine and control groups.

	Groups	Z1	Z2	Z3	Z4	Z5
P1 Amplitude (µV)	**patients**	853±289.9	415.7±140.9	359.4±118.3	342.5±125.8	345.5±134.9
	Controls	928.9±338	485.8±161.8	397.1±171.8	424.4±148.9	443.1±167.5
	P value	0.392	0.039*	0.202	<0.001*	<0.001*
P1 Implicit time (ms)	**Patients**	52±3	47.1±2.2	45.8±2.5	45.3±2.5	46.6±1.8
	Controls	53.4±4.2	48.9±4.6	47.7±75	44.6±4.4	48±4.4
	P value	0.209	0.147	0.074	0.302	0.425
***Significant at P<0.05**						

c. Pattern Electroretinogram

On comparing P50 latency and amplitude between both groups, there were no statistically significant differences between them with p values >0.05 as shown in table (5).

Table (5): Comparison between both groups as regards P50.

	Patients		Control		
	Mean ±SD	range	Mean ±SD	range	P value
P50 latency	48.9±4.2	42-62.3	50.2±3.9	42.4-59.3	0.060
P50 amplitude	7.1±2.7	1.9-16.2	7.1±2.5	2.4-13.3	0.820
***Significant at P<0.05**					

Discussion

In this study we tried to explore the visual pathway anatomically from the different layers of the retina up to the cortex, that's why we did full field, multifocal and pattern ERG and VEP. Assessment of cortical interictal changes revealed that P100 amplitude and latency showed no statistically significant differences between patients compared to controls and between patients with and without aura. These results agree with **Verroiopoulos, et al., 2016** (10), who found that there was no significant difference in P100 amplitudes or latencies between migraine patients and control group and **El-Shazly et al., 2017** (11) who found that P100 latency and amplitudes were normal in between headache attacks.

The brain of a migraine sufferer is hyperresponsive, and cortical information processing is aberrant. Glutamate, one of the main excitatory neurotransmitters, is elevated in the primary visual cortex, occipital lobe, and right thalamus of migraineurs, causing a hyperexcitable cortex. A growing amount of data indicates that the retina of migraine sufferers is hyperresponsive as well. In between attacks, migraineurs have decreased cortical preactivation and diminished thalamocortical drive. In contrast, migraine symptoms are caused by increased excitation and decreased intracortical inhibition, which disrupts the excitatory–inhibitory coupling (12). The underlying mechanisms are still mostly unknown and frequently invisible using current approaches, so the results were variable when using standard transient visual evoked potentials (13).

The findings of this study were consistent with several studies that reported no statistically significant difference in the means of latency and amplitude of pattern reversal VEP (PVEP) between migraine patients without aura and healthy persons, ((14), (15), (16), (17)) conducted research on migraine patients with and/or without aura, found that N75-P100, N75, and/or N145 amplitude and/or latency are within normal ranges. Additionally, **Ataç and Tuna 2020** (18) noted that the means of latency and amplitude of PVEP did not differ statistically between healthy subjects and migraine patients without aura.

Also, our results are in concordance with **Omland et al., 2016** (19); **Ozkul et al., 2001**(20); **Oelkers- Ax et al.,2005** (21); who stated that there was no difference in the VEPs amplitude between the migraine patients and the healthy controls.

Several studies have investigated the structural changes in the retinal layers in migraine patients, in this study the aim was to investigate the interictal functional and electrophysiological retinal changes in

migraine patients using different modalities of ERG (flash full field, multifocal and pattern).

The retina, according to embryology, is an extension of the cortex, and their angiogenesis configurations are similar throughout development. As a result, the blood vessels in the brain and retina have a close anatomical relationship and similar regulatory mechanisms (22), this is supported by a study done by **Farouk et al., 2021**(23) showed that mfERG amplitudes were significantly lower in the hypertensive group with retinopathy than in controls, and that N1 amplitude was significantly lower in the most eccentric ring (R3,R4) in the eyes of hypertensive patients with normal fundus. This could be because researchers hypothesized that sustained vasospasm in hypertension affects the macula's periphery and that patients with hypertension had a significantly lower number of perifoveal vessels, so based on the neurovascular pathophysiology of migraine, we used ERG to measure the interictal electrophysiological retinal changes in migraine patients.

Assessing the photoreceptor functions we found that there was a statistically significant difference between migraine patients and control groups in terms of flash full field ERG findings, for photopic and scotopic a and b wave latency was significantly delayed among migraine patients compared to controls, but no statically significant difference was found between migraine with and without aura. Photoreceptor dysfunction may result from ischemic damage to retinal tissues triggered by altered choroidal blood flow. (24).

Contradictory results were found by **Verroiopoulos, et al., 2016** (10); **Nguyen et al., 2014** (25); **Coutin-Churchman and Padrón 2003** (26); **Ozkul et al., 2001** (20) as they discovered that neither the latency nor the amplitude of the a nor b waves in the flash ERG differed significantly between migraineurs and the control group, and they came to the conclusion that migraineurs did not have significant retinal impairment. Similar conflicting findings were reported by **Bernstein et al., 2019** (27), who discovered that migraine patients had greater rod-mediated ERGs (scotopic response) b-wave amplitudes than healthy controls. Patients with migraines and healthy controls had similar a-wave amplitudes. There were no discernible variations in the b-wave or a-wave amplitudes between migraine patients and healthy controls in cones-mediated (photopic responses). Their results imply that the retinal rods, not the retinal cones or the visual cortex, may be the source of migraine patients' light hypersensitivity.

Also, in contrast to our results **Hamurcu and Bilen 2022** (12) revealed an increase of scotopic b-wave amplitudes in migraine with aura compared to controls. There was no statistically significant difference in photopic b-wave amplitudes between the groups. They explained their findings that migraine with aura patients had hyperexcitable retina and cortex.

As mfERG assess the inner retinal layer function, in this study it was found that the amplitude of N1 waves of mfERG in foveal (zone 1) and some parafoveal areas (zone 5), and P1 amplitude was significantly lower among patients in parafoveal areas (zones 2, 4 and 5) compared to controls, while N1 and P1 implicit time showed no significant difference between patients and control groups. There was no statistically significant difference in terms of N1 and P1 amplitudes or Implicit time between migraine with aura and migraine without aura patients, this came in accordance with **Verroiopoulos et al., 2016**

(10) who found that the mean retinal response density in ring 1 (foveal) was significantly diminished in migraine with and without aura subjects compared to healthy individuals indicating that migraineurs may have dysfunctional foveal cones and/or bipolar cell layers (10).

These results also agree with **Nguyen et al., 2024** (28), they discovered that in those who do not have severe visual field loss and are otherwise healthy and asymptomatic in between migraine attacks, there is an abnormally reduced amplitude of mfERG responses parafoveally, indicating a potential region of retinal neuronal dysfunction in migraineurs.

The probable explanation for a mfERG deficit in migraine is the peripheral vascular insufficiency that develops in the retinal blood supply and may impact the retina and optic nerve at any level., which could be a sign of a more widespread vascular dysregulation in migraineurs. However, it is possible that in certain migraineurs, retinal vascular dysregulation produces a neuronal stress environment in the retina, which makes the parafoveal region more vulnerable. It is impossible to determine whether the observed variation in the parafoveal mfERG response is due to a particular retinal vascular insult to that region or to a systemic vascular malfunction that makes retinal vascular changes more likely to appear in parafoveal region. (28)

This is also supported by the structural affection of retinal nerve fiber layer (RNFL) using Optical Coherence Tomography (OCT), where most of the data showed that several RNFL quadrants had decreased thickness, which is caused by vasospasm and inflammatory compromise resulting in axon loss and a decrease in RNFL diameter (29). Additionally, there may be Müller cell dysfunction because of transneuronal retrograde degeneration (30).

Since migraine is a neurovascular disorder, the optical coherence tomography angiography (OCTA) data supports the vascular alteration theory in migraine. As retinal vascular imaging techniques continue to progress, the use of OCTA to investigate possible retinal involvement of cerebrovascular alterations in migraines is gaining popularity. According to an OCTA-based systematic review and meta-analysis, migraineurs are more likely to experience disorders with retinal microcirculation, such as a greater avascular area in the fovea and a decrease in blood vessel density (22) and the results of **Kara et al., 2003** (31) supported this possibility as they discovered that, when compared to healthy control subjects, migraine patients had higher resistance arterial values in the central retinal artery and the posterior ciliary artery by doppler sonography. This suggests that vascular alteration in the ocular system could be a pathogenic factor or association with the migraine process.

In this study, assessment of ganglion cell layer (GCL) using pattern ERG (PERG) showed no significant difference either between patients with migraine and control group nor migraine with and without aura patients, this was consistent with the findings of other researchers who used pattern reversal ERG to elucidate the mechanisms underlying migraine and aura. The latency and amplitude of the P50 and N95 components of pattern reversal ERG did not significantly differ between migraineurs and control groups (32, 33, 34, 25, 10).

Nguyen et al., 2012 (35) revealed that both transient and steady-state PERG measures were normal. These results do not necessarily rule out the possibility of some retinal involvement in migraine. Instead, migraineurs do not exhibit anomalies according to the conventional clinical standards used in this investigation. This could occur if the test is not sensitive enough to the kind of dysfunction that migraines may exhibit. In contrast to glaucoma, migraine does not cause widespread retinal ganglion cell failure, for which the PERG is a sensitive marker (24). If pre-cortical dysfunction in migraine is mild or localized, usual full-field PERG paradigm may not detect it (35)

El-Shazly et al., 2017 (11) discovered that during aura, the N95 wave's latency increased, and its amplitude decreased; both then returned to normal during the quiescent phase. Cerebral ischemia during a migraine aura may be the cause of this. The findings in RNFL thickness affection and both PVEP and PERG changes may be explained by optic nerve head hypoperfusion, which leads to ganglionic retinal cell death and cerebral ischemia. The fact that functions returned to normal values but not RNFL thickness in between attacks may indicate that partial nerve loss is insufficient to change the functions in migrainous patients in between attacks. After the aura subsides, the RNFL thickness may not return to normal, which could indicate a fundamental RNFL pathology or the progressive nature of the migraine effect (11).

This can be supported by the findings of **Tunç et al., 2017** (36) revealed that no significant thinning in GCL thickness using OCT was shown in patients with migraine compared to the control group. These could be due to minimal or selective retinal dysfunction in migraine patients interictally that ERG cannot detect.

Changes in ganglion cell layers could be due to the disruption of the blood retinal barrier, which causes bleeding and exudate and subsequent nerve fiber layer ischemia, in addition to direct microvascular alterations caused by high blood pressure that impaire blood flow to the optic nerve. (37) is supported by a study done on hypertensive patient to assess the ganglion cell function and revealed that PERG P50 wave showed reduced amplitude and longer implicit time in hypertensive patients with signs of retinopathy compared to those with no signs of retinopathy and control group (38)

The results of this study were contradictory to **Ekinci et al., 2014** (24) who found that GCL was significantly thinner in the migraine patients with aura as compared with both the migraine patients without aura and the control subjects (24), this could be explained by the few number of patients with migraine with aura in this study, where the GCL is more affected.

Given the complex pathophysiologic mechanism of migraine, which is primarily explained by the neurovascular theory, trigeminovascular system activation results in the release of inflammatory and vasoactive neuropeptides from the extracranial nerve endings to the eye, causing vasospasm of the ophthalmic, retinal, and posterior ciliary arteries with hypoperfusion, axon loss accounting for RNFL and GCL thinning in migraineurs (29, 39). According to **Ascaso et al., 2017** (40), altered choroidal blood flow may be the cause of any macular alterations in migraine with aura, and the severity of these alterations can differentiate migraine with aura from migraine without aura.

It is also believed that oxidative stress and inflammation have a role in the pathogenesis of migraines through endothelial dysfunction, which is thought to contribute to the pathophysiology of migraines and is a known factor in initiating vasoconstriction and signaling vascular risk (41), moreover, retrograde trans-synaptic neuronal degeneration caused by cortical depression during the visual aura can impact retinal ganglion cells and the RNFL by destroying cerebral neurons (42).

It is currently uncertain how exactly these events relate to migraines and retinal abnormalities. This could suggest that the potential structural alterations in the retina are not always permanent, irreversible, or consistent in migraineurs. Even though some studies have found these alterations, the cause-and-effect link is still unclear because migraine etiology is complex (43).

In conclusion, we did not find interictal cortical or retinal hyperexcitability but there was an interictal functional and electrophysiological retinal changes in both migraine with and without aura patients in some retinal layers indicating that these changes could be due to vascular and/or neural dysfunction. These changes could be selective in certain retinal layers or could be reversible changes or related either to aura or the headache phases that were not assessed in this study with no interictal cortical changes.

Conclusion

Our findings suggest that migraines are associated with functional retinal changes, even during headache-free periods that could be related to selective neuronal and/ or vascular alterations. Preventive strategies that stabilize vascular dynamics may provide not only symptomatic relief but also neuroprotective benefits for retinal function. Further research into larger samples and concomitant use of OCT, OCTA with ERG during and after aura, is necessary to validate these findings and explore their clinical implications

Limitations:

VEP and ERG were not assessed during all headache phases to detect the consistency of the results throughout the headache cycle, also it is recommended to explore the visual pathway and compare it in migraine with and without aura patients.

Abbreviations

ERG
electroretinogram
GCL
ganglion cell layer
ISCEV
International Society for Clinical Electrophysiology of Vision
mfERG
multifocal electroretinogram

MRI
magnetic resonance imaging
OCT
Optical Coherence Tomography
OCTA
optical coherence tomography angiography
PERG
Pattern ERG
PVEP
pattern reversal VEP
RNFL
retinal nerve fiber layer
VEP
Visual evoked potential

Declarations

Ethics approval and consent to participate: The study was approved by Cairo University Ethics Committee (code:MD-229-2021), consent to participate was obtained

Consent for publication: Informed written consent was obtained from all participants

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: SF, AA, RS study idea and revision of data, AFH analyzed and interpreted the patient data electrophysiologically, SRS data collection and contribution in writing the manuscript, AAF ophthalmological assessment of patients, MME radiological assessment of patients, GH writing and revising the manuscript. All authors read and approved the final manuscript.

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Figures

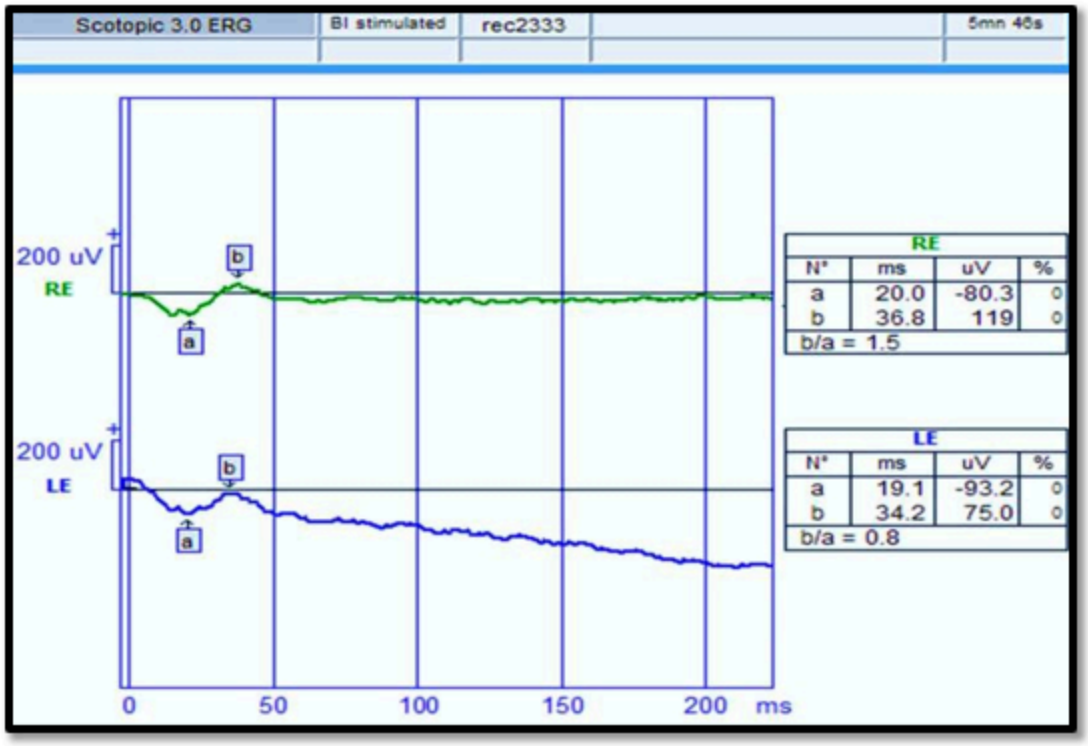

Figure 1

Flashfull field ERG scotopic response showing small amplitude b wave bilaterally more reduced over the left eye

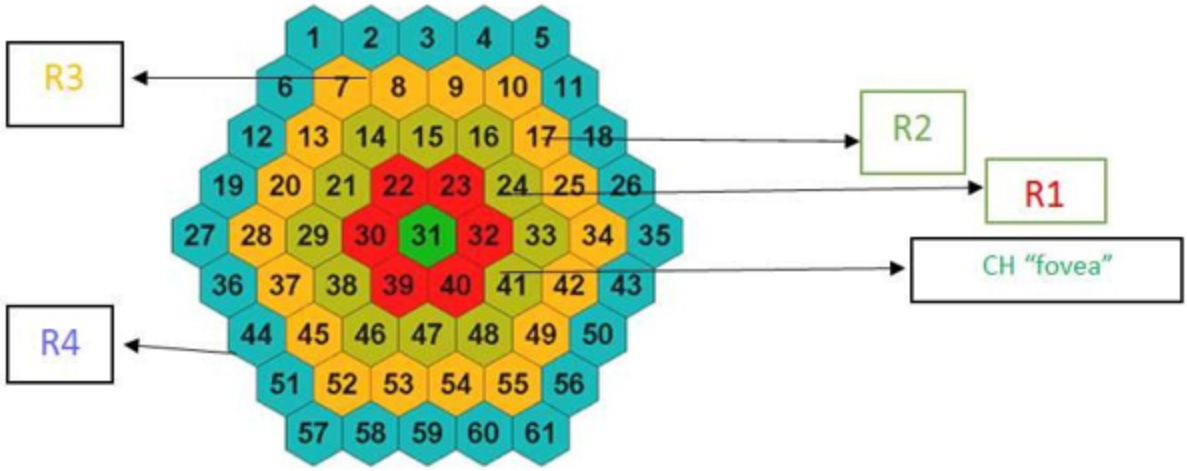

Figure 2

Ring Analysis, fovea corresponds to hexagon thirty-one.

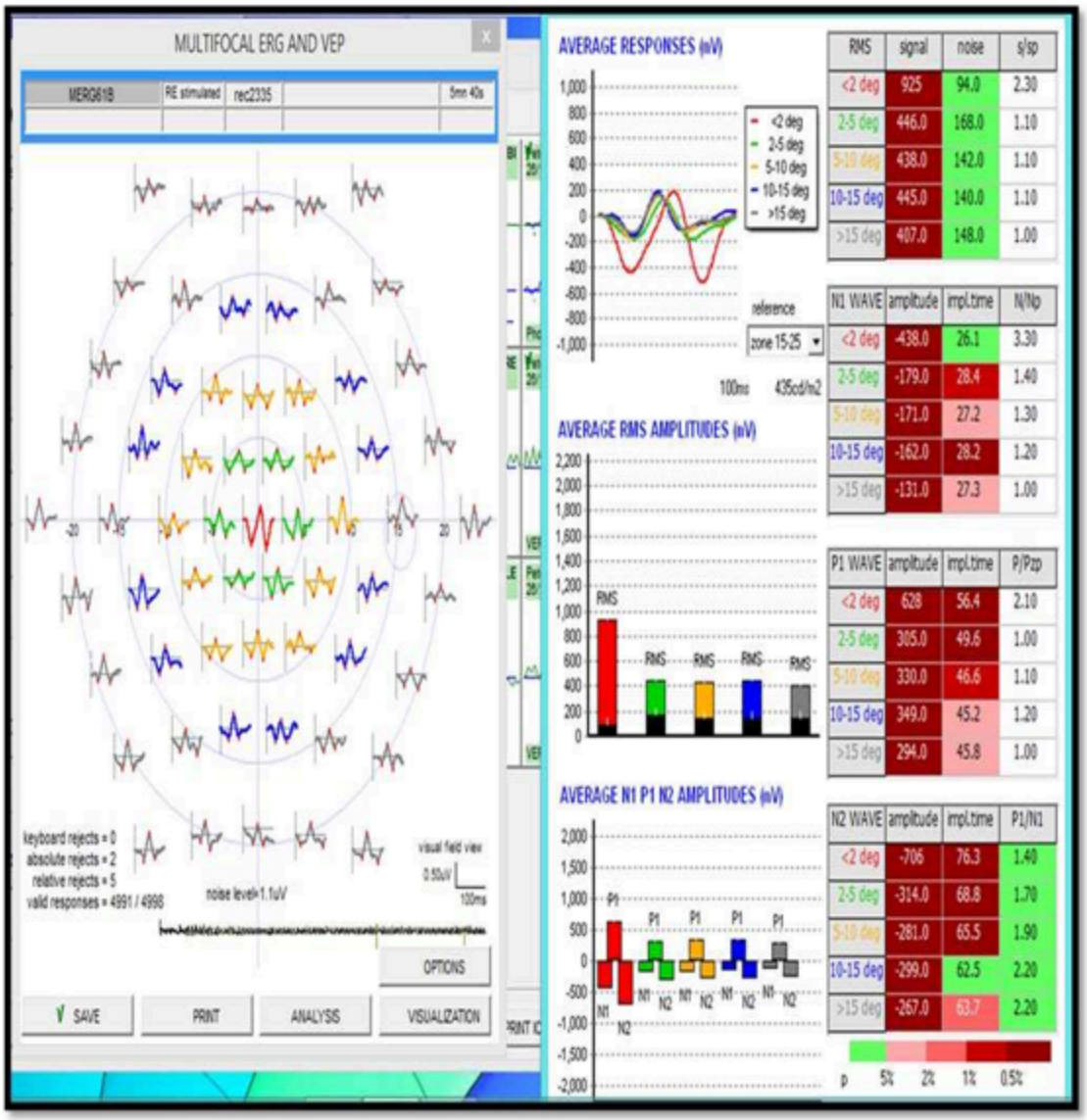

Figure 3

Right eye multifocal ERG in a migrainous patient showing reduced amplitudes of almost all the analyzed rings

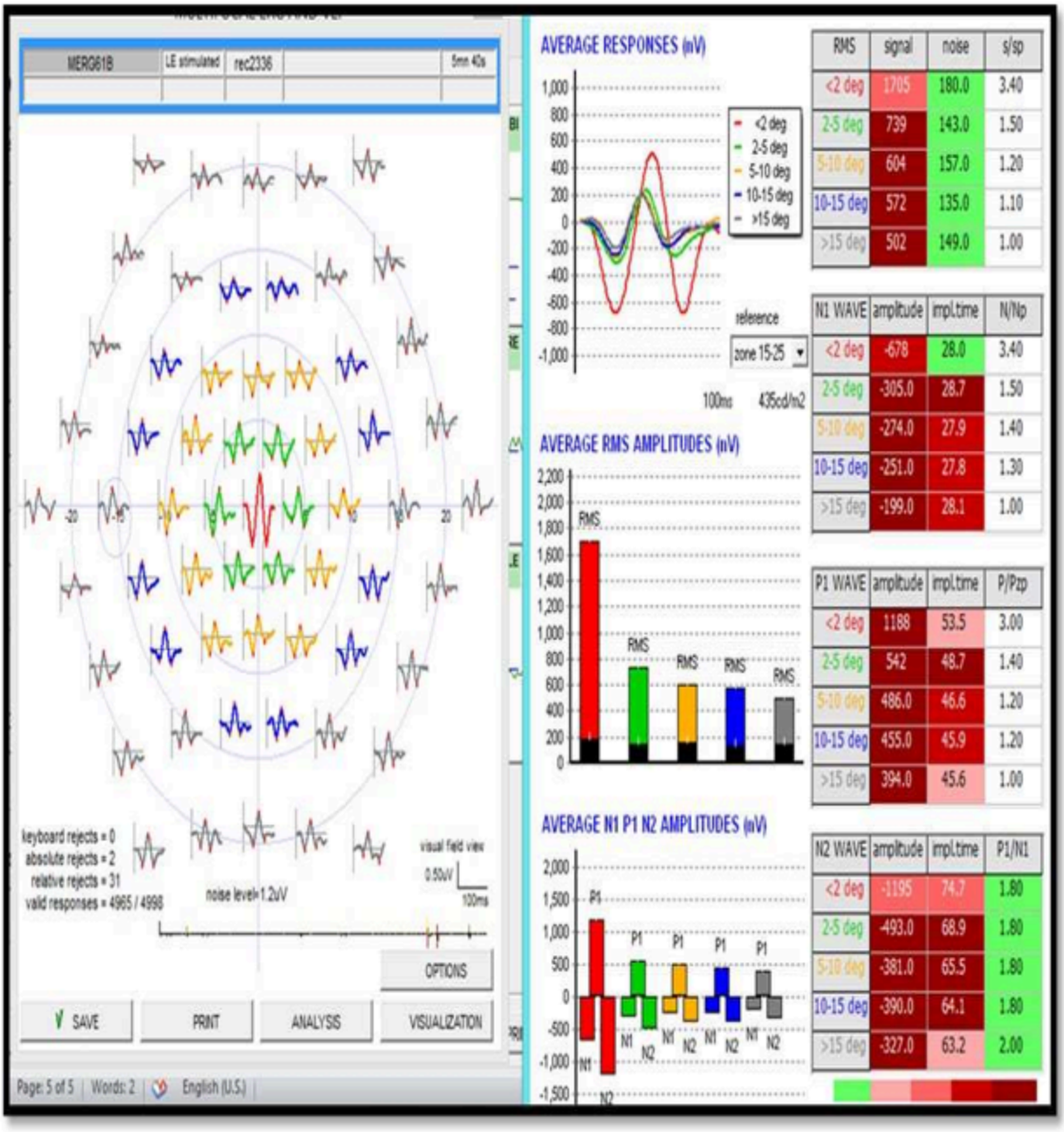

Figure 4

Left eye multifocal ERG in a migrainous patient showing reduced amplitudes of almost all the analyzed rings