Pattern Visual Evoked Potentials and Glaucoma

Elena Mermeklieva[1,2]

[1]*Medical Faculty, Sofia University "St. Kliment Ohridski"*
Sofia, Bulgaria
E-mail: elenamermeklieva@yahoo.com

[2]*University Hospital Lozenetz*
Sofia, Bulgaria

Received: September 17, 2019 **Accepted: February 28, 2020**

Published: June 30, 2020

Abstract: *Aim: The aim of the study was to explore the informativity of pattern visual evoked potentials (PVEPs) as an objective method for detection of early changes in the visual analyzer (VA) function in patients with preperimetric glaucoma.*

Material and methods: A group of 83 people was studied, of whom 36 patients with preperimetric glaucoma and 47 healthy individuals as controls. Full ophthalmological examination, standard automated perimetry (SAP), optical coherent tomography (OCT) and PVEPs were performed. The main variables that were considered in the results analysis were the latency (L), amplitude (A) and amplitude ratio (AR), reflecting the configuration of the wave forms. Statistical analysis was performed with IBM SPSS Statistics 23.0 statistical package.

Results: The comparative analysis between the PVEPs components values of patients from both groups demonstrated significant differences in the latencies of components P50, P100, N145 and P200 in central stimulation (15°). No significant differences were found in the paracentral stimulation (30°). The latencies of the glaucoma patients were longer than those of the controls. When we compared the PVEPs amplitudes in both groups we did not find statistically significant differences. They were found in the amplitude ratio "P50-N75 / N75-P100" in the central stimulation.

Conclusion: PVEPs could be used as an objective method for registration of early changes in the VA function in preperimetric glaucoma, before the presence of any functional changes in SAP and significant structural changes at OCT, and also to monitor the changes in dynamics as they are non-invasive, harmless, fast and repeatable.

Keywords*: Visual evoked potentials, Glaucoma, Optical coherent tomography.*

Introduction

According to European Glaucoma Society (EGS) the open-angle glaucomas are chronic progressive optic neuropathies that have characteristic morphological changes at the optic nerve head and retinal nerve fiber layer (RNFL) in the absence of other ocular disease or congenital anomalies. Progressive retinal ganglion cells (RGCs) death and visual field loss are associated with these changes. Glaucoma is the second leading cause of blindness in Europe and worldwide and the most frequent cause of irreversible blindness [11].

For this reason, scientists' efforts have been directed towards discovering methods for detection of very early changes in the normal vision function as a result of glaucoma [2, 7, 16, 17]. With the development of the medical science and technologies, the modern electrophysiological methods have recently been rediscovered as very sensitive in detecting very early manifestations of diseases such as glaucoma and diabetic retinopathy [12, 23].

It is known that RGCs and/or their axons start to die in the very early stages of glaucoma, although there is evidence to suggest that complete RGCs death takes months or years in the natural history of the disease [18, 22].

Nowadays optical coherence tomography (OCT) has become an important tool for assessing early signs of glaucoma [8, 9, 21]. According to some authors the loss of ganglion cells at the optic nerve may be observable at OCT before functional vision loss is demonstrated on visual field testing [34]. Recent studies have shown, however, that this structural damage is preceded by damage to the RGCs that causes them to lose their autoregulatory ability. OCT in glaucoma, though, has an important disadvantage – there must be death of a significant amount of ganglion cells to observe thinning of the nerve fiber layers at OCT [4, 27, 37]. Changes at OCT are therefore not so early sign of glaucoma [28].

The visual evoked potentials (VEPs) are the potentials recorded from the occipital region in response to visual stimuli. As the macula has a large representation in the visual cortex, the activation of VEPs is mainly due to impulses received from the center of the retina and the visual field. VEPs depend on the functional integrity of the entire visual pathway from the retina through the optic nerve, the optic tract, the optical radiation to the visual cortex [3, 5, 6, 20, 35].

PVEPs are an objective, minimally invasive, reproducible method for direct measurement of VA function. It is extremely sensitive, allowing us to detect abnormalities prior to RGCs death (particularly in glaucoma suspects) and if we start treatment it can help preserve the ganglion cells health. A possible indicator of the RGCs health is the latency of their response. VEPs latency can be used as a measurement of early glaucomatous damage before RGCs death occurs. Hence, it is used as a marker of reversible ganglion cell damage in trials of neuroprotective agents for the treatment of glaucoma [19, 31, 32, 36, 38].

The amplitude of the signal indicates the number of healthy retinal cells. The latency of the signal is the time it takes for the electrical signal to travel from the retina to the cortex. Pattern ERG also detects size and speed of the electrical signal, but through the retinal ganglion cell bodies rather than the optic nerve. Pattern electroretinography testing can be used together with VEPs tests to help the clinician differentiate between retinal and optic nerve disorders, as well as improve sensitivity and specificity in diagnosing neuropathies and maculopathies when used in conjunction to other tests [34].

The aim of the study was to explore the informativity of PVEPs as an objective method for detection of early changes in the visual analyzer (VA) function in patients with preperimetric glaucoma.

Material and methods

This is a prospective observation study with 3-year duration (2016-2019). A group of 83 people was studied of whom:

- 36 patients with preperimetric glaucoma (average age of 47.46 ± 12.2 years – 19 males and 17 females) with normal best corrected visual acuity (BCVA) (LogMar score 0.00 ETDRS (Early Treatment Diabetic Retinopathy Study) and acceptable refractive errors ± 2 dpt;
- 47 healthy individuals as controls with normal BCVA (LogMar score 0.00 ETDRS) and acceptable refractive errors ± 2 dpt. and without any known ophthalmological or neurological disease as well as other systemic diseases. The control group included individuals of an average age of 38.57 ± 12.37 years – 21 males and 26 females.

People were examined clinically by full ophthalmological examination, Goldmann applanation tonometry, indirect gonioscopy (Goldmann mirror), ultrasound pachimetry (Ocuscan RxP Alcon Forth Worth, Texas, USA) Central corneal thickness (CCT) testing, visual field testing (Humphrey HFA II, Carl Zeiss Meditec, Dublin, CA, USA) 30-2 Sita Standart program, OCT (Topcon 3D OCT 2000 FA plus, Topcon Corporation, Japan) OCT 3D disc protocol, OCT circle disc protocol and OCT Glaucoma Analysis Macula protocol, fundus photography (Topcon 3D OCT 2000 FA plus, Topcon Corporation, Japan) and funduscopy for C/D ratio detecting (Cap/Disc ratio – the ratio between the capping area and the whole disc area) [13]. Patients are tested electrophysiologically by PERG (NeuroMEP 4, Neurosoft Company).

We studied both eyes in all patients in both groups but decided to analyze the right eyes results only, to prevent the results from intereye correlation which doubles the sample size and increases the probability of false positive results.

The study met the criteria of standards for good medical practice. It was carried out with the informed consent of all participants in compliance with all ethics standards under Helsinki Declaration (2013).

Inclusion criteria

Glaucoma suspected patients with normal BCVA (LogMar score 0.00 ETDRS) and acceptable refractive errors up to 2 dpt. As patients with preperimetric glaucoma we considered those who had minimal structural defects in any of the OCT protocols (thinner average total peripapillar or macular RNFL or thinner sup. RNFL or inf. RNFL or impaired "ISNT" (Inferior – Superior – Nasal – Temporal) rule (the neuroretinal rim is usually widest in the inferior disc pole, followed by the superior disc pole, the nasal disc region and finally the temporal sector) [11] or patients had asymmetry of the disc cupping between both eyes, along with at least two other risk factors for developing glaucoma such as ocular hypertension, family history, thin corneas. The patients did not have any visual fields defects in perimetry according to the Ocular Hypertension Treatment Study (OHTS) criteria [13]. None of the patients instilled drops in the eyes before and during the examinations.

Exclusion criteria

Senile macular degeneration, advanced cataract, vascular eye diseases, optic neuritis, refractive errors more than 2 dpt, amblyopia. Multiple sclerosis, Parkinson's disease, epilepsy, dementia, brain tumor and diabetes mellitus were excluded.

Method of PVEPs

Standardized four channels equipment "Neuro-MEP 4" produced by Neurosoft Company, was used. The study was performed with a three-channel recording with equipment adjustments according to the latest published ISCEV standards for PVEPs (2016) [1, 24]. Simultaneously RERG was performed. The main variables that were considered in the analysis of PVEPs in the present study were latency (L), amplitudes (A) and amplitude ratio (AR), reflecting the configuration of the wave forms.

The patients were in a sitting position. The distance to the monitor was 100 cm. The patients were examined with the appropriate optical correction for that distance if it was necessary, under mesopic conditions, identical in all patients, without mydriasis. We used a classic cathode stimulator with a contrast-reversing pattern from black to white and vice versa with an equal number of black and white squares in a checkboard, with standard individual width of 1° for a

stimulating field of 30° for paracentral stimulation and 0.25° for a stimulating field of 15° for central stimulation.

We performed binocular PVEPs stimulation. The active electrode was placed on the scalp at standard location, depending on the head size, according to the International System 10/20 – at Oz (above the visual cortex – along the midline, about 3 cm above the inion). The reference electrode was at Fz (along the midline fronthally – about 12 cm above the nasion) and the ground electrode was placed on the right wrist. The frequency reversion was 1 Hz, which corresponds to 2 reversals per second (rps) [20]. We analyzed the L, A and AR of components P50, N75, P100, N145 and P200.

Statistical analysis was performed with IBM SPSS Statistics 23.0 statistical package. Descriptive statistical analysis was used, based on the calculation of the median and percentiles from the observed sample distribution with 95% reference interval as a limit of normal. The Refval program was used for calculating the laboratory normal ranges. Variation and comparative analyzes were also performed.

Results

Both groups were subjected to a variation analysis to determine the reference values of all studied parameters and their variability.

We performed a comparative analysis between all the studied values of right eyes of patients with preperimetric glaucoma and controls. The examination of the known obscuration factors sex and age showed no significant difference between the study groups.

Table 1 presents the mean age and the mean values ($\bar{X}$) and standard deviation (SD) of the studied parameters in both groups as well as the values with significant differences ($p < 0.05$) between both groups.

As we can see in Table 1, the glaucoma suspected patients had significantly thinner corneas, the difference between the C/D ratios in both group is also significant as well as the mean macular RNFL thickness and the mean total peripapilar RNFL (ppRNFL) thickness. That was the reason why we diagnosed those patients with preperimetric glaucoma.

The comparative analysis between the PVEPs components values of the right eyes of patients from both groups demonstrated significant differences in the latencies of components P50, P100, N145 and P200 at central stimulation (15°). No significant differences were found at paracentral stimulation (30°). The latencies of the glaucoma patients were longer than those of the controls (Table 2). Our conclusion was that the central stimulation was more sensitive, with a higher number of significantly different values between the two groups.

Table 1. Mean age and the mean values and standard deviation of the studied parameters in both groups, comparative analysis between the study parameters

	Controls (n = 47)		Patients (n = 36)		T-test
	$\bar{X}$	SD	$\bar{X}$	SD	p
Age	38.57	12.37	47.46	12.23	0.52
IOP	15.02	2.34	23.38	1.98	0.06
CCT	572.87	27.39	520.11	14.76	< 0.001
Mean total macular RNFL	34.89	1.92	32.88	4.40	0.003
Mean sup. macular RNFL	34.15	1.78	33.11	4.88	0.002
Mean inf. macular RNFL	34.91	1.99	33.5	5.86	0.001
Mean total disc RNFL	101.49	6.73	92.11	11.02	< 0.001
Mean sup. disc RNFL	102.66	11.02	107.5	2.92	0.13
Mean inf. disc RNFL	118.83	13.47	108.04	17.58	0.35
C/D	**0.02**	**0.05**	**0.34**	**0.15**	**< 0.001**

IOP – intraocular preasure;
inf ppRNFL – inferior peripapilar retinal nerve fiber layer thickness from 3D disc protocol on OCT;
mRNFL – macular RNFL thickness from OCT Glaucoma Analysis Macula protocol;
C/D – cap/disc ratio;
CCT – central corneal thickness;
ppRNFL – peripapilar retinal nerve fiber layer thickness from 3D disc protocol on OCT;
sup ppRNFL – superior peripapilar retinal nerve fiber layer thickness from 3D disc protocol on OCT.

These results correlated with the significant differences in the macular RNFL thickness between the two groups.

When we compared the PVEPs amplitudes in both groups we did not find statistically significant differences. They were found in the amplitude ratio "P50-N75 / N75-P100" at central stimulation (Table 2).

Discussion

Our results demonstrated that PVEPs were a sensitive method for detection of early functional changes in the VA before the functional changes in the visual field tests and before the significant RNFL thinning. We found changes in PVEPs latency in every component (except N75) which means ganglion cells dysfunction. More sensitive were PVEPs at central stimulation because the macular ganglion cells are more sensitive to damage. Similar results were also described by other authors in PVEPs [12, 25]. According to Grover et al. [15] the peripheral stimulation tests were more sensitive. Pan and Chen [25] did not find significant difference in N75 component also, without being able to explain the reason.

Table 2. Comparative analysis of PVEPs components between glaucoma suspect patients and controls

PVEPs		Controls (n = 47)		Patients (n = 36)		T-test
Component	**Stimulus**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	***p***
Amplitude ratio						
P50-N75 / N75-P100	15°	0.51	0.20	0.60	0.24	0.03
P50-N75 / N75-P100	30°	0.48	0.25	0.53	0.24	0.96
Latency						
P50	15°	53.78	4.16	58.33	10.25	0.007
N75	15°	78.03	4.26	81.68	5.11	0.64
P100	15°	102.29	4.96	107.71	8.27	0.001
N145	15°	145.57	11.80	152.54	20.39	0.002
P200	15°	207.55	16.37	217.15	25.42	0.04

We did not find significant reduction in amplitude which indicated cells death. In our study we found significant difference in amplitude ratio "P50-N75 / N75-P100" at central stimulation. Preiser et al. [29] also found that the amplitude ratio was more informative investigating patients with preperimetric glaucoma.

Thienprasiddhi et al. [33] studied VEPs in glaucoma suspected patients and patients with ocular hypertension without any changes in SAP and found abnormal VEPs latency in glaucoma suspects only. They did not find significant difference in VEPs A in patients from both groups. Other authors also investigated VEPs in patients with early glaucoma and ocular hypertension and found prolonged latency in glaucoma patients and in 24% of patients with ocular hypertension. They concluded that the abnormal prolongation of VEPs latency in those eyes might reflect subclinical optic nerve lesions that had not been covered with other techniques [34].

Pillai at al. [26] found that the low-contrast VEPs protocol was able to identify patients with structural abnormalities consistent with glaucoma, who also had normal achromatic perimetry. They also found VEPs latency elongation. In other studies authors also reported abnormal VEPs in glaucoma suspected patients without changes in SAP [10, 14, 30, 39]. We found only few studies of VEPs and glaucoma in the available literature.

We can conclude that in PVEPs the L, which is a sign of conduction changes, is a component that is affected earlier in glaucoma, while the A that is a sign of axonal destruction is affected in the later stages of the disease. Therefore, with PVEPs we detect changes in a reversible stage, and with appropriate treatment, we can expect improvement [36, 38].

Conclusion

PVEPs could be used as an objective method for registration of early changes in the VA function in preperimetric glaucoma, before the presence of any functional changes in SAP and significant structural changes at OCT, and also to monitor the changes in dynamics as they are non-invasive, harmless, fast and repeatable.

Disclosures

Financial support: No financial support was received for this submission.
Conflict of interest: The author has not conflict of interest with this submission.

References

1. American Clinical Neurophysiology Society (2006). Guideline 5: Guidelines for Standard Electrode Position Nomenclature, Journal of Clinical Neurophysiology, 23, 107-110.
2. Bach M., C. M. Poloschek (2013). Electrophysiology and Glaucoma: Current Status and Future Challenges, Cell Tissue Research, 353, 287-296.
3. Balachandran C., S. L. Graham, A. Klistorner, I. Goldberg (2006). Comparison of Objective Diagnostic Tests in Glaucoma: Heidelberg Retinal Tomography and Multifocal Visual Evoked Potentials, Journal of Glaucoma, 15(2), 110-116.
4. Banitt M. R., L. M. Ventura, W. J. Feuer, E. Savatovskiy, G. Luna, O. Shif (2013). Progressive Loss of Retinal Ganglion Cell Function Precedes Structural Loss by Several Years in Glaucoma Suspects, Investigative Ophthalmology & Visual Science, 54, 2346-2352.
5. Bengtsson B. (2002). Evaluation of VEP Perimetry in Normal Subjects and Glaucoma Patients, Acta Ophthalmologica Scandinavica, 80(6), 620-626.
6. Bergua A., F. K. Horn, P. Martus, A. M. Jünemann, M. Korth (2004). Stereoscopic Visual Evoked Potentials in Normal Subjects and Patients with Open-angle Glaucomas, Graefe's Archive for Clinical and Experimental Ophthalmology, 242(3), 197-203.
7. Blair Y., E. Eggenberger, D. Kaufman (2012). Current Electrophysiology in Ophthalmology: A Review, Current Opinion in Ophthalmology, 23, 497-505.
8. Bowd C., A. Tafreshi, L. M. Zangwill, F. A. Medeiros, P. A. Sample, R. N. Weinreb (2011). Pattern Electroretinogram Association with Spectral Domain-OCT Structural Measurements in Glaucoma, Eye (Lond), 25, 224-232.
9. Budenz D. L., M. J. Fredette, W. J. Feuer, D. R. Anderson (2008). Reproducibility of Peripapillary Retinal Nerve Fiber Thickness Measurements with Stratus OCT in Glaucomatous Eyes, Ophthalmology, 115, 661-666.
10. Derr P. H., F. L. Furlanetto, C. G. De Moraes, A. G. Garcia, C. Tello, J. M. Liebmann, R. Ritch (2014). Evaluation of Pre-perimetric Glaucoma Patients Using Short Duration Transient Visual Evoked Potentials (SD-tVEP), Investigative Ophthalmology & Visual Science, 54, 797.
11. European Glaucoma Society (2014). Terminology and Guidelines for Glaucoma, 4-th Ed., 80-89.
12. Fishman G. A., D. G. Birch, G. E. Holder, M. G. Brigell (2001). Electrophysiologic Testing in Disorders of the Retina, Optic Nerve and Visual Pathway, 2nd Ed., The Foundation of the American Academy of Ophthalmoilogy, Ophthalmology Monographs, 15-170.
13. Gordon M. O., M. A. Kass (1999). The Ocular Hypertension Treatment Study: Design and Baseline Description of the Participants, Archives of Ophthalmology, 117, 573-583.
14. Grippo T. M., D. C. Hood, F. N. Kanadani, I. Ezon, V. C. Greenstein, J. M. Liebmann, R. Ritch (2006). A Comparison between Multifocal and Conventional VEP Latency

Changes Secondary to Glaucomatous Damage, Investigative Ophthalmology & Visual Science, 47(12), 5331-5336.
15. Grover L., D. Hood, Q. Ghadiali (2008). A Comparison of Mulrifocal and Conventional Visual Evoked Potential Techniques in Patients with Optic Neuritis/multiple Sclerosis, Documenta Ophthalmologica, 117(2), 121-128.
16. Holder G. E. (2004). Electrophysiological Assessment of Optic Nerve Disease, Cambridge Ophthalmological Symposium, Eye, 18, 1133-1143.
17. Hood D. C., R. H. Kardon (2007). A Framework for Comparing Structural and Functional Measures of Glaucomatous Damage, Progress in Retinal and Eye Research, 26, 688-710.
18. Howell G. R., R. T. Libby, T. C. Jakobs, R. S. Smith, F. C. Phalan, J. W. Barter (2007). Axons of Retinal Ganglion Cells Are Insulted in the Optic Nerve Early in DBA/2J Glaucoma, Journal of Cell Biology, 179, 1523-1537.
19. Howell G. R., I. Soto, X. Zhu, M. Ryan, D. G. Macalinao, G. L. Sousa (2012). Radiation Treatment Inhibits Monocyte Entry into the Optic Nerve Head and Prevents Neuronal Damage in a Mouse Model of Glaucoma, Journal of Clinical Investigation, 122, 1246-1261.
20. Jha M. K., D. Thakur, N. Limbu, B. P. Badhu, B. H. Paudel (2017). Visual Evoked Potentials in Primary Open Angle Glaucoma, Journal of Neurodegenerative Diseases, Article ID 9540609, https://doi.org/10.1155/2017/9540609.
21. Leske M. C., A. Heijl, M. Hussein, B. Bengtsson, L. Hyman, E. Komaroff (2003). Early Manifest Glaucoma Trial Group, Factors for Glaucoma Progression and the Effect of Treatment: The Early Manifest Glaucoma Trial, Archives of Ophthalmology, 121, 48-56.
22. Leung C. K., C. Y. Cheung, R. N. Weinreb, K. Qiu, S. Liu, H. Li (2010). Evaluation of Retinal Nerve Fiber Layer Progression in Glaucoma: A Study on Optical Coherence Tomography Guided Progression Analysis, Investigative Ophthalmology & Visual Science, 51, 217-222.
23. Mermeklieva E., M. Matveev (2017). Electrophysiological Methods for Study of Changes in Visual Analyzer in Patients with Diabetes Mellitus, International Journal Bioautomation, 21(1), 69-102.
24. Odom J. V., M. Bach, M. Brigell, G. E. Holder, D. L. McCulloch, A. Mizota (2016). ISCEV Standard for Clinical Visual Evoked Potentials (2016 update), Documenta Ophthalmologica, 133(1), 1-9.
25. Pan C. H., S. S. Chen (1992). Pattern Shift Visual Evoked Potentials in Diabetes Mellitus, The Kaohsiung Journal of Medical Sciences, 8(7), 374-383.
26. Pillai C., R. Ritch, P. Derr, A. Gonzalez, L. K. Cox, J. Siegfried, J. M. Liebmann, C. Tello (2013). Sensitivity and Specificity of Short-duration Transient Visual Evoked Potentials in Discriminating Normal from Glaucomatous Eyes, Investigative Ophthalmology & Visual Science, 54, 2847-2852.
27. Porciatti V., L. M. Ventura (2012). Retinal Ganglion Cell Functional Plasticity and Optic Neuropathy: A Comprehensive Model, Journal of Neuroophthalmology, 32, 354-358.
28. Porciatti V. (2015). Electrophysiological Assessment of Retinal Ganglion Cell Function, Experimental Eye Research, 141, 164-170.
29. Preiser D., W. A. Lagrèze, M. Bach, C. M. Poloschek (2013). Photopic Negative Response versus Pattern Electroretinogram in Early Glaucoma, Investigative Ophthalmology & Visual Science, 54(2), 1182-1191.
30. Prata T. S., V. C. Lima, C. G. De Moraes, V. Trubnik, P. Derr, J. M. Liebmann, R. Ritch, C. Tello (2012). Short Duration Transient Visual Evoked Potentials in Glaucomatous Eyes, Journal of Glaucoma, 21(6), 415-420.
31. Saleh M., M. Nagaraju, V. Porciatti (2007). Longitudinal Evaluation of Retinal Ganglion Cell Function and IOP in the DBA/2J Mouse Model of Glaucoma, Investigative Ophthalmology & Visual Science, 48, 4564-7452.

32. Sehi M., D. S. Grewal, M. L. Goodkin, D. S. Greenfield (2010). Reversal of Retinal Ganglion Cell Dysfunction after Surgical Reduction of Intraocular Pressure, Ophthalmology, 117, 2329-2336.
33. Thienprasiddhi P., V. C. Greenstein, D. H. Chu, L. Xu, J. M. Liebmann, R. Ritch, D. C. Hood (2006). Detecting Early Functional Damage in Glaucoma Suspect and Ocular Hypertensive Patients with the Multifocal VEP Technique, Journal of Glaucoma, 15(4), 321-327.
34. Towle V. L., A. Moskowirz, S. Sokol, B. Schwartz (1983). The Visual Evoked Potential in Glaucoma and Ocular Hypertension: Effects of Check Size, Field Size, and Stimulation Rate, Investigative Ophthalmology & Visual Science, 24, 175-183.
35. Tyt T. (2018). Visual Evoked Potentials and Glaucoma, Asia-Pacific Journal of Ophthalmology (Philadelphia, Pa.), 7(5), 352-355.
36. Ventura L. M., V. Porciatti (2005). Restoration of Retinal Ganglion Cell Function in Early Glaucoma after Intraocular Pressure Reduction: A Pilot Study, Ophthalmology, 112, 20-27.
37. Ventura L. M., N. Sorokac, R. De Los Santos, W. J. Feuer, V. Porciatti (2006). The Relationship between Retinal Ganglion Cell Function and Retinal Nerve Fiber Thickness in Early Glaucoma, Investigative Ophthalmology & Visual Science, 47, 3904-3911.
38. Ventura L. M., W. J. Feuer, V. Porciatti (2012). Progressive Loss of Retinal Ganglion Cell Function Is Hindered with IOP-lowering Treatment in Early Glaucoma, Investigative Ophthalmology & Visual Science, 53, 659-663.
39. Waisbourd M., R. H. Gensure, A. Aminlari, S. B. Shah, N. Khanna, N. Sood, J. Molineaux, A. Gonzalez, J. S. Myers, L. J. Katz (2017). Short-duration Transient Visual Evoked Potentials and Color Reflectivity Discretization Analysis in Glaucoma Patients and Suspects, International Journal of Ophthalmology, 10(2), 254-261.

Dr. Elena Mermeklieva, Ph.D.
E-mail: elenamermeklieva@yahoo.com

Dr. Elena Mermeklieva graduated Medicine and Ophthalmology at the Medical University of Sofia, Bulgaria. Her Ph.D. degree is in Electrophysiology. She is an author of a monograph "Electrophysiology of Vision Basic Principles and Clinical Application" and a practical guide "Electrophysiological Methods in Ophthalmological and Ophthalmoneurological Practice". She has published more than 70 scientific publications.