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RESEARCH ARTICLE

Evaluating the clinical applications of visual evoked potentials in patients presenting with visual dysfunctions - A retrospective study

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ABSTRACT

Background: The clinical applicability of visual evoked potential (VEP) tests has been progressively extending in neuro-ophthalmological workups. The role in monitoring and follow-ups are emerging as even more useful applications. **Aims and Objectives:** The present study aimed to assess the clinical role of pattern-reversal VEP (PRVEPs) in visual disorders with presumptive optic nerve involvement. **Materials and Methods:** PRVEP records of 58 patients with unilateral/bilateral visual loss in a study period of 1½ year were retrospectively analyzed. P100 latencies and N75-P100 amplitudes were compared with those of 60 age and sex-matched controls. Variations beyond three standard deviations were applied to define significant abnormalities. PRVEP records obtained by follow-up in some conditions were also assessed. **Results:** Traumatic optic neuropathy (32.76%) was the most common condition confronted, with major PRVEP finding as absent waveforms/reduced amplitudes. Monitoring of VEP records revealed improvement in 50% of patients on corticosteroid therapy. Functional visual disorders constituted 27.6% with 93.75% of subjects confirmed by PRVEP. Ethambutol-induced toxic optic neuropathy (20.69%) was associated with significant P100 delay bilaterally, in the majority. Out of which, 50% showed improved PRVEP records after 1 month of cessation of drug. Multiple sclerosis and optic neuritis though rarer conditions (3.44% and 6.89%, respectively) exhibited characteristic electrophysiological findings which helped confirming the diagnosis. Diabetic optic neuropathy (3.4%) and some very rare conditions also constituted the referrals. **Conclusion:** VEPs provides sensitive adjuncts to diagnosis in various visual disorders and contributes as important monitoring tools for objectively assessing the recovery and ophthalmological status.

KEY WORDS: Electrophysiological; Monitoring; Optic Neuropathy; P100; Visual Evoked Potentials

INTRODUCTION

Although the diagnostic tools used by the clinicians in the field of neurology provide useful structural information and can be relied upon, yet they still fall short in providing insights into the functions. The search for relatively non-invasive, simple, and easy methods of investigations has led to the advent of evoked potential (EP) tests. Electrophysiological tests including visual EP (VEPs) are among the newer approaches to examination. These low-risk tests can provide new and objective informations about the functioning of the visual system. They have been investigated in the research field for many years, but since the last few decades, the clinical applications of these methods have also gained emphasis. VEPs provide discernment of the visual pathway functions

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from retina to visual cortex. Reproducible and quantitative data on the anterior visual pathway and optic nerve functions can be attained by means of the tests.[1]

Optic nerve involvement is found in various ophthalmological disorders including optic neuritis, multiple sclerosis, optic nerve and chiasma compressive lesions, and optic neuropathies with varied etiologies including traumatic brain injuries and toxic and nutritional causes. VEPs can particularly be useful when the history and/or neurological examination are vague and inconclusive. They can reveal the subclinical involvement of a sensory system (silent lesions) when demyelination is suggested by symptoms and/or signs in another area of the central nervous system (CNS).[2-4]

They can be helpful guide about the pathophysiology of a disease process and can evaluate the type of neurological abnormality, as demyelination produces slowing of conduction while axonal loss or axonal degeneration produces reduction in the amplitudes. Another valuable role the tests can play in optimizing the patient care is by monitoring the changes in a patient's neurological/neuro-ophthalmological status in various conditions. It is to be emphasized that the clinical use and the clinical applicability of the test is progressively increasing in neuro-ophthalmological workups and the role in monitoring and follow-up are emerging as even more useful applications. Patients with visual dysfunctions are being frequently referred for conventional VEP investigations in contrast with the past when the tests were used to be employed in the research fields only. Subclinical and early detection of optic nerve lesion by the tests has gained considerable importance. The contribution and role in supporting clinical diagnosis and prognosis need to be assessed as well. An account of the patients with clinical visual manifestations incorporating VEP investigations can help evaluating their electrodiagnostic importance. The extent of awareness among the clinicians and the ophthalmologists to utilize this test to aid in the diagnoses also needs to be found out. The present study hence was undertaken to obtain a clinical and electrophysiological profile of the patients referred to our neurophysiology laboratory for VEP tests. The study aimed to obtain a detailed account of the patients in terms of the frequency of different clinical conditions for VEP referral, characteristic electrophysiological findings, the diagnostic role of VEPs, and also their role in monitoring and follow-ups.

MATERIALS AND METHODS

The study was a retrospective case–control study. The study group comprised patients with unilateral/bilateral visual loss referred for VEP investigation in the Department of Physiology from the Department of Ophthalmology at Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Ambala, Haryana, India. The study period was of 1 year and 6 months. Pattern-reversal VEPs (PRVEPs) records of such 58 patients obtained in the study period were retrospectively analyzed. The control group consisted of 60 age and sex-matched healthy subjects. Every subject had undergone detailed neuro-ophthalmological examination.

VEP was performed on the equipment, Allengers Scorpio-electromyograph, EP, NCS system in the neurophysiology laboratory with uniform light levels and a quiet environment. Pattern stimulus with a black and white checker-board pattern reversing alternately at the rate of 2 Hz was presented on a video-monitor (Flash stimulus with LED goggles was presented in selected patients). The mean luminance was 50 candela/m^2 and contrast was 70%. 8 × 8 checkerboard pattern was presented as stimuli. Subjects were seated comfortably at about 100 cm away from the video-monitor fixating on the red spot at the center of the screen. More than one check size was employed in certain conditions. Scalp skin preparation was performed before the application of electrodes which were placed according to the international 10/20 system of electrode placement (active electrode at Oz, reference electrode at Fz and ground electrode at Fpz).[1] System bandpass filter was set at 2–200 Hz. 100 responses were averaged. Monocular stimulation was done with an eye-patch covering the other eye. Binocular tracings were also obtained in some patients. The latencies of P100, interocular latency differences (for P100 waves), and N75-P100 amplitude and interocular amplitude ratios were the parameters for the study. The data were expressed in percentages and mean ± standard deviations. Significant abnormality was defined as a variation beyond three standard deviations.

RESULTS

Traumatic optic neuropathy (TON) (32.76%) was the most common condition for the VEP referral; with major PRVEP finding as absent waveforms and reduced amplitude ratios (affected eye/fellow eye) [Table 1 and Figures 1-3]. 16 patients out of total 19 (those who presented within <3 days of the trauma) had methylprednisolone treatment (1 g/day intravenous dose for 3 days followed by 1 mg/kg/day orally and gradually tapered over >1 month). Monitoring of the records revealed improvement in 50% of the patients on corticosteroid therapy after 1 month [Figure 4].

Functional visual disorders constituted 27.6% with 93.75% of subjects confirmed by PRVEP [Figures 5-7]. Ethambutol-induced toxic optic neuropathy (20.69%) was characterized by a bilateral visual loss in the majority, visual field defects, and normal fundus examinations. Age of the patients was in the range of 35–65 years, while the dose of the drug ranged from 15 to 25 mg/kg/day and the duration of ocular toxicity manifestation ranged from 1.5 months to 8 months after treatment. VEP records demonstrated significant P100 delay bilaterally, in the majority. Out of which, 50% showed

improved PRVEP records after 1 month of cessation of the drug [Table 2]. Multiple sclerosis and optic neuritis were diagnosed in 3.44% and 6.89% patients, respectively, with significant P100 delays in multiple sclerosis. Extinguished waveform in acute and delayed P100 in chronic optic neuritis were found, respectively. Optic neuropathy due to diabetes presenting with visual impairment and normal fundus examination constituted 3.4% of the total referrals. Delayed P100 was found in both the patients investigated. One patient (1.72%) of tubercular meningitis was also referred with PRVEP findings as absent waveform in the affected eye. Another rare cause of optic neuropathy as Grave's ophthalmopathy was interestingly confronted (one patient out of the total 58 patients investigated for presumed optic neuropathy) (1.72%), in which the PRVEP record showed reduced amplitudes bilaterally. In two patients (3.44%) who presented clinically with visual dysfunctions, VEP record was abnormal, but the cause of the optic neuropathy could not be ascertained.

Table 1: Demographic and clinical features of the patients with TON (***n***=19) (32.76% of the study group)

Parameters	Value
Age	37.3±11.6 years (mean age)
Sex	
Males	100%
Females	0%
Eye	
Right	68%
Left	32%
Type of injury	
Motor vehicle accident	82%
Fall	16%
Assault	2%
Visual acuity (at the time of presentation)	
NLP	10.52% (2/19)
LP	36.84% (7/19)
HM	15.79% (3/19)
<6/60 to CF	26.3% (5/19)
≥6/60	10.5% (2/19)
Time elapsed after injury	
<24 h	47.37% (9/19)
1–2 days	36.84% (7/19)
4–7 days	15.79% (3/19)
Significant ophthalmological findings	
RAPD positive	100% (19/19)
Abnormal color perception	94.73% (18/19)
Intra-ocular pressure-normal	94.73% (18/19)
Subconjunctival hemorrhages	100% (19/19)
CT scan and orbital X-ray-normal	94.73% (18/19)
Fundus examination-normal	100% (19/19)

n: Number of patients, NLP: No light perception, LP: Light perception, HM: Hand movements, CF: Counting fingers, RAPD: Relative afferent pupillary defect. TON: Traumatic optic neuropathy, CT: Computed tomography

DISCUSSION

Despite the emergence of modern imaging techniques, EP tests have been employed by many neurologists in specific clinical conditions and the use has been found to be evolving in the clinical settings over the last decades. Its remarkable role in subclinical conditions is well appreciated, but the diagnosis in various clinical conditions presenting with visual dysfunctions has yet not been extended to take into account the electrophysiological findings which can help in comprehending the diagnosis and prognosis. The present study attained the detailed clinical and electrophysiological profile of those patients who were investigated for VEPs for different visual disorders.

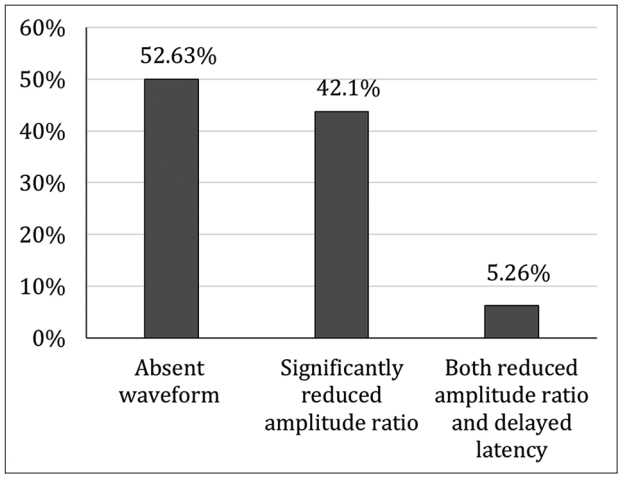

Figure 1: Visual evoked potential findings in 19 patients with traumatic optic neuropathy

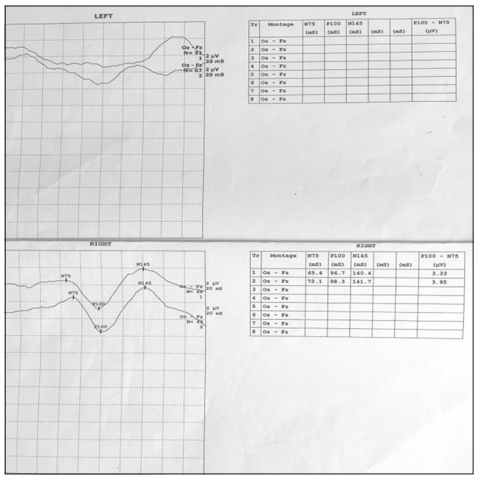

Figure 2: Absent/unidentifiable waveform in the left (affected) eye of a patient with traumatic optic neuropathy (34 years male with visual acuity as light perception and relative afferent pupillary defect present)

Table 2: PRVEP findings in 12 patients with ethambutol toxicity

PRVEP findings	Number of patients	
	PRVEP before the cessation of the drug	PRVEP after 1 month of cessation of the drug
Bilateral P100 delay*	5	3
Reduced N75-P100 amplitude* and undetected waveforms	4	2
Both delayed P100 latency and reduced amplitude*	3	1

PRVEP response improved in 6 patients (50%) including increase in the N75-P100 amplitude and reduced P100 latencies after 1 month (but improved values still beyond twice the standard deviation). *Beyond 3 standard deviation. PRVEP: Pattern-reversal visual evoked potential

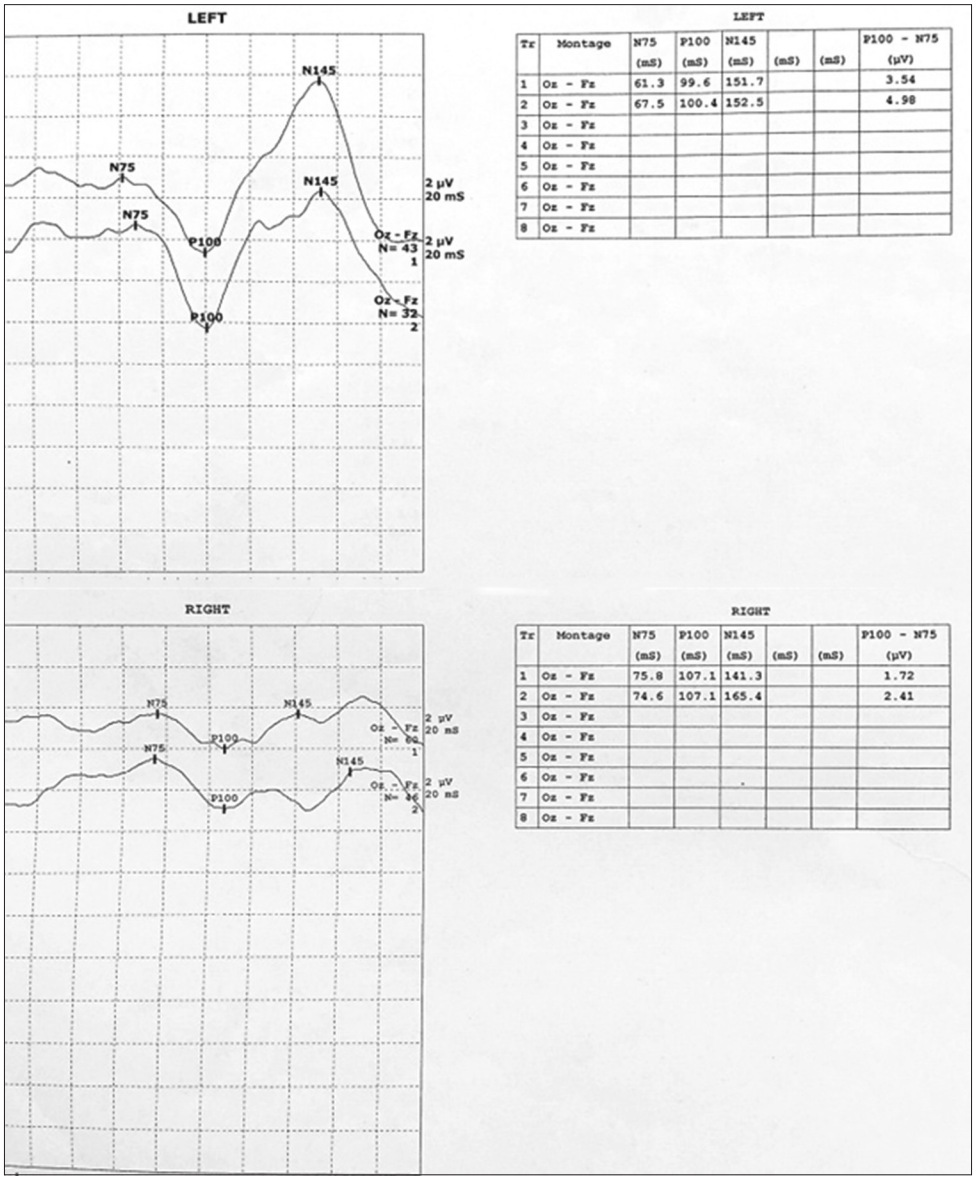

Figure 3: Reduced amplitude ratio (affected eye-right eye/fellow eye) in a patient with traumatic optic neuropathy (37 years male with visual acuity of 6/60 and relative afferent pupillary defect present)

TON, a potentially blinding complication after craniofacial injuries, was the most commonly confronted condition in the present study. The incidence of the condition has been reported to be as high as 5% in a recent survey.[5] Indirect TON is relatively more common which is due to blunt head or closed globe trauma, in which the concussive forces are transmitted to the nerve. The condition is characterized by no initial ophthalmoscopic evidence of injury to the eyeball or optic nerve with normal funduscopic examination in the majority, which was observed in the present study too [Table 1]. All the patients were male, with unilateral visual loss, with the mean age of 37.3 ± 11.6 years, and in the majority, the cause of the trauma was motor-vehicle accident [Table 1]. The findings comply with those of the previous studies.[6] TON exhibited

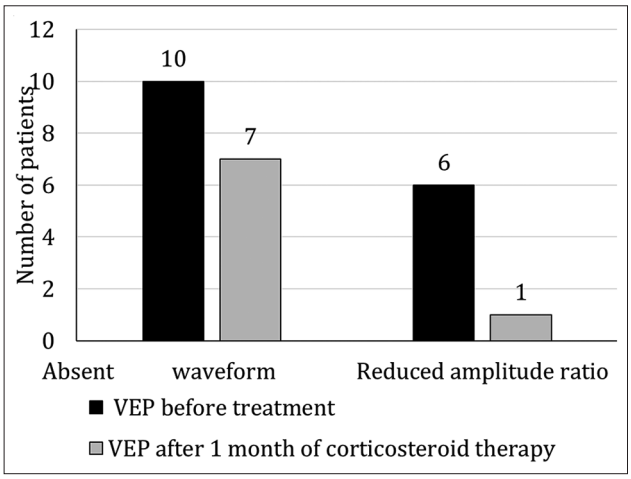

Figure 4: Visual evoked potential findings after 1 month of corticosteroid therapy in 16 patients (who presented <3 days) with traumatic optic neuropathy

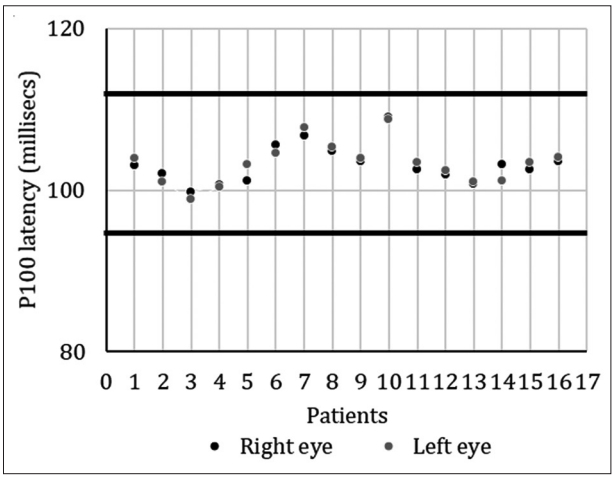

Figure 6: P100 latencies in 16 patients (27.6% of the study group) with functional visual loss (dark lines in the plot area represent upper and lower limits as determined in our laboratory)

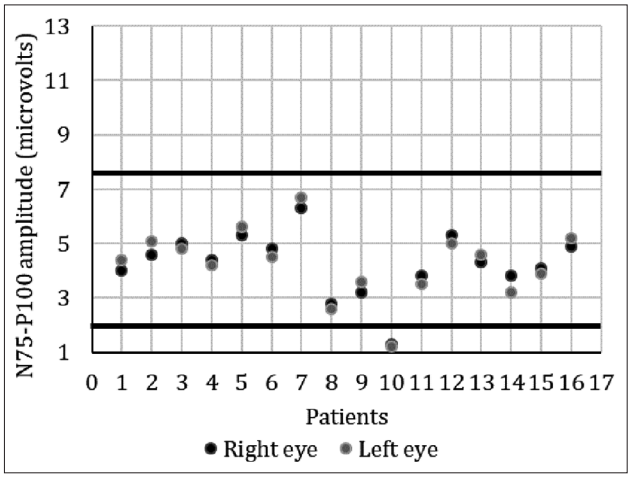

Figure 5: N75-P100 amplitude in 16 patients (27.6% of the study group) with functional visual loss (dark lines in the plot area represent upper and lower limits as determined in our laboratory)

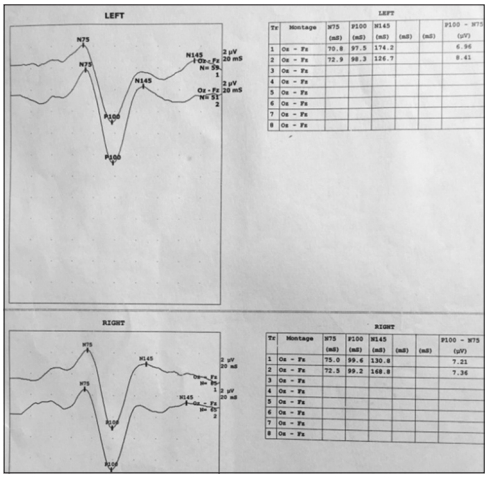

Figure 7: Normal pattern-reversal visual evoked potential records (both the eyes) in a subject with malingering

its major influence on the amplitudes of the VEPs presenting with absent VEP waveforms in the majority followed by reduced amplitude ratios (>3 standard deviations) [Figure 1]. The amplitude diminution in VEPs is suggested to reflect the axonal damage and impaired recruitment of the neuronal pools defining the pathophysiology in TON patients.[7-9] The electrophysiological findings of TON can hence be included to define the condition and TON can well be narrated as post-traumatic visual loss with relative afferent pupillary defect, normal fundus examination, and absent waveform/reduced amplitude ratios in VEP records. However, the role of VEP in this condition was found to be a little greater in the prognosis and prediction of visual recovery of the patients, especially in those with corticosteroid therapy. VEP findings before treatment and 1 month after treatment stated improvement in amplitudes and amplitude ratios (>2 standard deviation increase in the amplitude ratios and recordable VEPs were found with previously absent records) in 50% of the patients (8/16) [Figure 4]. The role of VEPs as predictors of visual recovery and as one of the important prognostic factors has been suggested in previous similar studies. The studies mentioned absent VEP, loss of consciousness, and visual acuity as important predictors.[10]

Functional visual disorders (malingering and factitious disorders) constituted the next common condition for the referral (27.6% of the patients). Patients presented with bilateral loss of vision in the majority. Visual acuity ranged from 6/24 to no light perception and normal funduscopic examinations. Normal VEP records in such patients confirm the diagnosis [Figure 7]. In our study too, VEP tests could confirm the condition in 15 out of 16 patients [Figures 5 and 6]. One patient exhibited VEP records with reduced amplitudes in both the eyes (below the lower limit for our lab). Voluntary or deliberate alterations of VEP response can be attributed to the findings.[11] Furthermore, VEP amplitudes are less consistent and less variable parameter as compared to the latencies and can vary due to various technical and subject factors.[1] An abnormal VEP in patients suspected of functional visual disease neither confirms nor

can exclude the condition. Careful monitoring of the subject during the procedure and recommended modifications in the technique which are suggested to be employed to attenuate the effect of defocusing and which can bring about a genuine response were seemingly not used for the above case of suspected malingering.[12,13] Recent researches also support the role of estimating objective visual acuity by means of PRVEPs in identifying the malingerers.[14] The tests are considered highly sensitive for the identification of malingering and factitious disorders.[15,16]

Patients with clinical diagnosis of presumed ethambutol optic neuropathy were also investigated for VEP tests to detect ethambutol-induced toxic optic neuropathy. VEP records were characterized by varied abnormalities; bilateral P100 delay or reduced amplitudes, while in some, undetected waveforms and both P100 delays and amplitude reduction were noticed [Table 2]. Bilateral optic nerve involvement has been a characteristic finding in previous similar studies.[17-20]

To assess the reversibility of the ocular toxicity, monitoring of the VEP records were performed which revealed increase in the N75-P100 amplitude and reduced P100 latencies after 1 month albeit the improved values were still beyond twice the standard deviation [Table 2]. The findings are in line with a previous similar study which demonstrates improvement in 80% of eyes after 1 month of stoppage of the drug.[18] Reversibility of ocular toxicity after the cessation of the drug has also been supported by other similar studies in the past.[17,19,20] Age of the patient, daily dose, duration of treatment, and renal dysfunctions have been suggested as the major risk factors for the development of the condition.[20,21] One of the principal theories for ocular toxicity has been the zinc-chelating effect of ethambutol and its metabolite inside the human mitochondria.[22-24]

Other rare causes of visual impairments and presumed optic neuropathy comprised multiple sclerosis (3.44%). Both the cases were of relapsing-remitting type with significant P100 delays (more than 3 standard deviations) in VEP records. Multiple sclerosis affect the CNS in dispersed areas, hence, the detection of an optic nerve lesion helps to define the disease. In our study, one out of two patients was with clinically silent optic nerve lesions, and VEPs could demonstrate significantly delayed P100 latencies despite normal optic nerve in the magnetic resonance imaging scan.[25] VEPs have been suggested to contribute to the diagnosis of multiple sclerosis by depicting demyelination Neurophysiological. Investigation is strictly related to function and has been reported to correlate well with the disability status.[26,27]

Optic neuritis (acute and chronic) without multiple sclerosis was detected too in 6.89% of the total patients. VEPs contributed in the diagnosis of both. In acute optic neuritis, patients had normal fundus but absent VEP waveforms while in chronic optic neuritis, characteristic P100 delay of more than three standard deviations were demonstrated. Optic disc pallor, however, was also found to be developed in these patients. The study also encompasses some rare causes of visual impairment as tubercular meningitis demonstrating absent waveforms in the affected eye and optic neuropathy due to thyroid disease, exhibiting reduced amplitudes bilaterally.[28] Compression of the optic nerve at the orbital apex by the swollen extraocular muscles has been implicated in the lesion. Electrophysiologic abnormalities in the form of abnormal PRVEPs have been reported to be the most sensitive indicator in this condition as well, in many previous studies.[29-31]

The present study thus provides an account of different visual disorders (with presumed optic nerve lesion) and their VEP findings including some rare and interesting referrals. Patients were followed up to find the recovery and reversibility of the damage evaluating the role in prognosis as well. The study provides information about the extent of awareness regarding conditions among the clinicians of the area of study where VEP tests can be utilized.

Limitations

Monitoring of the PRVEP records could have been conducted for a longer period to strengthen the findings. Furthermore, for aiding the diagnosis of functional visual disorders, acquisition of objective visual acuity by means of PRVEPs could have been included.

CONCLUSION

VEPs are valuable electrophysiological investigations to delineate optic neuropathy in a variety of visual disorders. They can provide useful evidence regarding the type of the neurological abnormality in visual disorders with optic nerve involvement. Conventional VEPs performed in most neurophysiological laboratories can effectively contribute and complement the diagnosis in visual dysfunctions. Some potentially blinding conditions like TON could also be evaluated with easy, short, and cheap implementation to find the severity of the optic nerve damage, to predict the recovery, and to monitor the effect of the treatment. Conclusive results in functional visual loss guide and support the clinicians in approaching the diagnosis. As an easy monitoring tool in toxic optic neuropathy due to ethambutol, reversibility of ocular toxicity can be investigated after the cessation of the drug. In some rare but disabling conditions such as multiple sclerosis and optic neuritis, PRVEP records provide characteristic electrophysiologic findings even in clinically silent lesions. To conclude, they are sensitive adjuncts to diagnoses in various visual disorders and can also contribute as important monitoring tools for objectively assessing the recovery and ophthalmological status.

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