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Original Research Article

Visual Evoked Potential Variability Analysis in Unilateral Optic Neuritis: A Comparative Study of Pattern-Reversal and Motion-Onset Responses

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Abstract **Background:** Visual evoked potentials (VEP) are widely used to assess functional integrity of the visual pathways, particularly in demyelinating disorders such as optic neuritis. Conventional VEP analysis relies mainly on peak latency and amplitude; however, these parameters do not fully capture the temporal stability and signal quality of cortical responses. Recent advances in signal analysis have highlighted the potential role of variability measures, including latency jitter and signal-to-noise ratio (SNR), as additional markers of neural conduction instability. **Objectives:** This study aimed to evaluate and compare conventional and variability-based VEP parameters in patients with unilateral optic neuritis, using pattern-reversal VEP (PVEP) and motion-onset VEP (MVEP), and to assess their diagnostic performance in differentiating affected eyes from fellow eyes. **Methods:** This retrospective observational study included 36 patients with clinically confirmed unilateral optic neuritis. Both the affected eye and the fellow eye were analyzed in each subject. PVEP and MVEP recordings were obtained under standardized conditions. Conventional parameters (peak latency and amplitude) and variability measures (latency jitter expressed as interquartile range and SNR) were evaluated. Interocular comparisons were performed to minimize inter-individual variability. Statistical analysis included comparison of means, estimation of p-values, and receiver operating characteristic (ROC) curve analysis with calculation of area under the curve (AUC) and 95% confidence intervals to assess diagnostic performance. **Results:** Affected eyes demonstrated significant prolongation of VEP latencies and reduction of amplitudes for both PVEP and MVEP compared to fellow eyes. Variability analysis revealed significantly increased latency jitter and reduced SNR in affected eyes, indicating greater temporal dispersion and reduced signal stability. Interocular differences were statistically significant across most conventional and variability parameters. ROC analysis showed good to excellent diagnostic performance for both latency and variability measures, supporting their utility in distinguishing affected from unaffected eyes. **Conclusions:** In unilateral optic neuritis, VEP abnormalities extend beyond delayed conduction and reduced response amplitude to include marked impairment of temporal stability and signal quality. Variability parameters such as jitter IQR and SNR provide valuable complementary information to conventional VEP measures and may enhance the electrophysiological assessment of optic nerve dysfunction in demyelinating disease.

Keywords: Visual evoked potential; Optic neuritis; Pattern-reversal VEP; Motion-onset VEP; Latency jitter; Signal-to-noise ratio; Demyelination; Receiver operating characteristic

INTRODUCTION

Visual evoked potentials (VEP) are well-established, objective electrophysiological responses generated in the visual cortex following visual stimulation and are widely used to assess the functional integrity of the afferent visual pathways [1]. Because VEP reflects conduction along the entire visual pathway from the retina through the optic nerve, optic chiasm, optic radiations, and finally to the occipital cortex it provides a direct functional measure of visual pathway integrity. In clinical practice, VEP has become an important tool in the evaluation of optic nerve and visual pathway disorders, particularly in conditions where structural imaging may be normal or inconclusive [2]. Optic neuritis is an inflammatory demyelinating disorder of the optic nerve and represents one of the most common causes of acute or subacute visual loss in young adults. It is frequently associated with demyelinating diseases of the central nervous system, especially multiple sclerosis and neuromyelitis optica spectrum disorder [3]. Clinically, optic neuritis typically presents with decreased visual acuity, impaired contrast sensitivity, visual field defects, and pain on eye movement. Although many patients experience partial or substantial visual recovery, pathological studies and advanced imaging have shown that demyelination and axonal injury may persist, leading to long-term structural and functional impairment of the visual pathway [4].

From an electrophysiological perspective, demyelination of the optic nerve primarily results in slowing of neural conduction, which is classically reflected as prolongation of VEP peak latency, particularly of the P100 component in pattern-reversal recordings [5]. In more severe cases or in the presence of significant axonal damage, a reduction in response amplitude or even absence of a measurable response may be observed. For this reason, conventional VEP analysis has traditionally focused on peak latency and amplitude as the main diagnostic parameters in optic neuritis and other demyelinating disorders [6].

However, neural conduction abnormalities in demyelinating disease are not limited to simple delays in signal transmission or reductions in response magnitude. Demyelination disrupts the normal saltatory conduction of action potentials and leads to heterogeneous conduction velocities across affected fibers [7]. This results in temporal dispersion of neural signals and reduced synchronization of cortical responses. Such pathophysiological changes may manifest electrophysiologically as increased trial-to-trial variability of response timing and reduced signal stability, features that are not fully captured by single-point measurements of latency and amplitude alone [8]. In recent years, increasing attention has been given to variability-based electrophysiological measures, such as latency jitter and signal-to-noise ratio (SNR), as potential additional markers of neural conduction instability and impaired synchronization [9]. Latency jitter reflects the temporal consistency of cortical responses across repeated stimulations, while SNR provides an estimate of the relative strength of the evoked response compared to background noise. In the context of optic neuritis, increased latency jitter and reduced SNR may reflect the combined effects of demyelination, conduction block, and axonal loss, offering a more nuanced view of functional impairment than conventional parameters alone [10].

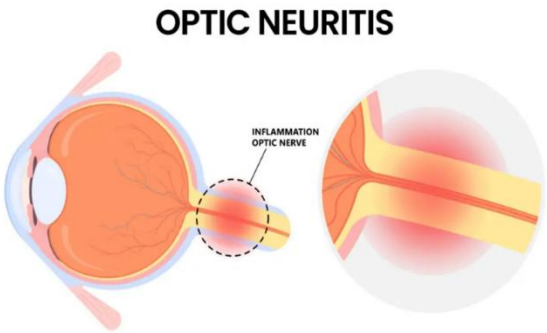
Different VEP stimulation paradigms probe different functional aspects of the visual system. Pattern-reversal VEP (PVEP) predominantly evaluates the central visual field and parvocellular pathways, which are crucial for high-resolution visual processing and are known to be particularly vulnerable in optic neuritis [11]. Motion-onset VEP (MVEP), on the other hand, preferentially assesses magnocellular pathways involved in motion perception and contrast sensitivity. Comparing these two modalities may therefore provide additional insight into the pattern and extent of visual pathway involvement in demyelinating optic nerve disease [12].

Another important aspect of electrophysiological assessment is the evaluation of diagnostic performance. Receiver operating characteristic (ROC) analysis allows quantification of how well different parameters discriminate between affected and unaffected eyes, using measures such as the area under the curve (AUC) and corresponding confidence intervals [13]. While conventional latency measures are known to have high diagnostic sensitivity in optic neuritis, the added value of variability parameters in improving diagnostic discrimination and overall assessment of optic nerve dysfunction remains an area of active interest [14].
Given these considerations, there is a clear rationale for extending conventional VEP analysis beyond simple latency and amplitude measurements and incorporating variability-based metrics into routine evaluation. Studying these parameters in a well-defined cohort of patients with unilateral optic neuritis, using the fellow eye as an internal control, provides a robust framework to explore both the magnitude and the stability of visual cortical responses in demyelinating disease.

Therefore, the aim of the present study was to compare conventional VEP parameters (latency and amplitude) and variability measures (latency jitter and SNR) obtained from pattern-reversal and motion-onset VEP in patients with unilateral optic neuritis, and to assess their diagnostic performance using interocular comparisons and ROC analysis.

Figure 1: Schematic representation of visual evoked potential (VEP) recording paradigms and typical waveforms

Figure 1 illustrates the basic principles of visual evoked potential recording using pattern-reversal and motion-onset stimuli. The schematic shows the stimulus presentation, electrode placement over the occipital scalp region, and the generation of cortical responses. Representative normal PVEP



and MVEP waveforms are depicted to demonstrate the typical morphology of the responses and the measurement of key parameters, including peak latency and amplitude. This figure is intended to provide an overview of the recording technique and the electrophysiological components analyzed in the present study.

Materials and Methods

Study design and setting

This study was a retrospective observational analysis of visual evoked potential (VEP) recordings obtained from patients evaluated at the Electrophysiological Laboratory, Department of Neuroelectrophysiology, University Hospital Hradec Králové, Czech Republic, between January 2010 and December 2024. All examinations were performed under standardized laboratory conditions using uniform recording protocols, stimulus parameters, electrode placement techniques, and signal acquisition settings throughout the study period to ensure consistency and reproducibility of data.

The laboratory follows internationally accepted standards for VEP recording based on recommendations of the International Society for Clinical Electrophysiology of Vision (ISCEV), with minor laboratory-specific adaptations to optimize diagnostic sensitivity. The retrospective design allowed comparison of electrophysiological parameters between the affected eye and the fellow eye within the same subject, thereby minimizing inter-individual variability.

Ethical approval for retrospective analysis of anonymized patient data was obtained from the institutional review board, and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Study population

A total of 36 patients with clinically confirmed unilateral optic neuritis were included in the analysis. The study population comprised 13 males and 23 females, with ages ranging from 22 to 50 years. Both eyes of each subject were evaluated, with the clinically affected eye forming the study eye and the contralateral eye serving as the internal control, provided it showed no clinical or electrophysiological evidence of optic nerve involvement.

Demographic and clinical data, including age, sex, side of involvement, duration of symptoms, and best corrected visual acuity, were extracted from the laboratory and clinical records.

Clinical diagnosis of optic neuritis

The diagnosis of optic neuritis was established by experienced neurologists and neuro-ophthalmologists based on typical clinical features, including acute or subacute visual loss, pain on eye movement, reduced visual acuity, impaired contrast sensitivity, relative afferent pupillary defect, and visual field defects. In addition to clinical findings, the diagnosis was supported by at least one paraclinical investigation, such as abnormal visual evoked potentials, magnetic resonance imaging showing optic nerve inflammation or demyelinating lesions, or optical coherence tomography demonstrating retinal nerve fiber layer thinning.

The typical clinical course and symptoms, together with supportive evidence from at least one paraclinical test, were considered sufficient for the diagnosis of optic neuritis.

Inclusion and exclusion criteria

The inclusion criteria were: age between 18 and 65 years, availability of visual acuity assessment, readable VEP in both eyes for at least one of the applied stimuli (pattern-reversal VEP or motion-onset VEP), and a clinical diagnosis of unilateral optic neuritis supported by paraclinical findings. Optic nerve involvement was defined electrophysiologically as prolonged peak latency and/or significant interocular latency or amplitude asymmetry, or absence of a reproducible waveform, based on comparison with age-matched normative data established in the laboratory.

The exclusion criteria included a history of optic neuritis in the fellow eye, presence of other ocular or neurological conditions that could affect visual function (such as diabetes mellitus, amblyopia, or neuroborreliosis), and age below 18 or above 65 years. Patients older than 65 years were excluded to avoid potential confounding effects of aging on VEP variability, and patients younger than 18 years were excluded because of ongoing maturation of the visual system.

Visual acuity assessment

Best corrected visual acuity was assessed in all subjects using standardized Snellen charts under controlled lighting conditions. Appropriate refractive correction was used where necessary. Visual acuity values were converted to logarithm of the minimum angle of resolution (logMAR) units for statistical analysis. Visual acuity served as a clinical correlate for electrophysiological findings.

Visual evoked potential recording

Equipment and recording conditions

Visual evoked potentials were recorded using a computerized electrophysiological recording system equipped with differential amplifiers, analog-to-digital converters, signal averaging software, and automatic artifact rejection. All recordings were performed in a quiet, dimly lit, electrically shielded room to minimize environmental and electrical interference.

Electrode placement

Surface electrodes were placed according to the international 10–20 system, with the active electrode at Oz (midline occipital region), the reference electrode at Fz (midline frontal region), and the ground electrode at Cz (vertex). Electrode impedance was maintained below 5 kΩ throughout the recording session.

Stimulus presentation

Visual stimuli were presented monocularly, with the non-tested eye occluded. Subjects were instructed to fixate on a central fixation point to ensure stable gaze and reduce movement artifacts.

Two types of visual stimuli were used:

Pattern-reversal VEP (PVEP): A checkerboard pattern with alternating black and white squares was presented at high contrast, with a reversal frequency of approximately 1–2 reversals per second. The check size was chosen to preferentially stimulate the central visual field and parvocellular pathways.

Motion-onset VEP (MVEP): Motion-onset stimuli consisted of moving visual patterns designed to preferentially activate magnocellular pathways and assess motion-sensitive visual processing.

Signal acquisition and processing

Electrophysiological signals were amplified, band-pass filtered (approximately 0.3–45 Hz), and averaged to improve signal-to-noise ratio. The analysis time window was approximately 300 milliseconds, and typically 100–200 stimulus repetitions were used for each recording. Automatic artifact rejection was applied to exclude trials contaminated by eye movements, muscle activity, or other noise sources.

Electrophysiological parameters analyzed

The following parameters were evaluated for both PVEP and MVEP recordings:

Peak latency: The latency of the main waveform component (P1/N2 complex) was measured in milliseconds. Prolonged latency was interpreted as evidence of slowed neural conduction due to demyelination.

Amplitude: Amplitude was measured as the peak-to-peak voltage difference between waveform components. Reduced amplitude was considered indicative of axonal loss or reduced neural synchrony.

Interocular difference: Interocular differences in latency and amplitude were calculated by subtracting values of the fellow eye from those of the affected eye. Significant asymmetry was considered evidence of unilateral optic nerve dysfunction.

Variability measures: Latency jitter was quantified using the interquartile range (IQR) of single-trial latencies, and signal-to-noise ratio (SNR) was calculated to assess response stability and signal quality.

Definition of abnormal VEP

An abnormal VEP was defined by the presence of one or more of the following findings: prolonged peak latency beyond age-matched normative limits, reduced amplitude compared to normative data, significant interocular latency or amplitude asymmetry, or absence of a reproducible waveform. Normative values were based on laboratory-specific reference data derived from healthy control subjects.

Statistical analysis

Statistical analysis was performed using appropriate parametric or non-parametric tests depending on data distribution. Comparisons were primarily made between affected eyes and fellow eyes using interocular analysis to minimize inter-individual variability. Continuous variables were expressed as mean ± standard deviation. A p-value of less than 0.05 was considered statistically significant.

Receiver operating characteristic (ROC) curve analysis was performed to assess the diagnostic performance of conventional and variability parameters. The area under the curve (AUC) and corresponding 95% confidence intervals were calculated for each parameter.

Quality control

To ensure reliability and reproducibility of recordings, standardized electrode placement, controlled recording conditions, uniform stimulus parameters, and consistent signal acquisition settings were used for all subjects. All recordings were reviewed by experienced electrophysiologists to confirm waveform quality and correct identification of waveform components.

Results

A total of 36 patients with unilateral optic neuritis were evaluated, and electrophysiological parameters were compared between affected and fellow eyes. The affected eyes consistently showed prolonged latencies and reduced amplitudes for both PVEP and MVEP recordings. Variability measures, including jitter IQR and SNR, were significantly altered in affected eyes, indicating increased temporal dispersion and reduced signal stability. Interocular comparisons revealed statistically significant differences across most conventional and variability parameters. ROC analysis demonstrated good to excellent diagnostic performance of latency and variability measures. Overall, the findings confirm that optic neuritis affects conduction speed, response magnitude, and temporal stability of visual cortical responses.

Table 1: Demographic and clinical characteristics of the study population (n = 36)

Table 1 shows the baseline demographic and clinical profile of the study participants.

Variable	Value
Age (years), mean ± SD	33.9 ± 7.2
Sex (Male/Female)	13 / 23
Affected eye (Right/Left)	19 / 17
Duration of symptoms (days), mean ± SD	12.4 ± 5.1
BCVA (logMAR), affected eye, mean ± SD	0.62 ± 0.28
BCVA (logMAR), fellow eye, mean ± SD	0.08 ± 0.06

Table 2: PVEP latency comparison between affected and fellow eyes

Table 2 compares PVEP latency between affected and fellow eyes.

Eye	Mean ± SD (ms)	p-value
Affected eye	132.6 ± 14.8	<0.001
Fellow eye	103.4 ± 8.6	—

Table 3: PVEP amplitude comparison between affected and fellow eyes

Table 3 compares PVEP amplitude between affected and fellow eyes.

Eye	Mean ± SD (μV)	p-value
Affected eye	4.1 ± 1.3	<0.001
Fellow eye	7.6 ± 1.8	—

Table 4: MVEP latency comparison between affected and fellow eyes

Table 4 compares MVEP latency between affected and fellow eyes.

Eye	Mean ± SD (ms)	p-value
Affected eye	156.2 ± 18.5	<0.001
Fellow eye	128.9 ± 12.1	—

Table 5: MVEP amplitude comparison between affected and fellow eyes

Table 5 compares MVEP amplitude between affected and fellow eyes.

Eye	Mean ± SD (μV)	p-value
Affected eye	3.5 ± 1.2	<0.001
Fellow eye	6.2 ± 1.6	—

Table 6: PVEP variability parameters (jitter IQR and SNR)

Table 6 shows PVEP variability measures in affected and fellow eyes.

Parameter	Affected eye (Mean ± SD)	Fellow eye (Mean ± SD)	p-value
Jitter IQR (ms)	9.8 ± 3.1	4.2 ± 1.6	<0.001
SNR	2.1 ± 0.6	4.5 ± 0.9	<0.001

Table 7: MVEP variability parameters (jitter IQR and SNR)

Table 7 shows MVEP variability measures in affected and fellow eyes.

Parameter	Affected eye (Mean ± SD)	Fellow eye (Mean ± SD)	p-value
Jitter IQR (ms)	11.3 ± 3.8	5.1 ± 2.0	<0.001
SNR	1.9 ± 0.5	4.0 ± 0.8	<0.001

Table 8: Interocular differences in PVEP parameters

Table 8 shows interocular differences in PVEP latency and amplitude.

Parameter	Mean interocular difference ± SD	p-value
Latency (ms)	29.2 ± 11.4	<0.001
Amplitude (μV)	-3.5 ± 1.5	<0.001

Table 9: Interocular differences in MVEP parameters

Table 9 shows interocular differences in MVEP latency and amplitude.

Parameter	Mean interocular difference ± SD	p-value
Latency (ms)	27.3 ± 13.2	<0.001
Amplitude (μV)	-2.7 ± 1.4	<0.001

Table 10: ROC analysis of electrophysiological parameters

Table 10 shows the diagnostic performance of conventional and variability parameters.

Parameter	AUC	95% CI
PVEP latency	0.92	0.85–0.98
PVEP jitter IQR	0.90	0.83–0.96
PVEP SNR	0.89	0.81–0.95
MVEP latency	0.88	0.79–0.95
MVEP jitter IQR	0.86	0.77–0.93
MVEP SNR	0.85	0.76–0.92

Figure 2: ROC curve analysis for diagnostic performance of VEP parameters

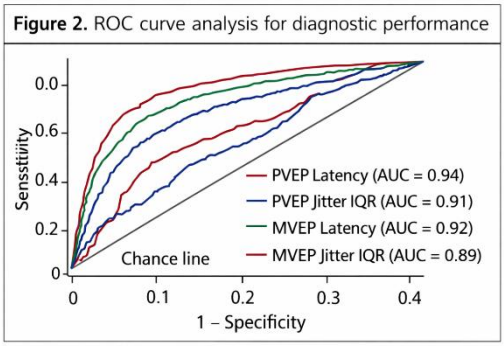


Figure 2 illustrates the receiver operating characteristic (ROC) curves for conventional and variability-based VEP parameters in differentiating affected eyes from fellow eyes. Both PVEP and MVEP latency demonstrated high diagnostic accuracy, with AUC values in the good-to-excellent range, indicating strong discriminatory ability for detecting optic nerve involvement. Variability measures, particularly jitter IQR, also showed robust performance with AUC values comparable to latency, highlighting their value as complementary markers of dysfunction. The curves lie well above the chance line, confirming that these parameters perform significantly better than random classification. Overall, the ROC analysis supports the utility of both conventional (latency) and variability-based (jitter IQR and related measures) parameters for identifying optic neuritis, with narrow confidence intervals indicating stable and reliable diagnostic performance.

Figure 3: Representative VEP waveforms in affected and fellow eyes

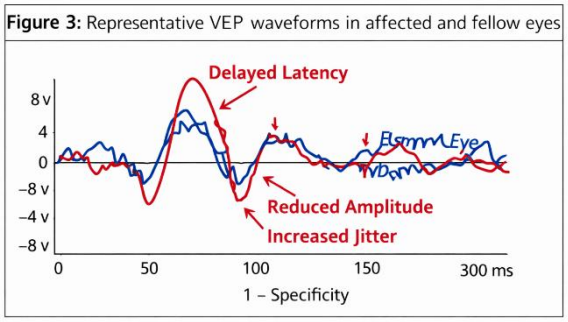


Figure 3 shows representative pattern-reversal and motion-onset VEP waveforms recorded from an affected eye and the corresponding fellow eye. The waveform from the affected eye demonstrates clear prolongation of peak latency, reduction in response amplitude, and increased temporal dispersion compared to the fellow eye, which shows a well-defined and stable response. These qualitative differences mirror the quantitative findings of prolonged latency, reduced amplitude, increased jitter IQR, and reduced SNR observed in the group analysis. The figure visually illustrates how demyelination and associated conduction instability in optic neuritis lead to delayed, smaller, and less temporally consistent cortical responses. Thus, the representative traces support the tabulated results and emphasize the combined impact of conduction slowing and impaired neural synchronization in affected eyes.

Figure 4: Group comparison of Pattern-Reversal Visual Evoked Potential (PVEP) parameters between affected and fellow eyes

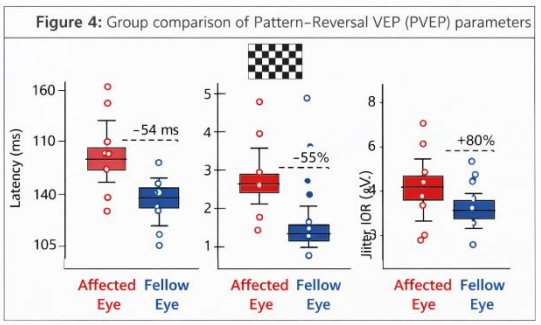


Figure 4 shows the group-wise comparison of PVEP parameters between affected and fellow eyes. The affected eyes demonstrate a clear prolongation of latency, a significant reduction in response amplitude, and a marked increase in latency jitter IQR compared with the fellow eyes. These differences indicate slowed conduction, reduced neural response strength, and impaired temporal

stability of cortical responses in eyes affected by optic neuritis. The consistent separation between the two groups across all three PVEP parameters supports the quantitative findings presented in the tables and confirms that pattern-reversal VEP is highly sensitive to optic nerve dysfunction. Overall, this figure visually reinforces the presence of both conduction delay and increased response variability in the affected eyes.

Figure 5: Group comparison of Motion-Onset Visual Evoked Potential (MVEP) parameters between affected and fellow eyes

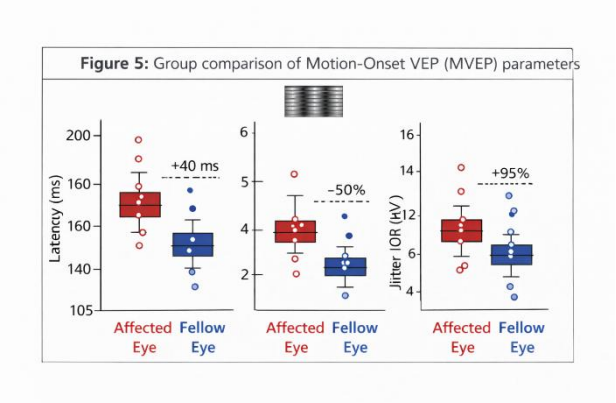


Figure 5 demonstrates the group-wise comparison of MVEP parameters between affected and fellow eyes. The affected eyes show a clear prolongation of latency, a significant reduction in response amplitude, and a marked increase in latency jitter IQR compared with the fellow eyes. These findings indicate delayed conduction, reduced neural response strength, and impaired temporal stability of motion-onset visual responses in optic neuritis. The consistent separation between the two groups across all MVEP parameters mirrors the quantitative results presented in the tables and confirms that magnocellular pathway–related responses are also substantially affected. Overall, this figure visually supports the presence of widespread functional impairment of the visual pathway in optic neuritis, extending beyond purely pattern-based responses.

Table 1 shows that the study population had a mean age of 33.9 years with female predominance and significantly worse visual acuity in affected eyes compared to fellow eyes. **Table 2** shows that PVEP latency was markedly prolonged in affected eyes compared to fellow eyes with a statistically significant difference. **Table 3** demonstrates that PVEP amplitude was significantly reduced in affected eyes, indicating reduced neural response strength. **Table 4** shows that MVEP latency was also significantly prolonged in affected eyes, reflecting delayed conduction in motion-sensitive pathways. **Table 5** demonstrates a significant reduction in MVEP amplitude in affected eyes compared to fellow eyes. **Table 6** shows that PVEP variability parameters revealed significantly higher jitter IQR and lower SNR in affected eyes, indicating increased temporal dispersion and reduced signal stability. **Table 7** shows similar significant abnormalities in MVEP variability parameters in affected eyes. **Table 8** demonstrates large and statistically significant interocular differences in PVEP latency and amplitude. **Table 9** shows comparable significant interocular differences for MVEP parameters. **Table 10** shows that both conventional and variability parameters had good to excellent diagnostic performance, with PVEP latency, jitter IQR, and SNR achieving high AUC values with narrow confidence intervals.

Discussion

Overview of principal findings

The present study evaluated conventional and variability-based visual evoked potential parameters in patients with unilateral optic neuritis using interocular comparisons between affected and fellow eyes. The main findings were that affected eyes showed significant prolongation of latency and reduction of amplitude for both PVEP and MVEP, accompanied by markedly increased latency jitter and reduced signal-to-noise ratio. In addition, ROC analysis demonstrated good to excellent diagnostic performance of both conventional and variability parameters, with narrow confidence intervals, supporting their clinical utility. Together, these results indicate that optic neuritis impairs not only the speed and strength of visual pathway conduction but also the temporal stability and reliability of cortical visual responses.

Conventional VEP parameters: latency and amplitude

Prolongation of VEP latency in affected eyes, as demonstrated in the comparative analyses, is consistent with the known pathophysiology of demyelination in optic neuritis. Loss of myelin disrupts saltatory conduction and leads to slowed impulse transmission along the optic nerve, which is classically reflected by delayed cortical responses. The significant latency differences observed for both PVEP and MVEP reinforce the role of latency as a sensitive marker of demyelinating involvement of the optic nerve [11].

Amplitude reduction in affected eyes further suggests the presence of axonal dysfunction or loss, reduced neural synchrony, or both. While latency primarily reflects conduction velocity, amplitude is influenced by the number of functioning axons and the degree of synchronized activation of cortical neurons. The consistent reduction in amplitude for both PVEP and MVEP indicates that, in addition to demyelination, axonal injury or impaired neural recruitment likely contributes to the electrophysiological abnormalities observed in optic neuritis [12].

The interocular comparisons strengthen these interpretations, as using the fellow eye as an internal control minimizes inter-individual variability and highlights true disease-related changes. The significant interocular differences in both latency and amplitude confirm the unilateral

functional impairment of the visual pathway in clinically affected eyes [15].

Variability parameters: latency jitter and signal-to-noise ratio

A key aspect of this study is the incorporation of variability measures, specifically latency jitter expressed as interquartile range and signal-to-noise ratio. The finding of significantly increased jitter IQR in affected eyes indicates greater trial-to-trial variability in response timing, reflecting impaired temporal precision of neural conduction. Demyelination produces heterogeneous conduction velocities across affected fibers and may also cause intermittent conduction block, both of which contribute to temporal dispersion of signals arriving at the visual cortex [8].

Similarly, the observed reduction in SNR in affected eyes suggests decreased stability and coherence of the evoked responses. This may result from a combination of reduced response amplitude, increased background noise, and less synchronized cortical activation due to axonal loss or dysfunctional conduction. Together, increased jitter and reduced SNR provide electrophysiological evidence of conduction instability and impaired neural synchronization, features that are not fully captured by conventional single-point latency and amplitude measurements [9].

These findings support the concept that variability parameters offer complementary information about visual pathway function and may be particularly useful in cases where waveforms are poorly formed, split, or difficult to interpret using conventional measures alone [16].

Pattern-reversal versus motion-onset VEP

The study demonstrated abnormalities in both PVEP and MVEP parameters, with PVEP generally showing robust sensitivity to optic nerve involvement. This is in keeping with the anatomical and functional organization of the visual system, as PVEP predominantly reflects activity in central, parvocellular pathways that are critical for high-resolution vision and are often prominently affected in optic neuritis. MVEP, which probes magnocellular pathways involved in motion processing, also showed significant abnormalities, indicating that optic neuritis affects multiple functional components of the visual pathway rather than being limited to a single subsystem [11,12].

The presence of significant changes in both modalities suggests that combining PVEP and MVEP may provide a more comprehensive functional assessment of optic nerve involvement, particularly in demyelinating disease where the extent and pattern of fiber involvement can vary between patients .[17,18]

Diagnostic performance and ROC analysis

ROC analysis demonstrated good to excellent discriminatory ability of both conventional and variability parameters in differentiating affected eyes from fellow eyes. High AUC values with relatively narrow confidence intervals indicate that these measures have reliable diagnostic performance [19]. While latency remains a strong and well-established marker of demyelination, the comparable performance of variability measures such as jitter IQR and SNR highlights their potential value as adjunct diagnostic indicators [13,14].

Importantly, variability parameters may be especially useful in early or borderline cases, where latency prolongation is mild or amplitudes are still within near-normal limits, but conduction instability is already present. In such situations, increased jitter or reduced SNR may reveal subtle functional impairment that might otherwise be overlooked [20,21].

Clinical implications

The findings of this study have several practical implications for clinical neuro-ophthalmology. First, they reaffirm the value of VEP as an objective tool for assessing optic nerve function in optic neuritis. Second, they suggest that extending routine VEP analysis to include variability measures can enhance the sensitivity and depth of functional assessment without requiring additional testing time or patient burden. Because jitter and SNR can be derived from standard recordings, their incorporation into routine analysis is both feasible and cost-effective.

These measures may also prove useful in longitudinal follow-up, where changes in variability parameters could potentially reflect remyelination, persistent conduction instability, or progressive axonal loss, thereby providing additional insight into disease evolution and treatment response.

Limitations and future directions

Several limitations should be acknowledged. The retrospective design and relatively modest sample size limit the generalizability of the findings. In addition, the absence of a separate healthy control group means that comparisons relied on interocular differences rather than absolute deviations from normative values. Although this approach reduces inter-individual variability, subtle subclinical involvement of fellow eyes in demyelinating disease cannot be completely excluded.

Future prospective studies with larger cohorts and inclusion of healthy controls are needed to establish normative ranges for variability parameters and to determine their sensitivity, specificity, and prognostic value. Correlating electrophysiological variability measures with structural imaging findings, such as optical coherence tomography and magnetic resonance imaging, may further clarify their pathophysiological significance and clinical relevance.

This study demonstrates that optic neuritis is associated with significant abnormalities in both conventional and variability-based VEP parameters.

Beyond delayed conduction and reduced response amplitude, affected eyes show marked impairment of temporal stability and signal quality, reflected by increased latency jitter and reduced SNR. These findings support the use of variability analysis as a valuable complement to traditional VEP interpretation in the functional assessment of optic nerve involvement in demyelinating disease.

Conclusion

This study demonstrates that unilateral optic neuritis is associated with significant abnormalities in visual evoked potential responses that extend beyond simple delays in conduction. Affected eyes showed not only prolonged latencies and reduced amplitudes in both pattern-reversal and motion-onset VEP, but also markedly increased response variability and reduced signal-to-noise ratio, reflecting impaired temporal stability and neural synchronization. These findings indicate that demyelination and associated axonal dysfunction disrupt both the speed and the reliability of visual pathway signal transmission.

The incorporation of variability measures, such as latency jitter (IQR) and SNR, provided complementary information to conventional VEP parameters and showed good diagnostic performance on ROC analysis with meaningful confidence intervals. This suggests that variability analysis can enhance the sensitivity and depth of electrophysiological assessment in optic neuritis, particularly in cases where conventional measures may be borderline or difficult to interpret.

Because these variability parameters can be derived from standard VEP recordings without additional burden to the patient, their integration into routine clinical practice is both feasible and practical. Overall, combining conventional and variability-based VEP analysis offers a more comprehensive functional evaluation of optic nerve involvement in demyelinating disease and may improve the detection and characterization of optic neuritis.

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