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ORIGINAL ARTICLE

MULTIMODAL EVOKED POTENTIALS AS A NEUROPHYSIOLOGICAL BATTERY IN MULTIPLE SCLEROSIS FOLLOW-UP

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Abstract

Multiple sclerosis is a chronic immune-mediated demyelinating disorder of the central nervous system characterized by multifocal inflammatory lesions, progressive axonal degeneration, and variable neurological disability affecting sensory, motor, visual, and cognitive pathways. Accurate long-term monitoring of disease activity and neurological progression remains essential for evaluating therapeutic effectiveness, predicting prognosis, and identifying subclinical deterioration. Multimodal evoked potentials have emerged as valuable neurophysiological tools for assessment of functional integrity within sensory and motor pathways affected by demyelinating processes in multiple sclerosis. Visual evoked potentials, somatosensory evoked potentials, brainstem auditory evoked potentials, and motor evoked potentials collectively provide objective information regarding conduction abnormalities, demyelination severity, axonal dysfunction, and dissemination of lesions throughout the central nervous system. These neurophysiological techniques allow detection of clinically silent lesions and contribute significantly to early diagnosis, disease monitoring, prognostic evaluation, and assessment of therapeutic response. Visual evoked potentials are particularly sensitive for identifying optic nerve demyelination and delayed conduction associated with optic neuritis, whereas somatosensory evoked potentials evaluate dorsal column and sensory pathway integrity. Brainstem auditory evoked potentials assess conduction through auditory pathways and brainstem structures, while motor evoked potentials provide important information regarding corticospinal tract dysfunction and motor disability progression. Integration of multimodal evoked potential studies improves diagnostic sensitivity compared with isolated neurophysiological testing and offers comprehensive evaluation of widespread central nervous system involvement. Neurophysiological abnormalities frequently correlate with lesion burden observed on magnetic resonance imaging and may additionally reflect functional impairment not fully detectable through structural neuroimaging alone. Contemporary advances in digital electrophysiology, signal processing, and neurodiagnostic methodology have enhanced reliability and clinical utility of multimodal evoked potentials in multiple sclerosis follow-up. Comprehensive neurophysiological monitoring therefore represents an important component of individualized disease management and contributes substantially to optimization of therapeutic strategies, prediction of neurological outcomes, and long-term assessment of disease progression in patients with multiple sclerosis.

Keywords: Multiple sclerosis, multimodal evoked potentials, visual evoked potentials, somatosensory evoked potentials, motor evoked potentials, neurophysiology,

demyelination, neurodiagnostics, magnetic resonance imaging, neurological monitoring

1. Introduction

Multiple sclerosis represents one of the most common chronic inflammatory demyelinating disorders affecting the central nervous system and is characterized by multifocal lesions involving the brain, spinal cord, optic nerves, and cerebellar pathways. The disease primarily affects young adults and demonstrates highly variable clinical manifestations including visual impairment, sensory disturbances, motor weakness, coordination abnormalities, fatigue, cognitive dysfunction, and progressive neurological disability. Pathophysiological mechanisms involve autoimmune-mediated destruction of myelin sheaths, inflammatory infiltration, gliosis, axonal degeneration, and disruption of neuronal conduction within central nervous system pathways. Disease progression frequently leads to cumulative neurological impairment and reduced quality of life despite advances in immunomodulatory treatment. Early identification of disease activity and accurate monitoring of neurological deterioration remain essential for therapeutic optimization and prevention of irreversible axonal damage. Magnetic resonance imaging currently represents the principal diagnostic tool for visualization of demyelinating lesions and assessment of inflammatory activity in multiple sclerosis. However, structural neuroimaging alone may not fully reflect functional impairment or subclinical conduction abnormalities affecting sensory and motor pathways. Neurophysiological techniques such as multimodal evoked potentials provide objective assessment of functional integrity and conduction velocity within neural pathways frequently involved in demyelinating processes. Evoked potentials measure electrophysiological responses generated by the nervous system following sensory or motor stimulation and therefore allow evaluation of conduction abnormalities associated with demyelination and axonal injury. Visual evoked potentials are among the most sensitive neurophysiological methods for detecting optic nerve dysfunction and are especially valuable in patients with optic neuritis or subclinical visual pathway involvement. Delayed P100 latency reflects slowed conduction caused by demyelination within optic pathways and may persist even after clinical recovery of visual function. Somatosensory evoked potentials evaluate dorsal column-medial lemniscus pathways and provide important information regarding sensory conduction abnormalities affecting spinal and cerebral structures. Brainstem auditory evoked potentials assess auditory conduction through brainstem nuclei and are useful for identification of subclinical lesions involving posterior fossa structures. Motor evoked potentials evaluate corticospinal tract integrity through transcranial magnetic stimulation and provide valuable information regarding motor pathway dysfunction, axonal degeneration, and disability progression. Combination of these neurophysiological modalities into a multimodal evoked potential battery significantly improves sensitivity for detecting disseminated central nervous system involvement compared with isolated electrophysiological studies. Multimodal assessment additionally allows monitoring of disease progression, evaluation of treatment response, and identification of subclinical neurological deterioration before manifestation of overt clinical relapse. Neurophysiological abnormalities frequently correlate with disability scores, lesion burden on magnetic resonance imaging, cognitive impairment, and long-term neurological prognosis. Contemporary developments in electrophysiological technology, computerized signal averaging, digital analysis, and neurodiagnostic methodology have considerably improved precision and reproducibility of evoked potential studies in multiple sclerosis follow-up. Integration of multimodal evoked potentials with neuroimaging, immunological biomarkers, and clinical neurological assessment therefore provides comprehensive evaluation of disease activity and contributes significantly to individualized management of patients with multiple sclerosis.

2. Materials and Methods

The study involved comprehensive neurophysiological evaluation of patients diagnosed with relapsing-remitting and progressive forms of multiple sclerosis according to established clinical and radiological diagnostic criteria. Neurological examination included assessment of sensory disturbances, visual dysfunction, motor weakness, coordination abnormalities, reflex changes, gait impairment, and disability progression using standardized neurological disability scales. Magnetic

resonance imaging of the brain and spinal cord was performed to evaluate demyelinating lesions, inflammatory activity, cerebral atrophy, and spinal involvement. Multimodal evoked potential studies included visual evoked potentials, somatosensory evoked potentials, brainstem auditory evoked potentials, and motor evoked potentials. Visual evoked potentials were recorded following pattern-reversal visual stimulation and analysis of P100 latency and amplitude. Somatosensory evoked potentials were obtained through peripheral nerve stimulation with assessment of central sensory conduction time and waveform abnormalities. Brainstem auditory evoked potentials were recorded using auditory click stimulation to evaluate conduction through auditory pathways and brainstem nuclei. Motor evoked potentials were performed through transcranial magnetic stimulation with measurement of central motor conduction time and corticospinal tract integrity. Comparative analysis was conducted between neurophysiological findings, magnetic resonance imaging abnormalities, clinical disability scores, disease duration, and therapeutic response.

3. Results

Neurophysiological evaluation demonstrated significant abnormalities across multiple sensory and motor pathways in patients with multiple sclerosis. Visual evoked potentials revealed prolonged P100 latency and reduced waveform amplitude in a substantial proportion of patients, indicating optic nerve demyelination and impaired visual conduction even in individuals without recent optic neuritis. Somatosensory evoked potentials demonstrated delayed central sensory conduction time, abnormal cortical responses, and impaired dorsal column transmission associated with spinal cord and sensory pathway involvement. Brainstem auditory evoked potentials revealed prolonged interpeak latencies and abnormal wave morphology reflecting subclinical demyelinating lesions within auditory pathways and brainstem structures. Motor evoked potentials demonstrated prolonged central motor conduction time, reduced motor response amplitude, and corticospinal tract dysfunction correlating with motor weakness and disability progression. Combination of multimodal evoked potential studies significantly increased detection of subclinical lesions compared with isolated electrophysiological assessment. Neurophysiological abnormalities frequently corresponded with lesion distribution observed on magnetic resonance imaging and additionally identified functional conduction disturbances not fully visible through structural neuroimaging. Patients with progressive disease forms demonstrated more pronounced abnormalities across multimodal evoked potential studies compared with relapsing-remitting disease. Longitudinal follow-up revealed worsening conduction abnormalities in association with clinical progression and increased neurological disability. Improvement or stabilization of electrophysiological parameters was observed in several patients receiving effective immunomodulatory therapy. Comprehensive neurophysiological evaluation demonstrated widespread conduction abnormalities affecting visual, sensory, auditory, and motor pathways in patients with multiple sclerosis. Visual evoked potentials revealed prolonged P100 latency, reduced waveform amplitude, and impaired visual conduction in a substantial proportion of patients, including individuals without recent episodes of optic neuritis. These findings indicated persistent demyelination and axonal dysfunction within optic pathways despite partial clinical recovery of visual function. Somatosensory evoked potentials demonstrated delayed central sensory conduction time, abnormal cortical responses, prolonged interpeak latencies, and impaired dorsal column transmission associated with spinal cord and sensory pathway involvement. Brainstem auditory evoked potentials revealed prolonged wave latencies and altered waveform morphology reflecting subclinical demyelinating lesions within auditory pathways and brainstem structures. Motor evoked potentials demonstrated prolonged central motor conduction time, reduced motor response amplitudes, impaired corticospinal tract conduction, and significant correlation with motor weakness and physical disability progression. Combination of multimodal evoked potential modalities significantly increased detection of subclinical lesions compared with isolated electrophysiological testing. Neurophysiological abnormalities frequently corresponded with lesion localization observed on magnetic resonance imaging while additionally identifying functional conduction disturbances not clearly visible through structural neuroimaging alone. Patients with progressive forms of multiple sclerosis demonstrated more severe and widespread electrophysiological abnormalities compared with individuals affected by relapsing-remitting disease. Longitudinal follow-up additionally revealed progressive worsening of conduction abnormalities associated with increased neurological disability and disease duration. Several patients receiving effective immunomodulatory therapy demonstrated stabilization or partial improvement of electrophysiological parameters suggesting reduced

inflammatory activity and functional recovery within affected neural pathways.

4. Discussion

The findings confirm that multimodal evoked potentials represent highly valuable neurophysiological tools for comprehensive evaluation and long-term monitoring of multiple sclerosis. Demyelinating lesions affecting visual, sensory, auditory, and motor pathways produce measurable conduction abnormalities that may persist even in clinically asymptomatic individuals. Visual evoked potentials remain particularly sensitive for detection of optic nerve involvement and frequently reveal subclinical demyelination despite absence of active visual symptoms. Somatosensory evoked potentials provide important information regarding spinal cord dysfunction and sensory pathway impairment frequently associated with progressive disease forms. Brainstem auditory evoked potentials contribute to identification of clinically silent lesions involving posterior fossa structures, whereas motor evoked potentials offer objective assessment of corticospinal tract degeneration and motor disability progression. Integration of multiple electrophysiological modalities substantially improves diagnostic sensitivity and allows evaluation of disseminated central nervous system involvement characteristic of multiple sclerosis. Neurophysiological abnormalities often correlate with magnetic resonance imaging findings, disability progression, and clinical severity; however, evoked potentials additionally provide unique functional information not always detectable through structural imaging alone. Multimodal electrophysiological assessment therefore contributes significantly to identification of subclinical disease activity, monitoring of therapeutic response, and prediction of long-term neurological prognosis. Contemporary advances in digital electrophysiology and signal processing have enhanced accuracy, reproducibility, and clinical applicability of evoked potential studies. Ongoing research increasingly focuses on integration of multimodal neurophysiological data with neuroimaging biomarkers, immunological parameters, and cognitive assessment to improve individualized disease monitoring and therapeutic decision-making in multiple sclerosis.

5. Conclusion

Multimodal evoked potentials constitute an important neurophysiological battery for comprehensive follow-up and functional assessment in patients with multiple sclerosis. Visual, somatosensory, auditory, and motor evoked potentials provide objective evaluation of demyelination, conduction abnormalities, axonal dysfunction, and dissemination of lesions throughout the central nervous system. Combined multimodal assessment significantly improves detection of subclinical neurological involvement and contributes to monitoring of disease progression and therapeutic effectiveness. Neurophysiological findings frequently correlate with clinical disability and magnetic resonance imaging abnormalities while additionally providing functional information not fully reflected by structural imaging. Integration of multimodal evoked potentials into routine neurological evaluation therefore enhances diagnostic precision, prognostic assessment, and long-term management of multiple sclerosis patients. Continued advances in electrophysiological technology and neurodiagnostic methodology will further strengthen the role of multimodal evoked potentials in contemporary multiple sclerosis care. Multimodal evoked potentials constitute an essential neurophysiological battery for comprehensive monitoring and functional assessment of patients with multiple sclerosis. Visual, somatosensory, auditory, and motor evoked potentials provide objective evaluation of demyelination, conduction abnormalities, axonal dysfunction, and dissemination of lesions throughout the central nervous system. Combined multimodal assessment significantly improves detection of subclinical neurological involvement and contributes to accurate monitoring of disease progression and therapeutic effectiveness. Electrophysiological findings frequently correlate with neurological disability and magnetic resonance imaging abnormalities while additionally reflecting functional impairment not fully detectable through structural neuroimaging alone. Integration of multimodal evoked potentials into routine neurological follow-up therefore enhances diagnostic precision, prognostic evaluation, and long-term management of multiple sclerosis. Continued advances in neurophysiology, digital electrophysiology, biomarker research, and neurodiagnostic technology will further strengthen the role of multimodal evoked potentials in modern multiple sclerosis care and individualized therapeutic planning.

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