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THE IMPACT OF MOTOR EVOKED POTENTIAL AMPLITUDE DECLINE DURING INTRAOPERATIVE SPINAL SURGERY MONITORING ON PATIENT OUTCOMES

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ABSTRACT

Introduction: Motor Evoked Potential (MEP) monitoring is essential in intraoperative neuromonitoring (IONM) for assessing motor tract integrity and predicting postoperative neurological deficits (PONDs) in spinal surgeries. A decline in MEP signals during surgery indicates potential neurological injury. This review assesses the impact of MEP amplitude decline on postoperative outcomes. **Objectives:** To evaluate the effectiveness of intraoperative MEP monitoring in predicting motor outcomes in spinal surgeries. **Materials and Methods:** A systematic review of PubMed, ScienceDirect, and Cochrane Library was conducted, adhering to PRISMA guidelines. The MINORS tool assessed study quality. The correlation between MEP amplitude changes and outcomes was synthesized qualitatively. **Results:** Of 15 identified studies, 7 cohort studies were analyzed. Significant MEP amplitude declines (≥80%) consistently correlated with higher postoperative motor deficits, while improvements indicated better recovery. **Conclusions:** MEP monitoring reliably predicts motor outcomes in spinal surgeries, allowing for intraoperative adjustments to prevent neurological complications. Further research is needed to optimize monitoring protocols and establish long-term outcome thresholds.

KEYWORDS: Motor-evoked potentials, intraoperative neurophysiological monitoring, IONM, spinal surgery, MEP amplitude decline, somatosensory evoked potentials, SSEP, neuroprotection, postoperative motor deficits, functional recovery.

INTRODUCTION

Motor Evoked Potential (MEP) monitoring is a vital component of intraoperative neuromonitoring (IONM).[1] MEPs are muscle action potentials that can be elicited through either transcranial stimulation (TcMEP) or trans spinal cord stimulation.[2] The ability to assess the functional integrity of motor circuits using MEPs, whether through invasive or noninvasive transcranial stimulation, is well-established. Notably, motor function operates independently of somatosensory function. MEPs are instrumental in monitoring the activity within the pyramidal tract, responding to stimuli originating from the neocortex, basal ganglia, and spinal cord, which then project to terminal nerve pathways.[3]

Motor pathways are stimulated using transcranial multi-pulse electrical stimulations, with recordings taken from needle electrodes inserted into the relevant muscles.[4] Noninvasive techniques such as MEP monitoring have become increasingly recognized as valuable diagnostic and predictive tools for various neurological conditions.[5] MEP monitoring proves beneficial in evaluating postoperative neurological deficits (PONDs) associated with spinal injuries. Research indicates that MEPs possess predictive qualities for PONDs in spinal surgeries, achieving a sensitivity of 83% and a specificity of 86%.[6] A decline in MEP signals observed during surgical procedures often indicates a primary neurological insult. It is important to note that perioperative factors—including the choice of anaesthetic agents, use of neuromuscular blockers, core temperature, oxygenation levels, and blood pressure—show minimal impact on MEP results.[7] One study reported a positive predictive value (PPV) of 12.9% and a negative predictive value (NPV) of 88% for MEPs in identifying new deficits.[8] Additional studies have demonstrated the utility of MEPs in predicting postoperative impairment in patients with cervical myelopathy, indicating a sensitivity of 71% and specificity of 94%.[9]

Moreover, MEPs have shown significant predictive capabilities regarding postoperative motor deficits following intradural extramedullary spinal tumour resections in pediatric patients. In a comprehensive study of 804 patients, 7.84% exhibited significant changes in MEP signals, while 4.6% developed PONDs.[6] However, ongoing discussions regarding the significance of MEP amplitude changes have prompted debate among experts. The observed variability in results related to MEP changes as prognostic indicators in spinal surgery may obscure the potential benefits of MEP monitoring. This systematic review aims to highlight the impact of MEP amplitude decline on patient outcomes in the context of spinal surgery.

MATERIALS AND METHODS

A systematic literature review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as outlined by Cochrane. This review involved a comprehensive search across three medical-scientific databases—PubMed, ScienceDirect, and the Cochrane Library—covering the period from January 2025 to February 2025. The search strategy was designed using the Population, Exposure, Comparison, and Outcomes (PECO) framework, as detailed in Table 1. The search utilized MeSH terms and keywords, including "spinal surgery," "motor evoked potential," "spinal decompression," "intraoperative monitoring," and "intraoperative neuromonitoring," respectively. Studies were included in the analysis only if they met the following criteria: published in English, full-text availability, and publication date after January 2015.

Table 1: Population, Exposure, Comparison, and Outcomes Search Strategy.

P (Population)	Individuals with spinal cord decompression regardless of its etiology (e.g. traumatic spinal cord injury, tumor, degenerative disease) undergoing intraoperative neurophysiological monitoring procedure
E (Exposure)	Changes in amplitude and latency of Motor Evoked Potentials
C (Comparison)	Documented MEP pre-surgery, during surgery or post-surgery
O (Outcome)	Functional and clinical outcome post-surgery regardless of its measurement instrument

RESULTS

A total of 30 records were initially retrieved from all databases (Fig. 1). After removing duplicates and applying filters for studies published from January 1, 2015, onward, 27 unique records remained. These records underwent title and abstract screening for eligibility, resulting in the exclusion of 13 studies that did not meet the predefined criteria. The full texts of the remaining 14 studies were reviewed in detail, and a backward citation search was conducted to identify any potentially relevant studies that may have been missed in the initial search. This process yielded one additional publication, bringing the total to 15 records. Of these, 8 studies were excluded due to lack of full-text availability, absence of direct use of intraoperative neurophysiological monitoring (IONM) for lead placement, or inappropriate outcomes (e.g., comparison of stimulator models) or study design.

The remaining seven studies were subjected to qualitative assessment using the Methodological Index for Non-Randomized Studies (MINORS) (Table 2). Intraoperative neurophysiological monitoring (IONM) techniques used for transcranial stimulator placement in these studies included Motor Evoked Potentials (MEPs) (n = 7), Somatosensory Evoked Potentials (SSEPs) (n = 4), or a combination of both modalities (n = 4). All included studies were cohort designs and utilized IONM under general anesthesia, with no comparisons made to an awake control group. Additional details on sample sizes, stimulation parameters, electrode types, and the number of columns per lead used are presented in Table 2, as reported in the individual studies.

MEP Monitoring in Spinal Surgery

Motor-evoked potential (MEP) monitoring is widely used during spinal surgeries to assess the functional integrity of motor pathways and predict postoperative neurological outcomes. MEP monitoring involves transcranial electrical stimulation, which elicits muscle responses, helping to detect any intraoperative neurological compromise. In this systematic review, seven cohort studies were analyzed to evaluate the correlation between MEP amplitude decline and postoperative patient outcomes.

Akbari et al. investigated 28 patients undergoing cervical spine surgery to assess the effects of intraoperative MEP and SSEP monitoring on functional recovery. Their findings indicated that patients showing intraoperative MEP improvement had significantly better outcomes, as measured by the modified Japanese Orthopaedic Association (mJOA) score ($P = 0.011$). MEP improvements were strongly associated with enhanced postoperative functional recovery, whereas patients without MEP improvement experienced poorer outcomes.

In a larger cohort study involving 723 patients, Kim et al. (2017) examined the relationship between intraoperative MEP amplitude declines and postoperative motor deficits. They observed that greater MEP amplitude reductions during surgery were significantly linked to an increased risk of both immediate and long-term motor deficits. These patients exhibited a worse prognosis, with a higher likelihood of immediate motor impairment and prolonged dysfunction.

Kim et al. (2024) studied 126 patients undergoing surgery for ossification of the posterior longitudinal ligament (OPLL) and reported that greater reductions in Tc-mMEP amplitude were closely associated with postoperative motor deficits (PMD). Specifically, they identified a 93% amplitude reduction as the optimal threshold for predicting deficits in cervical lesions, while a 50% reduction was used as the cutoff for thoracic lesions.

In a cohort of 38 pediatric patients undergoing complex cervical spine surgery, McDevitt et al. (2022) explored the relationship between intraoperative MEP/SSEP monitoring and functional outcomes. They found that significant MEP reductions (≥80%) were predictive of poorer postoperative motor function, as indicated by the Modified McCormick Scale (P = 0.002). Importantly, irreversible MEP declines were associated with lasting motor deficits, while reversible declines did not lead to permanent impairments.

In their study of 29 patients with cervical compressive myelopathy, Park et al. (2018) observed that significant intraoperative MEP amplitude declines correlated with worse short-term motor recovery. This was measured using the ASIA motor score and the Korean Modified Barthel Index (K-MBI). However, no significant differences were seen at 6 months, suggesting that MEP declines are more predictive of early recovery outcomes.

Similarly, Wang et al. (2016) evaluated 59 patients with cervical compressive myelopathy and demonstrated that intraoperative MEP amplitude improvement was a positive prognostic marker. Patients who experienced significant MEP improvements during surgery showed better recovery of motor and sensory functions, with higher mJOA scores compared to those who did not exhibit MEP changes or who experienced MEP deterioration.

Finally, Wang et al. (2015) conducted a study of 332 patients with preoperative spinal deficits and found that MEP amplitude declines (≥80%) were highly predictive of new postoperative spinal deficits. Rapid MEP signal loss during surgery was associated with both transient and permanent deficits, with a 100% sensitivity and 98.7% specificity for detecting spinal injury.

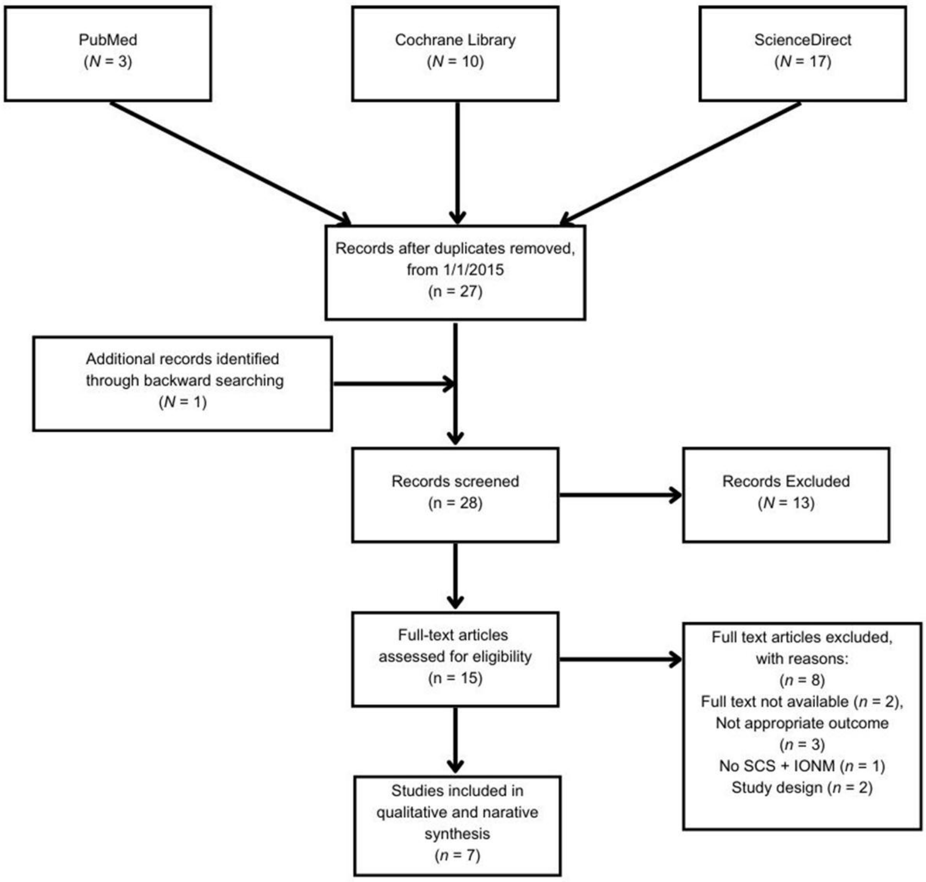

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. The diagram illustrates the number of records identified through the search strategy across the three databases—PubMed, Cochrane Library, and ScienceDirect—along with the sequential review process and eventual exclusion of studies.

Table 2: MINORS Performed In Human.

Author	Akbari et al. (2020)	Kim et al. (2017)	J. Kim et al. (2023)	McDevitt et al. (2022)	Park et al. (2018)	Wang et al. (2016)	Wang et al. (2015)
Item 1	2	2	2	2	2	2	2
Item 2	2	2	2	2	2	2	2
Item 3	2	0	0	0	0	2	0
Item 4	2	2	2	2	2	2	2
Item 5	1	2	1	1	2	1	1
Item 6	2	2	2	2	2	2	2
Item 7	2	0	0	0	0	0	0
Item 8	0	0	0	0	0	0	0
Item 9	0	0	0	0	0	0	0
Item 10	0	0	0	0	0	0	0
Item 11	0	0	0	0	0	0	0
Item 12	2	2	2	2	2	2	2
Total	15	12	11	11	12	13	11
The Methodological Index for Non-Randomized Studies (MINORS) includes several key criteria for evaluating study quality: a clearly stated aim (Item 1), inclusion of consecutive patients to avoid selection bias (Item 2), prospective data collection (Item 3), use of an appropriate endpoint aligned with the study's objectives (Item 4), unbiased evaluation of endpoints (Item 5), a follow-up period suitable for assessing the primary endpoint (Item 6), minimal loss to follow-up (≤5%) (Item 7), inclusion of a control group receiving the gold standard intervention (Item 8), use of contemporary groups (Item 9), baseline equivalence between groups (Item 10), prospective sample size calculation (Item 11), and statistical analyses tailored to the study design (Item 12).							

Table 3: Overview of Study Characteristics, End Points, and Stimulation Parameters for the Final Seven Records.

Author	No. of Patients	IONM Technique	End Points	Stimulation Parameters	Major Results
Akbari et al. (2020)[10]	28	MEP and SSEP	Nurick Grade Modified Japanese Orthopaedic Association (mJOA) Score Functional Recovery (motor, sensory, pain, grip, and release improvements)	MEP: 100-500V, Multipulse technique SSEP: Stimulated median and posterior tibial nerves	MEP improvement was significantly correlated with better mJOA scores (P = 0.011). Patients with improved MEPs during surgery had better functional recovery, suggesting a positive prognosis, while no MEP improvement correlated with poorer outcomes
Kim et al. (2017)[11]	723	MEP (Amplitude Decrement)	Immediate and 6-month postoperative motor deficits MRC score	MEP: 250–500V, 5 stimuli, 1 ms pulse duration, 2 ms interval	Greater MEP amplitude decline during surgery was associated with worse motor outcomes. Significant declines were correlated with an increased risk of immediate and long-term motor deficits, indicating poor prognosis.
J. Kim et al. (2023)[12]	126	Tc-mMEP	Postoperative motor deficit (PMD) MRC score	Tc-mMEP: 250-500V, 5 stimuli, 2-4 ms interval	A larger decline in Tc-mMEP amplitude correlated with a higher risk of postoperative motor deficit (PMD). A 93% reduction in

					cervical lesions and a 50% reduction in thoracic lesions were identified as the optimal cutoffs for predicting PMD
McDevitt et al. (2022)[13]	38	MEP and SSEP	Modified McCormick Scale (MMS) Sensorimotor function	MEP: 4-9 pulses, 50-75 µs pulse duration SSEP: 200-300 µs duration, 2.1-5.1 Hz	a
Park et al. (2018)[14]	29	MEP and SSEP	ASIA motor score K-MBI Score	MEP: Amplitude increase ≥50% and latency decrease ≥10% SEP: Median and tibial nerves	Significant MEP amplitude decline during surgery was associated with a worse short-term prognosis, including poorer motor recovery and functional outcomes. Patients with MEP improvement had better short-term recovery, while those with significant declines showed worse early postoperative symptoms
Wang et al. (2016)[15]	59	MEP	mJOA Score Neurological function improvement rate	MEP: Amplitude increase >50% Post- and pre-decompression amplitudes	A notable MEP amplitude decline correlated with worse neurological outcomes. Patients with MEP improvement had better early motor and sensory function recovery and improved mJOA scores compared to those without MEP changes or with MEP degeneration.
Wang et al. (2015)[16]	332	MEP	New spinal deficits Permanent vs transient deficits	MEP: 250-500V, 6-7 pulses, 200-400 µs pulse duration	Significant MEP amplitude decline (≥80%) was associated with a higher incidence of new spinal deficits (77.8%). Rapid MEP loss predicted both transient and permanent spinal deficits, with high sensitivity (100%) and specificity (98.7%)

DISCUSSION

This systematic review demonstrates a robust correlation between intraoperative MEP amplitude declines and postoperative motor outcomes in patients undergoing spinal surgery. Across all reviewed studies, significant reductions in MEP amplitude, particularly those exceeding 80%, were consistently associated with a higher incidence of postoperative motor deficits. For example, Kim et al. (2017) and Wang et al. (2015) reported that patients experiencing substantial MEP declines were at increased risk for both immediate and long-term motor dysfunction. Furthermore, Akbari et al. (2022) and Wang et al. (2016) observed that intraoperative MEP improvements correlated with better functional recovery, as evidenced by higher modified Japanese Orthopedic Association (mJOA) scores postoperatively. These findings underscore the predictive utility of MEP monitoring in intraoperative settings, enabling clinicians to anticipate postoperative neurological outcomes and adapt their surgical strategies accordingly. Across the studies analyzed, the consistent relationship between MEP changes and motor recovery reinforces the importance of MEP monitoring in improving surgical outcomes, particularly in spinal decompression procedures.

Our findings align with previous literature that emphasizes the critical role of MEP monitoring in predicting postoperative outcomes in spinal surgery. For instance, Deletis and Sala (2019) highlighted the prognostic value of intraoperative MEP declines, noting that a reduction greater than 80% in MEP amplitude is a strong predictor of postoperative motor deficits in cervical spine surgery.[17] Liu et al. (2024) investigated the utility of somatosensory- and motor-evoked potentials in predicting neurological outcomes in patients with ossification of the posterior longitudinal ligament (OPLL) and ossification of the ligamentum flavum (OLF) undergoing spinal surgery. Their results concluded that MEP amplitude reductions during surgery were associated with poor functional recovery, emphasizing the importance of MEP monitoring in detecting impending neurological injury.[18] Similarly, Kwon et al. (2024) examined the relationship between intraoperative MEP improvement and postoperative neurological outcomes in patients with cervical compressive myelopathy, suggesting that greater intraoperative MEP improvements correlated with better postoperative recovery, thus underscoring the significance of MEP monitoring in surgical planning.[19] Guo et al. (2020) explored the relationship between intraoperative MEP changes and postoperative motor deficits in patients with cervical compressive myelopathy. Their findings indicated that failure to improve MEP signals during surgery was associated with a higher risk of long-term motor dysfunction, reinforcing the value of MEP monitoring in surgical decision-making.[20] Liu et al. (2023) investigated the variability of somatosensory evoked potential (SSEP) and MEP changes during spinal surgery and their predictive value for postoperative motor deficits. Their research revealed that while MEP changes were predictive of short-term postoperative motor deficits, their predictive value diminished over time, suggesting reduced accuracy in forecasting long-term functional outcomes.[21] This observation is consistent with the findings from our review, where some studies indicated that MEP monitoring is most effective in predicting early postoperative deficits, but its predictive value diminishes over extended follow-up periods.

Intraoperative monitoring of MEPs plays a pivotal role in spinal surgeries by providing real-time assessments of corticospinal tract integrity. MEP amplitude declines during surgery serve as valuable indicators of potential neurological compromise, allowing surgeons to promptly adjust their operative strategies to mitigate the risks of postoperative motor deficits. The ability to detect significant MEP reductions, often before any visible neurological impairment occurs, provides a critical window for preventive interventions that may enhance patient outcomes. For instance, Hsu et al. (2009) highlighted that a decline in MEP amplitude greater than 50% during spinal surgery is predictive of postoperative neurological decline, underscoring the importance of vigilant MEP monitoring to guide surgical decisions and improve patient prognosis.[22]

The efficacy of MEP monitoring is particularly significant in high-risk spinal procedures, where prompt surgical adjustments in response to intraoperative MEP changes can lead to improved functional recovery. In a study by Iorio et al. (2023), intraoperative neurophysiological monitoring (IONM) during spinal deformity correction was shown to reduce iatrogenic injury in both pediatric and adult populations. The study emphasized that MEP monitoring provides real-time feedback on spinal cord function, enabling immediate surgical adjustments to prevent neurological deficits.[23] This finding corroborates the results of our review, wherein greater MEP amplitude declines were strongly associated with poorer postoperative outcomes.

Early identification of MEP deterioration during spinal surgeries is essential for preventing irreversible neurological damage. Intraoperative MEP monitoring facilitates real-time assessment of spinal cord function, allowing for prompt surgical adjustments in response to changes in MEP signals. Early intervention in response to MEP deterioration can prevent permanent spinal damage, emphasizing the importance of timely adjustments during surgery. Additionally, improvements in MEP signals during surgery are positively correlated with better functional recovery, underscoring the significance of continuous neurophysiological monitoring in predicting postoperative outcomes.[23]

Despite the compelling evidence supporting the use of MEP monitoring in spinal surgeries, several limitations must be considered in this review. First, many of the studies included were retrospective cohort designs, which are subject to inherent biases such as selection and recall bias. Retrospective studies rely on historical data, which may not account for all relevant factors influencing intraoperative monitoring and postoperative outcomes. Future prospective, randomized studies are needed to validate the thresholds and predictive value of MEP amplitude declines observed in this review.

Secondly, variability in MEP monitoring protocols across studies may influence the comparability of results. The interpretation of MEP signals requires both expertise and consistency. Differences in the analysis and understanding of MEP data can lead to varied conclusions regarding neural function. Standardized guidelines and protocols are essential for ensuring consistent interpretation of MEP signals across clinical environments. The American Clinical Neurophysiology Society (ACNS) has developed guidelines on transcranial electrical stimulation motor evoked potentials, which provide standardized protocols for MEP monitoring.[24]

To further validate the findings from this review, future research should focus on conducting prospective, multi-centre trials to assess the efficacy of MEP monitoring in spinal surgery. These studies should aim to standardize MEP monitoring protocols, including stimulation parameters, amplitude thresholds, and methods of signal interpretation, in order to minimize variability between centers. Moreover, establishing clear and widely accepted cutoff values for MEP amplitude declines would enable more consistent prediction of postoperative outcomes across different patient populations and surgical procedures.

CONCLUSION

This review confirms the predictive value of MEP amplitude declines during spinal surgery. Significant declines, especially those over 80%, strongly correlate with postoperative motor deficits, while MEP improvements during surgery are linked to better outcomes. MEP monitoring allows for real-time identification of potential neurological damage, helping to prevent postoperative complications. Although effective for predicting short-term outcomes, further research is needed to evaluate its long-term utility and to standardize monitoring protocols.

AUTHOR CONTRIBUTIONS

Wijaya K.O.: study design, data collection, and manuscript preparation; Utomo N.P., Bagaskara A.T., and Sadjiman E.B.: literature search and data collection; Wijaya K.O.: analysis of data; Sadjiman E.B.: study design and review of manuscript. All authors contributed to data analysis, drafting, and revising the paper and agreed to be accountable for all aspects of the work.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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