ORIGINAL ARTICLE

The Frequency of Motor Evoked Potential Alerts During Lumbar Spinal Surgeries

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ABSTRACT

Background: Spinal surgery is associated with a high rate of neurological sequelae due to damage to the spinal nerve roots. This study aims to determine the most common alert type during lumbar spinal surgeries, including either anesthetic/physiological, positioning, or surgical.

Methods: We retrospectively reviewed 1,159 extradural spinal surgeries with intraoperative neurophysiological monitoring (IONM) from January 2019 to March 2021 to evaluate the incidence of events. We analyzed the Motor Evoked Potentials (MEP) alerts and changes in the neurophysiological signals. Cases were categorized by procedure type, muscles, and then by the level (upper; or lower) that the MEP alert occurred.

Results: 131 of 1159 (11.3%) surgeries had an intraoperative MEP alert (55% female and 45% males). An MEP alert occurred with a possible risk of post-operative deficit, and 56% of those MEP alerts were due to anesthesia/pharmacological intervention. 50 of the 131 cases had multiple muscle group alerts. Of the five muscle groups we reviewed, quadriceps were most likely to cause an alert. However, the tibialis anterior is most at risk as loss of MEP to this muscle could lead to foot drop. Twenty-seven of the 131 cases had MEP alerts resolved intraoperatively by either repositioning, adjustment in anesthesia, or surgical action. Pre-existing conditions were not considered in this study. The MEP had a greater incidence than somatosensory evoked potentials (SSEP) and electromyography (EMG) in detecting intraoperative and postoperative neurological deficits, especially those involving a single nerve root.

Conclusion: During extradural lumbar procedures, MEPs provide accuracy to be required as a modality as SSEP and s-EMG lack the sensitivity that could lead to false negatives. MEPs allow for prompt, timely investigation, and initiation of intervention by the surgical team to mitigate the possible deficit. Though MEPs could lead to false positive alerts, this can be easily adjusted by correcting alert criteria. Utilization of a multimodal intraoperative neuromonitoring intervention avoided postoperative neurologic deficits in most cases. Our data shows that the overall incidence of MEP is higher in detecting nerve root injuries during lumbar spine surgeries than in SSEP and EMG. We recommend adding the MEP modality to the multimodality IONM protocol for all lumbar surgeries to minimize nerve root injuries and postoperative deficits.

INTRODUCTION

Approximately 0.2 to 31% of spinal surgeries result in neurological sequelae due to damage to the spinal nerve roots [1]. Incidence following lumbar fusion surgeries exceeds 25%. The gold standard approach used for Scoliosis correction surgeries is the posterior (back) approach and applies to most patients with scoliosis (Figure 1). The posterior column correction surgeries require pedicle screws for posterior column fixation. Due to the trajectory of the screw and its proximity to the spinal cord, these screws pose a higher risk of damaging sensory and motor pathways. Among the most injured nerve roots in posterior column surgeries are those that innervate the tibialis anterior and/or the extensor hallucis longus, ultimately leading to foot drop. The highest incidence of surgical events was in the lateral lumbar approach at 21.3%. The lowest number of surgical events was observed with the anterior lumbar approach.

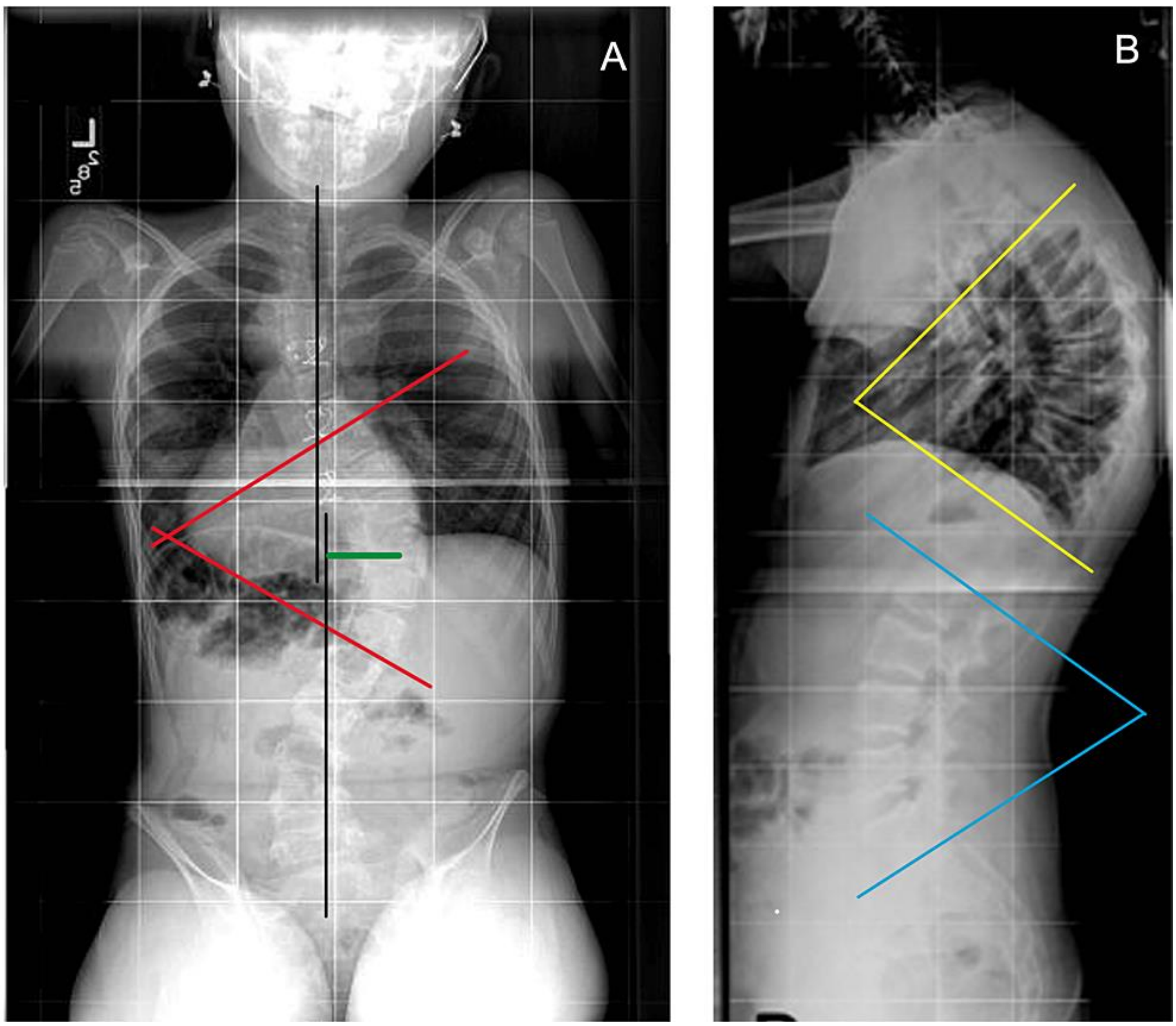

Figure 1: Representative radiographs with measurements.

A: Red angle - coronal Cobb angle; upper black line - C7 plumb line; lower black line - central sacral line; green line - apical vertebral translation; distance between black lines - global coronal balance.

B: Yellow angle - thoracic kyphosis; blue angle - lumbar lordosis [2].

Multimodal Intraoperative Neurophysiologic Monitoring (MIONM) has been routinely used to reduce the neurological complications of spinal surgery, providing a more sensitive and specific analysis [1,3]. During surgery, certain electrophysiological modalities such as Somatosensory Evoked Potentials (SSEP), Spontaneous Electromyography (S-EMG), Triggered Electromyography (T-EMG), Transcranial electrical Motor Evoked Potentials (MEP), Train of Four (TOF) and Electroencephalography (EEG) are utilized to monitor the functional integrity of various neuronal structures, such as the central and peripheral nervous systems. Therefore, a multimodality approach using SSEP, TCeMEP, EMG, and TOF can be incorporated during lumbar surgeries for early detection and prevention of injury to these pathways.

This paper aims to determine the frequency of MEP alerts during lumbar spinal surgeries, including either anesthetic/physiological, positioning, or surgical. It also identifies the type of surgical approach and the muscles with the highest incidence of alerts. In addition, it was to ascertain the modality with the highest incidence of alerts.

METHODS

Patient selection

All patients undergoing extradural lumbar spine surgeries such as posterior lumbar, lateral lumbar, anterior lumbar, sacral, and 360/540 procedures were included in this study. The patients consisted of 55% females and 45% males.

Anesthesia

All the surgeries were performed under Total Intravenous Anesthesia (TIVA) using propofol and remifentanil. In all procedures, short-acting neuromuscular blockers were only used for intubation. The level of muscle relaxant use was monitored by Train of Four (TOF) monitoring by stimulation of the posterior tibial nerve at the medial malleolus and recording abductor hallucis muscles in the feet bilaterally.

Intraoperative Neurophysiologic Monitoring (MIONM)

We retrospectively reviewed 1,159 extradural lumbar procedures with intraoperative neurophysiological monitoring (IONM) from January 2019 to March 2021 to evaluate the incidence of events. We reviewed the surgical events detected by intraoperative neurophysiological monitoring data changes. The surgical events included were the ones that required intraoperative intervention, a surgical pause, or preventive measures. We analyzed the Motor Evoked Potentials (MEP) alerts and changes in the neurophysiological signals (Figure 2). Cases were categorized by procedure type and then by the level (upper; or lower) that the MEP alert occurred.

The somatosensory (SSEP) function was monitored bilaterally by stimulating the ulnar and posterior tibial nerves. Bilateral ulnar and posterior tibial nerve stimulation was performed by placing adhesive surface electrodes at the wrist and medial malleolus for the upper and lower extremities. Standard stimulation parameters were used for SSEP, stimulating for a duration of 0.3 msec at a frequency of 2.66-3.79 hertz (Hz), with the ulnar nerve stimulated at 15-25 mA and posterior tibial nerves at 50-100 mA intensity. For SSEP recording, the subdermal needle electrodes were placed on the scalp according to the international 10-20 system at FPz, CPz, CP3, CP4, and 5th cervical spine (Cv5), Erb's point (EP), and the popliteal fossa (PF). The low-frequency filter was set up at 30 Hz, and the high-frequency filter was set up at 500 Hz for cortical and 1500Hz for subcortical and peripheral responses. To prevent any false positives and false negatives, the alarm criteria for SSEP were set as more than a 10% increase in latency or more than a 50% decrease in the amplitude of the waveforms [4].

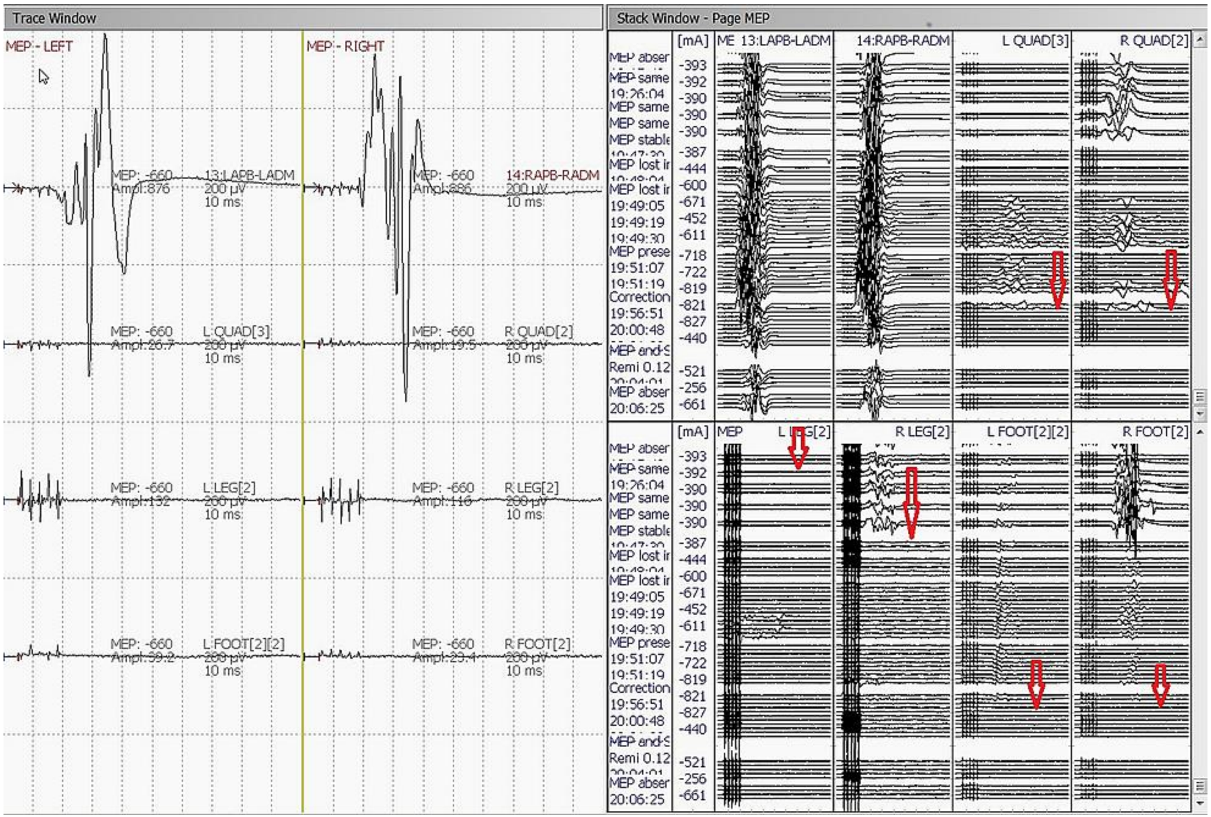

Figure 2. Loss of bilateral lower extremity motor-evoked potentials (TCeMEP) responses. Left: Average TCeMEP responses showing responses present in hand muscles with loss of responses in lower extremities. Right: Stack TCeMEP responses showing loss of lower extremity muscle responses. Source: www. Cureus.com (Reprinted with permission from Jahangiri et al. 2016). Notes: MEP: Motor Evoked Potentials, L: Left, R: Right, APB: Abductor Pollicis Brevis, ADM: Abductor Digiti Minimi, Quad: Quadriceps, LEG: Tibialis Anterior/Gastrocnemius, FOOT: Abductor Hallucis.

TCeMEP monitored the functional integrity of the corticospinal tracts and the nerve roots. The TCeMEP stimulation and recording were done according to the recommended guidelines [5]. For TCeMEP stimulation, corkscrew electrodes were placed on the scalp at C1, C2, C3, and C4. The TCeMEP stimulation parameters included monophasic square waves with five to seven trains, a pulse width of 50 or 75 µsec, and an intensity of 150-600 Volts. For recording the TCeMEP and EMG (both spontaneous and triggered), subdermal needle electrodes were placed bilaterally in abductor pollicis brevis, abductor digiti minimi in the upper extremities, and adductor brevis, quadriceps, tibialis anterior, gastrocnemius, abductor hallucis, and extensor hallucis brevis muscles in the lower extremities [6]. The low-frequency filters for TCeMEP and EMGs were set at 10 Hz, and the high-frequency filters at 5000 Hz. TCeMEP and triggered EMG sweep were set up at 10 msec/division (time base), whereas spontaneous EMG sweep was 300 msec/division. Triggered EMG was performed using a monopolar ball tip probe for pedicle screw stimulation and a monopolar fine tip for direct nerve stimulation. For TCeMEP, a significant alert was set at a 70% or more drop in amplitude, changes in signal morphology, and/or more than 100 volts increase in the stimulation threshold. An alert for EMG was set as sustained train activity or neurotonic discharges.

A two-channel scalp EEG was recorded during the entire procedure to monitor the depth of anesthesia. The bandpass filter setting for EEG was 0.5-70 Hz frequency. Sensitivity of 50-100 uV/division and recording sweep of 1000 ms/division [7].

Statistical Analysis

A chi-square test was applied to know the significant/insignificant difference in the distribution of procedure types, gender-wise alerts, and complications such as spondylolisthesis, myelopathy, spinal stenosis, and radiculopathy. A chi-square test of independence was applied between observed and expected values wherever applicable (i.e., procedures vs. average procedure time or alerts).

A logistic regression analysis was conducted to investigate whether there is an association between Stenosis and lower extremity (LE) MEP alerts. The predictor variable, stenosis in the logistic regression, explained significant variance in the dependent variable, LE alerts. The estimated odd ratio indicated that if the Stenosis increases by one unit, the odds of LE alerts increase. Therefore, Stenosis is a significant predictor of LE alerts.

A logistic regression analysis was conducted to investigate whether there is an association between body mass index (BMI) Procedure time and LE MEP alert. The logistic regression's predictor variables, BMI, and Procedure time explained significant variance in the dependent variable LE alerts. The estimated odd ratio indicated that if the BMI increases by one unit, the odds of LE alteration decrease. In contrast, the odd ratio of procedure time indicated that if procedure time increases by one unit, then the odds of LE alters increase. BMI and procedure time are significant predictors of LE alerts.

Results

A total of 1,159 cases were distributed based on gender and the types of procedures they underwent. 131 of 1159 (11.3%) surgeries had an intraoperative MEP alert. The male-to-female ratio was 45% to 55%. 27 of the 131 cases had MEP alerts resolved intraoperatively by either repositioning, adjustment in anesthesia, or surgical action. The types of procedures were statistically different by gender, as the cross-tabulation chi-square test was 28.74 (p-value < 0.00001). As per the chi-square test of independence association, a significant difference exists between the number of cases in different procedure types and their average times (p-value: 0). The measured effect size, phi, is substantial, measuring 0.54. The size of the Cramer V effect is 0.54. This implies that the size of the disparity between actual and predicted data is significant.

Procedures	**MEP Alerts**
Posterior Lumbar	**9.1%**
Lateral Lumbar	**16.4%**
Anterior Lumbar	**6.9%**
Sacral	**0%**
360/540	**10.9%**

Table 1: Incidence of alerts in correlation to procedure types.

Source: www.iomcworld.org (Reprint with permission of Umair et al. 2022).

Anesthesia has the highest incidence of MEP alerts, with the quadriceps most affected. Most MEP alerts were from the quadricep muscle group. Quadricep MEP alerts were primarily caused by anesthesia as shown in Table 1 and Figures 3-5.

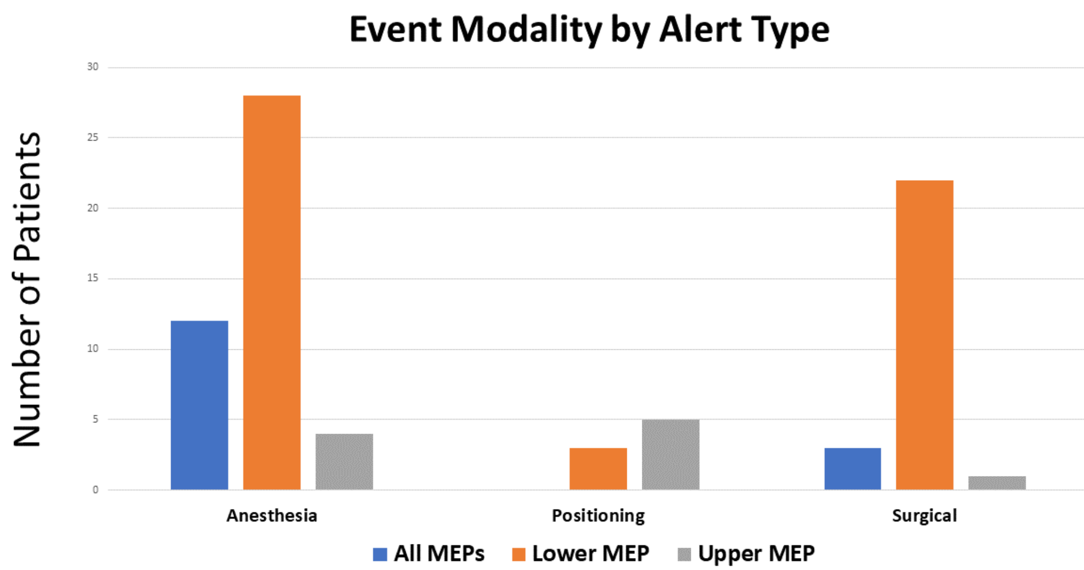

Figure 3. Event modality by alert type. This figure shows the number of patients with intraoperative alerts during lumbar surgeries. The three main categories of alerts recorded were changes in motor evoked potentials (MEP) data due to anesthesia, patient positioning, and surgically related. The changes described were either in the upper and lower extremities (All MEP), lower extremity (lower MEP), or upper extremity (Upper MEP). *Source: www.iomcworld.org (Reprint with permission of Umair et al. 2022)* [8].

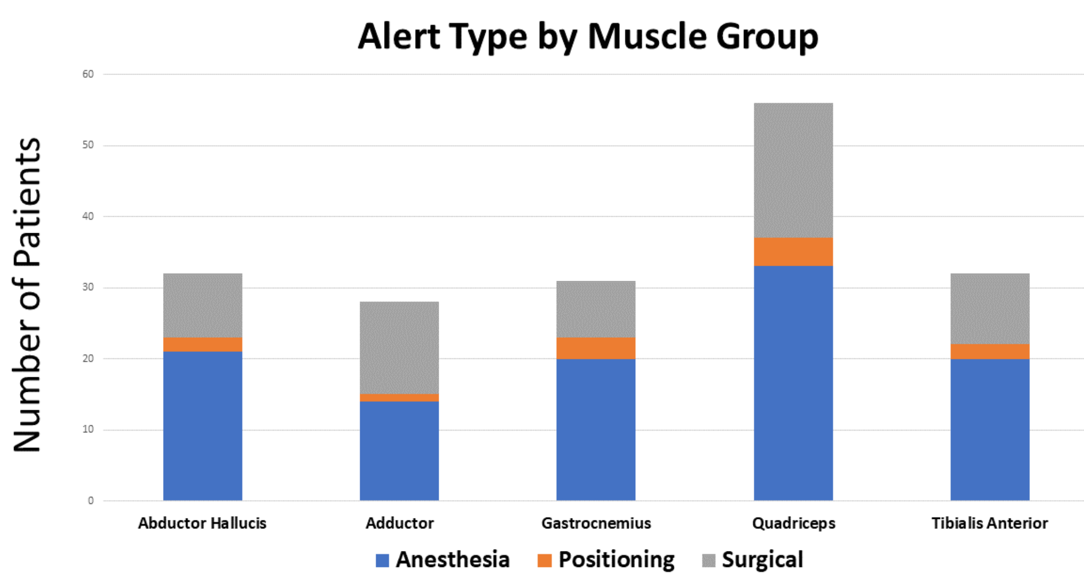

Figure 4. Event modality by muscle group. This figure shows the number of patients with intraoperative alerts by muscle groups during lumbar surgeries. The three main categories of alerts were changes in motor evoked potentials (MEP) data due to anesthesia, patient positioning, and surgically related. The muscle groups recorded were abductor hallucis, adductor brevis, gastrocnemius, quadriceps, and tibialis anterior. *Source: www.iomcworld.org (Reprint with permission of Umair et al. 2022)* [8].

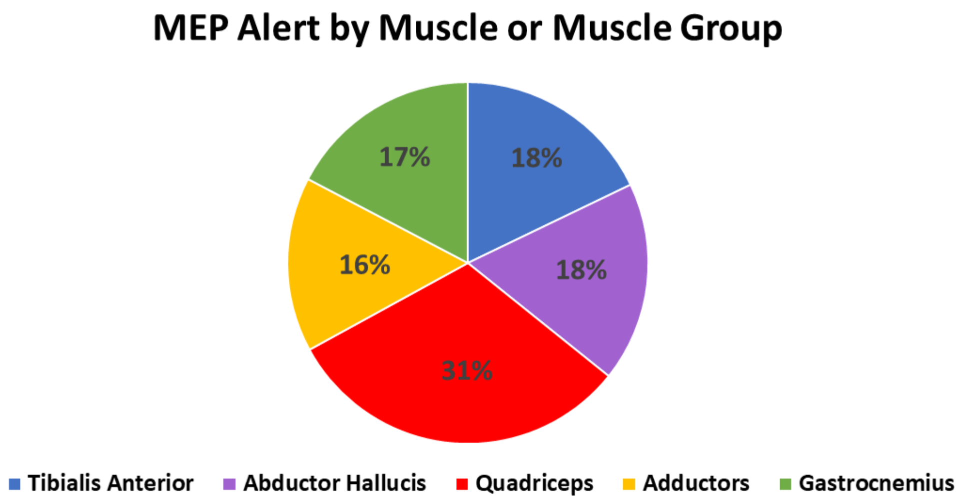

Figure 5. Motor evoked potential alerts by muscle or muscle group. This figure shows the percentage of patients with intraoperative alerts by muscle groups during lumbar surgeries. The muscle groups recorded and described were adductor brevis (16%), gastrocnemius (17%), tibialis anterior (18%), abductor hallucis (18%), and quadriceps (31%). *Source: www.iomcworld.org (Reprint with permission of Umair et al. 2022)* [8].

DISCUSSION

Even though surgical stabilization of the spinal cord is a common procedure, it is associated with a high rate of neurological complications due to the incorrect placement of the screws and rods [9]. The rate of malpositioned screws has been reported to be as high as 15.7% [10]. The use of multimodal intraoperative neuromonitoring (MIONM) in the present study proved useful in identifying signs of significant neurological changes during surgery. Monitoring the MEP may have helped reduce the overall morbidity by encouraging intraoperative modifications to the procedure.

During Lumbar Spinal Surgeries, a multimodality approach for IONM is most commonly used and includes SSEP, TCeMEP, and EMG. These are utilized to monitor the functional integrity of various neuronal structures, such as the central and peripheral nervous systems. Every modality used has its sensitivity and specificity and limitations and advantages [11]. However, EMG is of limited use for monitoring spinal nerve root function. By contrast, MEPs provide a continuous assessment of spinal nerve function as the procedure proceeds. It is preferable to use SSEP to detect ischemia in sensory pathways. At the same time, MEP, on the other hand, is most useful when monitoring ischemic damage in motor pathways during corrective spinal surgeries. [12-13]. When it comes to SSEP monitoring, it is often used continuously, while TCeMEP is often used intermittently during the instrumentation and correction phases of the surgery [14].

SSEPs can detect nerve root injuries, but the overall sensitivity of SSEPs during posterior spinal surgeries is reported to be low [15]. The few limitations/reasons responsible for the decreased sensitivity include, firstly, SSEPs cannot detect injuries in the nerve root of just one nerve; secondly, SSEPs do not monitor motor function directly; and thirdly, injury to nerves derived from multiple nerve roots may not affect the amplitude of the response to a level that warrants an alert [15]. Compared to EMG and SSEPs, MEPs are more sensitive in detecting intraoperative and postoperative neurological deficits, especially those involving a single nerve root, and can detect postoperative neurological deficits more efficiently. Nevertheless, the sensitivity of MEPs can also be limited by several factors. These include the muscle being supplied by more than one nerve, the transcranial stimulation of the corticospinal tract that leads to the activation of the motor neurons, the inherent variability present in the amplitude, threshold, and morphology of MEPs, as well as the effects of anesthesia and systemic factors on MEP response parameters [16]. The diagnostic skills of the IONM team and the communication between the surgical, anesthetic, and IONM teams also play a pivotal role in the justification of the TCeMEP.

CONCLUSION

Our data shows that the overall incidence of MEP is higher in detecting nerve root injuries during lumbar spine surgeries than in SSEP. S-EMG may provide additional alerts before any MEP change. Although MEP and SSEP are performed with a multimodality approach, they provide the highest alerts and possible sensitivity and specificity. In this study, multimodality intraoperative intervention avoided postoperative neurologic deficits in most cases. We recommend adding the MEP modality to the multimodality IONM protocol for all lumbar surgeries to minimize nerve root injuries and postoperative deficits.

During extradural lumbar procedures, MEPs provide accuracy that is required as a modality as SSEP and s-EMG lack the sensitivity that could lead to false negatives. MEPs allow for prompt, timely investigation and initiation of intervention by the surgical team to mitigate the possible deficit. Though MEPs could lead to false positive alerts, this can be easily adjusted by correcting alert criteria. Utilization of a multimodal intraoperative neuromonitoring intervention avoided postoperative neurologic deficits in most cases. Our data shows that the overall incidence of MEP is higher in detecting nerve root injuries during lumbar spine surgeries than in SSEP and EMG. We recommend adding the MEP modality to the multimodality IONM protocol for all lumbar surgeries to minimize nerve root injuries and postoperative deficits.

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