Human motor evoked potential responses following spinal cord transection: an in vivo study

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Motor evoked potential (MEP) monitoring has been used increasingly in conjunction with somatosensory evoked potential monitoring to monitor neurological changes during complex spinal operations. No published report has demonstrated the effects of segmental spinal cord transection on MEP monitoring.

The authors describe the case of an 11-year-old girl with lumbar myelomeningocele and worsening thoracolumbar scoliosis who underwent a T11–L5 fusion and spinal transection to prevent tethering. Intraoperative MEP and somatosensory evoked potential monitoring were performed, and the spinal cord was transected in 4 quadrants. The MEPs were lost unilaterally as each anterior quadrant was sectioned.

This is the first reported case that demonstrates the link between spinal cord transection and MEP signaling characteristics. Furthermore, it demonstrates the relatively minor input of the ipsilateral ventral corticospinal tract in MEP physiology at the thoracolumbar junction. Finally, this study further supports the use of MEPs as a specific intraoperative neuromonitoring tool. (10.3171/2010.3.FOCUS09201)

KEY WORDS • motor evoked potential • neurophysiological monitoring • spinal cord transection
that demonstrate that MEPs directly assay the integrity of the corticospinal motor pathways. Additionally, data elucidating the effect of the ipsilateral ventral corticospinal tract on MEP recordings are lacking. Finally, no published reports have detailed changes in MEPs following documented human spinal cord transection.

Case Report

History and Presentation. This 11-year-old girl was born with a lumbar myelomeningocele that was repaired at birth. She subsequently had neither sensory nor useful motor function in her lower extremities and no bowel or bladder sphincter function. Her thoracolumbar scoliosis was increasing, and it was beginning to cause respiratory compromise and skin breakdown; thus, surgery was recommended.

Operation. The patient subsequently underwent a thoracolumbar fusion from T-11 to L-5 with anterior and posterior fixation. As part of this procedure, the spinal cord was transected to prevent tethering and loss of upper-extremity function as a result of curvature correction.

Monitoring. Neurophysiological monitoring was used to monitor both tibial nerve SSEPs and transcranial electrical MEPs. The SSEP stimulation was a 0.2-msec duration pulse delivered to the tibial, medial, and ulnar nerves at 2.35 Hz with an intensity of 15–30 mA. The SSEPs were recorded at the midline scalp (Cz′-Fz) and contralateral scalp (C3′-Fz, C4′-Fz). Transcranial electrical MEP stimulation was an anodal pulse delivered to the contralateral scalp (C3 or C4) with a 0.05-msec duration pulse in a train of 6 pulses at an intensity of 250 V. The MEPs were recorded from the thenar and abductor hallucis muscles (or tibialis anterior).

The spinal cord was transected in stages via posterior laminectomy. The dorsal column quadrants were transected first, followed by the right anterior quadrant and then the left anterior quadrant.

Monitoring Results. The following baseline neurophysiological observations were made. Stable ulnar and median nerve SSEPs were obtained throughout the procedure. Tibial SSEPs could not be recorded. Thenar MEPs were recorded at baseline and throughout the procedure. The abductor hallucis MEPs were recorded at baseline but with much reduced amplitudes, consistent with pre-existing pathology.

When the posterior columns were transected, lower-extremity MEPs remained present (Fig. 1, transected quadrants 1 and 2). After transection of the right anterior quadrant, the right tibial MEPs disappeared, and the left tibial responses remained present (Fig. 1, transected quadrant 3). After spinal cord transection was completed with transection of left anterior quadrant (Fig. 1, transected quadrant 4), the left tibial MEP responses also disappeared (Fig. 2).

Discussion

This is the first reported case in which MEP responses have been demonstrated in spinal cord transection. It demonstrates that MEPs do not respond to dorsal column disruption. Furthermore, MEPs were able to distinguish transection of the right from the left anterior spinal cord. Finally, the case does not provide evidence of a clinically significant ipsilateral corticospinal tract effect given our MEP results.

Despite the absence of functional motor activity in our patient’s lower extremities, she did demonstrate markedly reduced but indeed intact corticospinal connectivity as measured by MEP monitoring that disappeared upon transection. This presence of signals in the setting of a clinical lack of function is likely due to long-standing deconditioning related to extremity disuse. As such, this case also illustrates the need for additional studies regarding the critical thresholds of MEP change since functional motor status was absent in the presence of MEPs prior to transection. These studies would be important as our data indicate that it might be possible to lose significant lower-extremity function from an intraoperative injury yet still have some MEP signals. Nevertheless, MEP monitoring should be regarded as a reliable proxy of corticospinal function in cases in which possible intraoperative injury to the anterior spinal cord is a concern.

The combination of MEP and SSEP monitoring was successful in this case. Motor evoked potentials can be recorded rapidly with brief stimulation, unlike SSEPs, which require signal averaging. Furthermore, MEPs may be more sensitive to ischemia than SSEPs and less likely to deteriorate after midline myelotomy, unlike SSEPs. Also, as demonstrated in this case, not only will MEPs often be present in neurologically compromised patients, but they may also be able to detect subclinical deficits, whereas SSEPs are significantly more likely to be absent in the normal and compromised neurological states. In a recent prospective trial, 38.7% of patients undergoing a variety of spinal procedures had either significantly diminished or absent tibial SSEPs. However, no patients with absent MEPs had useful SSEP signals. In this same study, the addition of MEPs to the
Monitoring scheme meant that only 3.8% versus 26.9% could not be monitored during their surgery.

To achieve aggressive resections or corrections in complex spine and spinal cord surgeries while also minimizing the possibility of intraoperative neurological deficit requires reliable neurophysiological monitoring that accurately identifies transient injury in real time to operating surgeons. As discussed above, SSEPs alone are not consistently present in many patient populations with baseline neurological compromise. However, in multimodality intraoperative monitoring (MIOM) with MEPs, the number of patients who can be monitored increases and provides further diagnostic information that should be part of the surgical armamentarium. A study by Hsu et al. demonstrated a low false-positive rate of 2.8% and a false-negative rate of 0%, suggesting that multimodality intraoperative monitoring represents the ideal confluence of intraoperative neurophysiological monitoring techniques available to protect patients from intraoperative injury.

**Fig. 2.** Recordings of the bilateral tibial nerve–gastrocnemius muscle MEPs, demonstrating that MEPs remained after the posterior columns were transected. The potentials disappeared after the corresponding anterior quadrant was transected.

**Conclusions**

This case demonstrates for the first time in a human that MEPs can directly predict unilateral loss of signal by transection of individual spinal cord quadrants. Therefore, MEPs can be considered as an additional tool for monitoring possible intraoperative spinal cord injury.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Acquisition of data: all authors. Analysis and interpretation of data: Ramakrishna, Nair, Kinney, Slimp, Ko, Avelino. Drafting the article: Ramakrishna, Nair. Critically revising the article: Ramakrishna.

References


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