Journal of Clinical Monitoring and Computing (2008) 22:319–326
DOI: 10.1007/s10877-008-9136-x

TRANSCRANIAL ELECTRIC MOTOR EVOKED POTENTIAL DETECTION OF COMPRESSIONAL PERONEAL NERVE INJURY IN THE LATERAL DECUBITUS POSITION

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Bhalodia VM, Sestokas AK, Tomak PR, Schwartz DM. Transcranial electric motor evoked potential detection of compressional peroneal nerve injury in the lateral decubitus position.
J Clin Monit Comput 2008; 22:319–326

ABSTRACT. The peroneal nerve is susceptible to injury due to compression at the fibular head for patients placed in the lithotomy, hemilithotomy or lateral decubitus positions during surgery. Upper extremity somatosensory and transcranial electric motor evoked potential monitoring has proven efficacious for identifying impending positional brachial plexopathy or upper extremity peripheral neuropathy in adult and pediatric patients undergoing spine surgery. We report on two cases to illustrate the usefulness of monitoring transcranial electric motor evoked potentials recorded from tibialis anterior muscle to identify emerging peroneal nerve compression secondary to lateral decubitus positioning.

KEY WORDS. peroneal nerve palsy, lateral decubitus position, intraoperative neurophysiological monitoring, motor evoked potentials, somatosensory evoked potentials.

INTRODUCTION

Neural injury secondary to intraoperative positioning is an unfortunate, but oftentimes preventable perioperative complication. The use of intermittent pneumatic pressure stockings [1–4] or placement in the lithotomy or hemilithotomy position during surgery has been associated with well-limb peroneal nerve palsy [5–7]. The lateral decubitus position may increase the risk for compartment syndrome and compressive peroneal nerve injury in the dependent leg [8, 9]. Consequently, despite efforts at careful positioning and limb padding, neurologic deficit as a result of intraoperative peroneal nerve compression remains problematic.

A number of studies have established the sensitivity of intraoperative ulnar nerve somatosensory evoked potentials (SSEP) to emerging brachial plexopathy or ulnar neuropathy secondary to positioning for cardiac [9–12] and spine surgery [13–18]. Kamel et al [17] performed a retrospective analysis of 1,000 consecutive spine surgeries during which upper extremity somatosensory evoked potentials were monitored for identification of positional brachial plexopathy or peripheral neuropathy. They found that the lateral decubitus and prone ''superman'' positions were associated with the highest incidence of position-related SSEP changes. Recently, Schwartz, et al. reported on the sensitivity of transcranial electric motor evoked potentials (tceMEP) to impending positional brachial plexopathy and upper extremity peripheral neuropathy in patients undergoing anterior cervical spine surgery [18].

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Received 30 July 2008. Accepted for publication 30 July 2008.

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In contrast to the number of studies and case reports lauding the benefits of upper extremity somatosensory evoked potential monitoring for the intraoperative detection of positional brachial plexopathy, there is a paucity of reports related to neurophysiological identification of position-related lower extremity peripheral nerve injury. We report on two cases to illustrate the benefits of monitoring transcranial electric motor evoked potentials (tceMEPs) recorded intraoperatively from tibialis anterior muscle to identify peroneal nerve compression secondary to lateral decubitus positioning.

CASE REPORTS

Case 1

A 65-year-old male initially presented with severe thoracic pain. Radiographic studies showed lesions in the thoracic and lumbar spines, with a compression fracture at T6. Magnetic resonance imaging studies showed retropulsion of bony fragments into the spinal canal. Physical exam revealed normal sensory and motor function in bilateral upper and lower extremities. This patient underwent a thoracotomy in the left lateral decubitus position and T6 corpectomy with interbody fusion.

The neurophysiological monitoring protocol included transcranial electric motor evoked potentials from bilateral first dorsal interosseous, rectus abdominis, quadriceps, tibialis anterior, and abductor hallucis muscles, as described elsewhere [19–25]. Cortical and sub-cortical somatosensory evoked potentials were recorded to interleaved stimulation of the left and right ulnar nerves, as well as to interleaved stimulation of the left and right posterior tibial nerves.

Anesthesia was maintained using a total intravenous anesthetic technique of propofol (100–250 mcg/kg/min) and remifentanil (0.05–0.5 mcg/kg/min) infusions, supplemented with boluses of midazolam (1–2 mg) as needed. Succinylcholine was used for intubation to facilitate rapid clearance of the neuromuscular junction for motor evoked potential monitoring during patient positioning. This total intravenous anesthesia protocol has been described in more detail elsewhere [23–25]

Prior to left lateral decubitus positioning, large-amplitude, bilaterally symmetrical transcranial electric motor evoked potentials were recorded from all monitored myotomes in the upper and lower extremities. There were no remarkable post-positioning changes in tceMEP and posterior tibial nerve SSEP amplitudes relative to pre-positioning as illustrated in Figures 1 and 2, respectively.

Prior to incision, a non-depolarizing paralytic agent (rocuronium 50 mg) was administered to facilitate surgical exposure, thereby precluding reliable tceMEP recordings as evidenced in Figure 3 by significant attenuation of abductor hallucis responses to train-of-four (TOF) electrical stimulation of the posterior tibial nerve. During this time, therefore, intraoperative monitoring was limited to somatosensory evoked potentials which remained stable and unchanged from pre-positioning baselines (Figure 2).

Upon adequate clearance of the neuromuscular junction, shown by return of four large responses to TOF stimulaton approximately 45 min following incision, tceMEP monitoring was resumed (see Figures 1, 3). At this time, motor evoked potentials from the majority of left and right lower extremity muscles were stable and consistent with baseline, indicative of uncompromised spinal cord function. Curiously, the tceMEP from left tibialis anterior muscle, though present, remained relatively attenuated. Peak-to-trough amplitude was approximately 200 μV, compared both to earlier responses measuring over 1,000 μV as well as those from right tibialis anterior muscle having amplitudes exceeding 600 μV, as illustrated in Figure 1.

Since the main focus of attention was on ensuring spinal cord integrity for a thoracic procedure, and since both the foot flexor tceMEP responses, as well as the cortical SSEPs to posterior tibial nerve stimulation remained stable bilaterally, thereby verifying intact spinal cord function, the incomplete return of left tibialis anterior muscle motor evoked potential amplitude after recovery from neuromuscular blockade was viewed as a puzzling anomaly. Moreover, since it remained stable for the balance of the procedure, albeit reduced in amplitude relative to baseline responses recorded prior to administration of neuromuscular blocking agent (see Figure 1), it was not considered clinically alarming. There were no other remarkable changes in the neurophysiological monitoring data during the surgical course.

Upon anesthesia emergence, the patient presented with profound left foot drop. Subsequent neurologic evaluation confirmed left peroneal nerve palsy, likely due to prolonged pressure on the nerve at the level of the fibular head. This gradually improved over the course of 9 months.

Case 2

A 39-year-old male presented initially with chief complaint of back pain secondary to osteomyelitis at T12 and L1. His past medical and surgical histories were unremarkable except for two previous lumbar discectomies. This patient underwent anterior T12 and L1 corpectomies

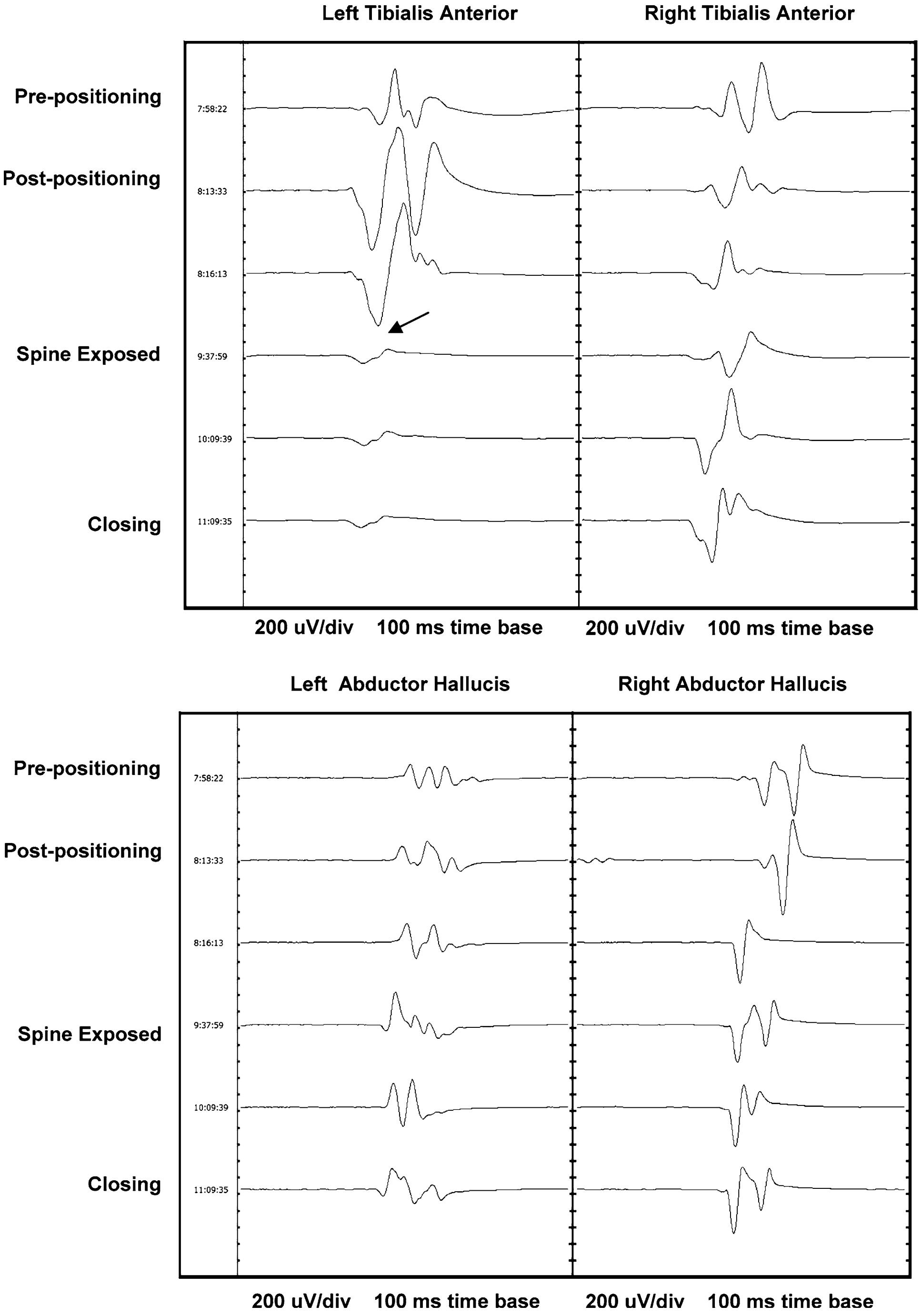

Fig. 1. Isolated decrease in motor evoked potential amplitude (marked by arrow) from the left tibialis anterior muscle in a 65-year-old male who underwent thoracotomy in the left lateral decubitus position (Case #1).

with interbody fusion and internal fixation in the right lateral decubitus position.

The neurophysiological monitoring protocol included transcranial electric motor evoked potentials from bilateral extensor carpi radialis, first dorsal interosseous, tibialis anterior and abductor hallucis muscles, as well as upper and lower extremity somatosensory evoked potentials, as described in case #1 and published elsewhere [19–25].

Anesthesia was maintained using a total intravenous propofol infusion (100–150 mcg/kg/min) supplemented

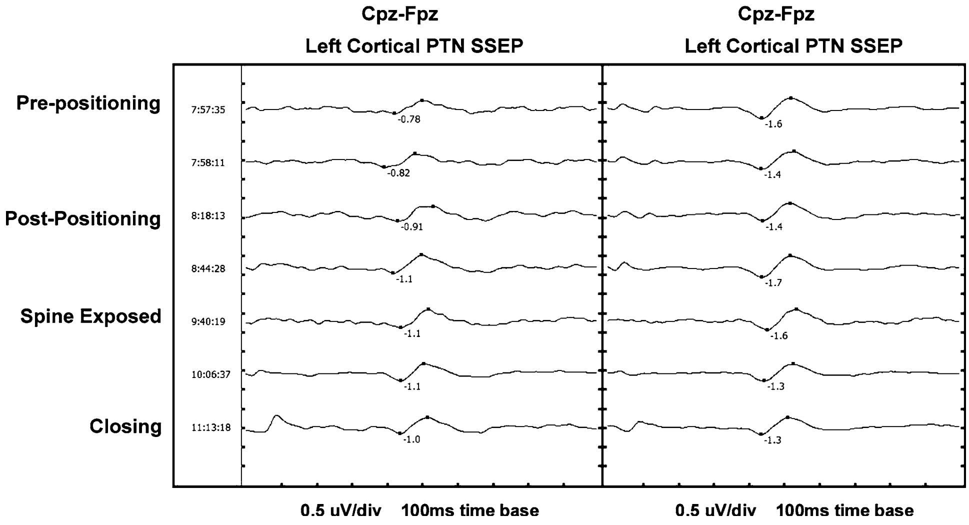

Fig. 2. Unchanged posterior tibial nerve somatosensory evoked potentials for a 65-year-old male who underwent thoracotomy in the left lateral decubitus position (Case #1).

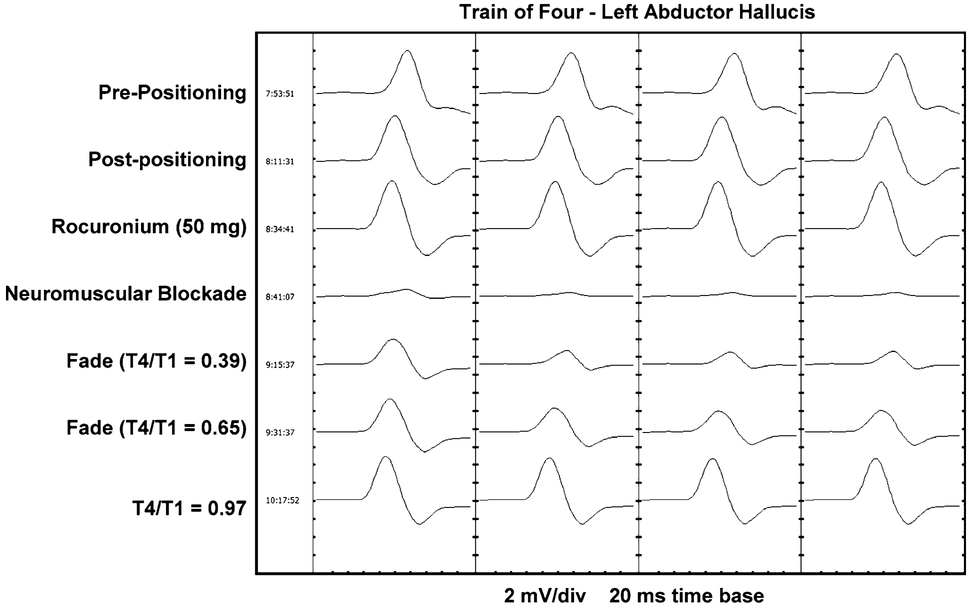

Fig. 3. Compound muscle action potentials triggered from the left abductor hallucis muscle to train-of-four electrical stimulation of the posterior tibial nerve for assessing the effects of neuromuscular blockade (Case #1).

with boluses of fentanyl (50–100 mcg); however, unlike Case #1, no paralytic agent was administered following intubation with succinylcholine. Here, there were four large and equal-amplitude responses to TOF stimulation shortly after intubation, supporting total clearance of the neuromuscular junction for optimal tceMEP generation during the entire procedure.

Following lateral decubitus positioning, large-amplitude, symmetrical transcranial electric motor evoked potentials were recorded from bilateral upper and lower extremities. Similarly, large-amplitude bilaterally symmetrical cortical responses were recorded to stimulation of the ulnar and posterior tibial nerves. Transcranial motor and somatosensory evoked potentials for the lower extremities are shown in Figures 4 and 5, respectively.

During the initial stages of decompression, there was an isolated tceMEP loss from the right tibialis anterior muscle recording site. At that time the right leg was carefully

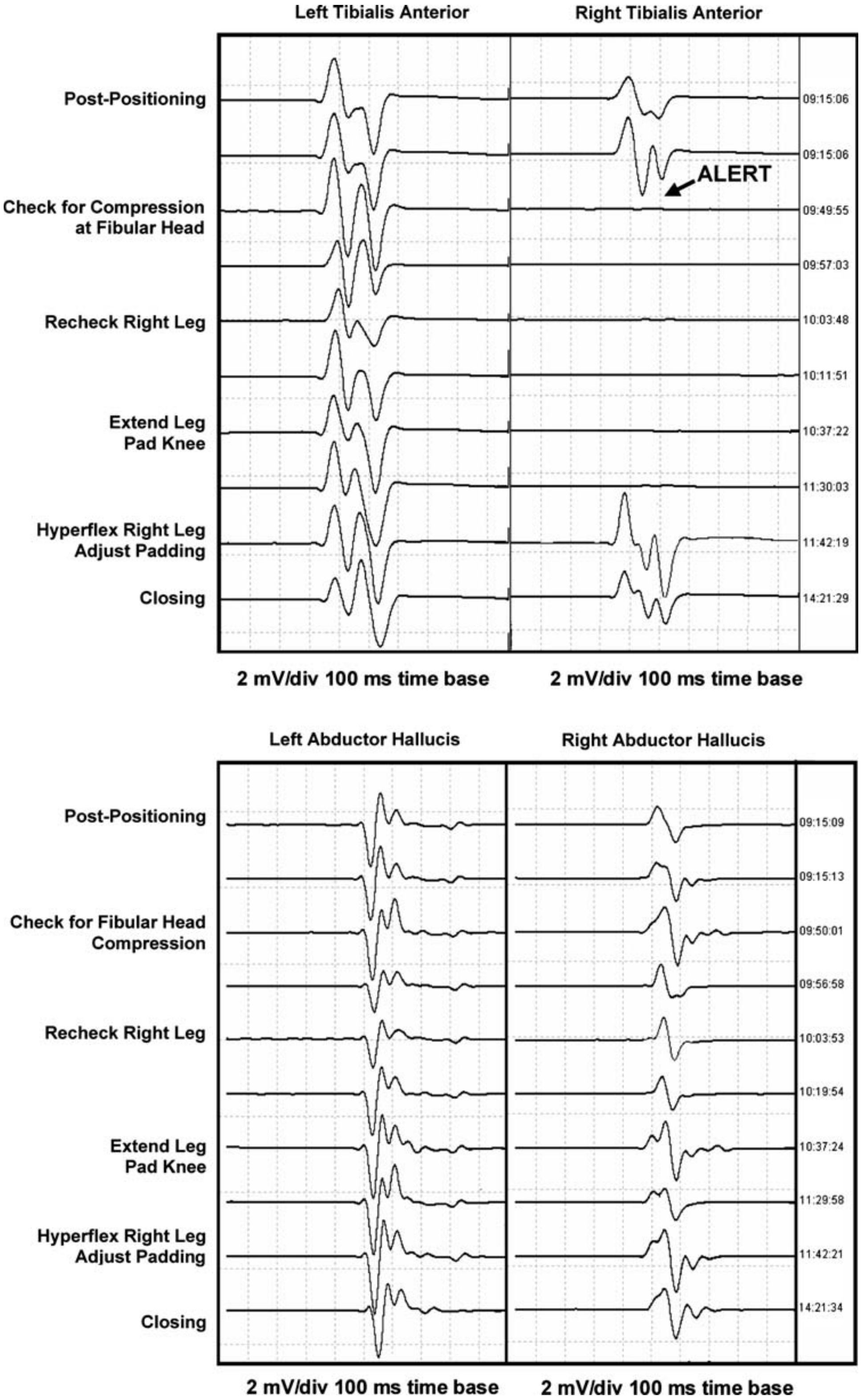

Fig. 4. Isolated loss of motor evoked potential amplitude from the right tibialis anterior muscle (noted by arrow) for a 39-year-old male who underwent anterior T12 and L1 corpectomies with interbody fusion and internal fixation in the right lateral decubitus position (Case #2).

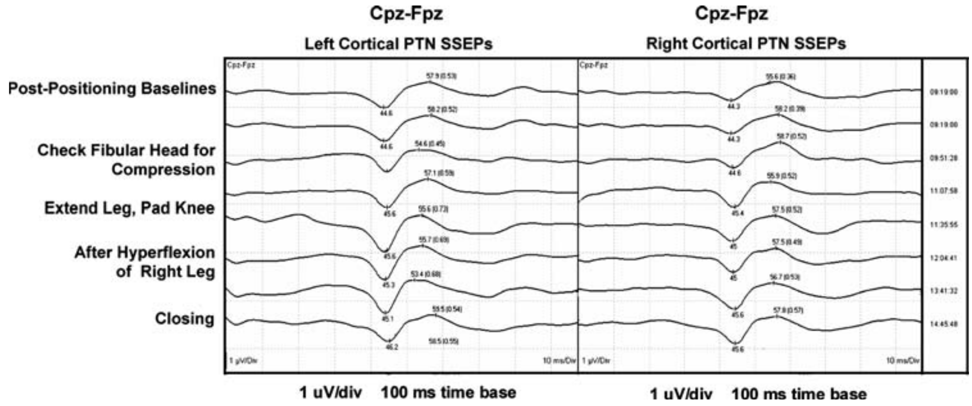

Fig. 5. Unchanged posterior tibial nerve somatosensory evoked potentials for a 39-year-old male who underwent anterior T12 and L1 corpectomies with interbody fusion and internal fixation in the right lateral decubitus position (Case #2).

inspected for pressure points; however, no points of compression were found despite the persisting absence of the tceMEP. Consequently, the right leg was extended from the partially flexed position, and additional padding was placed around the knee; however, again no improvement was noted. Finally, the padding was readjusted and the leg was hyperflexed as opposed to extended. Soon thereafter, the response reappeared, returning rapidly to baseline amplitude, as shown in Figure 5. There were no further neurphysiological monitoring changes for the remainder of the procedure. The patient emerged from anesthesia with no new neurologic deficits.

DISCUSSION

Peripheral nerve injury secondary to patient positioning is among the leading causes of perioperative morbidity in anesthesia practice [26–30]. Kamel and co-workers calculated the percentage of position-related upper extremity SSEP changes among five surgical positions and found the lateral decubitus and prone ''superman'' positions to be associated with the greatest risk for SSEP changes [17]. The lateral decubitus, as well as the lithotomy positions also can result in peroneal nerve injury and debilitating foot-drop [5–9].

Although peroneal nerve SSEP monitoring has been used to identify evolving sciatic nerve injury during hip arthroplasty and acetabular repair [30–33], the need for signal averaging to extract these small signals from background noise, and excessive movement of the stimulated limb in the unrelaxed patient limit its usefulness, particularly during spine surgery.

Historically, posterior tibial nerve somatosensory evoked potential monitoring has been a standard-of-practice for spinal surgery; however, focal injury to the peroneal nerve would not normally be reflected in a change in posterior tibial nerve SSEP amplitude, as was confirmed by the cases described herein, particularly Case #1 which resulted in post-operative foot drop.

Myogenic transcranial electric motor evoked potential monitoring is not only a highly-sensitive and specific tool for assessing the functional integrity of spinal cord motor tracts [20–25], but also has proven effective in identifying nerve root and peripheral nerve injury as indicated by response amplitude loss from the innervated muscle [34, 35]. Moreover, tceMEPs can be recorded simultaneously from multiple muscle sites following a single stimulus train, allowing for faster data acquisition than with averaged SSEPs, and enabling more rapid identification of impending neurologic injury.

Several important lessons were learned from Case #1 which occurred early in our experience with use of tceMEPs to detect peripheral nerve injury. First, the significance of an isolated unilateral tceMEP loss from an individual myotome was not fully appreciated. Because primary attention was focused on the spinal cord, and because there was ample evidence from other tceMEP and SSEP data that spinal cord conduction was intact, attenuation of a single myotomal response was discounted. Since that time we have come to recognize not only that such isolated change in a tceMEP can point to emerging peripheral nerve injury, but also that it can alert the surgeon to impending damage to a spinal nerve root or the root entry zone.

Second, inadequate clearance of the neuromuscular junction adds significant ambiguity to the interpretation of tceMEPs. Over the years, we have observed differential effects of muscle relaxants on tceMEPs recorded from various muscle groups, both within and across limbs. These varying effects confound the interpretation of tceMEP change, particularly in a single muscle, because of the challenges in distinguishing between pharmacologic and pathologic etiologies.

It is also important to note that the use of neuromuscular blockade for exposure in Case #1 produced a neuromonitoring blind spot for 45 min, during which injury to the left peroneal nerve likely evolved. There were no apparent changes in left peroneal nerve function immediately following lateral positioning, as evidenced by unchanged left tibialis anterior muscle tceMEPs; however, the introduction of rocuronium prior to incision precluded reassessment of function until the window of opportunity for effective intervention had passed. This highlights the importance of avoiding use of additional muscle relaxant after intubation to allow for regular tceMEP testing throughout the procedure, and certainly for a few minutes immediately following placement of the patient in the lateral decubitus position. It also argues strongly against the practice of titrating paralytic agents for partial neuromuscular blockade, which leads to variable tceMEP amplitudes over time, and results in interpretive ambiguity.

Third, it is important to react to graded tceMEP attenuation, rather than wait for total disappearance of the response before taking action. One school of thought within the neuromonitoring community advocates interpretation of tceMEPs on a present versus absent basis. Clearly, the results of the first case, in which foot drop occurred in the presence of partial tceMEP attenuation for tibialis anterior muscle, do not support this interpretive strategy.

Case #2 exemplified some of the lessons learned from the first case by demonstrating the cause-effect relationship between positioning and isolated unilateral loss of the tceMEP from tibialis anterior muscle, and the subsequent restoration of the response upon repositioning the right leg. It is important to emphasize that the cause of peroneal nerve dysfunction was not immediately apparent in Case 2, requiring several attempts at leg manipulation before a position was found in which the peroneal nerve of the dependent leg was protected from potential compression or stretch injury.

The two cases presented herein provide evidence of the unique sensitivity of transcranial electric motor evoked potentials from tibialis anterior muscle to evolving peroneal nerve compression injury. These findings have broad implications both for patient safety and professional liability. Under appropriate anesthetic conditions, tceMEPs are an effective modality for monitoring peripheral nerve function, and their use should be considered whenever there is risk of position-related injury to a peripheral nerve or nerve plexus.

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