Myogenic Response Distortion of Neurogenic Motor Evoked Potential Morphology

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SOMATOSENSORY evoked potentials (SSEPs) and neurogenic motor evoked potentials (NMEPs) are used to monitor intraoperative spinal cord function during surgeries that place the spinal cord at risk for physical or ischemic injury. Unlike transcranial electrical or magnetic stimulation for generation of motor evoked potentials, spinal cord-stimulated motor evoked potentials have been shown to be resistant to attenuation induced by general anesthesia.1-9 Motor evoked potentials are recorded either from peripheral muscles or from peripheral nerves. The myogenic motor evoked potential (MMEP) has a longer latency and higher amplitude than the NMEP. When the myogenic responses are superimposed onto the neurogenic responses, the neurogenic response may be obscured, causing interpretation to be difficult or impossible. In this paper, morphologic changes of the NMEPs due to the development of recordable MMEPs, corresponding to small fluctuations in the degree of patient muscle relaxation, are demonstrated in two cases.

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Received from the Departments of Anesthesia, Neurology, and Orthopedic Surgery, The Milton S. Hershey Medical Center, Pennsylvania State University College of Medicine, Hershey, Pennsylvania. Submitted for publication December 9, 1994. Accepted for publication April 10, 1995.

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Key words: Monitoring; measurement techniques; motor evoked potentials; spinal cord electromyography.

Anesthesiology, V 83, No 3, Sep 1995

A 25-year-old, 78-kg man was involved in a motorcycle accident and suffered a burst fracture of his first lumbar vertebra, which was associated with hypotension along sacral dermatomes. There was slight weakness of first toe flexion on the right foot. Gross sensation to the perianal area and rectal tone were intact. A preoperative computed tomography scan demonstrated 50% encroachment of the fracture fragments into the spinal canal. An open reduction with internal fixation and posterior spinal fusion from T10 to L2, with segmental instrumentation and iliac crest bone grafting, was performed on the 3rd day after injury. Anesthesia was maintained with nitrous oxide and a fentanyl infusion. Muscle relaxation was achieved using a vecuronium infusion of 0.7 mcg·kg⁻¹·min⁻¹ after an initial 8-mg bolus.

SSEPs were monitored from two cortical sites (F7-CZ, C3-C4) as determined by the international 10-20 system, subcortically over the spinous process of C7 and from the right and left popliteal fossa. Stimulation of the posterior tibial nerve at each ankle was at the rate of 4 Hz with a 0.2-ms duration and 30 mA constant current intensity. Reliable baseline SSEPs were observed before incision and remained well defined throughout the surgery.

MMEP stimulation was delivered through two 1/2-inch needle electrodes (JO-5, The Electrode Store, Yucca Valley, CA) inserted by the surgeon under direct vision into the spinous processes of the T8 (anode) and T9 (cathode) vertebral bodies after surgical exposure. The potentials were recorded from needle electrodes placed percutaneously over the sciatic nerves bilaterally at the popliteal fossa. The reference electrodes were placed 4–5 cm distally from the active electrodes. The rate of stimulation was 4 Hz with a 0.3-ms duration. The potentials were recorded with a 10-Hz low-frequency filter and a 5,000-Hz high-frequency filter; amplifier sensitivity was set at 100 μV.

The initial NMEP recording was reproducible (left 13.9 ms, 0.99 μV and right 14.2 ms, 1.58 μV) and the latencies and amplitudes, respectively, for T1A). As the case progressed, the NMEP gradually became obscured by a long-latency, high-amplitude potential (left 18.2 ms, 51.9 μV and right 18.5 ms, 56.4 μV, respectively, for T1B). The patient received a 6.5-μg·kg⁻¹ bolus of vecuronium, and within 5 min, the NMEP waveform returned to its initial morphology, latency, and amplitude values, which are within what are considered normal limits (fig. 1C).

Postoperatively, motor function of the patient's lower limbs was normal, with strength in the ankles, including toe flexors. Paresthesias in the soles of his feet persisted at the time of his discharge, although they were improving daily. Bowel and bladder function remained normal.

Case 2

A 16-year-old, 58-kg boy with progressive idiopathic scoliosis, presented with a large double thoracic curve, which measured 43 ° from

Fig 1. Neurogenic motor evoked potentials before recording from a 25-year-old patient was 200 V. Traces were the general nerves of the both the NMEP. A significant increase in amplitude was noted after vecuronium bolus: left 17.9 ms, right latency 14.5 ms, amplitude 85.3 μV.
a reproducible biphase response (left 15.3 ms, 1.63 μV and right 16.0 ms, 1.37 μV latencies and amplitudes, respectively; fig. 2A). After an increase in the vecuronium, a 0.9 μg·kg⁻¹ bolus, and the infusion rate increased to 0.9 μg·kg⁻¹·min⁻¹, the second peak of the biphase response disappeared, and a reproducible single peak response was recorded with normal latencies and amplitudes (left 15.3 ms, 0.68 μV and right 15.9 ms, 0.60 μV, respectively; fig. 2B). A gradual return of the biphase response appeared with a decrease in neuromuscular blockade (fig. 2C).

Postoperatively, the patient’s neurologic status was unchanged from baseline.

**Fig. 1.** Neurogenic motor evoked potential (NMEP) intraoperative recording from a 25-year-old man (case 1). Stimulation intensity was 240 V. Traces were recorded bilaterally from the peroneal nerves of the both the left and right popliteal fossa. A significant increase in amplitude and latency are seen as myogenic contamination distorts the NMEP. (A) Baseline: left latency 13.9 ms, amplitude 0.99 μV; right latency 14.2 ms, amplitude 1.58 μV. (B) 22 min after baseline: left latency 18.2 ms, amplitude 51.9 μV; right latency 18.3 ms, amplitude 36.4 μV. (C) 105 min after baseline, approximately 5 min after vecuronium bolus: left latency 13.5 ms, amplitude 0.94 μV; right latency 14.5 ms, amplitude 1.53 μV.

**Fig. 2.** Neurogenic motor evoked potential (NMEP) intraoperative recording from a 16-year-old boy (case 2). Stimulation intensity was 300 V. Traces were recorded bilaterally from the peroneal nerves of the left and right popliteal fossa. A significant decrease in amplitude and change in wave morphology are seen with the elimination of myogenic contamination, followed by the occurrence of the myogenic induced distortion. (A) Baseline: left latency 15.3 ms, amplitude 1.63 μV; right latency 5.9 ms, amplitude 0.60 μV. (B) 10 min after baseline, approximately 5 min after vecuronium increase: left latency 15.3 ms, amplitude 0.68 μV; right latency 15.9 ms, amplitude 0.60 μV. (C) 67 min after baseline, approximately 50 min after vecuronium infusion increase: left latency 15.1 ms, amplitude 0.70 μV; right latency 15.5 ms, amplitude 0.94 μV.
CASE REPORTS

Discussion

The latency and amplitude of the NMEP are followed closely throughout the surgical period. A 60% decrease in amplitude or a 10% increase in latency is a possible warning sign of spinal cord injury. The degree of muscle relaxation can influence the waveform of the neurogenic response through the presence of myogenic artifact contamination or elicited compound muscle action potentials. As demonstrated in the first case, the evoked response being followed had its amplitude increased by a factor of 52 and the latency prolonged by 50%. This high-amplitude, long-latency response directly correlated with the patient’s degree of muscle relaxation. In both cases, the monitored waveforms returned to a typical neurogenic response appearance within 5 min of an increase in the patient’s level of neuromuscular blockade. Owen reported, when a patient has two of four muscle twitches (with traditional visual evaluation of train-of-four (TOF) muscle twitch monitoring), the NMEP will contain a myogenic component with a longer latency and a greater amplitude.”

At no time did either of the patients reported here have more than one twitch present, with visual evaluation of traditional TOF monitoring, throughout the period of NMEP monitoring. TOF monitoring with evoked electromyography is more sensitive than evoked mechanomyographic TOF monitoring, although the differences are clinically insignificant during surgery.[12]

Visual evaluation of traditional TOF responses after facial or ulnar nerve stimulation may not be adequate for controlling contamination of NMEP waveforms by electromyographic activity. The use of controlled neuromuscular relaxation during the recording of NMEPs has been reported. Adams et al. reported robust MMEPs, recorded from the vastus medialis and tibialis anterior, with either epidural or subarachnoid stimulation (depending on surgical access) in 19 patients with a greater than 90% neuromuscular blockade from infusions of vecuronium. Kallman et al. demonstrated that a myogenic response could be recorded from the tibialis anterior muscle after transcranial electrical stimulation in the presence of complete suppression of mechanical twitch responses after vecuronium-induced neuromuscular blockade. The myogenic motor response, although significantly decreased in amplitude, was still present.

Several methods of eliciting a motor evoked potential have been developed. Levy et al. reported use of transcranial electric stimulation of the motor cortex. Edmunds reported using transcranial magnetic stimulation of the motor cortex in scoliotic patients undergoing surgery for posterior spinal fusion. Machida described direct stimulation of the spinal cord from an electrode placed in the epidural space, recording NMEPs and MMEPs. The transcranial techniques place limitations on the anesthetic technique administered because of the large attenuation of the evoked responses caused by most anesthetics agents. Monitoring techniques that record a myogenic potential also place limitations on the level of neuromuscular blockade used. Machida described placement problems for stimulating epidural electrode: Off-center positioning of the epidural electrode caused amplitude differences between the right and left leg.52

The NMEP stimulating and recording technique has the advantage of generation and recording of quality potentials despite neuromuscular blockade use, elimination of patient movement induced by the stimulation, and generation a potential resistant to anesthetic-induced attenuation.9,15 The NMEP consists of a large orthodromic response, followed by smaller, unreliable antidromic responses. The orthodromic response represents firing of the motor fibers, whereas the antidromic response records the retrograde firing of the slower-conduction velocities of nonsynapsing sensory fibers.52 When the distance between the point of stimulation and the recording sites is large enough, the two responses separate. Placement of the recording electrodes at the popliteal fossa allows sufficient distance for this separation to occur.15

NMEP and SEP monitoring provide the surgeon with a means of accessing the functional and electrical status of the spinal cord intraoperatively. Constant communication, regarding the degree of the patient’s neuromuscular blockade, between the anesthesiologist and the neurophysiologist is needed regardless whether MMEPs or NMEPs are being monitored. The key to successful intraoperative spinal cord monitoring is a technique that gives consistently reproducible results when the spinal cord has not suffered harm and distinct changes when cord injury is likely. Despite clinically acceptable neuromuscular blockade with elimination of twitches on TOF monitoring, a myogenic artifact can be elicited that may distort the NMEP waveform.

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Anesthesiology, Vol 83, No 3, Sep 1995
morbidity and alter clinical assessment by changing measured waveform latency and amplitude.

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