The Incidence of Unacceptable Movement with Motor Evoked Potentials During Craniotomy for Aneurysm Clipping

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Key words
- Intracranial aneurysm
- Intraoperative monitoring
- Motor evoked potentials

Abbreviations and Acronyms
MEP: Motor evoked potential
PPV: Positive predictive value
SEP: Somatosensory evoked potential

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OBJECTIVE: **To review the experience at a single institution with motor evoked potential (MEP) monitoring during intracranial aneurysm surgery to determine the incidence of unacceptable movement.**

METHODS: **Neurophysiology event logs and anesthetic records from 220 craniotomies for aneurysm clipping were reviewed for unacceptable patient movement or reason for cessation of MEPs. Muscle relaxants were not given after intubation. Transcranial MEPs were recorded from bilateral abductor hallucis and abductor pollicis muscles. MEP stimulus intensity was increased up to 500 V until evoked potential responses were detectable.**

RESULTS: **Out of 220 patients, 7 (3.2%) exhibited unacceptable movement with MEP stimulation—2 had nociception-induced movement and 5 had excessive field movement. In all but one case, MEP monitoring could be resumed, yielding a 99.5% monitoring rate.**

CONCLUSIONS: **With the anesthetic and monitoring regimen, the authors were able to record MEPs of the upper and lower extremities in all patients and found only 3.2% demonstrated unacceptable movement. With a suitable anesthetic technique, MEP monitoring in the upper and lower extremities appears to be feasible in most patients and should not be withheld because of concern for movement during neurovascular surgery.**

INTRODUCTION

Despite advances in neuroendovascular techniques, craniotomy for clip ligation of aneurysms remains a fundamental method for definitive treatment. Reported morbidity rates for clipping of unruptured aneurysms range from 4%–11% (1). Morbidity is often due to inadvertent ischemic injury from brain retraction, compromise of small perforating arteries during dissection, temporary arterial occlusion, or permanent clips impinging on the parent vessel or perforating arteries (20, 24).

Neurophysiologic monitoring during surgery can help prevent permanent neurologic injury by alerting the surgeon and anesthesiologist to the need for modifying the surgical strategy and/or patient management (30). Transcranial motor evoked potential (MEP) monitoring that is added to standard somatosensory evoked potential (SEP) and electroencephalogram monitoring may increase the sensitivity of electrophysiologic monitoring during aneurysm surgery and improve outcome (5, 29). Because MEPs and SEPs provide complementary information about the patient's nervous system, one of these modalities alone might be less likely to reflect the patient's true postoperative neurologic status (30). In up to 25% of cases in which a new postoperative deficit (mostly paresis) manifests, there were unaltered intraoperative SEP recordings; this is likely because the motor pathways derive some blood supply from arteries that are anatomically distinct from arteries supplying sensory cortical pathways (20). In addition, likely owing to differences in the amount of collateral circulation to the vulnerable area, MEP monitoring can give relatively early warning of potential ischemic injury (8, 9).

Transcranial MEPs have become a critical modality for intraoperative monitoring of motor pathway integrity in spine surgery, and the technical aspects and safety of MEP monitoring have previously been demonstrated (14, 21, 27). Combining MEPs with SEPs has been recommended in intracranial aneurysm surgery, and MEPs have been found to be superior to SEPs in many situations during cerebral aneurysm surgery (4, 23). It has even been suggested that with MEP monitoring the incidence of motor deficits after aneurysm clipping could be reduced to at least the level obtained with aneurysm coiling procedures (31). However, MEPs in intracranial neurovascular surgery have often not been employed because of concern for unacceptable movement in a nonparalyzed patient anesthetized with a limited amount, or in the absence, of inhaled volatile anesthetic (26, 29). A survey sent to all members of the American Society of Neurophysiological Monitoring and the American Clinical Neurophysiology Society revealed that only two centers used MEPs during craniotomies for intracranial lesions (from

57 responding centers) (12). Even in spine surgery where transcranial MEPs are much more commonplace (although a survey published in 2007 showed transcranial MEPs were available in only 41% of spine surgical facilities), concern about transcranial MEP–induced movement remains, particularly with surgeons inexperienced with transcranial MEPs (15, 25). We reviewed our experience with transcranial MEPs during intracranial aneurysm surgery to determine the incidence of unacceptable movement in the absence of neuromuscular blockade while monitoring upper and lower extremity transcranial MEPs.

METHODS

After institutional review board approval, electronic neurophysiology event logs and anesthetic records from 220 craniotomies for aneurysm clipping between August 2006 and May 2009 were retrospectively reviewed for unacceptable patient movement or reason for cessation of MEP monitoring (Table 1). The neurophysiology event logs, based on our standard practice, document any change in stimulation, explain the reason for the change, and document any inability to acquire MEPs once baseline signals are obtained.

Perioperative management was consistent with routine anesthetic management for cerebral aneurysms at our institution, and it followed a modification of a protocol previously described for intracranial surgery (3). Patients were premedicated as needed with midazolam, 0–0.05 mg/kg, and standard American Society of Anesthesiologists monitors were applied. An intraarterial catheter was placed for invasive arterial pressure monitoring either before induction or after tracheal intubation, at the discretion of the anesthesiologist. Anesthesia was induced with propofol, 1–2 mg/kg, or etomidate, 0.1–0.2 mg/kg, and remifentanil infusion at 0.1–1 μg/kg/minute, or a single bolus of 0.3–1 μg/kg, or fentanyl, 1–7 μg/kg. Tracheal intubation was facilitated by a single intravenous bolus of intermediate-acting nondepolarizing muscle relaxant (rocuronium, 0.6–1.2 mg/kg, or cisatracurium, 0.15–0.2 mg/kg) or, when indicated, succinylcholine, 0.3–1.1 mg/kg. No additional neuromuscular junction–blocking agent was administered after tracheal intubation because of planned transcranial MEP monitoring. The trachea was ventilated with an air/oxygen mixture (fraction of inspired oxygen, 0.5–1), and ventilation was adjusted to achieve an arterial carbon dioxide pressure of 28–32 mm Hg. Anesthesia was usually maintained with ≥0.1 μg/kg/minute of remifentanil, ≤0.5 minimum alveolar concentration of volatile anesthetic (usually desflurane), and 0–150 μg/kg/minute of propofol.

Table 1. Aneurysm Location and Size

	Number (Percentage)
Aneurysm Location	
Middle cerebral artery	57 (25.9)
Anterior communicating artery	56 (25.5)
Posterior communicating artery	26 (11.8)
Carotid/periophthalmic artery	23 (10.5)
Internal carotid artery bifurcation	23 (10.5)
Basilar tip	17 (7.7)
Distal anterior cerebral artery	9 (4.1)
Posterior inferior cerebral artery	7 (3.2)
Vertebral artery	1 (0.5)
Posterior cerebral artery	1 (0.5)
Aneurysm Size	
<5 mm	79 (35.9)
5–10 mm	108 (49.1)
11–20 mm	24 (10.9)
>20 mm	8 (3.6)
Unreported	1 (0.5)

In cases where multiple aneurysms were clipped, the largest aneurysm is reported.

While maintaining a fixed dose of volatile anesthetic, remifentanil and propofol were titrated to maintain the mean arterial pressure within 20% of the awake, baseline value and, when used, a bispectral index (BIS; Covidien, Norwood, Massachusetts, USA) value of 30–50. If needed, a phenylephrine infusion was added to maintain the target mean arterial pressure.

Temperature was adjusted to achieve mild hypothermia or normothermia at the time of permanent aneurysm clip placement. When requested, before temporary arterial occlusion or aneurysm clipping, a burst suppression ratio of approximately 0.7–0.8 was achieved with propofol and confirmed by electroencephalogram.

Since August 2006, SEP, MEP, and electroencephalogram monitoring have been routinely performed on all patients undergoing craniotomy for clip ligation of intracranial aneurysms at Northwestern Memorial Hospital. MEP tracings were generated by multipulse transcranial electrical stimulation (Cadwell TCS-1; Cadwell Laboratories, Inc, Kennewick, Washington, USA) at sites 2 cm anterior to the C3 and C4 positions of the international 10–20 system using 3–7 square-wave, monophasic, anodal, constant-voltage electrical pulses of 50-μsec duration with an interstimulus interval of 2 msec. MEPs were recorded (16-channel Cadwell Cascade) from the contralateral upper and lower extremities simultaneously with needles placed in bilateral abductor hallucis and abductor pollicis muscles paired with reference needles in corresponding abductor digiti minimi muscles. MEPs were displayed and recorded within a 100-msec epoch after being filtered (band-pass 30–10,000 Hz) and amplified (× 10,000).

Stimulus intensity was increased by 50-V increments from 100 V to a maximum of 500 V until evoked potential responses were detectable in the lower extremities above a minimum of approximately 50 μV. MEPs were commonly recorded every 30 minutes throughout surgery and more frequently during critical surgical manipulation (e.g., at 1 minute after temporary clip placement, then every 2 minutes until 10 minutes passed, and every 5 minutes thereafter until temporary clip release). It was standard practice that once baseline signals were obtained, any change in stimulation intensity was documented and justified in the neurophysiology event log. Decreases in MEP amplitudes >50% from baseline or increases in stimulation intensity of >50 V or in train number to maintain signal amplitude were considered minimum alert thresholds.

To avoid movement of the microsurgical field during critical surgical maneuvers, brief surgical pauses (a few seconds) for monitoring of MEPs were coordinated between the neurosurgery, anesthesia, and electrophysiology teams. Specifically, most MEP acquisitions coincided with