Ankle Clonus and Wakeup Tests During Posterior Spinal Fusion: Correlation With Bispectral Index

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Spinal cord injury and its resultant neurologic deficits are recognized complications of posterior spinal fusion (PSF) for correction of scoliosis. Spinal cord injuries are identified with various methods, including intraoperative monitoring using somatosensory evoked potentials (SSEPs) and/or motor evoked potentials (MEPs), intraoperative wakeup test, and demonstration of ankle clonus.[1-4]

The wakeup test, originally reported (in the 1970s) to be a means of monitoring spinal cord integrity, involves gradually decreasing anesthesia depth until the patient is able to follow commands and voluntarily move the lower extremities[5,6]; then anesthesia is returned to its previous level, and the surgery is completed. Although this test and potential intraoperative awareness are discussed with the patient before surgery, recall may occur during the test. In addition, as anesthesia lightens, hemodynamic changes may cause bleeding, and excessive patient movement may cause bodily harm or dislodge intravascular catheters or even the endotracheal tube. Given these issues, alternative means of monitoring spinal cord integrity are desirable.

The ankle clonus test was the first test to be used to assess spinal cord integrity during surgery. Ankle clonus is a neurologic sign that is usually considered pathologic but can normally appear during emergence from general anesthesia.[7,8] During the normal awake state, descending inhibitory fibers prevent clonus in response to an ankle stretch. As the patient emerges from general anesthesia, lower motor neuron function returns before descending inhibitory cortical fibers regain their normal function, thereby disinhibiting the lower motor neurons and resulting in the ability to elicit clonus. If the spinal cord has been damaged, flaccid paralysis will be present, thereby preventing spinal reflexes, including ankle clonus.[3] The ankle clonus reflex is elicited by rapid dorsiflexion of the foot followed by continued application of pressure to hold the foot in slight dorsiflexion. Rhythmic contractions of the gastrocnemius muscle result in repetitive plantar flexion of the foot.

Compared with the wakeup test, the ankle clonus test can usually be elicited before the patient regains consciousness, at a deeper level of anesthesia.[9] In this article, we describe the cases of 3 adolescents whose SSEPs or MEPs changed during intraoperative monitoring for PSF. In these cases, the Bispectral Index (BIS) monitor (Aspect Medical Systems, Inc., Newton, Mass) was used to judge the depth of anesthesia and to provide numeric data regarding the anesthesia level at which ankle clonus can be elicited, versus the point at which the patient is able to voluntarily move the lower extremities.

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Case Reports

The institutional review board of the University of Missouri approved our case reviews and data presentation. In all 3 cases, the ankle clonus test was performed by the attending anesthesiologist, Dr. Tobias.

Patient 1

A 13-year-old, 74-kg girl presented for PSF for thoracic scoliosis (Cobb angle, 48°). Past medical history was unremarkable, and there were no comorbid features. During the preoperative interview, the potential need for a wakeup test was discussed. After inhalational induction of anesthesia with sevoflurane, 2 large-bore peripheral intravenous catheters were placed, and endotracheal intubation was facilitated with a single dose of rocuronium 0.3 mg/kg. Central venous and arterial cannulae were placed. Then the inhalational anesthetic agent was discontinued, and total intravenous anesthesia was provided with dexmedetomidine 0.5 µg/kg/h,

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propofol 30 to 100 µg/kg/min titrated to maintain a BIS value of 40 to 60, and remifentanil 0.2 to 0.6 µg/kg/min to maintain mean arterial pressure (MAP) at 55 to 65 mm Hg. When MAP exceeded 65 mm Hg (despite use of remifentanil 0.6 µg/kg/min), intermittent doses of either labetalol or hydralazine were administered to control it. As part of our routine intraoperative care, SSEPs and MEPs were monitored. After placement of the second rod and spinal distraction with rod fixation, the right lower extremity had an amplitude decrease of more than 50% and an increase in SSEP latency. There were no acute changes in anesthesia depth, blood pressure, oxygenation, ventilation, or any other factor to account for these developments. It was decided to perform a wakeup test. Propofol and remifentanil were discontinued, and, over the next 12 to 15 minutes, the BIS value increased from 40–43 to 60. At a BIS of 62, ankle clonus could be reproducibly elicited on both sides. When BIS reached 81, the patient moved her lower extremities in response to commands. Then a bolus dose of propofol was administered, and infusions of propofol and remifentanil were restarted. The surgical procedure (T2–T12 PSF) was completed without incident.

Patients 2 and 3

Both patients underwent PSF with an anesthetic similar to what was used for patient 1. In patients 2 and 3, SSEP or MEP changes necessitated a wakeup test.

Patient 2 was a 16-year-old, 68-kg boy with thoracic scoliosis (Cobb angle, 58°) treated with T1–T12 PSF. After placement of a pedicle screw, the left lower extremity had an amplitude decrease of more than 50% and an increase in SSEP latency. These changes persisted after screw removal. Ankle clonus was elicited at a BIS value of 58, and voluntary movement in response to commands occurred at a BIS of 85.

Patient 3 was a 15-year-old, 62-kg girl with thoracic scoliosis (Cobb angle, 54°) treated with T2–T12 PSF. After placement of a pedicle screw, the left lower extremity had an MEP amplitude decrease of more than 50%. This change persisted after screw removal. Ankle clonus was elicited at a BIS value of 59, and voluntary movement in response to commands occurred at a BIS of 84.

Discussion

Our current practice includes use of SSEPs and MEPs for continuous monitoring of spinal cord function during PSF. Despite the efficacy of this practice, false-positive findings may occur when there are alterations in readings in the absence of spinal cord injury. However, changes noted on neurophysiologic monitoring may indicate a need for physical assessment, including use of the wakeup test or demonstration of ankle clonus.

Advocates of the ankle clonus test emphasize its accuracy in identifying spinal cord injury; ability to assess anterior cord function; ability to maintain an anesthesia level that may prevent intraoperative awareness; prevention of full awakening, excessive patient movement, and dislodgement of vascular cannulae or endotracheal tubes; and quicker assessment (full awakening not required).[3] In addition, our clinical practice has suggested that younger pediatric patients may not comprehend and be able to respond to the wakeup test.

To avoid potential intraoperative recall, we include BIS monitoring in our practice. The BIS monitor, which uses a predetermined algorithm, developed by comparing the different aspects of the processed electroencephalogram (EEG) with the depth of anesthesia, has been proposed as a tool for measuring anesthesia depth.[10,11] For a comprehensive review of the technology, see Rampil[10] and Drummond.[11]

The BIS monitor records the EEG from an adhesive patch with 4 electrodes placed on the forehead. Three monitor components—amplitude and frequency of EEG, suppression ratio, and bispectrum—are interpreted and converted to a digital readout, from 0 (isoelectric EEG) to 100 (awake). These components change as anesthesia level changes. As depth of anesthesia increases, amplitude and frequency of EEG decrease. The suppression ratio is the time during which the EEG is isoelectric or flat. During the awake state, there is virtually no time when the EEG is isoelectric (in which case the suppression ratio is 0%); during deeper levels of anesthesia, there are more periods when the EEG is isoelectric. The bispectrum compares various parts of the cortex on the same hemisphere of the brain. During the awake state, the amplitudes and frequencies of the different areas of the hemisphere vary; as anesthesia depth increases, these amplitudes and frequencies become similar. Reports from the literature suggest that the appropriate depth of anesthesia for preventing intraoperative awareness ranges from 40 to 60–70.[10,11] In our 3 patients, ankle clonus was elicited at BIS values of 58, 59, and 62, whereas movement of the lower extremities in response to commands occurred at BIS values of 81, 84, and 85. Given these numbers, recall would be unlikely during the demonstration of ankle clonus and possible during the wakeup test. The BIS monitor may also be helpful in judging when attempts at either the ankle clonus or wakeup test should be initiated. Although anecdotal, these data demonstrate that ankle clonus can usually be elicited at a BIS value of approximately 60, whereas wakeup is not feasible until BIS has reached 80 to 85.

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Similar anesthesia-depth differences for ankle clonus test and wakeup test were demonstrated by Chang and colleagues[9] in a cohort of 30 children ranging in age from 5 to 15 years. They found that ankle clonus could be elicited with an end-tidal sevoflurane concentration of 0.4% to 0.5%, though arousal state was judged as either "none" or "slow, inappropriate movement," an anesthesia level at which the wakeup test would not be feasible. McCann and colleagues[12] evaluated the potential for recall with the wakeup test during 37 wakeup tests in 34 patients. During the wakeup test, patients were shown a color; later, in a test of intraoperative recall, they were asked to identify the color. No patient recalled intraoperative pain, 1 patient recalled the wakeup test but not the color, and 5 patients recalled the color but not the wakeup test. The mean BIS value at the time patients moved in response to commands was 90 (SD, 8).

We have demonstrated that, with use of BIS monitoring during PSF, the ankle clonus test can be elicited at a deeper level of anesthesia than the wakeup test can be. An obvious limitation of this report is that we present only 3 cases. Given the small number of patients who we have found to exhibit intraoperative changes in SSEPs or MEPs, we felt that we would not accumulate a large enough cohort for a prospective study. These data suggest that ankle clonus can be elicited at a BIS value of 58 to 62, whereas movement in response to commands occurs at a BSI of 81 to 85.

A final issue is the event sequence that we usually follow when there are SSEP or MEP changes. We continue to recommend reversal of any recent surgical maneuver that may have led to the neurophysiologic changes observed on monitoring. If there is no return of SSEPs and/or MEPs, we suggest using either the ankle clonus test or the wakeup test. Hoppenfield and colleagues[3] suggested that the ankle clonus test may be adequately sensitive and specific to eliminate the need for the wakeup test. In their cohort of 1121, no patient with a normal result on the ankle clonus test demonstrated any neurologic deficit. Three patients, all having Harrington rods placed, demonstrated absence of ankle clonus and yet had no neurologic deficit (false positives). Six patients lacked ankle clonus and had some form of postoperative neurologic deficits. Overall, sensitivity was 100%, and specificity was 99.7%. The authors recommended performing the wakeup test after an abnormal ankle clonus test (and before reversing any steps of the surgical procedure) and indicated that they do not perform the wakeup test after a normal ankle clonus test.

Authors' Disclosure Statement

Dr. Tobias wishes to note that he is on the Speaker's Bureau for and has received honoraria from Aspect Medical Systems, Inc., the manufacturer of the BIS monitor. The other authors report no actual or potential conflict of interest in relation to this article.

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