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Editorial

Monitoring

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Various techniques have been advocated to optimize pedicle screw positioning. Intraoperative fluoroscopy and plain radiography, fluoroscopy and CT-based image guidance, robotic screw placement systems, direct visualization of the medial wall after laminotomy, and a variety of electrophysiological monitoring techniques have been suggested as methods to improve placement accuracy or reduce complications. Surgeons are increasingly faced with revision cases in which normal anatomical landmarks have been distorted or are absent and with complex spinal deformity cases in which distorted anatomy or spinal rotation make pedicle screw placement a challenge. Unfortunately, none of the radiographic, image guidance, or monitoring techniques has completely eliminated misplaced screws or nerve injury.

A number of prior studies have evaluated the clinical utility of continuous electromyographic (EMG) monitoring, electrically evoked compound muscle action potential monitoring (triggered EMG activity), and EMG monitoring in combination with somatosensory and/or motor evoked potential recording.[1–6] Generally these studies have demonstrated some clinical utility, but almost all studies have instances of both false-positive and false-negative results.[1,3,5,6] The sensitivity of EMG monitoring (defined as the number of true-positive results divided by the sum of true-positive and false-negative results) has been relatively low.[1,3,5,6] Considering that a false-positive finding can result in the temporary removal of a pedicle screw to evaluate the screw tract, performing a laminotomy to check screw position, repositioning or complete removal of a pedicle screw, or aborting a planned portion of the procedure, the potential for adverse effects on outcome exists.

The medical literature has demonstrated a benefit associated with electrophysiological monitoring during major spinal deformity correction procedures performed at the level of the spinal cord. The benefit of electrophysiological monitoring during routine lumbar instrumentation procedures has been far less clearly defined. Electrophysiological monitoring can require additional preparation time, changes in standard anesthetic technique, and a substantial increase in the cost. The preparation time, cost, and potential complications further increase as multimodality monitoring involving somatosensory evoked potentials, motor evoked potential, and triggered EMG monitoring is used. Unfortunately, despite the use of even multimodality monitoring, new neurological deficits can still occur.[4]

In their large series, Parker and associates[2] evaluated the utility of intraoperative EMG monitoring during placement of 2450 consecutive lumbar pedicle screws in 418 patients. Each of the screws was stimulated at 10 mA after being inserted. Screws that exhibited a negative response at 10 mA were assumed to be accurately positioned without medial pedicle breach. When a positive response occurred at 10 mA, the authors undertook further investigation by determining the EMG threshold of stimulation. A threshold of less than 7 mA was interpreted as representing a potential medial cortical breach, and an attempt to visualize the medial pedicle intraoperatively and/or revise the screw was performed by the surgical team.

One hundred fifteen pedicle screws showed positive stimulation during intraoperative EMG monitoring. A false-positive finding was reflected by pedicle screws stimulated at less than or equal to 10.0 mA, which were confirmed to be placed accurately on both intraoperative inspection and postoperative CT scanning. There were 100% false-positive results at an 8.0–10.0-mA stimulation threshold, 88.9% false-positive results at a 5.0–7.9-mA threshold, and 9.1% false-positive results at a 2.0–4.9-mA threshold. The sensitivity was 69.6% when a threshold cutoff of 10.0 mA was used and 43.4% when a threshold cutoff of 5.0 mA was used. Most concerning, even using a stimulus threshold cutoff of 5.0 mA, there were 13 false-negative cases.

Increasingly, the decision to use electrophysiological monitoring during routine lumbar surgery is driven more by medicolegal concerns than by medical evidence. To date, none of the major studies evaluating EMG monitoring for lumbar surgery have performed either a cost-benefit analysis or a detailed outcome analysis comparing matched cases with or without monitoring. The authors of a recent series used 8 different neurophysiological testing modalities during surgery but still had 18 of 409 patients sustaining new neurological deficits.[4] This current series neither evaluated the cost of monitoring nor provided a control group to compare outcomes between patients with and without monitoring. Despite the large number of patients included, the value of EMG monitoring or the impact on patient outcome cannot be fully determined. Considering the instances of false-positive and false-negative results, the conclusion by the authors that "we certainly do not believe that the results of this study suggest that the use of EMG monitoring of lumbar pedicle screws should be adopted as a standard of care" is valid.

The decision whether to use monitoring should be determined by the complexity of the surgery, the surgeon's and institution's experience with monitoring, and the likelihood that the results of the monitoring will actually modify the surgical procedure to reduce risk. The benefits of identifying the relatively rare patient in whom a substantially misplaced pedicle screw causing potential neural injury is identified with EMG monitoring must be weighed against the impact of the false-positive and false-negative results in the procedure. Electromyographic and other neurophysiological monitoring techniques, image guidance, and advanced radiographic imaging techniques such as intraoperative CT scanning are all options potentially available to the surgeon to assist with pedicle screw placement. A much more detailed prospective study would be needed to determine whether electrophysiological monitoring and other techniques are cost-effective methods of reducing surgical morbidity for most lumbar surgical procedures.

Disclosure

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

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Response

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We appreciate the relevant issues raised by Dr. Shaffrey concerning our article. We would agree that despite the use of radiographic techniques, image guidance, and neurophysiological monitoring, misplaced pedicle screws and nerve injury in the thoracolumbar spine have not been eliminated. Because of the high false-positive and false-negative rates involved in stimulated EMG monitoring for lumbar pedicle screw placement, the technology certainly should not be adopted, at this point, as the standard of care for lumbar pedicle screw placement.

As Dr. Shaffrey correctly points out, the use of electrophysiological monitoring does result in increased preparation time, changes in anesthetic management, increased cost, and a greater potential for additional complications. However, it is our opinion based on this study, and those of others,[1-3] that the information gained from stimulated EMG monitoring for lumbar pedicle screw placement can be useful to the surgeon intraoperatively, and this technique should be continued to be actively studied. At our institution, the use of neurophysiological monitoring is a routine part of almost every spine procedure that involves lumbar pedicle screw instrumentation placement. Although this undoubtedly adds to the cost of the procedure, the practice does allow for increased efficiency with preparation, anesthetic techniques, and hopefully a reduced complication rate intrinsic to the monitoring. We do feel that continued refinement of stimulated EMG monitoring techniques will benefit patients in certain circumstances that are continuing to be defined.

There were 13 cases in which EMG stimulation was associated with a false-negative result. However, at a threshold cutoff of 5.0 mA or less, a positive response indicates a medially placed pedicle screw with a specificity of 99.9%. We believe this to be the most significant finding in our study, which has changed the way that our group utilizes intraoperative information derived from EMG stimulation for lumbar pedicle screw placement. We have also shown that a very low rate (1.7%) of misplaced pedicle screws can be achieved using the free-hand pedicle screw placement technique for thoracolumbar screws in combination with EMG stimulation of the screws.[4] Because of this finding and other data from the current manuscript, we continue to use EMG monitoring at our institution. There is no question that it is not a

perfect technique, which at this time, must serve as only a potentially useful adjunct to present experience, clinical judgment, and imaging modalities for the successful placement of lumbar pedicle screws. There is no question that further study of this modality is warranted before it could be considered for widespread use or a so-called standard of care. We would agree with Dr. Shaffrey that future studies to analyze the cost-effectiveness and reduce the surgical morbidity should be performed in a prospective fashion against matched cases without monitoring. We are appreciative of the interest in this manuscript.

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