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Intraoperative Neurophysiological Monitoring for Minimally Invasive 1- and 2-Level Transforaminal Lumbar Interbody Fusion: Does It Improve Patient Outcome?

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ABSTRACT

Background: Despite the widespread use of intraoperative monitoring (IOM) in many types of spinal surgeries, an absence of data comparing monitored a nd unmonitored postoperative outcomes places IOM's efficacy into question. A lack of consensus among surgeons about when to use monitoring also raises concerns about its overuse in routine and low-risk procedures.

Methods: We performed a retrospective database review of 112 patients undergoing a 1- or 2-level minimally invasive surgery transforaminal lumbar interbody fusion (MIS-TLIF). Our analysis focused on patient demographics, use of IOM, length of surgery, hospital length of stay, the perioperative complication of pedicle screw malposition, and average hospital cost.

Results: For the 73 patients who underwent MIS-TLIF with intraoperative neuromonitoring, their hospital length of stay (P=0.8) and need for pedicle screw revisions (P=0.93) were not statistically significant compared to the 39 patients who underwent MIS-TLIF procedures without IOM. The incidence of reoperation was 5.48% and 5.13%, and average length of stay was 3.25 days and 3.13 days, respectively. However, the cost of surgery and the length of surgery were significantly higher in the monitored group compared to the nonmonitored group (P=0.008 and P=0.009, respectively).

Conclusion: IOM is widely used in spine surgery, but our retrospective review shows that its use does not necessarily decrease the incidence of malpositioning of pedicle screws. In fact, no statistical difference was detected in the incidence of screw malposition in the 2 groups of patients. On the other hand, IOM adds cost and increases the length of surgery. Because the use of IOM did not make a difference in the incidence of pedicle screw malpositioning and because of the comparative cost analysis for both groups of patients, we believe that the use of IOM for MIS-TLIF provides no added benefit.

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INTRODUCTION

Spinal cord injury has always been one of the most feared complications of any type of spinal surgery. With sequelae ranging from pain to paralysis, surgeons have long sought ways to minimize the inherent dangers of operating near the spinal cord and nerve roots. Methods such as intraoperative and postoperative imaging have been used to confirm the proper placement of correction hardware, but many surgeons desire immediate feedback regarding patients' neurologic status during surgery. To this end, intraoperative (neurophysiological) monitoring (IOM) was developed and has become increasingly common in the past few decades as surgeons seek to reduce the risk of neurologic complications resulting from spinal cord injury during spinal correction surgery.[1,2]

By using multimodal monitoring, including somatosensory evoked potentials (SSEPs), motor evoked potentials (MEPs), and electromyograms (EMGs), surgeons can monitor spinal cord and nerve root function in real time and take measures to prevent or lessen irritation and potential damage.[3,4] Good evidence indicates that monitoring can detect intraoperative neurologic injuries, but evidence that monitoring actually helps to reduce the risk of new neurologic deficits is low.[5] Despite the widespread

Table 1. Patient Demographics

Intraoperative Monitoring	N	Male	Female	Average Age (Range)	Average Number of Surgery Levels
Yes	73	32	41	63.3 (29-86)	1.11
No	39	21	18	62 (39-83)	1.08

Note: Patients in both groups had the following preoperative diagnoses: grade 1-2 spondylolisthesis, spondylosis, degenerative disc disease, and herniated nucleus pulposus. Surgery was performed on levels L2-L3, L3-L4, L4-L5, and L5-S1.

use of IOM in many types of spinal surgeries, an absence of data comparing monitored and unmonitored postoperative outcomes places its efficacy into question.[6,7]

A lack of consensus among surgeons about when to use monitoring also raises concerns about its overuse in routine and low-risk procedures. Current variability in IOM use among spine surgeons is fueled largely by the beliefs of individual surgeons, with monitoring during routine lumbar surgeries identified as being particularly controversial.[8-10] Kulik et al conclude that IOM may be regarded as the standard of care for all surgical procedures except uncomplicated lumbar disc decompression.[11] Other studies have identified IOM as a valuable supplemental measure for thoracic and cervical spinal procedures but only rarely necessary for the lumbar spine.[12]

The cost of IOM also must be considered if monitoring is speculated to be unnecessary in certain types of procedures.[13] The equipment, operator, and technical costs associated with IOM increase the cost of an already expensive surgery by an estimated $1,535 per case.[14] In today's cost-conscious healthcare climate, deciding not to use IOM in uncomplicated lumbar surgeries may be a way for surgeons to help contain costs for patients and third-party payers.

METHODS

We performed a retrospective chart review of patients undergoing 1- or 2-level transforaminal lumbar interbody fusion (TLIF) by minimally invasive surgery (MIS) in a single institution performed by the senior author (WS) from 2010 to 2012. Patients were followed for a minimum of 1 year. The study was approved by the institutional review board.

Our objective was to compare the primary outcomes of average hospital costs, hospital length of stay (LOS), duration of surgery, and the need for revision due to screw malpositioning in patients receiving monitoring versus those who were not monitored. The data were analyzed using a 2-tailed, 2-sample *t* test.

RESULTS

A total of 112 patients underwent 1- or 2-level MIS-TLIF procedures from 2010 to 2012. Of these patients, 73 (65%) underwent surgery with IOM, including SSEPs, free-running EMGs, and triggered EMGs for pedicle screw stimulation, and 39 patients (35%) underwent surgery without IOM (Table 1). A larger number of patients was monitored because of the influence from the standard of care to provide IOM. The reasons 39 patients were not monitored were lack of availability of personnel to cover the cases and randomization.

Patient ages averaged 63.3 years and 62 years in the IOM and non-IOM groups, respectively. The patients in each group had similar preoperative diagnoses and comorbidities. Preoperative diagnoses included degenerative disc disease (DDD), degenerative spondylolisthesis grades 1 and 2, herniated nucleus pulposus (HNP), and spondylosis. All patients underwent the same preoperative clearance, and the surgical procedure was exactly the same for both groups. Surgery was performed on levels L2-L3, L3-L4, L4-L5, and L5-S1.

The hospital accounting and billing office provided direct hospital costs for all patients included in this study. The costs include labor, medical supplies, and other costs such as equipment and general/administrative costs that are expensed to all of the hospital cost centers. The cost of IOM was averaged based on whether the case was 1-level or 2-level and the general price package in place at our institution. The result was an average of $4,000 per case for IOM use. This cost data did not represent billing or charges but rather cost center-level expenditures incurred by the hospital to deliver care allocated to personnel, resource consumption, and overhead cost, among others. Direct costs also did not include cost of use of IOM because it is billed separately.

The Figure and Table 2 show a comparison of costs, surgical time, LOS, and need for revision surgery in monitored and unmonitored patients. The average hospital cost for the 73 patients undergoing MIS-TLIF with IOM was $30,734, and their average LOS was 3.25 days. Surgery time for MIS-TLIF patients with IOM was 262 minutes. The percentage of these patients who were taken back because of screw malpositioning was 5.48% (4 of 73). The average hospital cost for the 39 patients without IOM was $25,544, their average LOS was 3.13 days,

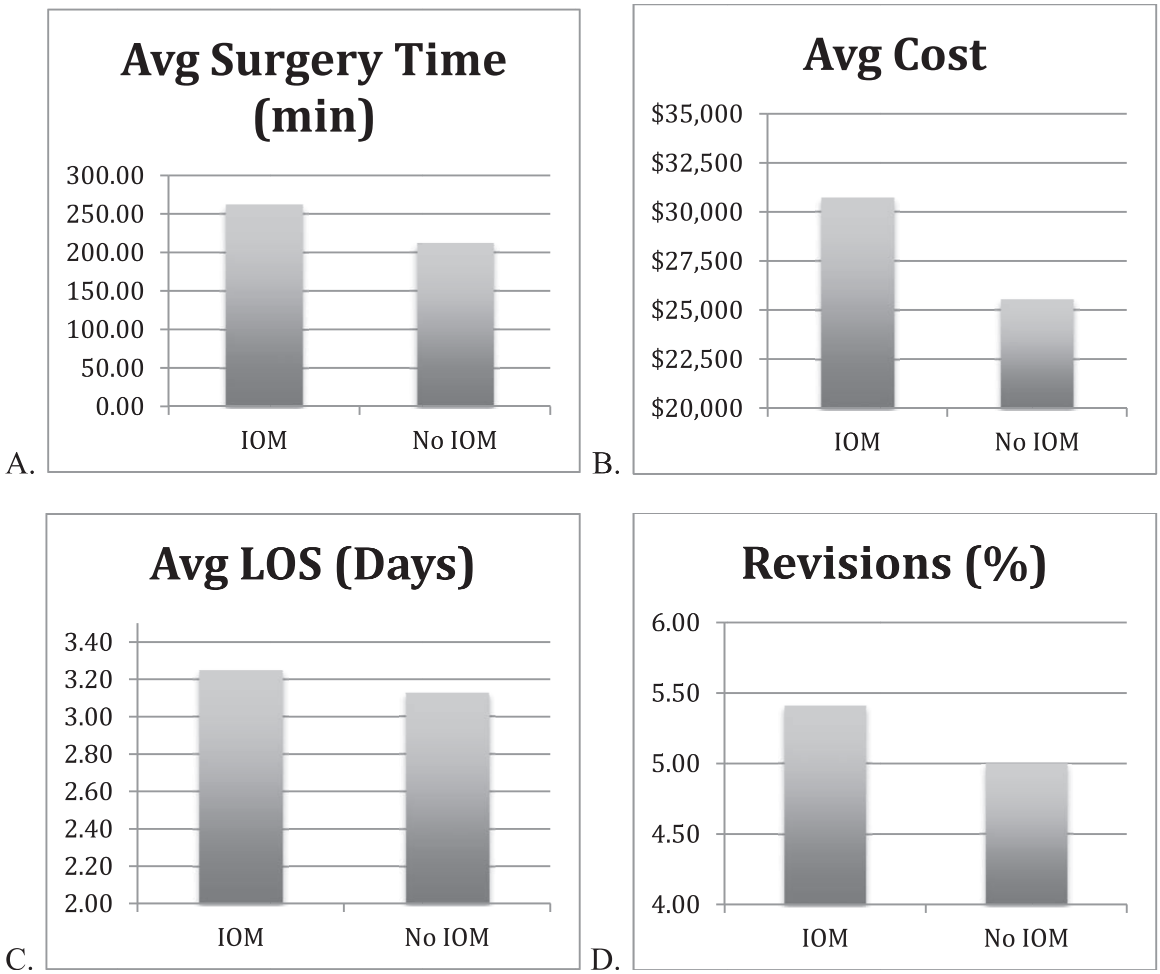

Figure. Time, cost, length of stay, and postoperative complication rates in monitored versus unmonitored patients. A: The average surgery time for patients receiving intraoperative monitoring (IOM) was significantly higher than the surgery time for patients who were not monitored (No IOM) ($P=0.009$). B: The total average hospital cost for patients receiving IOM was significantly higher than the cost for patients who did not receive IOM ($P=0.008$). C: The average length of hospital stay was comparable in the 2 groups ($P=0.8$). D: The percentage of patients requiring revisions for surgical malposition ($P=0.93$) was not statistically significant between the 2 groups.

and their average surgery time was 212.46 minutes. Of the patients undergoing MIS-TLIF surgery without IOM, 5.13% (2 of 39) were taken back to the operating room because of screw malpositioning.

Average direct hospital cost ($P=0.45$), average length of stay ($P=0.8$), and the percentage of patients taken back because of screw malposition ($P=0.93$) were not statistically significant. However, patients who underwent MIS-TLIF with IOM cost on average an additional $4,000 per case specifically at our institution, and when the cost of IOM is added to the direct hospital cost, the total cost of the surgery with IOM is significantly higher than the cost of the surgery without IOM ($P=0.008$).

Table 2. Patient Cost, Time, Length of Stay, and Revision Results

Intraoperative Monitoring	N	Average Hospital Cost	Average Surgery Time (Minutes)	Average Length of Stay (Days)	% Revisions
Yes	73	$30,734	262	3.25	5.48%
No	39	$25,544	212.46	3.13	5.13%

Likewise, the surgery takes longer when IOM is used, and the difference in average surgery time—262 minutes for the IOM group versus 212.46 minutes for the non-IOM group—was statistically significant ($P=0.009$).

DISCUSSION

IOM is a valuable technique for assessing the nervous system while a patient is under general anesthesia, especially during spinal or cranial neurosurgical cases, and replaces the neurologic examination while the patient is asleep. IOM allows for the assessment of many neural structures, including the neuromuscular junction, peripheral nerve, spinal cord, brainstem, and cortex during surgery. The most commonly employed techniques during spinal procedures are (1) MEPs, (2) upper and lower SSEPs, (3) pedicle screw stimulation, and (4) spontaneous EMGs. A number of other techniques have been used over the years, including direct spinal cord stimulation and reflex monitoring. We used SSEPs, pedicle screw stimulation, and EMGs in all our monitored spine cases.

In the IOM group, monitoring did not detect the malposition of pedicle screws that necessitated revision in 5.48% of patients. In fact, the incidence of screw malpositioning was similar in both surgical groups, suggesting that the use of IOM made no difference to the incidence of pedicle screw malpositioning.

Although direct hospital cost was similar in both groups, total cost was significantly higher in the IOM group because of the added cost of using IOM. The surgery time was also significantly longer in the IOM group and probably accounts for added costs that we did not take into account in this study.

Because the analysis of our patient database showed that the use of IOM did not make a difference in the incidence of pedicle screw malpositioning and because of the comparative cost analysis for both groups of patients, we believe that the use of IOM for MIS-TLIF provides no added benefit.

Given the current climate of cost-effective medicine, developing an evidence-based algorithm for determining which spine surgeries should be monitored is important. Many surgeons want to monitor every spine case even if the chance is tiny that a patient could benefit. They argue that some patients will have improved outcomes if the IOM picks up impending damage to the nervous system. In our series, the use of IOM did not pick up medial bridge of the pedicles and nerve root irritation in 5.48% of the patients. Consequently, we think the added cost of IOM is not justified in our series. The significance of nerve root irritation or medial bridge would allow the surgeon to intraoperatively reposition the screw, but that was not noted in our experience.

Several other arguments can be made for IOM and perhaps more objective ways can be devised to analyze its cost effectiveness. Stecker[15] provided a good mathematical analysis (2012) of the cost of responding to an IOM warning during surgery and other associated costs. He stated that each time the monitoring team issues an IOM warning, a number of events occur. The surgical and anesthesia teams double check what they are doing. They will commonly attempt to increase the blood pressure, administer medications, or change the level of anesthesia. Thus, operating room time and medications have a cost: $C_o(W)$, the operative cost of responding to a warning. The cost can be expressed as $C_o(W) \times P(W)$, where $P(W)$ is the probability that a warning will be issued. In addition, the cost of providing the monitoring for each case, C_m, is not dependent on the rate of issuing a warning. Steckler proposed that the total cost of monitoring is $C_m + C_o(W) \times P(W) - C(I) \times P(I/W)P(W) \times PC$ where $C(I)$ is the cost of an injured patient, $P(I/W)$ is the probability of injury given a warning, and PC is the probability that a true warning can be acted on to prevent injury. He concluded that if the resulting number is positive, monitoring is not cost effective. If the resulting number is negative, then monitoring is cost effective. Hence, injuries to the spinal cord resulting in permanent disability that translate into millions of dollars in medical costs make the use of IOM cost effective. For surgical procedures in which the cost of an injury is less, monitoring becomes cost effective by this calculation only when the risk of injury is high.

In our series, 5.13%-5.48% of patients had medialized screws that needed repositioning. Our incidence is comparable to the published incidence of pedicle screw malposition of 5%-10%, and only 0.5%-2% of these patients have significant nerve root irritation injuries.[16,17] Therefore, the risk of permanent nerve injury from pedicle screw malposition is not high, making the cost effectiveness of using IOM during lumbar spine surgery further questionable. We definitely did not see any benefit of the monitoring in our series. Further analysis of cost-effectiveness is required to make conclusive remarks.

The limitations of this study are as expected for a retrospective study. In addition, we did not provide any long-term data on the sequelae of pedicle screw malpositions to the patients. Our results cannot be generalized to more complex spine cases for which IOM is almost mandatory, such as microsurgical resection of intramedullary tumor or complex deformity surgeries. We plan to perform further analyses of our data in terms of costs and long-term functional outcomes.

CONCLUSION

In patients undergoing 1- or 2-level MIS-TLIF for degenerative spondylolisthesis, spondylosis, HNP, or DDD, IOM is conventionally used to assess for nerve injury and screw malposition. Based on the results of our study, we conclude that the use of IOM for patients undergoing this surgery adds unnecessary costs, has little effect on postoperative outcomes, and increases surgery time.

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