A socioeconomic analysis of intraoperative neurophysiological monitoring during spine surgery: national use, regional variation, and patient outcomes

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Object. In the United States in recent years, a dramatic increase in the use of intraoperative neurophysiological monitoring (IONM) during spine surgeries has been suspected. Myriad reasons have been proposed, but no clear evidence confirming this trend has been available. In this study, the authors investigated the use of IONM during spine surgery, identified patterns of geographic variation, and analyzed the value of IONM for spine surgery cases.

Methods. In this retrospective analysis, the Nationwide Inpatient Sample was queried for all spine surgeries performed during 2007–2011. Use of IONM (International Classification of Diseases, Ninth Revision, code 00.94) was compared over time and between geographic regions, and its effect on patient independence at discharge and iatrogenic nerve injury was assessed.

Results. A total of 443,194 spine procedures were identified, of which 85% were elective and 15% were not elective. Use of IONM was recorded for 31,680 cases and increased each calendar year from 1% of all cases in 2007 to 12% of all cases in 2011. Regional use of IONM ranged widely, from 8% of cases in the Northeast to 21% of cases in the West in 2011. Iatrogenic nerve and spinal cord injury were rare; they occurred in less than 1% of patients and did not significantly decrease when IONM was used.

Conclusions. As costs of spine surgeries continue to rise, it becomes necessary to examine and justify use of different medical technologies, including IONM, during spine surgery.

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Key Words • socioeconomic • neurophysiological monitoring • spine surgery

Abbreviations used in this paper: ICD-9 = International Classification of Diseases, Ninth Revision; IONM = intraoperative neurophysiological monitoring; NIS = Nationwide Inpatient Sample.
Incorporated). For all statistical comparisons, an alpha level of 0.05 was used to determine statistical significance. Use of IONM was reported as a percentage of total queried cases per year. Statistical comparison between groups was performed by using the Fisher exact test for categorical variables and analysis of variance tests in SAS 9.2 (SAS Institute Incorporated). For all spine surgery cases in 2011, IONM use increased remarkably from 1% of all spine surgery cases in 2007 to a high of 12% of spine surgeries or for patients with other diagnoses was statistically significant benefit for use of IONM during other spine surgeries or for patients with other diagnoses was statistically less significant (p = 1.000). The only surgery for which IONM was associated with improved independence at discharge was posterior thoracic fusion (OR 1.102, p = 0.05). No statistically significant benefit for use of IONM during other spine surgeries or for patients with other diagnoses was detected (Table 4).

Among the patients sampled, iatrogenic nerve injury and spinal cord injury during elective procedures were extraordinarily rare. Of the 443,194 spine surgery cases queried, only 20 iatrogenic nerve injuries were reported; incidence (p = 1.000) did not differ significantly among patients for whom IONM had been used (19 events among 349,561 patients). Similarly, spinal cord injury was reported for 229 patients; incidence (p = 1.000) did not differ significantly among those in whom IONM had been used (1 event among 27,687 patients) and those for whom IONM had not been used (98% vs 98%, respectively, p = 1.000). The only surgery for which IONM was associated with improved independence at discharge was posterior thoracic fusion (OR 1.102, p = 0.05). No statistically significant benefit for use of IONM during other spine surgeries or for patients with other diagnoses was detected (Table 4).

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Increased use of intraoperative monitoring during spine surgery

This study illuminates several trends in the use of IONM during spine surgery in the United States. First, use has increased notably in recent years. Second, this increase is associated with marked variation in a hospital’s geographic location, relative population density, and teaching status. And third, use increased steadily across all types of spine surgery, even those that have traditionally been viewed as lower-risk surgeries (e.g., anterior cervical discectomy and fusion in the absence of myelopathy, posterior lumbar fusion for lumbago, and lumbar discectomy).

The reasons for increased use of IONM remain unanswerable by this data set. We speculate that the reasons

<table>
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<th>Percentage of Patients Discharged to Home</th>
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might include the willingness of surgeons to adopt new technology, increasing availability of IONM, medicolegal concerns, and even financial incentive. Although the increased use of IONM during 2007, after introduction of an ICD-9 code for IONM, might reflect, in part, more accurate coding, we suspect that the trend observed over the 4 years is not simply artificial. The lack of change in use in hospitals in the Northeast over this time frame might even indicate an internal control, displaying a relative regional constant in use of IONM.

To date, there is no established consensus regarding the use of IONM during low-risk spine surgeries. In fact, studies have argued against the use of this monitoring modality during lumbar discectomy. Use of IONM for lumbar spinal fusion procedures has also been shown to be of no clear benefit; it can introduce misleading or unreliable intraoperative findings.

Similar to lack of consensus for low-risk lumbar surgeries, there is not yet consensus supporting the use of IONM during low-risk cervical spine surgeries. Indeed, our study showed no difference in independence at discharge between patients in whom IONM was used versus patients in whom IONM was not used during elective anterior cervical disectomy and fusion surgery. The absence of IONM use during low-risk cervical spine surgery is supported by other studies that have reported a lack of iatrogenic nerve and spinal cord injury among patients who underwent cervical spine surgery without use of IONM. Other studies suggest that use of IONM during cervical spine surgeries can actually misinform the surgeon and result in inaccurate intraoperative findings. Alternatively, some researchers argue that IONM contributes to prevention of new postoperative neurological deficits in patients undergoing low-risk cervical spine surgeries. Roh et al. reported that somatosensory evoked potential monitoring prompted an intervention for 2.1% of 809 patients consecutively undergoing cervical spine surgery and probably prevented neurological sequelae in 82% of patients for whom an intervention was made. Additionally, Epstein et al. compared morbidity and mortality rates among 218 unmonitored patients and 100 monitored patients who underwent cervical spine surgery and found rates to be 3.7% and 0.5%, respectively, among unmonitored patients and 0% among monitored patients, a difference that was attributed to early somatosensory evoked potential detection of spinal cord compromise and immediate corrective action.

Some evidence suggests that IONM prevents postoperative neurological deficits in patients undergoing more complex spinal procedures, particularly deformity correction. Indeed, use of IONM with somatosensory evoked potentials and transcranial motor evoked potentials represents the minimum standard of care for patients undergoing scoliosis surgery. Additionally, one would expect use of IONM to prevent neurological deficits in patients undergoing spine surgery in which the spinal cord or its nerve roots are intimately involved with the pathology (e.g., spinal cord tumor and spinal dysraphism). There is evidence to support use of IONM during revision spine surgeries, which inherently pose higher risk for neurological injury.

In an era when iatrogenic nerve and spinal cord injury are rare, the increased use of IONM during spine surgery could be attributed to a developing culture in surgery that is quick to adopt new technologies, thereby increasing medicolegal concerns among spine surgeons, or it could be attributed simply to artifact (increased application of the ICD-9 code for IONM after its introduction in 2007). The variation seen in association with geographic region, urban versus rural settings, and status as a teaching hospital strongly endorses the notion that there is a tangible trend toward increased use, particularly in western states, urban centers, and nonteaching institutions. This increase goes hand-in-hand with the possibility that the increased use of IONM might be a reflection of medicolegal pressures or financial interests.

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The limitations of the NIS should be briefly discussed. This data set is an administrative data set that fails to capture the true clinical variables at play. Data abstraction is prone to errors. Incorporation of a new ICD-9 code might lead to some lag in its full utilization. The true economic implications are also very difficult to assess by using this data set alone. Although hospital charges are captured, hospital costs are not, and the relationship between these can be rather opaque.

Despite these limitations, our findings display a clear lack of consensus on the value of this technique; data to support its use in low-risk spine surgeries are equivocal at best. Thus, the trend of increased use of IONM, particularly during low-risk spine surgeries, might warrant further exploration with large prospective trials. In the absence of higher-quality data to drive guidelines, we recommend limiting use of IONM to procedures with a theoretically greater likelihood of intraoperative cord or nerve injury, such as cases of severe spinal cord compression or deformity correction, and abstaining from its use during simpler surgeries, such as anterior cervical fusion without myelopathy and lumbar microdiscectomy.

Conclusions

Use of IONM during spine surgery has increased dramatically in recent years; use varies markedly according to hospital region, relative population density, and teaching status. In this data set, use of IONM did not strongly correlate with improved patient independence at discharge or prevention of iatrogenic nerve or spinal cord injury. The trend of increased use of IONM in general, and during low-risk spine surgeries in particular, may warrant further exploration, given a lack of consensus to support its use in such cases. We recommend limiting use of IONM to procedures with a theoretically greater likelihood of intraoperative value (e.g., severe spinal cord compression or deformity correction) and abstaining from its use for simpler surgeries (e.g., anterior cervical fusion without myelopathy and lumbar microdiscectomy).

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Increased use of intraoperative monitoring during spine surgery

Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Dumont. Analysis and interpretation of data: Sheen James, Dumont. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript: all authors. Reviewed submitted version of paper: Administrative/technical/material support: Dumont. Study supervision: Dumont.

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