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

WHITNEY SHEEN JAMES, M.D., M.H.S.,¹ ANAND I. RUGHANI, M.D.,²
AND TRAVIS M. DUMONT, M.D.¹

¹Division of Neurosurgery, University of Arizona, Tucson, Arizona; and ²Neuroscience Institute, Maine Medical Center, Portland, Maine

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

As costs of modern health care rise, it is prudent to frequently examine the use of different medical technologies and justify the rationales for their use. We examined use of intraoperative neurophysiological monitoring (IONM) during spine surgery, which commonly includes measuring and monitoring somatosensory evoked potentials, motor evoked potentials, electromyographic recordings, or any combination,^{5,12} during spine surgery.

Since the early 2000s, use of IONM for spine surgery is believed to have increased in almost every region of the country. Anecdotal evidence suggests that its use extends beyond cases such as scoliosis surgery and intrinsic spinal cord tumor surgery to now include relatively low-risk surgeries such as simple discectomy and anterior cervical discectomy and fusion. We investigated the use of IONM during spine surgery and patterns of its use in the United States.

Abbreviations used in this paper: ICD-9 = International Classification of Diseases, Ninth Revision; IONM = intraoperative neurophysiological monitoring; NIS = Nationwide Inpatient Sample.

Methods

The Nationwide Inpatient Sample (NIS) was obtained from the Agency for Healthcare Research and Quality for the years 2007 (the 1st year of the International Classification of Diseases, Ninth Revision, [ICD-9] code for IONM) to 2011 (the most recent year with available data). Allowing for collection of up to 24 diagnoses in addition to a patient's primary diagnosis, this database includes roughly 8 million annual entries. It is designed to produce a representative sample of approximately 20% of all annual hospital inpatient admissions in the United States. For the most recent years available, 44 states (representing 95% of the US population) contributed to the NIS. The NIS stratifies data from hospital-based factors such as hospital size, location, teaching affiliation, and not-for-profit versus for-profit designation. Individual clinical records are generated by data abstraction. For the purposes of this study, individual cases were isolated on the basis of ICD-9 codes for common spine disorders (Table 1) and common spine surgery procedures (Table 2).

Each case was queried for use of IONM (ICD-9 code 00.94), and an estimate of premorbid condition was deter-

TABLE 1: Common spinal disorders queried from the NIS database, 2007–2011

Diagnosis	ICD-9 Code*
malignant neoplasm of spinal cord	192.2
malignant neoplasm of spinal meninges	192.3
benign neoplasm of spinal cord	225.3
benign neoplasm of spinal meninges	225.4
intervertebral disc disorders	722.x
acquired spondylolisthesis	738.4
fracture of vertebral column w/o mention of spinal cord injury	805.x
fracture of vertebral column w/ spinal cord injury	806.x

* x designates 0–9, codes based on diagnosis level/location.

mined according to the Elixhauser comorbidity score² (an ICD-9 diagnosis–based system that considers a patient's comorbid state, which could be associated with prolonged hospitalization). The score is based on summation of the presence or absence of diagnostic codes listed for up to 30 disease groups; scores range from 0 to 3. Use of IONM was compared between calendar years across primary diagnoses, surgical levels operated on, US geographic regions, hospital locations (urban or rural), and hospital teaching status. Nerve injury (ICD-9 957.9) and spinal cord injury (ICD-9 252.0–252.9) for elective procedures were considered new diagnoses, and we compared their incidence with or without use of IONM.

For analysis of discharge disposition, we compared patient independence at discharge (defined as routine or with in-home services) with discharge to a facility other than home. 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 and analysis of variance tests in SAS 9.2 (SAS Institute Incorporated). For all statistical comparisons, an alpha level of 0.05 was used to determine statistical significance.

Results

We identified 443,194 spine procedures, of which 85% were elective and 15% were not elective. Use of IONM was reported for 31,680 (7.15%) of these cases. Use of IONM increased each calendar year, from a low of 1% of all spine surgery cases in 2007 to a high of 12% of all spine surgery cases in 2011. IONM use increased regardless of diagnosis or surgical location (Table 3). Even

TABLE 2: Common spine surgery procedures queried from NIS database, 2007–2011

Procedure	ICD-9 Code*
laminectomy or laminotomy	3.09
spinal fusion	81.0x
laminectomy w/ excision of intervertebral disc	80.51

* x designates 0–9, codes based on fusion level and approach.

TABLE 3: Yearly percentage use of IONM in the United States, by diagnosis and surgical level

Variable	IONM Use (%)				
	2007	2008	2009	2010	2011
diagnosis					
fracture	0.6	6.5	7.7	11.5	12.0
disc degeneration	0.8	5.6	8.7	13.0	14.8
disc displacement	0.5	2.9	6.3	7.4	8.9
myelopathy	0.5	7.0	8.6	12.0	14.1
tumor of meninges	3.6	16.9	30.3	35.6	35.7
tumor of spinal cord	5.0	24.2	33.6	38.1	45.9
location					
cervical	0.6	4.6	8.0	8.7	10.5
thoracic	0.7	6.1	7.6	11.6	11.6
thoracolumbar	0.5	3.4	6.7	9.3	10.9
lumbar	0.6	7.2	7.5	11.8	12.6

discectomy for “disc displacement” showed a steady rise in use of IONM from 2.9% in 2008 to 8.9% in 2011.

IONM use between hospital geographic regions, relative population (urban/rural), and teaching status was not uniform. Regional variations were most pronounced in 2011 (the most recent year studied), when the regional low was 8% of cases in the Northeast and the regional high was 21% of cases in the West (Fig. 1). With the exception of the Northeast, use of IONM during spine surgery increased in all other US regions from 2007 to 2011 (Fig. 1). Use of IONM during spine surgeries was more common in hospitals in urban (7%) than in rural settings (4%) and in nonteaching (8%) than in teaching (6%) hospitals.

For elective and nonelective spine surgery patients, the likelihood of independence at discharge was diminished for patients in whom IONM was used (OR 0.842, $p < 0.001$, and OR 0.846, $p < 0.001$, respectively). When individual types of spine surgery performed were compared and admission type and comorbidities were controlled for, among patients without myelopathy who underwent anterior cervical discectomy and fusion surgery, independence at discharge did not differ among those in whom IONM was or was not 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).

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 (1 event among 27,687 patients) and those for whom IONM had not been used (19 events among 349,561 patients). Similarly, spinal cord injury was reported for 229 patients; incidence did not differ significantly ($p = 0.203$) among patients for whom IONM had been used (22 events among 27,688 pa-

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Fig. 1. Illustration showing the increase in percentage use, by geographic region, of IONM during anterior cervical discectomy and fusion surgeries, microdiscectomy surgeries, and all spine surgeries in the United States, 2008–2011.

tients) and those for whom IONM had not been used (207 events among 349,561 patients).

Discussion

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 hospi-

tal'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 4: Role of IONM regarding patient independence at discharge after common spine procedures and diagnoses

Variable	No.	Percentage of Patients Discharged to Home		Multivariate Analysis	
		IONM	No IONM	OR	p Value
procedure					
laminectomy	51,981	82	86	0.796	<0.0001
microdiscectomy	252,472	91	94	0.771	<0.0001
atlantoaxial fusion	800	67	73	0.741	0.062
anterior cervical fusion	92,603	97	98	0.907	0.062
posterior cervical fusion	6,175	76	78	0.976	0.71
anterior thoracic fusion	1,258	68	71	1.099	0.432
posterior thoracic fusion	5,702	60	60	1.102	0.05
anterior lumbar fusion	30,925	86	89	1.015	0.756
posterior lumbar fusion	135,582	84	85	1.033	0.183
diagnosis					
disc degeneration	156,875	88	90	0.946	0.029
disc displacement	194,817	94	95	0.849	<0.0001
fracture	5,009	67	68	0.828	<0.0001
myelopathy	29,572	89	90	0.981	0.725
scoliosis	11,591	74	74	1.072	0.213
spinal tumor of meninges	708	73	74	0.456	<0.0001
spinal cord tumor	526	73	69	1.104	0.587

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 artifactual. 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.¹ Use of IONM for lumbar spinal fusion procedures has also been shown to be of no clear benefit;¹⁶ it can introduce misleading or unreliable intraoperative findings.⁶

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.¹⁵ 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 discectomy 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.¹⁹ Other studies suggest that use of IONM during cervical spine surgeries can actually misinform the surgeon and result in inaccurate intraoperative findings.^{11,18} 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.¹⁷ 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.⁴

Some evidence suggests that IONM prevents postoperative neurological deficits in patients undergoing more complex spinal procedures, particularly deformity correction.^{13,14} Indeed, use of IONM with somatosensory evoked potentials and transcranial motor evoked potentials represents the minimum standard of care for patients undergoing scoliosis surgery.¹³ 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).^{8,10} There is evidence to support use of IONM during revision spine surgeries, which inherently pose higher risk for neurological injury.⁷

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,^{9,12} thereby increasing medicolegal concerns among spine surgeons,⁴ 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.^{3,13}

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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Disclosure

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

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Address correspondence to: Whitney Sheen James, M.D., M.H.S., University of Arizona, 1501 N. Campbell Ave., P.O. Box 245070, Tucson, AZ 85724-5070. email: whitney.sheen.james@gmail.com.