Original Article

The utility of intraoperative neuromonitoring on simple posterior lumbar fusions—analysis of the National Inpatient Sample

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Background: Several studies have demonstrated the utility of intraoperative neuromonitoring (IOM) including somatosensory evoked potentials (SSEPs), motor-evoked potentials (MEPs), and electromyography (EMG), in decreasing the risk of neurologic injury in spinal deformity procedures. However, there is limited evidence supporting the routine use of IOM in elective posterolateral lumbar fusion (PLF).

Methods: The National Inpatient Sample (NIS) was analyzed for the years 2012–2015 to identify patients undergoing elective PLF with (n=22,404) or without (n=111,168) IOM use. Statistical analyses were conducted to assess the impact of IOM on length of stay, total charges, and development of neurologic complications. These analyses controlled for age, gender, race, income percentile, primary expected payer, number of reported comorbidities, hospital teaching status, and hospital size.

Results: The overall use of IOM in elective PLFs was found to have increased from 14.6% in the year 2012 to 19.3% in 2015. The total charge in hospitalization cost for all patients who received IOM increased from $129,384.72 in 2012 to $146,427.79 in 2015. Overall, the total charge of hospitalization was 11% greater in the IOM group when compared to those patients that did not have IOM (P<0.001). IOM did not have a statistically significant impact on the likelihood of developing a neurological complication.

Conclusions: While there may conceivably be benefits to the use of this technology in complex revision fusions or pathologies, we found no meaningful benefit of its application to single-level index PLF for degenerative spine disease.

Keywords: Intraoperative neuromonitoring (IOM); posterolateral lumbar fusion (PLF); National Inpatient Sample (NIS); lumbar spine; somatosensory evoked potentials (SSEPs)

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Introduction

Since their introduction in the 1970s, intraoperative neuromonitoring (IOM) techniques such as somatosensory evoked potentials (SSEPs), motor-evoked potentials (MEPs), and electromyography (EMG) have grown to become a routinely used technology in many spine procedures (1). SSEPs are the most commonly used technique, wherein electrodes are used to stimulate peripheral nerves, generating controlled repetitive action potentials that monitor the dorsal column-medial lemniscus pathway (2). MEPs allow for a direct measurement of corticospinal motor tract function while EMGs continuously monitor peripheral nerve roots responsible for specific muscle innervation (2,3). IOM technology is used to potentially detect neurologic injury in real time during these procedures, theoretically reducing the rate of new postoperative neurological deficits.

Several studies have demonstrated the utility of IOM in

Table 1 ICD-9 diagnosis codes and descriptors for indications of surgery between groups

Non-IOM (n=111,168)			IOM (n=22,404)		
ICD-9 diagnosis	N	%	Diagnosis	N	%
72402: Lumbar spinal stenosis	19,873	17.88	72252: Lumbar/lumbosacral disc degeneration	4,237	18.91
72252: Lumbar/lumbosacral disc degeneration	17,064	15.35	7384: Acquired spondylolisthesis	3,647	16.28
7384: Acquired spondylolisthesis	16,397	14.75	72210: Lumbar disc displacement	2,995	13.37
72210: Lumbar disc displacement	15,090	13.57	72402: Lumbar spinal stenosis	2,976	13.28
7213: Lumbosacral spondylosis	11,554	10.39	7213: Lumbosacral spondylosis	2,489	11.11

IOM, intraoperative neuromonitoring.

decreasing the risk of neurologic injury in spinal deformity procedures, likely contributing to the overall increase in IOM usage over the years. However, the routine use of IOM in elective posterolateral lumbar fusions (PLFs) remains controversial (4-9). A number of studies analyzing IOM use in PLF procedures have demonstrated little benefit in reducing postoperative complications (3,10-12). Moreover, several other studies have shown IOM use in spine procedures leads to increased hospitalization cost and procedural time without any change in the rate of neurologic injury (5,11).

The authors queried the National Inpatient Sample (NIS) data set for all patients who underwent a first time elective instrumented PLF for degenerative pathology between 2012 and 2015 in order to gain a better understanding of the efficacy of IOM in the prevention of neurological complications in elective PLF as well as how its use relates to the hospitalization cost and length of stay.

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/jss-20-679).

Methods

Data source

The NIS was analyzed for the years 2012–2015 to identify patients undergoing elective PLF. The NIS is the largest national health database of its kind, consisting of a 20% stratified random sample of all non-federal US hospital discharges. The database contains patient demographics, hospital information, and ICD-9 diagnosis and procedure codes billed for a single hospitalization. The years 2012–2015 were chosen because the database was redesigned in 2012, making analysis of the preceding time period difficult to combine with post-redesign data, and 2015 was chosen as an endpoint because starting in the third quarter of the year, the database was converted from ICD-9 to ICD-10 codes, which also complicates analysis.

Data selection and inclusion/exclusion criteria

Discharges with ICD-9 procedure codes for posterior lumbar fusion (81.07 and 81.08) were identified for patients ≥18 years or older. Patients undergoing thoracolumbar fusions, anterior lumbar fusions, fusions for spinal deformity, and revision fusions were intentionally not included so that the population of interest consisted of routine index lumbar fusions for degenerative spine disease. For similar reasoning, also excluded were discharges with diagnoses of spinal tumors, infections, or trauma. Included patients were then divided into those with and without an ICD-9 procedure code for neuromonitoring (ICD-9 CM 00.94, *Table 1*). Patient demographics consisting of age, sex, race, primary payer, income quartile of patient ZIP code, and medical comorbidities were extracted along with length of stay, cost of hospitalization, development of postoperative neurological complications, and hospital factors such as teaching status, geographic region, urban or rural location, and hospital bed size. Comorbidities were identified and analyzed using the Elixhauser classification of comorbidities which were analyzed on the basis of count (0, 1, 2, or ≥3). Neurological complication was a binary variable based on the presence or absence of any of the ICD-9 codes 997.00, 997.01, 997.02, 997.09 for "neurologic complications resulting from any services or procedures" (*Table 2*). Only neurological complications were studied, as opposed to other surgical (e.g., wound infection) and medical [deep vein thrombosis (DVT), pulmonary embolism (PE)] perioperative complications. The three primary outcomes analyzed in the monitoring and non-monitoring patient sub-populations were length of stay, total charge of hospitalization, and development of neurological complications. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). No IRB approval was necessary given the de-identified nature of this national database. No informed consent was obtained as it did not apply to the study.

Statistical analysis

Statistical analysis accounted for the complex NIS sample design through the use of appropriate stratification, clustering, and discharge weighting. Missing data was analyzed and imputed using a Markov Chain Monte Carlo method. Age was converted into a categorical variable for three age groups (age 18–40, 41–60, and >60). Number of comorbidities was coded as 0, 1, 2, or ≥3 comorbidities per discharge. Differences in proportions between groups were analyzed with χ^2, and differences in means were analyzed with Student's *t*-tests. Generalized linear mixed models with hospital as a random intercept using SAS PROC GLIMMIX were used to model length of stay, total charges, and development of complications using Poisson, lognormal, and binary distributions, respectively. Variables included in these statistical models included sex, payer, race, hospital type, hospital geographic region, income quartile by ZIP code, age, hospital bed size, number of comorbidities, year, length of stay, and presence or absence of intraoperative monitoring, in order to adjust for any potential confounding effects of these variables.

Table 2 ICD-9 codes and descriptions used to identify the presence of neurological complications on a given discharge record in the NIS

Code	Description
997.00	Nervous system complication, unspecified
997.01	Central nervous system complication
997.02	Iatrogenic cerebrovascular infarction or hemorrhage
997.09	Other nervous system complications

NIS, National Inpatient Sample.

Results

The demographic characteristics of all patients with and without IOM utilization are shown in *Table 3*. Between the years 2012 and 2015, 22,404 patients were identified in the database that received IOM during their operation. In this same time period, 111,173 patients were identified that underwent a PLF without IOM. The above populations were further broken down into age, gender, race, income percentile, the primary expected payer, number of reported comorbidities, hospital type, and hospital size (*Table 3*). Our study demonstrated that 27.79% of the IOM cohort were in the top income quartile and 20.60% were in the bottom quartile, in comparison to 22.77% and 24.11% in the group without IOM respectively (P<0.0001). In the IOM group,

Table 3 Comparison of baseline +IOM and –IOM patient populations (complete case analysis before imputation of missing data)

Characteristics	IOM (n=22,404)		Non-IOM (n=111,168)		P value
	N	%	N	%	
Year					
2012	5,099	22.76	29,848	26.85	0.0018
2013	5,783	25.81	29,704	26.72	0.4864
2014	6,231	27.81	29,540	26.57	0.3300
2015	5,291	23.62	22,081	19.86	0.0003
Age					
18 to 40 years	2,294	10.24	10,660	9.59	0.0092
41 to 60 years	8,799	39.27	41,634	37.45	<0.0001
>60 years	11,311	50.49	58,879	52.96	<0.0001

Table 3 (*continued*)

Table 3 (*continued*)

Characteristics	IOM (n=22,404)		Non-IOM (n=111,168)		P value
	N	%	N	%	
Gender					
Female	12,317	54.99	62,347	56.08	0.0029
Male	10,081	45.01	48,819	43.92	0.0029
Race					
Asian	301	1.40	1,241	1.18	0.0245
Black	1,435	6.69	8,056	7.66	0.0001
Hispanic	1,456	6.79	6,031	5.73	0.0004
White	17,426	81.27	86,870	82.56	0.0097
Other	697	3.11	2,576	2.32	0.0003
Income quartile					
First (bottom)	4,534	20.60	26,311	24.11	<0.0001
Second	5,407	24.57	29,362	26.90	<0.0001
Third	5,932	26.95	28,540	26.15	0.0779
Fourth (top)	6,116	27.79	24,847	22.77	<0.0001
Primary expected payer					
Medicaid	1,270	5.68	6,618	5.96	<0.0001
Medicare	9,418	42.11	50,865	45.82	<0.0001
Private	9,425	42.14	43,226	38.94	<0.0001
Self-pay	187	0.84	993	0.89	0.4656
Other	2,049	9.15	9,181	8.26	0.0053
No charge	15	0.07	96	0.09	0.4469
Number of comorbidities					
Zero	4,168	18.60	22,364	20.12	<0.0001
One	5,605	25.02	28,654	25.77	0.0248
Two	5,170	23.08	26,397	23.74	0.0326
Three	7,461	33.30	33,758	30.37	0.0001
Hospital type					
Rural	814	3.63	4,929	4.43	0.1216
Urban non-teaching	8,455	37.74	38,392	34.53	0.0123
Urban teaching	13,135	58.63	67,852	61.03	0.0680
Hospital size					
Small	4,511	20.13	19,091	17.17	0.0060
Medium	5,780	25.80	30,598	27.52	0.1500
Large	12,113	54.07	61,484	55.30	0.3673

IOM, intraoperative neuromonitoring.

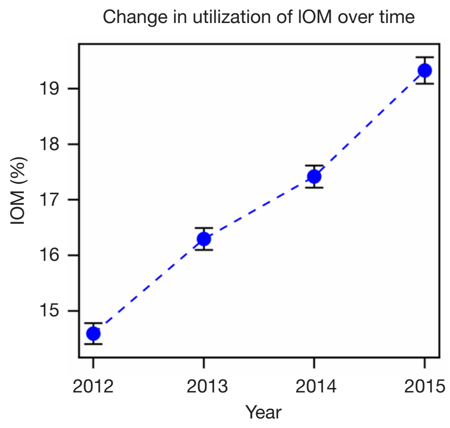

Figure 1 Change in utilization of IOM over time. IOM, intraoperative neuromonitoring.

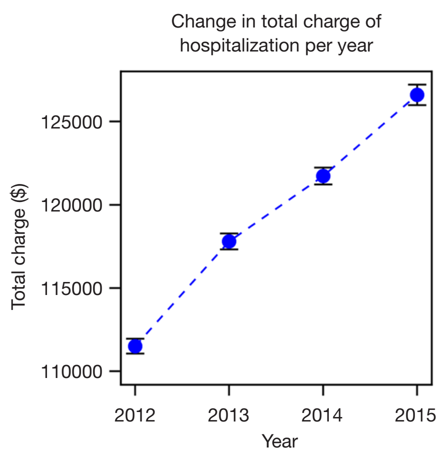

Figure 2 Combined change in total charge of hospitalization over time.

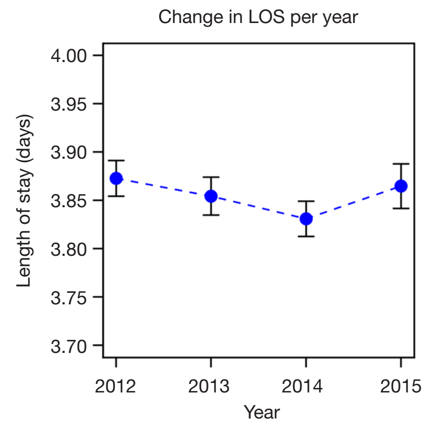

Figure 3 Combined change in length of stay over time.

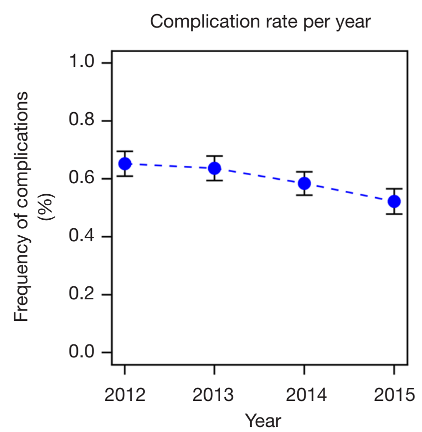

Figure 4 Combined change in complication rate over time.

42.14% were privately insured in comparison to those that were primarily Medicare (42.11%) and Medicaid (5.68%) covered (P<0.0001). In the group without IOM however, 38.94% were primarily privately insured in comparison to those covered through Medicare (45.82%) or Medicaid (5.96%) (P<0.0001).

IOM use in elective PLFs was found to have increased from 14.6% in the year 2012 to 19.3% in 2015, which is an overall increase of 1.2% per year (*Figure 1*). The total charge in hospitalization cost was also found for all patients who received IOM to have increased from $129,384.72 in 2012 to $146,427.79 in 2015 (*Figure 2*). Cost of stay of the non-IOM patients was $108,503.52 in 2012 and $121,898.88 in 2015. Overall, the total charge of hospitalization was 11% greater in the IOM group when compared to those patients that did not have IOM (95% CI: 11–12%, P<0.001, *Figure 2*, *Table 4*). Changes in length of stay over the study period did not demonstrate any identifiable significant trend (*Figure 3*, *Table 4*).

The complication rate for those patients who received IOM during their PLF are shown in *Figure 4*. IOM did not have a statistically significant impact on the likelihood of developing a neurological complication when adjusting for potential confounders (*Figure 4*, *Table 4*).

Discussion

The widespread increase in the use of IOM for spine

Table 4 Effect of IOM on outcomes of interest estimated via generalized linear mixed models controlling for confounders

Statistic	Total charge of hospitalization	Neurological complications	Length of stay
Result	11% increase with IOM	OR 0.87 with IOM	–0.04 days with IOM
95% CI	11–12%	OR 0.70–1.07	–0.03 to –0.05 days
P value	<0.001	0.1875	<0.001

IOM, intraoperative neuromonitoring.

surgery over the last decade may be partially a result of several studies which have demonstrated efficacy of IOM use in the prevention of new neurological deficits after spinal deformity operations in particular (4,8). In a retrospective study of 3,436 monitored pediatric spinal deformity procedures over 23 years, for example, Thuet *et al.* concluded that IOM use reduced the incidence of permanent post-operative neurological deficit to only 6 patients (0.17%) while accurately predicting permanent neurologic status in 99.6% of patients (9). In a study analyzing 108,419 cases from the Scoliosis Research Society morbidity and mortality database in which 65% received IOM during surgery, neuromonitoring changes were observed in 11% of patients developing post-operative nerve root deficits, 8% developing cauda equina deficits, and 40% with spinal cord deficits (7). They ultimately found that combined SSEP and MEP use had a sensitivity of 0.43 but a specificity of 0.98 for the detection of neurologic injury (7). Feng *et al.* similarly reported a sensitivity and specificity of combined MEPs and SSEPs of 92.9% and 99.4%, respectively, in detecting neurologic injury in 175 patients undergoing spinal deformity correction (6).

While there may be some benefit for IOM use in more complex deformity cases, there remains no established consensus on routine IOM use in lower risk elective spine surgery, and evidence in the literature demonstrating a clear, objective benefit for IOM use in instrumented PLF in particular is lacking (4,12-15). Cole *et al.*, for example, retrospectively evaluated the outcomes of 85,640 patients who underwent anterior cervical discectomy and fusion (ACDF), lumbar discectomy, lumbar laminectomy, or lumbar fusion, of which 10,842 patients had IOM. They found that IOM use did not correlate with a reduction in neurologic complications (16). Ajiboye *et al.* demonstrated a postoperative neurological injury rate of 1.34% without EMG monitoring and 1.36% with EMG monitoring in patients undergoing PLFs, suggesting that routine EMG use may not decrease risk of neurological complications in these procedures (3). Similarly, Alemo *et al.* evaluated the efficacy of pedicle probe EMG stimulation in 86 patients who underwent placement of 414 lumbar pedicle screws (10). Although pedicle probe EMG stimulation suggested possible neurological compromise in 28 (6.7%) of screws in this series, resulting in 21 being removed and redirected. There were 4 false positives confirmed through direct visualization of the pedicle and nerve root intra-operatively and three false negatives wherein a new neurologic deficit and abnormal CT scan were seen postoperatively in the absence of any indication of nerve root compromise on EMG intraoperatively (10). In a retrospective study by Ajiboye *et al.*, IOM was used in 2,627 out of 15,395 patients who underwent an ACDF with no significant difference in the rate of neurologic injury between groups (0.23% *vs.* 0.27%) (4). A more recent study analyzing the NIS data set for IOM use in a large group of patients undergoing ACDF similarly showed no significant association between the use of IOM and the development of neurological complications (17).

Another important factor to consider when deciding whether to utilize IOM is cost. In our analysis, an 11% increase in the total charge of hospitalization was detected in the IOM group in comparison to those who did not receive IOM (P<0.001). Additionally, we found that the average length of stay decreased by 0.04 days in the IOM group (P<0.001), although this difference is not clinically significant. Similar results were reported in a study that analyzed 112 patients who underwent a minimally invasive surgery (MIS) transforaminal lumbar interbody fusion (TLIF) at a single institution, 73 of which underwent the procedure with IOM (11). They found that the total surgical cost for patients receiving IOM was significantly higher (P=0.008) by a mean $4,000 (11). They also demonstrated a statistically significant (P=0.009) increase in mean surgical time in the IOM group when compared to those that did not receive IOM (262 *vs.* 212.46 minutes, respectively) (11). The NIS does not include data on procedural time, and thus this factor could not be included in our analysis.

The results of this study indicate that the use of IOM for

PLFs is steadily increasing. Between the years of 2012 and 2015, we found that there was an increase in the utilization of IOM from 14.6% to 19.3%. Interestingly, we found that 27.79% of the patients that received IOM were in the top income quartile and 20.60% were in the bottom quartile, in comparison to 22.77% and 24.11% in the group without IOM respectively (P<0.0001). In the IOM group, 42.14% were privately insured in comparison to those that were primarily Medicare (42.11%) and Medicaid (5.68%) covered (P<0.0001). In the group without IOM however, 38.94% were primarily privately insured in comparison to those covered through Medicare (45.82%) or Medicaid (5.96%) (P<0.0001). Laratta *et al.* similarly utilized the NIS dataset to assess overall IOM use between the years of 2008 and 2014. They found that IOM use increased by 296% in this time period, with a utilization rate of 45% in privately insured patients when compared to Medicare (36.8%) or Medicaid (9.2%) patients (8). Ajiboye *et al.* retrospectively queried the PearlDiver Database to evaluate IOM use in scoliosis surgeries between the years of 2005 and 2011, demonstrating a similar increase in overall IOM use from 27% to 46.9% over this time period (18).

These findings challenge the value of IOM in patients undergoing PLFs. The studies discussed above suggest that there may not be any clear benefit to IOM in this scenario and is associated with increased cost and procedural time for patients. A formal cost-benefit analysis of IOM use in spine procedures may be an avenue for further study.

While the choice to use IOM in a procedure is often based partially on surgeon preference or training, the choice may have medicolegal implications as well. IOM records are a part of the medical record that should accurately reflect the patient's medical history, surgical history, and demographic data as well as being as thorough as possible (19). Additionally, any IOM changes or events that are concerning for potential neurologic injury should be recorded along with any concurrent anesthesia changes or procedural events (20). A log should also be kept detailing the communication of IOM changes to the surgeon at the time of detection (20). Brook *et al.* reported on the litigation aspects of IOM for neurosurgical procedures, with court case examples from several spine procedures. They state that IOM can potentially be used to support a ruling of direct liability to a surgeon, technologist, or even anesthesiologist, while at other times IOM records can be exculpatory (21). They anticipate that IOM may soon be considered standard of care in the courtroom but, as of now, there are no specific standards for deciding if the misuse or nonuse of IOM technology constitutes as a deviation from the standard (21).

Limitations

A number of limitations are inherent within the use of a large database such as the NIS. The NIS data is pooled from several hospitals nationwide, with varying hospital structures and surgeon practice patterns. Specific clinical information, including the severity of individual patient pathologies, intraoperative events, or the skill of both IOM teams and surgeons themselves, cannot be ascertained. Additionally, the NIS database uses ICD-9 coding systems, which leaves the records subject to inaccuracies in billing, under or overreporting of procedures, and errors in data reporting. One must rely on the accuracy of a given hospital's coders, who may misclassify diagnoses and procedures. Complications were identified using ICD-9 diagnosis codes for these complications, which may not have been billed consistently between hospitals included in the NIS. In reviewing the financial analysis pertaining to this study, it should be noted that hospital charges do not necessarily reflect payments received by the hospital and this discrepancy was not analyzed in this study. Finally, the single ICD-9 diagnosis code for the use of IOM does not distinguish between the different modalities of neuromonitoring, which would be interesting to analyze independently.

Conclusions

The results of this analysis call into question the routine use of IOM for simple posterior index lumbar fusions for degenerative spine disease. Over 4 years of nationwide hospital data, IOM was associated with an 11% increase in total hospital charges without a statistically significant reduction in complication rate or a clinically significant reduction in length of stay. These relationships hold true when adjusting for patient demographics, hospital factors, year of surgery, and comorbidities. While there may conceivably be benefits to the use of this technology in complex revision fusions or pathologies such as spinal tumors or trauma, we found no meaningful benefit of its application to single-level index posterior lumbar fusions for degenerative spine disease.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at http://dx.doi.org/10.21037/jss-20-679

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jss-20-679). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). No IRB approval was necessary given the de-identified nature of this national database. No informed consent was obtained as it did not apply to the study.

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