INTERNATIONAL JOURNAL of SPINE SURGERY

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Int J Spine Surg 2017, 11 (5)
doi: https://doi.org/10.14444/4033
https://www.ijssurgery.com/content/11/5/33

The International Journal of Spine Surgery
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Aurora, IL 60504, Phone: +1-630-375-1432

Demographic Trends in the Use of Intraoperative Neuromonitoring for Scoliosis Surgery in the United States

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Abstract

Background

Intraoperative neuromonitoring (ION) such as motor-evoked potential (MEP), somatosensory evoked potentials (SSEP) and electromyography (EMG) are used to detect impending neurological injuries during spinal surgery. To date, little is known on the trends in the use of ION for scoliosis surgery in the United States.

Methods

A retrospective review was performed using the PearlDiver Database to identify patients that had scoliosis surgery with and without ION from years 2005 to 2011. Demographic information (such as age, gender, region within the United States) and clinical information (such as type of ION and rates of neurological injury) were assessed.

Results

There were 3618 patients who had scoliosis surgery during the study period. ION was used in 1361 (37.6%) of these cases. The number of cases in which ION was used increased from 27% in 2005 to 46.9% in 2011 ($p < 0.0001$). Multimodal ION was used more commonly than unimodal ION (64.6% vs. 35.4%). The most commonly used modality was combined SSEP and EMG while the least used modality was MEP only. Neurological injuries occurred in 1.8% and 2.0% of patients that had surgery with and without ION, respectively ($p = 0.561$). ION was used most commonly in patients < 65 years of age and in the Northeastern part of the United States (age; $p = 0.006$, region; $p < 0.0001$).

Conclusions

The use of ION for scoliosis surgery gradually increased annually from 2005 to 2011. Age and regional differences were noted with neuromonitoring being most commonly used for scoliosis surgery in non-elderly patients and in the Northeastern part of the United States. No differences were noted in the risk of neurological injury in patients that had surgery with and without ION. Although the findings from this study may seem to suggest that ION may not influence the risk of neurologic injury, this result must be interpreted with caution as inherently riskier surgeries may utilize ION more, leading to an actual reduction in injuries more dramatic than observed in this study.

OTHER AND SPECIAL CATEGORY
KEYWORDS: SCOLIOSIS, NEUROMONITORING, MOTOR-EVOKED POTENTIAL, SOMATOSENSORY EVOKED POTENTIAL, ELECTROMYOGRAPHY

VOLUME 11 ISSUE 5 DOI: 10.14444/4033
PAGES 271 - 277

Introduction

Neurological injuries are known complications of spine surgery. In spinal deformity surgery, the risk of neurological injury is estimated to be 0.5% to 3%.[1-7] These injuries are thought to occur from implant-related damages, correction maneuvers or ischemia.[8] To decrease the risk of these adverse events, intraoperative neuromonitoring (ION) such as motor-evoked potential (MEP), somatosensory evoked potential (SSEP) and electromyography (EMG) are used to detect impending injury of neural elements. SSEPs have been used clinically since 1977 and work by monitoring the ascending sensory afferent pathways in the spinal cord.[9] MEPs work by monitoring peripheral muscle activity from direct stimulation of the motor cortex, while (triggered or spontaneous) EMGs monitor muscle contractions from nerve root stimulation. Prior to the widespread use of ION, the Stagnara wake-up test served as the only way to assess the functional integrity of the spinal cord intraoperatively.[10] The Stagnara wake-up test is performed by waking a patient up during surgery and checking for gross motor movements. Some surgeons advocate for the adjunctive use of the Stagnara wake-up test when there is no improvement in ION signals despite actions to reverse a suspected intraoperative neurological injury or when reliable ION signals cannot be obtained.[11]

In 2009, the scoliosis research society (SRS) released an updated position statement stating that ION is the preferred method for early detection of an evolving or impending neurological injury during deformity surgery.[12] However, the decision to use ION during spinal deformity surgery is often guided by the type of surgery, surgeon choice and experience, and there is no consensus on the optimal neuromonitoring modality to use. In addition, most of the published studies on the use of ION for scoliosis surgery are from academic centers and little is known on how neuromonitoring is used in the "real world" i.e. in academic and non-academic settings. The goal of this study was to evaluate the trends in the use of neuromonitoring for scoliosis surgery in the United States.

Materials and Methods

A retrospective review was performed using the PearlDiver Patient Record Database (www.pearldiver.com; PearlDiver, Inc., Warsaw, IN, USA) to search through the patient records within both the Standard Analytical Files (SAF) of Medicare and the United Healthcare (UHC) databases. The PearlDiver database is commercially available and contains de-identified patient data that is Health Insurance Portability and Accountability Act (HIPAA) compliant and allows researchers to construct queries to identify patient groupings that meet specified criteria of interest. The raw datasets are filtered by characteristics such as age group, gender, region of the country, and year. The SAF dataset used in this study spans from 2005-2011 and contains more than 40 million patients per year whereas the UHC set contains 21 million patients with records from 2007-2011.

Data collection

The database was used to identify cases of scoliosis undergoing spinal surgery with neuromonitoring from years 2005 to 2011 using both current procedural terminology (CPT) and international classification of diseases, ninth revision (ICD-9) codes (see appendix). Each record provided demographic information (such as age, gender, and region within the United States) and clinical information (such as type of neuromonitoring modality used and rates of neurological injury (See appendix). Neurologic injury was defined as neurologic weakness within 30 days after the index surgery.

Statistical analysis

The STATA statistical software version 11.0 (STATACorp, College Station, TX) was used to perform the analyses. The chi-square test was used to detect any differences in the variables of interest (i.e. temporal trends, complications, age, gender, and region). Significance level was set at the $p < 0.05$.

Results

Neuromonitoring use in the United States during the study period (2005 – 2011)

During the study period, 3618 patients underwent scoliosis surgery. Overall, neuromonitoring was used in 1361 (37.6%) of these cases. There was a statistically significant steady increase in the use of neuromonitoring for scoliosis surgery from 27% in 2005 to 46.9% in 2011 ($p < 0.0001$) (Figure 1, Table 1).

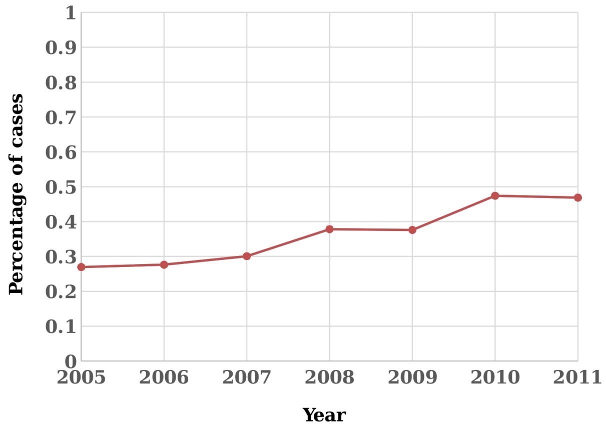

Fig. 1. Percentage of scoliosis surgery performed with neuromonitoring during the study period (2005-2011).

Type of neuromonitoring modality

Out of a total of 1361 patients that had scoliosis surgery with neuromonitoring, multimodal neuromonitoring was used in 64.6% of cases compared to 34.6% with unimodal neuromonitoring. In terms of specific combinations of neuromonitoring, the most commonly used modality was SSEP+EMG while the least used modality was MEP only (SSEP+EMG = 37.4%, EMG only = 22.9%, SSEP+MEP+EMG = 20.8%, SSEP only = 12.4%, SSEP+MEP = 5.7%, MEP+EMG = 0.8%, and MEP only = 0%) (Table 2).

Table 1. Demographic information of patients from 2005 to 2011.

	Total number of scoliosis surgery with neuromonitoring	Total number of scoliosis surgery	p-value
Year			$p < 0.0001$
2005	93	345	
2006	123	445	
2007	154	512	
2008	213	563	
2009	258	686	
2010	183	386	
2011	195	416	
Age			$p = 0.006$
< 65	255	580	
65-69	372	1002	
70-74	337	931	
75-79	267	741	
80-84	113	352	
>84	30	88	
Gender			$p = 0.106$
Female	935	2542	
Male	421	1062	
Region			$p < 0.0001$
Midwest	336	919	
Northeast	231	436	
South	640	1516	
West	341	852	
Total *	1361	3618	

* Discrepancies between total value and summation of values in each group are attributed to the transfer of patients between subgroups.

Neurological injury

Neurological injuries within 30 days from the date of the index surgery occurred in 1.8% (24/1361) and 2.0% (46/2257) of patients that underwent surgery with and without ION, respectively ($p = 0.561$) (Table 3).

Age

Neuromonitoring was used in 44.0% (255/580), 37.1% (372/1002), 36.2% (337/931), 36% (267/741), 32.1% (113/352), and 34% (30/88) of patients in age groups <65 years, 65-69 years, 70-74 years, 75-79 years, and 80 years and over, respectively ($p = 0.006$) (Table 1).

Table 2. Types of neuromonitoring modality used for scoliosis surgery.

Unimodal neuromonitoring	
SSEP only	169
MEP only	0
EMG only	313
Multimodal neuromonitoring	
SSEP and MEP	77
SSEP and EMG	509
MEP and EMG	11
SSEP, MEP and EMG	283
Total*	1361

*Discrepancies between total value and summation of values in each group are attributed to the transfer of patients between subgroups.

Table 3. Risk of neurological injury after scoliosis surgery with and without neuromonitoring.

	With neuromonitoring	Without neuromonitoring	p-value
Risk of neurological injury	24/1361 (1.8%)	46/2257 (2.0%)	0.561

Gender

Neuromonitoring was used in 36.8% (935/2542) of women compared to 39.6% (421/1062) of men ($p = 0.106$) (Table 1).

Region

Neuromonitoring was used in 53% (231/436) of scoliosis surgery in the Northeastern part of the United States compared to 42.2% (640/1516) in the South, 40.0% (341/852) in the West and 36.6% (336/919) in the Midwest ($p < 0.0001$) (Table 1).

Discussion

The goal of this study was to evaluate the trends in the use of neuromonitoring for scoliosis surgery in the United States. To that end, we found increased utilization rates of neuromonitoring from 2005 to 2011, the vast majority of monitoring was multimodal, and the risk of neurological injury was not significantly altered by its use. Although there were no gender-related differences noted in the utility of neuromonitoring, age and regional differences were noted with neuromonitoring being most commonly used for scoliosis surgery in non-elderly patients and in the Northeastern part of the United States.

ION has emerged as a component of the standard of care for scoliosis surgery with data from this study showing that its use has increased from 2005 to 2011. The intuitive reasons for the utility of ION is to raise warning against devastating neurologic complications that can be prevented with intervention such as reducing the degree of distraction, adjusting retractors, removing hardware, and minimizing the length of surgery.[13] In a retrospective study of 443,194 patients by James et al., the utilization of ION within the United States increased from 1% of all spine procedures in 2007 to 12% in 2011, which are lower than the 37.6% overall utilization rate in scoliosis surgery found in this study.[14] This difference can be accounted for by the inclusion of a wide-range of spinal procedures including microdiscectomy in the study by James et al. These procedures traditionally do not utilize ION to the same degree as scoliosis surgery. Furthermore, studies have shown no clear benefit or even recommended against ION in certain "low-risk" spinal procedures.[15,16]In their single institutional study of 4467 neurosurgical procedures performed at Texas Children's Hospital, Vadivelu et al. found ION use increased from 2008 to 2011 with surgeon-related factors such as less than 10 years of practice and subspecialty interest in spine positively associated with its use.[17] Although the inclusion criteria of the aforementioned studies may differ, the overall trend of increased ION utilization in the last decade is seemingly well established.

When considering the absolute utilization rate of 37.6% in our study, it may be interpreted as a low especially in comparison to a recent study of 108,419 procedures by members of the SRS morbidity and mortality committee in which ION was used in 65% of cases.[18] There are several factors that account for the differences in utilization rates for ION in both studies. Members of the SRS morbidity and mortality committee are primarily from high-performing academic centers that perform cases of higher complexity. This current study utilizes a national database, which captures practice patterns from both academic and non-academic centers. In addition, there may be over-coding for the diagnosis of "scoliosis" in this study as varying degrees of coronal deformity occur concurrently with lumbar stenosis and other "low-risk" spinal procedures. Lastly, the lack of availability of ION (especially in non-academic centers) and the increased cost associated with its use may account for the low overall utilization rate observed in the current study.

With regard to the specific modalities of use, we found that combined SSEP with EMG was the most commonly utilized modality. Unimodal neuromonitoring comprised only 35.3% of monitoring use in our study, which is somewhat comparable to the rate of 22.6% reported by Hamilton et al.[18] Multimodal ION is commonplace as it can monitor both spinal cord and nerve root function.[19] Multimodal ION has resulted in increases in the sensitivity and specificity for neurologic injury to nearly 100%.[19-22]

Neurologic injury within 30 days from the date of index surgery occurred in 1.8% and 2.0% of patients that underwent scoliosis surgery with and without ION, respectively. These rates are within the range of 0.5% to 3% risk of neurological injury reported in the literature for deformity surgeries.[1-7] Although the findings from this study may seem to suggest that ION may not influence the rate of neurologic injury, this result must be interpreted with caution as inherently riskier surgeries may utilize neuromonitoring more leading to an actual reduction in injuries more dramatic than observed in this study. Fu et al. reported higher rates of neurologic deficits with ION in pediatric spine cases, which were attributed to the disproportionate use of monitoring in higher risk cases.[23] To this end, no randomized-controlled trials have been undertaken to elucidate the true effect of neuromonitoring on neurological injuries following scoliosis surgery.

Our results revealed no difference with regard to gender, but showed a proclivity of ION to be utilized for scoliosis surgery more in non-elderly patients (<65 years of age) and in the Northeastern region of the United States. To our knowledge, this is the first study to review the age or gender-related differences with respect to ION utilization. James et al. examined the regional use of neuromonitoring from 2008-2011 and the lowest utilization was noted to be in the Northeastern part of the United States, which conflicts with the results from our study.[14] This difference may stem from the fact that our study exclusively studied scoliosis surgery as opposed to a heterogeneous group of neurosurgical spinal procedures examined by James et al. Within our dataset, the increased utility of ION in the Northeastern region of the United States may be influenced by medicolegal concerns and malpractice premiums in these areas.[24] According to a recent report, the top five states with the highest medical malpractice payout per capita are New York, New Jersey, Pennsylvania, Massachusetts and Rhode Island, all of which are located in the Northeastern region of the United States.[25] This finding highlights the fact that litigation and malpractice claims in various parts of the United States may have an influence on physicians' pattern of practice.

Limitations

There are some limitations inherent to using an administrative database for research. Inaccuracies in the coding of diagnosis and procedures codes may have influenced the results of this study. In addition, important detailed clinical information such as operative time, disease severity, complexity of surgery, intraoperative events, neuromonitoring sensitivity, specificity, false positive and negatives, and information on type and severity of neurological complications are not recorded in this database. Despite these limitations, this study is valuable because it of its large sample size which makes it suitable to study national trends and captures a heterogeneous sample of the practice patterns of surgeons with regards to ION use for scoliosis surgery in both academic and non-academic centers. In addition, we believe that the information from this study will help shed light on disparities associated with neuromonitoring usage and/or availability across different regions of the United States especially in the current political and economic climate whereby healthcare cost and patient safety are currently being scrutinized.

Conclusions

The use of neuromonitoring for scoliosis surgery gradually increased annually from 2005 to 2011. No differences were noted in the rates of neurological injury in patients that underwent scoliosis surgery with and without neuromonitoring. Although there were no gender-related differences noted in the utility of neuromonitoring, age and regional differences were noted with neuromonitoring being most commonly used for scoliosis surgery in non-elderly patients and in the Northeastern part of the United States.

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Disclosures & COI

The authors declare no relevant financial disclosures or conflicts of interest.

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Published 5 December 2017.