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

Remi M. Ajiboye MD,1 Howard Y. Park MD,1 Jeremiah R. Cohen BS,2 Evan E. Vellios MD,1 Elizabeth L. Lord MD,1 Adedayo O. Ashana MD,1 Zorica Buser PhD,2 Jeffrey C. Wang MD2
1UCLA Medical Center, Department of Orthopaedic Surgery, Los Angeles, CA, 2Keck Medicine of USC, Department of Orthopaedic Surgery, Los Angeles, CA

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.

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 as-
ess the functional integrity of the spinal cord intraoperatively. 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.

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. 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).
Type of neuromonitoring modality
Out of a total of 1361 patients that had scoliosis

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of scoliosis surgery with neuromonitoring</th>
<th>Total number of scoliosis surgery</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>93</td>
<td>345</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>2006</td>
<td>123</td>
<td>445</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>154</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>213</td>
<td>563</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>258</td>
<td>686</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>183</td>
<td>386</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>195</td>
<td>416</td>
<td></td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Gender</th>
<th>Total number of scoliosis surgery with neuromonitoring</th>
<th>Total number of scoliosis surgery</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>935</td>
<td>2542</td>
<td>0.106</td>
</tr>
<tr>
<td>Male</td>
<td>421</td>
<td>1062</td>
<td></td>
</tr>
</tbody>
</table>

Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Total number of scoliosis surgery with neuromonitoring</th>
<th>Total number of scoliosis surgery</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>336</td>
<td>919</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Northeast</td>
<td>231</td>
<td>436</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>640</td>
<td>1516</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>341</td>
<td>852</td>
<td></td>
</tr>
<tr>
<td>Total*</td>
<td>1361</td>
<td>3618</td>
<td></td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Unimodal neuromonitoring</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSEP only</td>
<td>169</td>
</tr>
<tr>
<td>MEP only</td>
<td>0</td>
</tr>
<tr>
<td>EMG only</td>
<td>313</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multimodal neuromonitoring</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSEP and MEP</td>
<td>77</td>
</tr>
<tr>
<td>SSEP and EMG</td>
<td>509</td>
</tr>
<tr>
<td>MEP and EMG</td>
<td>11</td>
</tr>
<tr>
<td>SSEP, MEP and EMG</td>
<td>283</td>
</tr>
<tr>
<td>Total*</td>
<td>1361</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Risk of neurological injury</th>
<th>With neuromonitoring</th>
<th>Without neuromonitoring</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/1361 (1.8%)</td>
<td>46/2257 (2.0%)</td>
<td>0.561</td>
<td></td>
</tr>
</tbody>
</table>
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. 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. 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. In their single institution-
the literature for deformity surgeries. 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. 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. 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. 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. 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 nonacademic 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.

References


Disclosures & COI

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

Corresponding Author

Remi M. Ajiboye, M.D., UCLA Department of Orthopaedic Surgery, 10833 LeConte Avenue, 76-119 CHS, Los Angeles, CA 90095-6902. Remi.Ajiboye@gmail.com.

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