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


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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.

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. 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-
sess the functional integrity of the spinal cord intra-
operatively. The Stagnara wake-up test is per-
formed 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 can-
not 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) data-
bases. 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, gen-
der, region of the country, and year. The SAF dataset
used in this study spans from 2005-2011 and con-
tains 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 proce-
dural terminology (CPT) and international classifica-
tion of diseases, ninth revision (ICD-9) codes (see
appendix). Each record provided demographic infor-
mation (such as age, gender, and region within the
United States) and clinical information (such as type
of neuromonitoring modality used and rates of neu-
rological 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 (STAT-
Acorp, 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. tem-
poral 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 statisti-
cally significant steady increase in the use of neuromon-
toring 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).

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 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>

<table>
<thead>
<tr>
<th>Age</th>
<th>p = 0.006</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 65</td>
<td>255</td>
</tr>
<tr>
<td>65-69</td>
<td>372</td>
</tr>
<tr>
<td>70-74</td>
<td>337</td>
</tr>
<tr>
<td>75-79</td>
<td>267</td>
</tr>
<tr>
<td>80-84</td>
<td>113</td>
</tr>
<tr>
<td>&gt;84</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>p = 0.106</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>935</td>
</tr>
<tr>
<td>Male</td>
<td>421</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>p &lt; 0.0001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>336</td>
</tr>
<tr>
<td>Northeast</td>
<td>231</td>
</tr>
<tr>
<td>South</td>
<td>640</td>
</tr>
<tr>
<td>West</td>
<td>341</td>
</tr>
</tbody>
</table>

| Total * | 1361 | 3618 |

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

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

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.

<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 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. 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. 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. Multimodal ION is commonplace as it can monitor both spinal cord and nerve root function. Multimodal ION has resulted in increases in the sensitivity and specificity for neurologic injury to nearly 100%. 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. 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.

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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.

Conclusions
The use of neuromonitoring for scoliosis surgery gradually increased annually from 2005 to 2011. No differences were noted in the rates of neurologic 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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