Cervical Spinal Cord, Root, and Bony Spine Injuries
A Closed Claims Analysis

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ABSTRACT

Background: The aim of this study was to characterize cervical cord, root, and bony spine claims in the American Society of Anesthesiologists Closed Claims database.

Methods: A Closed Claims database was searched to identify cervical spinal cord injuries (n = 15 y; 73% male) comprised less than 1% of all general anesthesia claims (1970 –2007). In addition, Dr. Traynelis holds the following patents from which he has received patent and/or licensing royalties: U.S. patent 7 727 266, Artificial spinal discs and method to extract data from claim summaries and judge probable contributors to injury.

Results: Cervical injury claims (n = 48; mean ± SD age 47 ± 15 yr; 73% male) comprised less than 1% of all general anesthesia claims. When compared with other general anesthesia claims (19%), cervical injury claims were more often permanent and disabling (69%; P < 0.001). In addition, cord injuries (n = 37) were more severe than root and/or bony spine injuries (n = 10; P < 0.001), typically resulting in perinoperative cervical spinal cord injury is perceived to be associated with anesthesiologists to be associated with airway management in the setting of trauma and/or cervical spine instability.

What This Article Tells Us That Is New
• In a review of the American Society of Anesthesiologists Closed Claims database, the great majority of cervical spinal cord injuries occurred in the absence of trauma, cervical spine instability, or airway management problems. Instead, these injuries were associated with cervical spine surgery, sitting procedures, and cervical spondylosis.

What We Already Know about This Topic
• Perioperative cervical spinal cord injury is perceived to be associated with airway management in the setting of trauma and/or cervical spine instability.

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Presented in part at the annual Midwest Anesthesia Residents Conference, Saint Louis, Missouri, April 14, 2007, and at the annual meeting of the American Society of Anesthesiologists, San Diego, California, April 18, 2010.

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in quadriplegia. Although anatomic abnormalities (e.g., cervical stenosis) were often present, cord injuries usually occurred in the absence of traumatic injury (81%) or cervical spine instability (76%). Cord injury occurred with cervical spine (65%) and noncervical spine (35%) procedures. Twenty-four percent of cord injuries were associated with the sitting position. Probable contributors to cord injury included anatomic abnormalities (81%), direct surgical complications (24% [38%, cervical spine procedures]), preprocedural symptomatic cord injury (19%), intraoperative head/neck position (19%), and airway management (11%).

**Conclusion:** Most cervical cord injuries occurred in the absence of traumatic injury, instability, and airway difficulties. Cervical spine procedures and/or sitting procedures appear to predominate. In the absence of instability, cervical spondylisis was the most common factor associated with cord injury.

**Cervical spinal cord injury** is a rare but catastrophic complication in the practice of surgery and anesthesia. It results in central cord syndrome, Brown-Séquard syndrome, quadriparesis, quadriplegia, or death. Patients considered to be at greatest risk are those with cervical spine instability in whom the forces of direct laryngoscopy and tracheal intubation are thought to cause pathologic cervical spine motion and critical cord compression. This concern has dominated anesthesia airway-management research, with a large number of studies devoted to techniques and devices intended to accomplish intubation with little or no cervical spine motion.

The surprising fact is, however, that the actual number of published case reports ascribing cervical cord injury to intubation in patients with unstable spines is remarkably small—no more than ten cases. Of these reports, few provide sufficient data to support firm conclusions regarding causation. One reason why there are so few reports may be that perioperative cervical cord injury may truly be an exceedingly rare event. When cervical spine instability is known or suspected, anesthesia care providers may take great precautions to avoid cervical cord injury. Alternatively, or in addition, these events may not be reported because of potential or actual medical malpractice liability. We hypothesized that the American Society of Anesthesiologists (ASA) Closed Claims database might contain a relatively large and heretofore unreported series of perioperative cervical cord injuries. The aim of this study was to systematically review claims for injury to the cervical cord, roots, and/or bony spine to formulate hypotheses regarding clinical risk factors and possible mechanisms of injury.

**Materials and Methods**

**General Closed Claims Methods**

The ASA Closed Claims Project is an ongoing structured evaluation of adverse anesthetic outcomes obtained from the closed claim files of 35 professional liability insurance companies in the United States. Claims for dental damage are not included in the ASA Closed Claims database.

The data collection process has been described in detail previously. In brief, each closed claim file was reviewed on site (insurance company) by a practicing anesthesiologist. Files typically consisted of relevant medical records; narrative statements from involved healthcare personnel; expert and peer reviews; depositions from plaintiffs, defendants, and expert witnesses; outcomes reports; and the dollar amount of any settlements or jury awards. The on-site reviewer completed a standardized form that recorded information about patient characteristics, surgical procedures, the sequence and location of events, critical incidents, clinical manifestations of injury, standard of care, and outcomes.

The injury-causing event for which the plaintiff was seeking compensation was determined by the on-site reviewer and later confirmed by the Closed Claims Committee. Each claim was assigned an injury severity score that was designated by the reviewer using the insurance industry’s 10-point severity scale that ranges from 0 (no injury) to 9 (death). For the purposes of this analysis, injuries were grouped into one of three categories: temporary or nondisabling (scores 0–5), permanent and disabling (scores 6–8), and death (score 9).

On-site reviewers judged whether injuries were theoretically preventable by the use of any form of additional monitoring such as pulse oximetry or capnography, assuming optimal use and response to these monitors. Based on reasonable and prudent practice at the time of the injury, the on-site reviewer also judged whether the anesthesia care met standards (appropriate), was substandard, or was impossible to judge. Previously published studies have found the reliability of reviewer judgments to be acceptable. Finally, on-site reviewers wrote a brief claim summary narrative to describe and explain the circumstances and outcomes of each claim.

**Cervical Injury Claim Reviews**

Before claim analysis, this study was reviewed and approved by the Institutional Review Board for Human Subjects at the University of Iowa (Iowa City) and the University of Washington (Seattle). Inclusion criteria were claims for cervical cord, root, and/or bony spine injury (“cervical injury”) in the Closed Claims database originating from 1970 and collected through December 2007 (n = 7,740). Injuries caused by regional anesthesia, chronic pain procedures/treatments, or patient falls were excluded. A total of 48 cervical injury claims were identified.

A preliminary claim review was conducted (B.J.H., J.P.P., K.L.P., K.B.D.) to develop a standardized cervical injury claim review form. The form was designed to extract information from the claim summary narratives written by the primary on-site reviewers. As part of this initial review, information regarding age, sex, type of surgical procedure, position during surgery, antecedent trauma, obesity, diabetes mellitus, and other comorbidities was collected.

Thereafter, the claim summary narratives of each cervical injury claim were independently reviewed by three reviewing teams. Each team was comprised of an anesthesiologist and a...
neurosurgeon. All anesthesiologists (B.J.H., L.A.L., M.M.T.) were in academic practice, specializing in neuroanesthesia. All neurosurgeons specialized in spine surgery. Two of the three neurosurgeons (V.C.T., T.L.T.) were in academic practice and one neurosurgeon (P.D.S.) was in community practice. Each reviewing team used the standardized cervical injury claim review form to extract information from claim summary narratives. Each team characterized patient condition and the status of the cervical spine before injury, airway management techniques and difficulties, other intraoperative difficulties, the nature of the injury (cervical cord, root, bony spine), and when the injury was first recognized. For example, the criteria for difficult airway management were as follows: (1) case coded as difficult intubation in the primary Closed Claims database, (2) the narrative explicitly stated it was difficult airway or there were three or more attempts at intubation, (3) multiple airway devices or techniques were used during airway management, or (4) airway management help was requested. In contrast, hypotension was not rigorously defined. Because the diagnosis of hypotension depends on the patient and clinical context, it is not possible to create a universally applicable numeric value for hypotension. In addition, some claim summary narratives did not provide numeric values for blood pressure, but instead would state that the patient had been hypotensive. Each reviewing team came to a consensus as to whether or not the claim summary narrative provided sufficiently detailed information that they could be confident that meaningful hypotension had been present. If teams could not be confident as to its presence, hypotension was not recorded on the review form.

Finally, based on all available information, each reviewing team judged the extent to which each of the following factors contributed to cervical injury: (1) preprocedural symptomatic neurologic injury, (2) preprocedural anatomic abnormality, (3) airway management, (4) head and neck position during the procedure, (5) direct surgical complications, and (6) other intraoperative problems. Each of the six potential contributing factors was rated as to its likely contribution to cervical injury using a six-point Likert scale ranging between 1 (definitely no contribution) to 6 (definite contribution), with “cannot determine” as a seventh option. A score of 3 was the greatest value that could be assigned to a factor not considered as contributing to the injury, whereas 4 was the least value that could be assigned to a factor that was considered as contributing to the injury.

To obtain final results for each claim, responses to each claim review question were compared among the three teams. For an affirmative result, at least two of the three teams must have provided the same answer. For the assessment of contributing factors, scores of 4, 5, and 6 were collectively considered as “probable” contributors. Accordingly, if two of three reviewing teams rated a factor between 4 – 6, that factor was judged to be a probable contributor. Likewise, if 2 of 3 teams responded with “cannot determine,” that was the final response. In some cases, no majority response could be obtained; such cases were recorded as “no majority.”

Statistical Methods
Differences in proportions were tested by Fisher exact test. Payments were adjusted to 2007 dollar amounts using the Consumer Price Index. Payment amounts were compared for differences in the distribution using the Kolmogorov-Smirnov test with Monte-Carlo significance calculated from 10,000 sample tables. All tests were two-sided with the threshold of significance set at $P < 0.05$, without correction for multiple comparisons. Agreement among all three reviewing teams was characterized using Krippendorff’s $\alpha$ reliability coefficient. With perfect agreement among all observers, $\alpha_K$ equals 1.0; when agreement is no better than chance, $\alpha_K$ equals 0.0. All calculations were performed using PASW Statistics (version 18.0.2; SPSS Inc., Chicago, IL).

Results
Cervical Injury Claims versus Other General Anesthesia Claims: Data from the Primary Database
Claims for cervical cord, root, and/or bony spine injuries ($n = 48$) comprised 0.9% of all claims for general anesthesia ($n = 5,231$). The proportion of claims for cervical injuries increased over time. From 1970–1989, cervical injury claims comprised 0.5% of all general anesthesia claims (14 of 2,754), increasing to 1.3% in the interval from 1990–2007 (32 of 2,456; $P = 0.0002$). As summarized in table 1, cervical injury claims occurred disproportionately in males (73%) as compared with other general anesthesia claims (45%; $P < 0.001$), but did not otherwise differ in other characteristics. Cervical injury claims differed from other general anesthesia claims in severity ($P < 0.001$). Although cervical injury claims were more often permanent and disabling (69%) versus other general anesthesia claims (19%), they were less frequently fatal (8% vs. 36%, respectively). Better monitoring was judged as likely to improve outcomes in only 9% of cervical injury claims versus 22% of all other general anesthesia claims ($P = 0.043$). Anesthesia standard of care was considered to be appropriate in 90% of cervical injury claims versus 55% of other general anesthesia claims ($P < 0.001$). There was no difference between cervical injury and other general anesthesia claims in the proportion and amount of payments ($P = 0.082$).

Cervical Cord Injury versus Root and/or Bony Spine Injury
Based on claim summary narratives, cervical injury claims ($n = 48$) were categorized as cervical cord injury (37 [77%]) or as cervical root and/or bony spine injury (10 [21%]). The etiology...
of postoperative bilateral arm weakness could not be determined in one claim. Patients with cervical cord injuries were characterized as having quadriaparesis or quadriplegia (33 [89%]), central cord syndrome (2 [5%]), or other undefined cord injury (2 [5%]). No patient with cervical cord injury had concomitant root and/or bony spine injury. Patients with cervical root and/or bony spine injuries exhibited root symptoms such as radicular pain (7 [70%]), sensory changes (3 [30%]), and/or neck pain (5 [50%]). Five patients had root and spine symptoms. No patient had radicular motor symptoms. As summarized in table 2, cervical cord injuries were more severe than root and/or bony spine injuries. As summarized in table 2, cervical root and/or bony spine injuries exhibited root symptoms such as radicular pain (7 [70%]), sensory changes (3 [30%]), and/or neck pain (5 [50%]). Five patients had root and spine symptoms. No patient had radicular motor symptoms. As summarized in table 2, cervical cord injuries were more severe than root and/or bony spine injuries.

Clinical Characteristics Based on Claim Summary Narratives

Clinical characteristics of all cervical injury claims are summarized in table 3. Fourteen of 20 variables had \( \alpha \) values of 0.66 or more, indicating good agreement among the three reviewing teams for most variables. In most claims (41 [85%]), claim summary narratives described one or more forms of cervical spine anatomic abnormality that were present before the procedure. Anatomic abnormalities included cervical stenosis/spinal stenosis (17 [41%]), cervical disc herniation (9 [22%]), cervical spine fracture (4 [10%]), cervical facet or ligament abnormality (2 [5%]), ankylosing spondylitis (2 [5%]), and cervical spinal cord tumor (1 [2%]). Preprocedural spinal anomalies were present in almost all cervical cord injury claims (35 [95%]) versus root and/or bony spine injury claims (5 [50%]; \( P = 0.003 \)). Preprocedural cervical spine

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Cervical Injury Claims (n = 48)*</th>
<th>Other General Anesthesia Claims (n = 5,183)†</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>47 ± 15</td>
<td>42 ± 20</td>
<td>0.101</td>
</tr>
<tr>
<td>Pediatric (age ≤16 yr)</td>
<td>1 (2)</td>
<td>562 (11)</td>
<td>0.057</td>
</tr>
<tr>
<td>Male</td>
<td>35 (73)</td>
<td>2,293 (45)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ASA category P1 or P2</td>
<td>25 (64)</td>
<td>2,435 (62)</td>
<td>0.870</td>
</tr>
<tr>
<td>Obese</td>
<td>11 (46)</td>
<td>1,167 (43)</td>
<td>0.837</td>
</tr>
<tr>
<td>Emergency procedure</td>
<td>7 (16)</td>
<td>1,006 (24)</td>
<td>0.220</td>
</tr>
<tr>
<td>Difficult intubation recorded as primary or secondary event</td>
<td>5 (10)</td>
<td>558 (11)</td>
<td>1.00</td>
</tr>
<tr>
<td>Severity of injury</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Death</td>
<td>4 (8)</td>
<td>1,847 (36)</td>
<td>—</td>
</tr>
<tr>
<td>Permanent and disabling</td>
<td>33 (69)</td>
<td>983 (19)</td>
<td>—</td>
</tr>
<tr>
<td>Temporary or non-disabling</td>
<td>11 (23)</td>
<td>2,348 (45)</td>
<td>—</td>
</tr>
<tr>
<td>Preventable by better monitoring</td>
<td>4 (9)</td>
<td>1,089 (22)</td>
<td>0.043</td>
</tr>
<tr>
<td>Appropriate anesthesia care</td>
<td>35 (90)</td>
<td>2,466 (55)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Payment made‡</td>
<td>21 (50)</td>
<td>2,840 (59)</td>
<td>0.269</td>
</tr>
<tr>
<td>Median</td>
<td>$482,250</td>
<td>$231,000</td>
<td>0.082</td>
</tr>
<tr>
<td>Range</td>
<td>$27,350–13,000,000</td>
<td>$43–44,760,000</td>
<td>—</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD or No. (%). \( P \) values are calculated using Fisher exact test (proportions), Mann–Whitney U test (age), and Kolmogorov–Smirnov test (median payment).

* Unless otherwise stated, the denominator for all cervical injury claims is 48. Claims with missing data are excluded. Variables with different denominators are as follows: age, \( n = 46 \); male, ASA category P1 or P2, \( n = 39 \); obese, \( n = 24 \); inpatient procedure, \( n = 42 \); emergency procedure, \( n = 44 \); preventable by better monitoring, \( n = 45 \); appropriate anesthesia care, \( n = 39 \); payment made, \( n = 42 \).

† Unless otherwise stated, the denominator for other general anesthesia claims is 5,183. Claims with missing data are excluded. Variables with different denominators are as follows: age, \( n = 4,984 \); pediatric, \( n = 5,181 \); male, \( n = 5,135 \); ASA category P1 or P2, \( n = 3,910 \); obese, \( n = 2,722 \); inpatient procedure, \( n = 3,805 \); emergency procedure, \( n = 4,137 \); severity of injury, \( n = 5,178 \); preventable by better monitoring, \( n = 4,996 \); appropriate anesthesia care, \( n = 4,454 \); payment made, \( n = 4,787 \).‡ Payment amounts are based only on claims in which payment was made.

ASA category = ASA (American Society of Anesthesiologists) Physical Status Classification System category.
inability was described in claim summary narratives in nine (19%) cervical injury claims—all in cord injury claims. Therefore, the majority of all cervical injury claims (38 [81%]) and the majority of cord injury claims (28 [76%]) occurred in patients who appeared to have anatomically stable cervical spines before the procedure.

Claim summary narratives indicated that almost all (46 [96%]) patients were intubated for their procedure, with at least 87% of these intubations being accomplished by direct laryngoscopy. Fiber-optic intubation and cervical spine stabilization techniques were used infrequently. The great majority of all cervical injury claims (40 [87%]), as well as cervical cord injury claims (34 [92%]), occurred in the apparent absence of a difficult airway. One or more discrete events that could have potentially contributed to cervical injury were described in claim summary narratives in 29% of all cervical injury claims. Hypotension (6 [13%]) and difficult airway management (5 [10%]) being the most common. In a majority of all cervical injury claims (34 [71%]), as well as a majority of cervical cord injury claims (26 [70%]), the periprocedure course was apparently technically unremarkable (table 3).

Claim summary narratives indicated that, in the majority of all cervical injury claims (35 [73%]), the symptoms of cervical injury were entirely new. In eight other claims (17%), although cervical injury symptoms were not entirely new, they were worse after the procedure. The apparent contribution of preprocedural symptomatic neurologic injury differed between cervical cord root and/or bony spine injury claims ($P = 0.015$). Cervical cord injuries were more often entirely new (30 [81%]) versus root and/or bony spine injuries (4 [40%]). Cervical cord injury was entirely new in all 13 patients (100%) who sustained injuries after a noncervical spine procedure. Although most cervical cord injuries associated with cervical spine procedures (n = 24) were also entirely new (17 [71%]), some (5 [21%]) cervical spine surgery patients exhibited cord injuries that were not entirely new, suggesting the presence of at least some preoperative cord injury. Claim summary narratives indicated that first detection of injury differed between cervical cord versus root and/or bony spine injury claims ($P < 0.001$). New or increased cervical cord injury or dysfunction was more commonly detected immediately after the procedure (26 [79%]) versus root and/or bony spine injury (1 [11%]). In root and/or bony spine injury claims, injury was commonly first detected more than 24 h after the procedure (5 [56%]), while there was no such delay in the detection of cervical cord injury.

### Probable Contributors Based on Claim Summary Narratives

Factors judged by the reviewing teams to be probable contributors to cervical injuries are summarized in table 4.
Table 3. Clinical Characteristics of Cervical Injuries Based on Claim Summary Narratives

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Cervical Injury Claims (n = 48)</th>
<th>Overall Agreement (αₚ)</th>
<th>Cervical Cord Injury (n = 37)*</th>
<th>Root and/or Bony Spine Injury (n = 10)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preprocedural cervical spine anatomic abnormality†</td>
<td>41 (85)</td>
<td>0.76</td>
<td>35 (85)</td>
<td>5 (50)</td>
<td>0.003</td>
</tr>
<tr>
<td>Preprocedural cervical spine instability</td>
<td>9 (19)</td>
<td>0.91</td>
<td>9 (24)</td>
<td>0 (0)</td>
<td>0.172</td>
</tr>
<tr>
<td>Disc herniation</td>
<td>9 (22)</td>
<td>0.69</td>
<td>5 (14)</td>
<td>3 (60)</td>
<td>0.046</td>
</tr>
<tr>
<td>Stenosis and/or spondylosis</td>
<td>17 (41)</td>
<td>0.90</td>
<td>15 (43)</td>
<td>2 (40)</td>
<td>1.00</td>
</tr>
<tr>
<td>Cervical spine fracture</td>
<td>4 (10)</td>
<td>0.84</td>
<td>4 (11)</td>
<td>0 (0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Facet and/or ligament abnormality</td>
<td>2 (5)</td>
<td>0.30</td>
<td>2 (6)</td>
<td>0 (0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Cervical stabilization during airway management</td>
<td>3 (7)</td>
<td>0.66</td>
<td>2 (6)‡</td>
<td>1 (20)§</td>
<td>0.338</td>
</tr>
<tr>
<td>Cannot determine or no majority</td>
<td></td>
<td></td>
<td>8 (20)</td>
<td>0.53</td>
<td>8 (23)</td>
</tr>
<tr>
<td>Airway Management</td>
<td></td>
<td>0.80</td>
<td></td>
<td></td>
<td>0.384</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Intubation</td>
<td>46 (96)</td>
<td>36 (97)</td>
<td>9 (90)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Direct laryngoscopy (intubation cases only)</td>
<td></td>
<td>0.71</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Yes or probable</td>
<td>40 (87)</td>
<td>30 (83)</td>
<td>9 (100)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>No (fiber-optic intubation)</td>
<td>3 (7)</td>
<td>3 (8)#</td>
<td>0 (0)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Cannot determine</td>
<td>3 (7)</td>
<td>3 (8)</td>
<td>0 (0)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Cervical stabilization during airway management</td>
<td>4 (8)</td>
<td>0.82</td>
<td>4 (11)**</td>
<td>0 (0)</td>
<td>0.564</td>
</tr>
<tr>
<td>Any difficulty in airway management</td>
<td>6 (13)</td>
<td>0.93</td>
<td>3 (8)</td>
<td>3 (30)</td>
<td>0.101</td>
</tr>
<tr>
<td>Narrative describes discrete event during procedure that could contribute to injury</td>
<td>14 (29)</td>
<td>11 (30)</td>
<td>3 (30)</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Hypotension</td>
<td>6 (13)</td>
<td>0.90</td>
<td>6 (16)</td>
<td>0 (0)</td>
<td>0.337</td>
</tr>
<tr>
<td>Airway management</td>
<td>5 (10)</td>
<td>1.00</td>
<td>2 (5)</td>
<td>3 (30)</td>
<td>0.035</td>
</tr>
<tr>
<td>Bleeding</td>
<td>2 (4)</td>
<td>0.70</td>
<td>2 (5)</td>
<td>0 (0)</td>
<td>1.000</td>
</tr>
<tr>
<td>Head/neck/spine position</td>
<td>2 (4)</td>
<td>0.62</td>
<td>2 (5)</td>
<td>0 (0)</td>
<td>1.000</td>
</tr>
<tr>
<td>Direct surgical complication</td>
<td>1 (2)</td>
<td>0.55</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>1.000</td>
</tr>
<tr>
<td>Other</td>
<td>1 (2)</td>
<td>0.11</td>
<td>1 (3)††</td>
<td>0 (0)</td>
<td>1.000</td>
</tr>
<tr>
<td>Type of cervical injury</td>
<td></td>
<td>0.56</td>
<td></td>
<td></td>
<td>0.015</td>
</tr>
<tr>
<td>New</td>
<td>35 (73)</td>
<td>—</td>
<td>30 (81)</td>
<td>4 (40)</td>
<td>—</td>
</tr>
<tr>
<td>Not new but worse than preprocedure</td>
<td>2 (4)</td>
<td>0.70</td>
<td>2 (5)</td>
<td>0 (0)</td>
<td>—</td>
</tr>
<tr>
<td>Not new but not worse than preprocedure</td>
<td>8 (17)</td>
<td>—</td>
<td>3 (8)</td>
<td>5 (50)</td>
<td>—</td>
</tr>
<tr>
<td>Cannot determine</td>
<td>3 (6)</td>
<td>—</td>
<td>2 (5)</td>
<td>1 (10)</td>
<td>—</td>
</tr>
<tr>
<td>First detection of new or worse cervical injury††‡‡</td>
<td>—</td>
<td>0.72</td>
<td>—</td>
<td>—</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Immediately postprocedure</td>
<td>28 (65)</td>
<td>—</td>
<td>26 (79)</td>
<td>1 (11)</td>
<td>—</td>
</tr>
<tr>
<td>Within 24 h postprocedure</td>
<td>4 (9)</td>
<td>—</td>
<td>3 (9)</td>
<td>1 (11)</td>
<td>—</td>
</tr>
<tr>
<td>&gt; 24 h postprocedure</td>
<td>5 (12)</td>
<td>—</td>
<td>0 (0)</td>
<td>5 (56)</td>
<td>—</td>
</tr>
<tr>
<td>Cannot determine</td>
<td>6 (14)</td>
<td>—</td>
<td>4 (12)</td>
<td>2 (22)</td>
<td>—</td>
</tr>
</tbody>
</table>

Data are presented as No. (%). Unless otherwise stated, the denominator for all cervical injury claims is 48; cervical cord injury claims, 37; and root and/or bony spine injury claims, 10. Overall agreement among three reviewing teams for all 48 cervical injury claims was calculated using Krippendorff’s α (αₚ). P values refer to comparisons between patients with cervical cord injury (n = 37) versus root and/or bony spine injury (n = 10). All P values are calculated using Fisher exact test.

* Cervical cord injury was associated with cervical spine (n = 24) and noncervical spine (n = 13) procedures. † All cervical injury claims, n = 41; cord injury claims, n = 35; and root and/or bony spine claims, n = 5. ‡ Cervical spinal cord tumor, n = 1; ankylosing spondylitis, n = 1. § Cannot determine, n = 4; no majority, n = 4. Agreement αₚ value is based on four claims where majority was “cannot determine.” # Fiber-optic intubation used in unstable (n = 2) and stable (n = 1) cervical spine. ** Cervical stabilization used in unstable (n = 2) and stable (n = 2) cervical spine. †† Claim in which horseshoe headrest came loose, resulting in cervical hyperextension. †‡ All cervical injury claims, n = 43; cord injury claims, n = 33; root and/or bony spine claims, n = 9. Agreement αₚ value is based on all cervical injury claims in which injury was assessed as “new or worse.” n = 43.

There were five claims (10%) in which no factor could be identified as a probable contributor to injury. In 27 claims (56%), two or more factors were judged to be probable contributors. Preprocedural anatomic abnormalities were judged by the reviewing teams as probable contributors to injury in most cervical injury claims (36 [75%]), contributing more commonly in cord injury (30 [81%]) versus root and/or bony spine claims (5 [50%]; P = 0.043).

Preprocedural symptomatic neural injury or dysfunction was judged as a probable contributor to injury in 27% (n = 13) of all cervical injury claims, more commonly contributing in root and/or bony spine (6 [60%]) versus cervical cord injury claims (7 [19%]; P = 0.006). Direct surgical complications were judged as probable contributors to injury in nine cervical cord injury claims (24%), all of which occurred with cervical spine procedures. Head/neck position during the procedure (n = 8) was judged to be a probable contributor in 17% of all cervical injuries.

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Table 4. Factors Probably Contributing to Cervical Injuries Based on Claim Summary Narratives

<table>
<thead>
<tr>
<th>Probable Contributor</th>
<th>All Cervical Injury Claims (n = 48)</th>
<th>Overall Agreement α(K) Value</th>
<th>Cervical Cord Injury (n = 37)*</th>
<th>Root and/or Bony Spine Injury (n = 10)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preprocedural anatomic abnormality of the cervical spine, ligaments, discs, cord or roots</td>
<td>36 (75)</td>
<td>0.42</td>
<td>30 (81)</td>
<td>5 (50)</td>
<td>0.043</td>
</tr>
<tr>
<td>Preprocedural neurologic symptoms involving the cervical spine, cord, or roots</td>
<td>13 (27)</td>
<td>0.61</td>
<td>7 (19)</td>
<td>6 (60)</td>
<td>0.006</td>
</tr>
<tr>
<td>Direct surgical complications</td>
<td>9 (19)</td>
<td>0.37</td>
<td>9 (24)</td>
<td>0 (0)</td>
<td>0.044</td>
</tr>
<tr>
<td>Head or neck position for procedure</td>
<td>8 (17)</td>
<td>0.30</td>
<td>7 (19)</td>
<td>1 (10)</td>
<td>0.327</td>
</tr>
<tr>
<td>Other intraoperative problems</td>
<td>7 (15)</td>
<td>0.73</td>
<td>7 (19)</td>
<td>0 (0)</td>
<td>0.396</td>
</tr>
<tr>
<td>Airway management</td>
<td>6 (12)</td>
<td>0.58</td>
<td>4 (11)</td>
<td>2 (20)</td>
<td>0.654</td>
</tr>
<tr>
<td>Factors probably contributing to injury, No.</td>
<td>0</td>
<td>5 (10)</td>
<td>3 (8)</td>
<td>2 (20)</td>
<td>0.291</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>16 (33)</td>
<td>13 (35)</td>
<td>2 (20)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19 (40)</td>
<td>13 (35)</td>
<td>6 (60)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7 (15)</td>
<td>7 (19)</td>
<td>0 (0)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1 (2)</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>—</td>
</tr>
</tbody>
</table>

Data are presented as No. (%). Unless otherwise stated, the denominator for all cervical injury claims is 48; cervical cord injury claims, 37; and root and/or bony spine injury claims, 10. Overall agreement among three reviewing teams for all 48 cervical injury claims was calculated using Krippendorff’s α (α(K)). P values refer to comparisons between patients with cervical cord injury (n = 37) versus root and/or bony spine injury (n = 10). All P values are calculated using Fisher exact test.

* Cervical cord injury was associated with cervical spine (n = 24) and noncervical spine (n = 13) procedures. For preprocedural anatomic abnormality of the cervical spine, ligaments, discs, cord, or roots, the difference between cervical spine (19 [79%]) versus noncervical spine (11 [85%]) procedures was not statistically significant. Likewise, for preprocedural neurologic symptoms involving the cervical spine, cord, or root, the difference between cervical spine (6 [25%]) versus noncervical spine (1 [8%]) procedures was not statistically significant. Direct surgical complications were a probable contributor in nine cervical spine procedures (38%). Head or neck position was a probable contributor in one (4%) cervical spine versus six (46%) noncervical spine procedures (P = 0.002). Although other intraoperative problems were probable contributors in three (13%) cervical spine procedures (all hypotension) and four (31%) noncervical spine procedures (hypotension, n = 3; accidental hyperextension, n = 1), the difference was not statistically significant. Airway management was a probable contributor in one (4%) cervical spine and three (23%) noncervical spine procedures (P = 0.044).

with 88% of these injuries (7 of 8) being cord related.

Head/neck position during the procedure was judged to be probable contributor to cervical cord injury in nearly half (6 [46%]) of noncervical spine procedures versus only one (4%) cord injury from cervical spine procedures (P = 0.002). One or more intraoperative problems (7 [15%], usually hypotension) and airway management (6 [12%]) were also judged to be probable contributors to cervical injury, with no difference between cord versus root and/or bony spine injury claims. However, airway management was more commonly judged to be a probable contributor to cervical cord injury with noncervical spine procedures (3 [23%]) versus cervical cord injury with cervical spine procedures (1 [4%]; P = 0.044).

**Discussion**

**Approach and Limitations**

Cervical cord, root, and/or bony spine injury claims represented a very small fraction (less than 1%) of all general anesthesia malpractice claims. However, when injury occurred it was often severe, particularly when the injury involved the cervical cord and resulted in quadriplegia. Despite severe outcomes and large payments, on-site reviewers considered anesthesia care to be appropriate in 90% of all cervical injury claims. Likewise, on-site reviewers considered additional monitoring to be unlikely to have prevented cervical injury in 90% of these claims. Thus, in the majority of all cervical injury claims, the anesthesiologist met the standard of care and yet the patient was severely injured and the anesthesiologist sued. Clearly, there are gaps in our knowledge as to how these injuries occur and, consequently, how they might be prevented.

In this study, we used the ASA Closed Claims database to review a relatively large number of these rare injuries in order to formulate hypotheses regarding clinical circumstances and causation. These data have a number of well-described limitations, including selection bias, lack of denominators, inability to estimate risk, retrospective data collection, and brief and nonstandardized narrative summaries. Important data could be missing from the narratives and there was no way to retrospectively determine whether all relevant information was included. To maximize the reliability of information extracted from the claim summary narratives, three independent reviewing teams used a standardized data collection form. To minimize specialty-related bias, each team was comprised of an experienced anesthesiologist and neurosurgeon, and each team provided consensus responses.

To further enhance reliability, two of the three teams had to
provide the same answer for a data element to be considered present. Our reliability measure, \( \alpha_k \), indicated good-to-excellent agreement in most items related to narrative content. Each team was also asked to use all claim information to judge whether various factors were probable contributors to injury—again requiring agreement in two of three teams for an affirmative response. These latter assessments were necessarily more subjective and speculative. As expected, \( \alpha_k \) values for probable contributing factors indicated less agreement and reliability, particularly for the less common contributors. Accordingly, we view all of our findings as tentative and all of our conclusions as hypotheses.

**Primary Findings and Hypotheses**

In this case series, cervical injury claims occurred predominately in healthy middle-aged men who underwent elective nontrauma surgery. Most cervical injuries occurred in patients who appeared to have stable cervical spines. Difficult airway management was no more common than is found in other general anesthesia claims in the ASA Closed Claims database. Although our study cannot distinguish between whether these characteristics are the result of bias from malpractice litigation, various legal strategies, or relative risks of cervical cord injury in surgical patients, our findings suggest current concepts regarding how cervical injuries occur in the perioperative setting are not complete.

Based on this case series, we hypothesize the following: (1) the cervical cord can be injured in the presence of an anatomically stable spine by mechanisms not heretofore widely recognized, (2) in clinical practice, these other mechanisms may result in injury more often than cervical spine instability, and (3) degenerative disease of the cervical spine is the underlying condition that may most often place patients at risk of perioperative cervical cord injury in the absence of anatomic instability.

**Cervical Spondylosis and Stenosis Pathophysiology**

The human cervical spine undergoes progressive age-related noninflammatory degenerative changes collectively referred to as spondylosis. Disc desiccation, narrowing of intervertebral spaces, and/or disc herniation are present in 20–30% of patients by age 40 yr. With increasing age, progressive bony and ligamentous changes occur, such that 10–30% of patients older than 50–60 yr have radiographic evidence of root and/or cord compression at one or more cervical levels. Cord compression occurs anteriorly from both osteophytes and ossification of the posterior longitudinal ligament. Posterior cord compression can also occur from thickening and buckling of the ligamentum flavum, which is exacerbated with extension. Advanced cervical spondylosis can cause sufficient canal stenosis and cord compression that some patients develop cervical myelopathy, with hyperreflexia, motor weakness, and/or sensory changes in the upper and/or lower extremities. Patients with severe cervical stenosis often experience neck pain or stiffness and/or radiculopathy before the onset of myelopathic symptoms, but not always. Initial myelopathic symptoms can be subtle and easy to miss, such as minor hand clumsiness and/or a slowing gait. Even so, severe cervical stenosis can exist in the apparent absence of any clinical signs and symptoms.

Dynamic imaging studies show spondylotic cord compression present in the neutral position can markedly increase with either cervical flexion or, more commonly, with extension (fig. 1). Two case series provide compelling evidence that patients who have severe cervical stenosis are susceptible to cervical cord injury from otherwise minor insults. In the larger of the two series, Koyanagi et al. described 42 patients who became acutely quadriplegic after minor trauma (mostly low velocity falls) in the absence of any fracture or dislocation of the cervical spine. In that series, in 39 patients (93%), cervical stenosis was present that resulted in chronic cervical cord compression at one or more levels. The authors ascribed cord injury (quadriplegia) to additional acute cord compression during the brief period of cervical hyperextension.

The chronically compressed cervical cord also appears to have limited perfusion reserves and, as a result, may be more susceptible to ischemic injury. In a canine model of hemorrhagic hypotension, dogs with chronic cervical cord compression (although clinically asymptomatic when normotensive) exhibited signs of cord dysfunction at systemic arterial blood pressures 20–25 mmHg greater than dogs without cord compression. Collectively, these findings indicate that patients with severe cervical stenosis may be susceptible to cervical cord ischemic injury by neck movement and/or physiologic derangements (e.g., hypotension) that would not otherwise cause injury in the absence of this condition.

**Cervical Cord Injury**

**Cervical Spine Surgery.** In this case series, injury to the cervical cord was the most frequent (37 [77%]) and most severe form of injury, resulting quadriaparesis, quadriplegia, or central cord syndrome in at least 35 patients. In addition, in this case series, the group of patients most readily identifiable as being at risk of cervical cord injury were those who underwent cervical spine procedures. Specifically, 65% of cervical cord injuries (24 of 37) occurred in patients who underwent cervical spine surgery.

In the United States between 1990 and 2000, surgery to treat degenerative cervical spine disease increased twofold, from 29 to 55 cases per 100,000 people (~100,000 hospitalizations per year). In contemporary practice, the great majority (~90%) of cervical spine surgery is performed to treat degenerative disease, with 5–7% of cervical spine surgery undertaken to treat trauma and/or instability. Contemporary reports place the incidence of severe intraoperative cervical cord injury (quadriplegia) during cervical spine surgery at 0.1–0.4% (1–4 per 1,000). Two recent studies provide insight into events that are associated
with acute cervical cord electrophysiological dysfunction during cervical spine surgery. Events most commonly associated with intraoperative evoked potential abnormalities were direct surgical interventions (44–46%), hypotension (10–40%), shoulder taping (4–31%), neck positioning for surgery (4–11%), and intubation (3%).37,40 Patients with preoperative cervical myelopathy were more likely to experience evoked potential deterioration during surgery,37 suggesting that preexisting cord dysfunction predisposes patients to additional abnormalities.

In our case series, for the great majority of patients who underwent cervical spine surgery and experienced cervical cord injury (n = 24), the injury was either entirely new (17 [71%]) or worse (3 [13%]) than before surgery. In the great majority of these patients (16 [80%]) cervical cord injury was detected immediately after the procedure, indicating that the injury took place during the procedure. Cervical spine anatomic abnormalities were judged to be the most common probable contributor to cord injury (19 [79%]) and most commonly consisted of cervical spondylosis. Direct surgical complications were judged by the reviewing teams to be probable contributors to cord injury in nine patients (38%) who underwent cervical spine procedures. This estimate of the relative contribution of direct surgical injury to cervical cord injuries is consistent with the two aforementioned evoked potential studies.37,40 Preprocedural symptomatic cord injury was judged to be a probable contributor to cervical cord injury in six patients (25%) who underwent cervical spine procedures. It appears that half of the patients (3 of 6) with cord-related neurologic symptoms before cervical spine surgery were worse after surgery. This is also consistent with prior observations that patients with preexisting neurologic injury, either from trauma44 or myelopathy,42,45,46 are more susceptible to intraoperative injury. Other intraoperative problems (specifically, hypotension) were judged to be probable contributors to cord injury in three cervical spine procedures (13%; see Other Intraoperative Problems). In only one instance (4%) was airway management judged to be a probable contributor to cord injury in a cervical spine surgery patient (see Cervical Spine Instability).

On the basis of both this case series and other studies,34,36,37,41,43,45 we hypothesize that intraoperative cervical cord injury during cervical spine surgery may often be due to direct surgical complications. However, almost equally often, one or more nonsurgical factors may unfavorably affect the cervical cord, particularly in susceptible patients. These factors appear to include head/neck position during surgery or intubation, and/or arterial blood pressure, with patients who have preexisting cord injury from either trauma or myelopathy being the most susceptible.

Cervical Spine Instability. Although associated with a minority of cervical cord injuries in this case series (9 [24%]), preprocedural cervical spine instability appears to be an important risk factor for developing this severe complication. Seven of nine patients (78%) with preprocedural cervical spine instability experienced antecedent traumatic injury, with six of the seven undergoing cervical spine surgery. Two patients had cervical spine instability from an unknown nontraumatic cause, one of whom underwent a cervical spine procedure. Thus, seven of nine patients (78%) with cervical spine instability underwent cervical spine procedures; the...
remaining two (21%) underwent a noncervical spine procedure. Of the nine patients with cervical spine instability, intubation was accomplished using fiber-optic methods in two patients (22%); cervical spine immobilization techniques were used during intubation in two patients (22%).

In this case series, airway management was considered to be a probable contributor to cord injury in two of the nine patients (22%) with cervical spine instability (cervical spine surgery, n = 1; noncervical spine surgery, n = 1). These two patients were neurologically intact before the procedure, and underwent a direct laryngoscopy without cervical stabilization.

Concerns regarding cervical cord injury during intubation in patients with known or suspected cervical spine instability have had a major effect on clinical practice. Nevertheless, only a few case reports regarding this complication have been published.1–8 When critically reviewed,9 most of these case reports lack sufficient detail to be certain that direct laryngoscopy and intubation truly caused cervical cord injury. This fact, coupled with the very small number of reported cases has provided little evidence regarding how the airway might best be managed in the setting of cervical spine instability, although recommendations certainly exist.47–49

Our findings cannot address whether fiber-optic intubation and/or cervical stabilization techniques might decrease the frequency of cervical cord injury in patients with unstable spines who require intubation. However, our findings do indicate that, in patients with cervical spine instability who had new or worse spinal cord injury: (1) these techniques do not appear to have been commonly used, and (2) even when used, they did not necessarily guarantee prevention of perioperative cord injury either during intubation or subsequent surgery.

Noncervical Spine Surgery. We hypothesize that the various nonsurgical mechanisms by which a susceptible cervical cord may be injured during cervical spine surgery may be equally likely to occur in similarly susceptible patients who undergo noncervical spine surgery. In our case series, a significant proportion of cervical cord injury claims (13 [35%]) originated from patients who underwent noncervical spine procedures. Therefore, direct surgical injury to the spinal cord can be totally ruled out in these 13 claims. In addition, the great majority of these patients (11 [85%]) also had apparently stable cervical spines, which eliminates another major mechanism of injury. Of the 11 cervical cord injury patients with stable spines undergoing noncervical spine procedures, the most common factor was preexisting severe cervical spine degenerative disease (cervical spondylosis, n = 6; disc herniation, n = 1 or 2). In virtually all of these cases, it appears that cervical spine disease was not recognized before the procedure. Based on the pathophysiology of cervical spondylosis, we hypothesize that this condition may have been the underlying factor that predisposed these patients to intraoperative cervical cord injury through means that would not ordinarily cause such injury.

Head/Neck Position during the Procedure

In this case series, there were a total of eight claims (cord, n = 7; root and/or bony spine, n = 1) wherein head/neck position during the procedure was judged to be a probable contributor to injury. The majority of these claims (6 [75%]) were for cervical cord injury after noncervical spine procedures. With the exception of a patient with ankylosing spondylitis, all of these cord injury patients (n = 5) were found postoperatively to have significant cervical spondylosis. Three of the five patients were positioned with marked cervical extension during surgery and, in the remaining two, intraoperative cervical extension was possible. An additional cord injury claim in which head/neck position was judged to be a probable contributor originated from a patient who underwent cervical spine surgery in extreme hyperextension. Based on these observations, we hypothesize that, in the presence of severe cervical spondylosis, sustained cervical extension (e.g., from either deliberate or accidental positioning) may cause cervical cord compression sufficient to cause spinal cord injury. Several recent case reports support this hypothesis.50–52

In this case series, there was one claim in which head/neck position was judged to be a probable contributor to a root injury in a patient with Down syndrome (see Ankylosing Spondylitis and Down Syndrome).

The Sitting Position. In this case series, nine of 37 patients (24%) with cervical cord injury had surgery performed in the sitting position; none had cervical spine instability. The proportion of patients who had sitting surgery was the same between cervical spine (6 [25%]) and noncervical spine (3 [23%]) procedures. We hypothesize that the sitting position carries a disproportionate risk of cervical cord injury. This is not a new concept. The first report to suggest that the sitting position may place neurosurgical patients at risk of cervical cord injury was made in 1980.53 Cervical spine hyperflexion and/or impaired cord perfusion from postural hypotension were hypothesized as probable contributors to cord injury.54 Subsequent case series55,56 and case reports57–59 continue to document this rare but catastrophic complication of neurologic surgery in the sitting position.

We hypothesize that the sitting position may increase the risk of cervical cord injury in noncervical spine surgery as well. In our case series, all three nonneurosurgical sitting cases with cervical cord injury (quadriaparesis) had undergone sitting shoulder surgery, and all three had evidence of cervical spondylosis. These cases are similar to a recent case report of acute postoperative quadriaparesis in a patient who underwent sitting shoulder surgery with unrecognized cervical stenosis.60 As discussed previously, in the presence of cervical stenosis, a nonneutral head/neck position may result in additional, sometimes severe, symptomatic cervical cord compression. In addition to systemic hypotension, which is common in the sitting position,61,62 posture-related gravitational effects on cervical cord blood flow63–67 may contribute to cervical cord ischemia.68
Other Intraoperative Problems

In this case series, there was a total of seven cervical cord injury claims (cervical spine procedure, n = 3; noncervical spine procedure, n = 4) in which other intraoperative problems were judged to be probable contributors to cervical cord injury. In six of these seven claims, it appears that substantial intraoperative hypotension was present and, in four of these six, severe cervical stenosis was simultaneously present. We hypothesize that hypotension, which might otherwise be innocuous, may cause cervical cord injury in patients with significant cervical stenosis. As discussed previously, severe cervical stenosis may increase the susceptibility of the affected cord to hypotensive stress, resulting in ischemic dysfunction at systemic blood pressures that would not otherwise be detrimental.

Ankylosing Spondylitis and Down Syndrome. In this case series, two claims (cord, n = 1; root and/or bony spine, n = 1) originated from patients with ankylosing spondylitis who underwent noncervical spine surgery. Airway management (intubation, mask airway) was judged to be a probable contributor to injury in both. Ankylosing spondylitis is a multisystem autoimmune spondyloarthropathy primarily affecting the spine and sacroiliac joints, eventually causing spine fusion and rigidity (“bamboo spine”).69,70 When the cervical spine is affected, these patients are generally regarded as being difficult to intubate. Although not unstable per se, these patients are susceptible to cervical spine fractures with minor trauma and/or cervical spine extension.69,70 There is only one previous case report of quadriplegia after intubation in a patient with ankylosing spondylitis.71 Unfortunately, in this case series, the claim summary narratives did not provide details regarding cervical spine abnormalities (e.g., radiographic findings) after the apparent injurious events. However, these two cases confirm that patients with ankylosing spondylitis are likely to be difficult to intubate with conventional direct laryngoscopy and that cervical extension, achieved either by laryngoscopy or even mask ventilation, may increase the risk of cervical injury.

In this case series, only a single claim originated from a patient with Down syndrome, with the injury claim for symptoms of cervical disc herniation, not cord injury. Down syndrome (trisomy 21) is present in approximately 0.15% of the population, with approximately 20% having ligamentous and bony abnormalities at the cranio cervical junction that result in various forms of cranio cervical instability.72–74 Existing case reports, and the implications of these abnormalities with regard to airway management, tracheal intubation, and intraoperative head and neck position have recently been reviewed.75

Airway Management

In this case series, there was a total of six claims (cord, n = 4; root and/or bony spine, n = 2) wherein airway management was judged by the reviewing teams to be a probable contributor to injury. Two cervical cord injury claims were associated with patients with cervical spine instability; see (Cervical Spine Instability). Two claims (cord, n = 1; root and/or bony spine, n = 1) occurred in patients with ankylosing spondylitis (see Ankylosing Spondylitis and Down Syndrome). The fourth cord injury claim originated from a patient who underwent supine noncervical spine surgery and was subsequently found to have severe cervical spondylosis and cord compression. Intraoperative head/neck position was also judged to be a probable contributor to this patient’s cervical cord injury. This latter case is consistent with three recent case reports of perioperative cervical cord injury in patients with cervical stenosis where the authors ascribed cervical cord injury to cervical extension during intubation and/or subsequent positioning.60,75,76 However, in none of these case reports was sufficient information provided to exclude other potential contributing factors.

Identification of Patients at High Risk for Cervical Cord Injury

In this case series, the group of patients most readily identifiable as being at risk of cervical cord injury were those who underwent cervical spine procedures. Because of the risk of severe neurologic injury during cervical spine surgery, there has been considerable interest in the use of evoked potential monitoring to detect and prevent these injuries. In this case series, only two patients had intraoperative electrophysiological monitoring, both during posterior cervical spine surgery. Although there are advocates for the use of evoked potential monitoring during cervical spine surgery,37 a recent systematic evidence-based review concluded that there is not sufficient evidence to recommend the use of evoked potential monitoring as a means to decrease the incidence of neurologic injury during routine surgery to treat cervical spondylotic myelopathy or radiculopathy.77

In this case series, 11 of 37 patients (30%) who experienced cervical cord injury did so in the absence of instability and while undergoing a noncervical spine procedure. Most of these patients had preexisting severe cervical spondylosis. As discussed previously, this condition may increase the risk of cervical cord injury from events such cervical extension, the sitting position, and/or systemic hypotension. Certain patients may be more likely to have significant cervical spondylosis and, in the presence of a suggestive history or physical examination, might be considered for preoperative imaging studies—although this is not currently a standard of care. Patients with a previous history of spinal degenerative disorders may be one such group. Laroche et al.78 observed that nine of 30 patients (30%) with symptomatic lumbar stenosis had coexisting cervical stenosis, with four (13%) having signs of cervical myelopathy. In a different study of 290 patients scheduled to undergo lumbar spine surgery,79 36 (12%) were found...
to have a positive Hoffmann sign.## Twenty of these patients (64%) were found to have cervical cord compression on magnetic resonance imaging.79 Although other studies have also found patients with a positive Hoffmann sign to have a high incidence of cervical stenosis,80 the negative predictive value of this sign has not been established (i.e., absence of the sign indicating the absence of cervical stenosis). Accordingly, currently there is no symptom, sign, or screening test that consistently identifies all patients with significant cervical stenosis. A limited range of motion of the neck is likely to be present, but this is a non-specific sign.

**Root and/or Bony Spine Injury**

Root and/or bony spine claims were less frequent and much less severe than cervical cord injury claims. In contrast to cord injury claims, only a minority (20%) of root and/or bony spine claims were associated with cervical spine procedures. This finding is surprising inasmuch as root injury occurs in 1 or 2% of cervical spine surgeries.36,40,43 However, it may be that root injuries during cervical spine surgery are considered by plaintiffs and their attorneys as more readily linked to the surgeon. In contrast, in most noncervical spine procedures, the anesthesia care provider is solely responsible for manipulations of the head and neck during intubation, with shared responsibility with the surgeon for positioning thereafter.

In contrast to cervical cord injury claims, only half of root and/or bony spine claims were associated with definable pre-procedural anatomic abnormalities, 95 versus 50%, respectively. Not surprisingly, however, preoperative disc herniation was more common in root and/or bony spine claims (60%) than in cord injury claims (14%). In half of the root and/or bony spine claims, injury was not entirely new, but was worse after the procedure. This finding suggests that many of the root and/or bony spine claims originated in patients who had at least some preoperative root and/or bony spine injury. This finding differs considerably from cord injury claims in which preoperative cord-related symptoms appear to have been much less common. Another major difference is that root and/or bony spine injuries appear to have been detected much later after surgery than cord injuries. Perhaps because root and/or bony spine symptoms are less severe than cord symptoms, such symptoms received less immediate attention. Alternatively, or in addition, the delayed onset of postoperative radiculopathy after cervical spine surgery is well described.81

**Conclusion**

Claims for injury to the cervical cord, roots, and/or bony spine are rare in the ASA Closed Claims database. Cervical cord injury claims were most severe, almost always resulting in quadriplegia. In this case series, 65% of all cervical cord injuries occurred in patients who underwent cervical spine surgery. During cervical spine surgery, we hypothesize that direct surgical injury may account for a substantial proportion of cervical cord injuries. Nevertheless, we hypothesize that other factors, such as airway management, head/neck position, and arterial blood pressure, also have the potential to contribute to cord injury in this setting.

A substantial fraction of cord injury claims were associated with the sitting position and we hypothesize patients who require surgery in this position may be at increased risk. Patients with cervical spine instability, particularly those with antecedent traumatic injury and/or symptomatic cord injury, appear to be another high risk group. Nevertheless, it appears that the large majority of cervical cord injuries occurred in patients who had stable cervical spines. In almost all of these cases, it appears that severe cervical spondylosis was present, in patients undergoing cervical spine surgery as well as patients who experienced cord injury during noncervical spine procedures.

On this basis of these observations, we hypothesize that cervical spondylosis: (1) may confer a risk of cervical cord injury that is no less significant than cervical instability, and (2) because of its prevalence, may contribute to cervical cord injury more often than cervical spine instability. Rather than being directly injurious, we hypothesize that cervical spondylosis may increase the susceptibility of the cervical cord to injury from deviations in neck position and/or arterial blood pressure that would not otherwise cause injury.

We suggest future studies should consider how to: (1) reliably screen and identify patients with severe cervical spondylosis, (2) best position the head and neck during surgery in patients with this condition, (3) effectively monitor the status of the cervical cord in high risk patients and surgeries, considering cost versus benefit.

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