ABSTRACT. Objective. Pediatric victims of blunt trauma have developmental and anatomic characteristics that can make it difficult to assess their risk of cervical spine injury (CSI). Previous reports, all retrospective in nature, have not identified any cases of CSI in either children or adults in the absence of neck pain, neurologic symptoms, distracting injury, or altered mental status. The objective of this study was to examine the incidence and spectrum of spine injury in patients who are younger than 18 years and to evaluate the efficacy of the National Emergency X-Radiography Utilization Study (NEXUS) decision instrument for obtaining cervical spine radiography in pediatric trauma victims.

Methods. We performed a prospective, multicenter study to evaluate pediatric blunt trauma victims. All patients who presented to participating emergency departments underwent clinical evaluation before radiographic imaging. The presence or absence of the following criteria was noted: midline cervical tenderness, altered level of alertness, evidence of intoxication, neurologic abnormality, and presence of painful distracting injury. Presence or absence of each individual criterion was documented for each patient before radiographic imaging, unless the patient was judged to be too unstable to complete the clinical evaluation before radiographs. The decision to radiograph a patient was entirely at the physician’s discretion and not driven by the NEXUS questionnaire. The presence or absence of CSI was based on the final interpretation of all radiographic studies. Data on all patients who were younger than 18 years were sequestered from the main database for separate analysis.

Results. There were 3065 patients (9.0% of all NEXUS patients) who were younger than 18 years in this cohort, 30 of whom (0.98%) sustained a CSI. Included in the study were 88 children who were younger than 2, 817 who were between 2 and 8, and 2160 who were 8 to 17. Fractures of the lower cervical vertebrae (C5–C7) accounted for 45.9% of pediatric CSIs. No case of spinal cord injury without radiographic abnormality was reported in any child in this study, although 22 cases were reported in adults. Only 4 of the 30 injured children were younger than 9 years, and none was younger than 2 years. Tenderness and distracting injury were the 2 most common abnormalities noted in patients with and without CSI. The decision rule correctly identified all pediatric CSI victims (sensitivity: 100.0%; 95% confidence interval: 87.8%–100.0%) and correctly designated 603 patients as low risk for CSI (negative predictive value: 100.0%; 95% confidence interval: 99.4%–100.0%).

Conclusions. The lower cervical spine is the most common site of CSI in children, and fractures are the most common type of injury. CSI is rare among patients aged 8 years or younger. The NEXUS decision instrument performed well in children, and its use could reduce pediatric cervical spine imaging by nearly 20%. However, the small number of infants and toddlers in the study suggests caution in applying the NEXUS criteria to this particular age group. Pediatrics 2001;108(2).

ABBREVIATIONS. CSI, cervical spine injury; NEXUS, National Emergency X-Radiography Utilization Study; CT, computed tomography; MRI, magnetic resonance imaging; SCIWORA, spinal cord injury without radiographic abnormality.
adults in the absence of neck pain, neurologic symptoms, distracting injury, or altered mental status. Although this suggests that such criteria could be useful in limiting radiography among pediatric patients, limitations in the quality of such data make any such conclusions tenuous. The National Emergency X-Radiography Utilization Study (NEXUS) recently validated a decision instrument, based on 5 low-risk criteria, that allows physicians to identify a subset of patients in whom radiographic evaluation can be avoided safely. In this article, a substudy of NEXUS that deals with blunt trauma victims who are younger than 18 years, we define the characteristics of CSI and evaluate the performance of the NEXUS decision instrument for all pediatric patients and in various subgroups defined by age.

METHODS

NEXUS was a prospective observational study, and radiographs were ordered entirely at the discretion of the examining physician, dictated only by each physician's usual and customary practice for obtaining such films. The study protocol neither mandated nor directed any element of patient care and thus posed no risk to patients. Waivers of informed consent were granted to each participating institution that participated in the study. The methods of the NEXUS study have been described in detail elsewhere. Pediatric and nonpediatric cases were classified as low-risk only when all 5 of the low-risk criteria were met. The low-risk criteria were defined as the absence of each of the following: midline cervical tenderness, evidence of intoxication, altered level of alertness, focal neurologic deficit, and presence of a distracting painful injury. At each participating center, physicians undertook a brief training program in the application of the NEXUS criteria before initiation of the study. Physicians could indicate that they were unable to measure an individual criterion (eg, tenderness in a comatose patient), in which case, the patient was considered not to have met the low-risk criterion. A patient was considered to have met the decision instrument classification of low-risk only when all 5 of the low-risk criteria were fulfilled.

All findings were entered into a computer data terminal, which then issued the voucher that was required to obtain cervical spine radiographs. If an attending physician believed that even the minimal delay associated with completing the brief NEXUS questionnaire potentially might be harmful to the patient, then he or she could obtain the study voucher by indicating that the patient was unstable. In such cases, clinicians were encouraged to complete a full assessment of all criteria as soon as feasible, preferably before radiograph results were known. Instability of this type was considered to represent a surrogate for significant injury and exclusion from low-risk classification.

Study radiologists at each site interpreted all radiographic studies. The presence or absence of CSI and unstable CSI was based on the final interpretation of all radiographic studies (including special imaging techniques such as plain tomography, CT, and MRI). When these reports were ambiguous, study investigators reviewed both the reports and the original radiographs to determine final fracture classification. Neither the official radiology interpretation nor the coding of injuries was done with knowledge of the findings on the NEXUS data form.

Cases in which the victim had a CSI and was not defined as low-risk by the decision instrument were considered to be true positive, whereas those who were diagnosed as having an injury in the presence of all low-risk criteria were classified as false negative. Cases that met all low-risk criteria and had no CSI were classified as true negative, whereas those without injury but failing to meet at least 1 of the criteria were classified as false positive. Sensitivity and negative predictive value (as well as specificity and positive predictive value) of the decision instrument for CSI were calculated in the standard manner.

RESULTS

A total of 34,069 patients, of all ages, were enrolled in NEXUS (see Table 1), including 3,065 children (9%) who were younger than 18 years. The age distribution for pediatric cases is shown in Fig 1. Age groupings are presented on the basis of lack of verbal ability (0–2), immature cervical spine (2–8), the older pediatric population (9–17), and the adult population (18+). Thirty children were found to have a CSI, representing 0.98% of all pediatric patients and 3.7% of all injuries reported in NEXUS. No pediatric patient who was defined as low risk sustained a CSI in this study.

Compared with the adult population, a larger percentage of the pediatric population (603 [19.7%]) was considered low-risk by the decision instrument (Table 1), and none of these children had a CSI. Table 2 shows that the percentage of (stable) patients who underwent radiographic evaluation, despite being defined as low-risk by the decision instrument, decreased with every increase in age group.

Applying the NEXUS criteria to the pediatric population, sensitivity, specificity, negative predictive value, and positive predictive value are noted in Table 3 and compared with the results from the overall NEXUS population. The NEXUS decision instrument identified all pediatric patients with CSI.

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**TABLE 1.** NEXUS Summary

<table>
<thead>
<tr>
<th>Factor</th>
<th>Pediatric</th>
<th>Nonpediatric</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>3065</td>
<td>31,004</td>
<td>34,069</td>
</tr>
<tr>
<td>Number of patients with CSI</td>
<td>30 (0.98%)</td>
<td>788 (2.54%)</td>
<td>818 (2.4%)</td>
</tr>
<tr>
<td>Injury rate</td>
<td>0.98%</td>
<td>2.54%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Number of low-risk patients</td>
<td>603 (19.7%)</td>
<td>3706 (12.0%)</td>
<td>4309 (12.6%)</td>
</tr>
<tr>
<td>Number of low-risk patients with injury*</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

* By NEXUS decision instrument.
precise age is not known. For stable patients whose age is known; omits patients whose NEXUS instrument, and there was no evidence of intoxication. In 3 more, there was a small number of children with CSI, the 95% confidence interval is relatively wide (87.8%–100.0%).

Table 4 compares the NEXUS findings in the 30 injured and 3035 noninjured patients. Tenderness and distracting injury were the 2 most common abnormalities noted in patients both with and without CSI. Evidence of intoxication was noted infrequently among children, occurring in none of the injured patients and in only 110 of the others.

Of 30 patients with CSI, 21 were male, and their ages ranged between 2 and 17 years, with two-thirds being teenagers. No CSI was present in an infant who was younger than 2 years. CSIs among these children were distributed throughout the cervical spine, with the majority occurring in the lower cervical spine (Table 5).

Table 6 provides details of all 30 pediatric patients who sustained CSI. Most of these patients (24) were classified as clinically stable, and only a small number of the individual low-risk criteria (16 of 150 [11%]) were unable to be evaluated. There was no case of spinal cord injury without radiographic abnormality (SCIWORA) in this series. Among the 30 children with CSI, 5 (17%) had radiographic proof of spinal cord injury. Neurologic deficit also was recorded on the NEXUS data form in 3 other children with CSI and could not be determined in 3 more.

None of the injured children was low risk by the NEXUS instrument, and there was >1 non–low-risk finding in 13 of the 30, with an average of 1.8 positive among this group. (Of children without CSI, the average number of positive criteria was 1.4.) No patient was identified as non–low risk by the decision instrument solely because clinicians were unable to assess 1 or more of the criteria. Furthermore, in no case was intoxication the only non–low-risk finding in any of these 30 children.

**DISCUSSION**

No CSI was identified in the pediatric population without at least 1 positive NEXUS risk factor. No CSI would have been missed had the NEXUS criteria been applied to this population, but 20% fewer radiographs would have been performed. This is consistent with the findings of the NEXUS study, which validated a clinical decision instrument designed to identify patients who are at extremely low risk of CSI.

Our study does not prove definitively that the NEXUS low-risk criteria can be applied to children with complete safety. Although NEXUS was large enough to define the overall sensitivity of the instrument with substantial precision, there were few children with CSI. Thus, although the decision rule correctly identified all 30 children with CSI, the lower confidence interval for sensitivity in this group is only 87.8%. There were only 4 injured children who were younger than 9 years with CSI; thus, we are even less confident about application of the NEXUS decision instrument to that group.

Given that it would require a prospective study of approximately 80 000 children to be able to define confidence intervals for sensitivity of 0.5% (and vastly more to do so for younger children), a definitive answer is unlikely to be forthcoming. Nevertheless, we believe that it is reasonable, particularly in the adolescent age group, to endorse cautiously the use of the NEXUS decision instrument in children, for several reasons.

First, there is not a single case in the medical literature of a child with an occult CSI who would have been classified as low risk by the NEXUS criteria. Previous studies that attempted to define criteria for obtaining cervical spine radiographs in children are based on retrospective chart reviews. However, even in such retrospective studies, essentially all pediatric patients with CSI were reported to have neck pain or tenderness, abnormal neurologic findings, or altered mental state. There have been no reports of CSI among children who are old enough to communicate and who have normal mental status, no neck pain, no neurologic abnormality, and no distracting injury.

Second, although there are anatomic differences between adults and small children, which lead to different types and locations of injuries, there are no clear reasons to believe that symptoms of injury and thus the low-risk criteria would be different in these groups, with the exception of children who are too small to express themselves or to localize complaints. Although CSI is exceedingly rare in very young children (Finally, there was a substantial number of children in NEXUS (603) who were iden-
Identified as low risk for CSI, none of whom proved to have fracture. Thus, not only was the negative predictive value of the decision instrument among children 100%, but also the confidence interval places the negative predictive value at no worse than 99.4%. For all of these reasons, therefore, we believe that cervical spine imaging rarely should be undertaken in children who clearly are negative by the low-risk criteria. Again, given the small number of infants and toddlers in this study, these conclusions may not be applicable to that group.

None of the 30 children with CSI were identified by the presence of intoxication alone, whereas each of the other 4 criteria was necessary for the instrument to have attained 100% sensitivity. This probably reflects the relative rarity of intoxication among children and the small number of CSI identified. Because the overall NEXUS study19 demonstrates clearly that intoxication can obscure other findings in CSI, it certainly should remain part of the decision instrument in children, although it will be important only occasionally.

CSI was present in only 0.98% of the children in whom radiography was performed, which is less than half the rate seen in adults in NEXUS. This may reflect more liberal ordering on the part of clinicians, a lower risk of injury among small children (because of anatomic differences or, more likely, less exposure to dangerous mechanisms of injury), or some other undefined factor. More liberal ordering also is suggested by the fact that the percentage of patients who met the low-risk criteria and for whom radiographs were ordered decreased with each increasing age group (Table 2). There are substantial anatomic differences in younger children (up to age 8), whereas from ages 8 to 12 there is a transitional period, after which the cervical spine is almost fully developed and for all practical purposes is comparable to that of an adult.2–5 This may help to explain differences in susceptibility to injury or the basis for a different ordering policy among many clinicians.

CSI did not occur among infants who were younger 2 years, only 88 of whom were enrolled in the study. This is strong testimony to the rarity of CSI in this age group. It also is possible that cases in infants, when they do occur, present differently. Because injuries in this age group have been reported to occur predominantly to the higher cervical cord,7–10 they frequently are lethal at the scene and thus never identified. The smaller number of cases in this age group is consistent with the lower incidence of exposure to a mechanism of injury that causes CSI compared with other age groups.

Almost all of the pediatric CSI in NEXUS occurred in older children, and the pattern of injury in that group was not dissimilar from that seen in adults. The rare cases of CSI in younger children occurred primarily in the upper cervical spine. This confirms observations of most but not all earlier studies, in which the distribution of CSI in children who are older than 12 years is similar to that of adults, whereas the preponderance of injuries in younger children is in the C1 and C2 regions.3–5,15–17 SCIWORA has been described prominently among children,7,25,26 but the only such cases in NEXUS occurred among adults. Because for the purpose of

<p>| Table 3. Operator Characteristics of the NEXUS Decision Instrument, by Age |
|---------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pediatric</th>
<th>Overall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>100% (87.8%–100.0%)</td>
<td>99.02% (98.0%–99.6%)</td>
<td></td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>100% (99.2%–100.0%)</td>
<td>99.91% (99.6%–100.0%)</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>19.9% (18.5%–21.3%)</td>
<td>12.93%</td>
<td></td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>1.2% (0.8%–1.8%)</td>
<td>2.72%</td>
<td></td>
</tr>
</tbody>
</table>

<p>| Table 4. Prevalence of Individual Low-Risk Criteria in Children With and Without CSI |
|---------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Positive</th>
<th>Negative</th>
<th>N/A*</th>
<th>Positive</th>
<th>Negative</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness</td>
<td>21</td>
<td>4</td>
<td>5</td>
<td>1179</td>
<td>1333</td>
<td>523</td>
</tr>
<tr>
<td>Distracting injury</td>
<td>11</td>
<td>17</td>
<td>2</td>
<td>878</td>
<td>1915</td>
<td>242</td>
</tr>
<tr>
<td>Altered LOC</td>
<td>6</td>
<td>21</td>
<td>3</td>
<td>520</td>
<td>2326</td>
<td>189</td>
</tr>
<tr>
<td>Neurologic findings</td>
<td>8</td>
<td>19</td>
<td>3</td>
<td>176</td>
<td>2611</td>
<td>248</td>
</tr>
<tr>
<td>Intoxication</td>
<td>0</td>
<td>27</td>
<td>3</td>
<td>110</td>
<td>2730</td>
<td>195</td>
</tr>
<tr>
<td>Classified as stable</td>
<td>24</td>
<td>6</td>
<td>0</td>
<td>2764</td>
<td>271</td>
<td>0</td>
</tr>
</tbody>
</table>

LOC indicates level of consciousness; N/A, unable to be assessed.

<p>| Table 5. Injuries for Pediatric and Nonpediatric Patients |
|---------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Injury</th>
<th>Pediatric</th>
<th>Nonpediatric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occipital condyle</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>C1</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>C2 (nonodontoid)</td>
<td>2</td>
<td>192</td>
</tr>
<tr>
<td>Odontoid</td>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>C3</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>C4</td>
<td>5</td>
<td>79</td>
</tr>
<tr>
<td>C5</td>
<td>9</td>
<td>170</td>
</tr>
<tr>
<td>C6</td>
<td>9</td>
<td>233</td>
</tr>
<tr>
<td>C7</td>
<td>10</td>
<td>218</td>
</tr>
<tr>
<td>Cord injuries (documented)</td>
<td>5</td>
<td>64</td>
</tr>
<tr>
<td>Interspace injuries (by level)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atlanto-occipital</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>C1-C2</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>C2-C3</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>C3-C4</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>C4-C5</td>
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<td>C5-C6</td>
<td>5</td>
<td>53</td>
</tr>
<tr>
<td>C6-C7</td>
<td>2</td>
<td>52</td>
</tr>
<tr>
<td>C7-T1</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

SCIWORA has been described prominently among children,7,25,26 but the only such cases in NEXUS occurred among adults. Because for the purpose of
this study we could confirm the presence of a cord injury only when it was diagnosed radiographically (typically by MRI) at the participating institution, it is possible that the 5 children who were reported to have cord injury represent an underestimate of the true number of children with cord injury. There were no children, however, in whom CSI was identified, either by imaging or clinically, who had negative plain cervical spine radiographs (and thus met the standard definition of SCIWORA). Given that our methodology included mandatory data entry for all participants, as well as institutional follow-up of risk management and neurosurgical logs, it is extremely unlikely that cases of SCIWORA occurred but were not captured. Because all children who underwent radiography were included, it is virtually unimaginable that a child with clinical findings of cord injury would not have undergone radiographic evaluation. Because a number of tertiary care facilities participated in the NEXUS Group, referral bias is unlikely to explain the absence of pediatric SCIWORA. Finally, our methodology did in fact identify 22 cases

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Stable</th>
<th>Intoxicated</th>
<th>Tender</th>
<th>Injury</th>
<th>Altered LOC</th>
<th>Neurologic Findings</th>
<th>Fracture Type</th>
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<tr>
<td>2</td>
<td>F</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>C2 type III odontoid fracture</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Occipital condylar fracture</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>Craniovertebral dissociation</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C1 anterior and posterior arch fracture, C2 type II odontoid fracture</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>C4 flexion tear drop fracture</td>
</tr>
<tr>
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<td>M</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Craniovertebral dissociation</td>
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<td>No</td>
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<td>No</td>
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<td>M</td>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<td>C5 anterior-inferior body fracture</td>
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<td>Yes</td>
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<td>Yes</td>
<td>No</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C2 spinous process fracture</td>
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<tr>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C6 spinous process fracture</td>
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<tr>
<td>14</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C7 wedge compression fracture</td>
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<td>14</td>
<td>F</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>C4–C5 subluxation, C5–C6 subluxation, C5 body and posterior element fractures, C4–C6 cord contusion*</td>
</tr>
<tr>
<td>16</td>
<td>F</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<td>C7 compression fracture</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>C6 burst fracture and bilateral laminar fractures, C7 body and bilateral laminar fractures</td>
</tr>
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<td>16</td>
<td>F</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>C6–C7 subluxation/dislocation, C7 fracture†</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C5 burst fracture and bilateral laminar fractures; C5–C6 subluxation</td>
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<tr>
<td>16</td>
<td>M</td>
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<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
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<td>N/A</td>
<td>C5 body fracture; C5–C6 subluxation</td>
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<td>16</td>
<td>M</td>
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<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
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<td>M</td>
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<td>No</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>C6 articular facet fracture; C6 compression fracture; C5–C6 bilateral interfacial dislocation; C5–C6 cord contusion*</td>
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<tr>
<td>16</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C4 compression fracture; C3–C4 subluxation; C4–C5 cord contusion*</td>
</tr>
<tr>
<td>16</td>
<td>F</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>C4 burst fracture; C4–C5 subluxation; C4–C5 cord contusion*</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C1 posterior arch fracture</td>
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<tr>
<td>17</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>C7 spinous process fracture</td>
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<tr>
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<td>Yes</td>
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<td>C7 body fracture</td>
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<td>No</td>
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<td>Yes</td>
<td>C6–C7 facet and capsular injury</td>
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<tr>
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<td>Yes</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>C5 flexion teardrop, C5 laminar fracture, C6 body fracture, C5–C6 interfacial dislocation, C5–C6 cord contusion*</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>C3–C4 subluxation</td>
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<tr>
<td>17</td>
<td>M</td>
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<td>No</td>
<td>C1 burst fracture, C6 and C7 spinous process fractures</td>
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<tr>
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<td>F</td>
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<td>Yes</td>
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<td>No</td>
<td>No</td>
<td>Axis body fracture</td>
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CSI indicates cervical spine injury; LOC, level of consciousness.
* Cord injury documented by magnetic resonance imaging.
† Missed by computed tomography.
of SCIWORA in adults. Thus, despite the previous sporadic reports, our data, collected systematically in a very large number of consecutive patients, make it clear that SCIWORA is at most very rare among children. This most likely reflects the rarity with which any spinal cord injury is seen in younger age groups. This rarity is supported by a review of all cases in the National Pediatric Trauma Registry over a 5-year period (24 740 total cases), during which an average of 81 cases of CSI per year were reported in children aged 0 to 20, with fewer than 8 per year in children who were younger than 2.27

This prospective observational study, the largest (and only prospective) study ever done regarding pediatric CSI, provides a great deal of information about this entity and strongly suggests that children who meet all of the NEXUS low-risk criteria generally do not need to undergo cervical spine imaging. Given the small number of children with CSI in this series, we urge caution in applying the decision instrument to individual patients, particularly in the youngest age groups, in which the number of study participants was relatively small. Nevertheless, our data suggest that CSI is at most extremely rare among children who are defined as low risk by the decision instrument, concordant with both the absence of any report of occult fracture in the pediatric literature and the overall results among all 34 069 NEXUS participants. We believe that this strongly supports the safety and utility of the NEXUS criteria in children, application of which could reduce cervical spine imaging in children by approximately 20%, limit the time in which children are forced to remain immobilized, and decrease their exposure to radiation. Finally, utilization of the NEXUS decision instrument should lead to a substantial reduction in health care costs through avoidance of unnecessary radiographs.

APPENDIX: NEXUS STUDY PARTICIPANTS

The following centers and investigators collaborated in this study. Principal investigator: W. Mower. Co-investigator: J. Hoffman. Steering Committee: J. Hoffman, W. Mower, K. Todd, A. Wolfson, and M. Zucker. Site investigators: Antelope Valley Medical Center (Los Angeles): M. Brown and R. Sisson; Bellevue Hospital (New York): W. Goldberg and R. Siegmund; Cedars-Sinai Medical Center (Los Angeles): J. Geiderman and B. Pressman; Crawford Long Hospital (Atlanta): S. Pitts and W. Davis; Children’s Health care of Atlanta (Atlanta): H. Simon and T. Ball; Emory University Medical Center (Atlanta): D. Lowery and S. Tiggess; Grady Hospital (Atlanta): C. Finney and S. Tiggess; Hennepin County Medical Center (Minneapolis): B. Mahoney and J. Hollerman; Jacobi Medical Center (Bronx): M. Touger, P. Gennis, and N. Nathanson; Maricopa Medical Center (Phoenix): C. Pollack and M. Connell; Mercy Hospital of Pittsburgh (Pittsburgh): M. Turturro and B. Carlin; Midway Hospital (Los Angeles): D. Kalmanson and G. Berman; Ohio State University Medical Center (Columbus): D. Martin and C. Mueller; Southern Regional Hospita l (Decatur): W. Watkins and E. Hadley; State University of New York at Stony Brook (Stony Brook): P. Vecchione and S. Choch; University of California, Davis, Medical Center (Sacramento): E. Panacek and J. Holmes; University of California, Los Angeles, Center for the Health Sciences (Los Angeles): J. Hoffman and M. Zucker; University of California, San Francisco, Fresno University Medical Center (Fresno): G. Hendeby and R. Lesperance; University of Maryland Medical Center (Baltimore): B. Browne and S. Mirvis; University of Pittsburgh Medical Center (Pittsburgh): A. Wolson and J. Towers; University of Texas Health Science Center/Hermann Hospital (Houston): N. Adame, Jr., and J. Harris, Jr.

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REFERENCES

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