Spinal Cord Injury without Radiographic Abnormality: Results of the National Emergency X-Radiography Utilization Study in Blunt Cervical Trauma

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Background: **The purpose of this study was to better define the incidence and characteristics of patients with spinal cord injury without radiographic abnormality (SCIWORA), using the database of the National Emergency X-Radiography Utilization Study (NEXUS).**

Methods: **This was a prospective, observational study of blunt trauma patients in 21 U.S. medical centers undergoing plain cervical radiography. SCIWORA was defined as spinal cord injury demonstrated by magnetic resonance imaging, when a complete, technically adequate plain radiographic series revealed no injury.**

Results: **Of the 34,069 patients entered, there were 818 (2.4%) with cervical spine injury, including 27 (0.08%) patients with SCIWORA. Over 3,000 children were enrolled, including 30 with cervical spine injury, but none had SCIWORA. The most common magnetic resonance imaging findings among SCIWORA patients were central disc herniation, spinal stenosis, and cord edema or contusion. Central cord syndrome was described in 10 cases.**

Conclusion: **In the large NEXUS cohort, SCIWORA was an uncommon disorder, and occurred only in adults.**

Key Words: **SCIWORA, NEXUS, Spinal cord injury, Cervical radiography.**

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Cervical spinal cord injury (SCI) can be devastating for patients and their families. Most often, cervical SCI is caused by fracture or subluxation, and is detected by plain radiography or computed tomographic (CT) scanning. However, SCI may also occur in the absence of a bony abnormality. This entity has been named spinal cord injury without radiographic abnormality (SCIWORA).[1]

Since the term SCIWORA was coined by Pang and Wilberger in 1982, this syndrome has been thought to occur primarily in children.[1] There have been other reports of children with SCIWORA, but most are retrospective case series, and the estimated incidence of the syndrome varies widely.[2–7]

We undertook a secondary analysis of data from the large prospective National Emergency X-Radiography Utilization Study (NEXUS) of blunt cervical spinal trauma to better characterize SCIWORA, and to calculate its frequency in a multicenter database that includes adults and children.

MATERIALS AND METHODS

A detailed description of the methodology of the NEXUS study has been previously published and is briefly summarized here.[8–10] Twenty-one medical centers participated in this prospective, observational study. These institutions included university, community, and public hospitals, with and without residency training programs, with a variety of emergency department volumes and trauma center categorizations.

All blunt trauma victims who underwent cervical spine radiography in the emergency department of a participating institution were included, and the decision to order cervical spine radiographs was left to the discretion of the treating physician. Patients selected for radiographic imaging underwent a standard three-view examination, including cross-table lateral, anteroposterior, and odontoid views. All other radiographic studies, including flexion-extension views, CT scan, and magnetic resonance imaging (MRI), could be ordered at the discretion of the treating physicians.

Treating physicians recorded demographic data and ascertained the presence or absence of each of the five low-risk criteria before ordering cervical spine radiographs (Table 1). Radiologists at each site interpreted all radiographic studies, and the final reports of all cervical spine imaging studies were collected for all study patients. Waivers of informed consent were obtained from the institutional review board at each participating center.

SCIWORA was defined for this study as the presence of SCI, as shown by MRI, when a complete and technically adequate plain radiographic series consisting of at least three views revealed no injury. For every case with an identified SCI on MRI, we reviewed the following: the NEXUS data collection form, all plain film radiology reports, MRI reports, and CT scan or any other radiology reports.

Descriptive statistics were calculated for the SCIWORA patients, as well as the sensitivity and 95% confidence interval

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Table 1 NEXUS Defined "Low-Risk" as Meeting None of the Listed Criteria

1. Altered level of alertness
2. Intoxication
3. Posterior midline cervical spine tenderness
4. Distracting painful injury
5. Focal neurologic deficit

for the NEXUS clinical decision rule in the detection of SCIWORA patients. A statistician reviewed the calculated statistics.

RESULTS

There were 34,069 patients entered into the NEXUS database from the 21 participating sites, and 818 (2%) had a cervical spine injury (CSI). SCIWORA was present in 27 (0.08%) patients. Twenty-two (81%) were men, half were Caucasian, and the median age was 42 years (range, 21–89 years) (Table 2). Twelve additional patients with SCI on MRI had negative, but incomplete, plain films, although all 12 had fractures detected on CT scan. There were 3,065 pediatric patients (age $<$ 18 years) in the study population, including 30 who sustained CSI, but no cases of SCIWORA were found among this population.

By definition, all 27 SCIWORA patients were evaluated with MRI. Twenty-five (93%) had evidence of spinal cord edema or contusion, 13 (48%) had central or paramedian disc herniation, and 11 (41%) had spinal stenosis. The central cord syndrome was specifically noted as the indication for MRI in 6 (22%) of 27 cases, and upper extremity weakness or numbness was described in another 4 cases (15%).

All 27 SCIWORA patients had at least one of the five NEXUS criteria documented as being present. Thus, the criteria were 100% (95% confidence interval, 88–100%) sensitive for identifying that such patients required imaging. Fifteen (56%) had posterior spinal tenderness, 12 (44%) had a distracting injury, 10 (37%) were intoxicated, and 6 (22%) had an altered level of alertness. Sixteen of 27 (59%) had a focal neurologic deficit documented on study entry, 7 (26%) had no deficit recorded, and 4 (15%) were prospectively classified as unknown.

DISCUSSION

The NEXUS cohort is a very large patient sample drawn from 21 heterogeneous medical centers throughout the United States. On the basis of the findings in patients with SCIWORA from among this cohort, we make the following observations: SCIWORA was an uncommon injury pattern in general, occurring in only 3% of cervical spine injury victims and 0.08% of all patients enrolled; pediatric cases of SCIWORA were conspicuously absent in this large series; the central cord syndrome was prospectively identified in one third of SCIWORA patients; and the NEXUS criteria appeared to be highly sensitive in identifying that these patients required imaging.

Table 2 SCIWORA Patients from the NEXUS Database

Patient	Level of Injury	Gender	Age (yr)	MR Findings
1	C2–C3	M	51	Central disc herniation, cord edema
2	C3–C4	M	38	Central disc herniation, cord edema
3	C3–C4	F	80	Spinal stenosis, cord edema
4	C3–C4	M	56	Paramedian disc herniation, cord edema
5	C3–C6	M	72	Spinal stenosis, cord compression, and edema
6	C3–C6	M	42	Multiple disc herniations, cord contusion
7	C3–C6	M	38	Central disc herniation, cord contusion
8	C3–C7	M	83	Spinal stenosis, central disc herniation, cord contusion
9	C3–C7	M	42	Ligamentous injury, cord contusion
10	C3–C7	M	48	Spinal stenosis, cord contusion
11	C3–C7	M	25	Cord edema
12	C4–C5	M	43	Central disc herniation, cord edema
13	C4–C5	M	36	Disc herniation
14	C4–C5	M	37	Spinal stenosis, cord edema
15	C4–C5	M	48	Central disc herniation, cord edema
16	C4–C6	F	53	Central disc herniation, cord edema
17	C4–C5	M	42	Central disc herniation, cord edema
18	C4–C5	F	89	Spinal stenosis, cord compression, and edema
19	C4–C5	M	57	Spinal stenosis, cord compression, and edema
20	C4–C6	M	34	Spinal stenosis, cord contusion
21	C4–C7	F	83	Spinal stenosis, cord contusion
22	C5–C7	M	42	Cord contusion
23	C6–C7	F	42	Spinal stenosis, ligamentous injury, cord contusion
24	C6–C7	M	36	Paramedian disc herniation, cord compression
25	C6–C7	M	45	Spinal stenosis, cord contusion
26	C6–C7	M	36	Ligamentous injury, cord contusion
27	C1–T1	M	21	Paramedian disc herniation, cord edema

We defined SCIWORA strictly as radiographic evidence of cord injury by MRI after a complete series of cervical spine plain films that revealed no fracture or subluxation. One might define SCIWORA more simply as a neurologic deficit in the face of normal plain films, but we wanted to be certain that each case was indisputable, and to exclude patients with peripheral neurologic deficits such as nerve root or brachial plexus injury. The disadvantage of using a strict definition is that we may have underestimated the incidence of SCIWORA in this series. It is possible that some patients with the clinical syndrome of SCIWORA had no evidence of spinal cord injury on MRI and were thus excluded by our definition. In a retrospective review of 32 cases of pediatric SCIWORA, Baker et al. reported that only 7 of the 14 patients undergoing MRI had a detectable lesion.[3] In contrast, all 15 SCIWORA patients reported by Gupta et al. and all 11 reported by Demetriades et al. had abnormalities on MRI.[11,12] The true incidence of SCI without a detectable abnormality on modern MRI is unknown.

It is also possible that some patients with cord contusion never underwent MRI because of clinical findings that were subtle or transient. In addition, some patients with a focal deficit may have been sent straight to CT scanning or MRI, never completing a plain film series. Our review of all SCI patients in the NEXUS database revealed 12 adult patients who, although they had findings of SCI on MRI, were not classified as having SCIWORA because they did not have an adequate plain film series. All 12 were evaluated with CT scans and had fractures detected. It is possible that had these patients undergone complete plain radiography but not CT scanning, some of these fractures might not have been detected, and such patients could have been classified as having SCIWORA. However, this seems unlikely, given that adequate plain films identified almost all patients with significant bony injury.[10] Even if all 12 patients with inadequate plain films were included in the SCIWORA group, the total number of cases would only be 39 (0.11% of those enrolled), with no children.

The overall rarity of SCIWORA that we report is similar to that found by Demetriades et al. in a 5-year trauma registry review.[12] They reported only 11 (3.8%) SCIWORA patients out of 292 with CSI, or 0.07% of 14,755 trauma admissions. The most common injury pattern was the central cord syndrome, and the mean age was 44 years, although it is unclear whether any children were included.

It is somewhat surprising that there were no children with SCIWORA in our series. Most prior reports of SCIWORA have been in pediatric patients.[1–7] However, there are many reports of adults with spinal cord injuries, including the central cord syndrome, in the absence of radiologic abnormalities.[11–17] Some authors have theorized that the pediatric cervical spine is more susceptible to SCIWORA because of a number of anatomic features.[1,2,4,5] However, our data and the data of others suggest that spinal stenosis and intervertebral disc disease play a prominent role in the development of SCIWORA in adults.[11,13–18] Even if it were true that SCIWORA represents a higher percentage of all CSI lesions among children than among adults, the absolute number of SCIWORA cases is still likely to be far greater in adults, given that CSI is so much less common in children.

Many reports of pediatric SCIWORA are retrospective case series from children's hospitals, each identifying one to two SCIWORA cases per year over many years. These reports appear to be subject to referral bias, since many were conducted at tertiary referral centers that may have preferentially received unusual cases in transfer. More importantly, they may have greatly overestimated the incidence of SCIWORA in children because they were unable to ensure the accuracy of the diagnosis, which was determined on the basis of implicit chart review. Without documentation that an adequate series of plain radiographs was interpreted by a competent reader as being negative, it is uncertain that all such cases were "without radiographic abnormality." Furthermore, in the absence of MRI or documentation of actual cord injury, it is possible that some of these cases may have had brachial plexus, nerve root, or peripheral nerve injury, rather than SCI. The methodology of such reports lies in stark contrast to the prospective design and rigorous definitions used in compiling the NEXUS database.

Furthermore, children were not underrepresented in our database, as we enrolled over 3,000 patients under 18 years of age (9% of the total), and 30 had a CSI. There were no pediatric patients who had MRI evidence of cord contusion who were excluded because of incomplete plain films. However, it remains possible that some children had a clinical diagnosis of SCIWORA but never underwent an MRI, or that an MRI did not detect any cord abnormality. We believe that there were few, if any, such cases.

The central cord syndrome was either specifically noted on the MRI report (6 cases), or implied from the deficit described (4 cases) in 10 (37%) of our SCIWORA patients. Beginning with the original description by Schneider et al. in 1954, the mechanism of the central cord syndrome has been ascribed to cervical hyperextension in older patients, as a hypertrophic ligamentum flavum buckles and impinges on the cord.[14–17] However, we found the central cord syndrome across a broad age range (36–89 years old). It is also of interest that most of our SCIWORA patients had either central disc herniation or spinal stenosis, along with evidence of cord edema or contusion. As noted by Bhatoe, degenerative disease and spinal stenosis might predispose some patients to SCIWORA when they are injured, and this issue merits further study.[18]

The NEXUS criteria were highly sensitive in identifying these 27 SCIWORA patients as needing imaging. At least one of the five criteria was present in all 27 cases. In seven of these cases, however, evidence of neurologic deficit was recorded on the NEXUS data form as being absent. Conversely, a neurologic deficit was noted on the MRI report as the indication for performing the study in four of these seven cases. No indication was listed on the other three, so we can only speculate as to why MRI was ordered. It is also impossible to know whether a neurologic deficit was not recorded on the NEXUS form because it was missed by the initial

physician and found by a subsequent examiner, because it was initially absent and developed later, or because the data form was filled out inaccurately.

There are some important limitations to our analysis of SCIWORA. First, we may have underestimated the incidence of the disease by using a strict definition that requires evidence of cord injury on advanced imaging. Some authors have noted that the term "SCIWORA" has become a misnomer because most patients actually have a "radiographic abnormality" detectable on MRI.[11] As imaging technology continues to improve, patients with a cord injury that is not detectable by any radiographic study may become exceedingly rare. It may be more accurate to refer to patients as having a cord injury without evidence of a bony abnormality such as fracture or subluxation.

Furthermore, we have only limited data on individual patients. Although our database includes detailed information on the radiographic studies obtained on each patient, we have no information about the type and severity of neurologic deficits or about patient outcomes. Some authors have described patients with a delayed onset of SCIWORA, and others with recurrent symptoms, neither of which can be fully addressed in this analysis.[1,4,6,7]

In conclusion, in the large, multicenter NEXUS cohort, SCIWORA was very uncommon, and occurred only in adults. The most common abnormalities seen on MRI among SCIWORA patients were central disc herniation, spinal stenosis, and cord edema or contusion. The NEXUS criteria were highly sensitive in identifying patients with SCIWORA.

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APPENDIX

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