Distribution and Patterns of Blunt Traumatic Cervical Spine Injury

From the Department of Emergency Medicine, Bellevue Hospital, New York, NY*; the Department of Radiology, The Ohio State University, Columbus, OH‡; the Department of Emergency Medicine, UC Davis Medical Center, Davis, CA§; the Department of Radiology, Emory University School of Medicine, Atlanta, GA||; and the UCLA Emergency Medicine Center, UCLA School of Medicine, Los Angeles, CA.¶

Author contributions are provided at the end of this article.

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Address for reprints: *William L. Goldberg, MD, Department of Emergency Medicine, Bellevue Hospital Center, First Avenue at 27th Street, New York, NY 10016; 212-562-7356; E-mail wlg2@is4.nyu.edu.*

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William Goldberg, MD*
Charles Mueller, MD‡
Edward Panacek, MD, MPH§
Stefan Tigges, MD||
Jerome R. Hoffman, MA, MD¶
William R. Mower, MD, PhD¶
For the NEXUS Group

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Study objective: Previous studies of cervical spine injury involve individual institutions or special populations. There is currently little reliable information regarding natural cervical spine injury patterns after blunt trauma. This substudy of the National Emergency X-Radiography Utilization Study project was designed to accurately assess the prevalence, spectrum, and distribution of cervical spine injury after blunt trauma.

Methods: We prospectively enrolled all patients with blunt trauma undergoing cervical spine radiography at 21 diverse institutions. Injury status was determined by review of all radiographic studies obtained on each patient. For each individual injury, we recorded which specific films revealed the injury, the level and location of injury on each vertebra, and the age and sex of the patient.

Results: Of 34,069 enrolled patients with blunt trauma, 818 (2.4%) individuals had a total of 1,496 distinct cervical spine injuries to 1,285 different cervical spine structures. The second cervical vertebra was the most common level of injury (286 [24.0%] fractures, including 92 odontoid fractures), and 470 (39.3%) fractures occurred in the 2 lowest cervical vertebrae (C6 and C7). The vertebral body, injured in 235 patients, was the most frequent site of fracture. Nearly one third of all injuries (29.3%) were considered clinically insignificant.

Conclusion: Cervical spine injuries occur in a small minority of patients with blunt trauma who undergo imaging. The atlantoaxial region is the most common site of injury, and the sixth and seventh vertebrae are involved in over one third of all injuries. Other spine levels are much more commonly involved than has previously been appreciated. A substantial minority of radiographically defined cervical spine injuries are of little clinical importance.

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INTRODUCTION

Injuries to the cervical spine occur in only 2% to 3% of all patients with blunt trauma but are significant because of their high level of associated mortality and morbidity.[1,2] Previous reports regarding the epidemiology of cervical spine injury have typically been based on review of inpatient records of trauma victims admitted to single institutions or special populations.[3-8] Data from these sources typically reflect the spectrum of injuries seen in large referral centers but do not provide reliable information on the overall characteristics of cervical spine injury.

To date, there have been no reliable investigations of the spectrum and distribution of cervical spine injuries. The purpose of this study is to examine cervical spine injury patterns by using prospective representative methodology and to determine the incidence, spectrum, and distribution of these injuries.

MATERIALS AND METHODS

We performed a secondary analysis of the National Emergency X-Radiography Utilization Study (NEXUS) relational database. A detailed description of this study and its methodology are included elsewhere, including a separate report in this issue.[9,10] Briefly, NEXUS was a prospective, observational study performed with institutional review board approval at 21 diverse emergency departments in the United States. The study included all patients with blunt trauma who underwent cervical spine radiography in the participating EDs at the discretion of the treating physician. The study collected limited demographic information (age, race, and sex), presence or absence of low-risk criteria, and interpretations from all radiographic studies obtained on the enrolled patients.

We determined whether injuries were present or absent by reviewing the final interpretations of all radiographic studies obtained on each enrolled patient. We recorded the cervical spine level and a detailed anatomic description of all injuries identified by this review.

RESULTS

Of 34,069 enrolled patients, 818 (2.4%) had a radiographic cervical spine injury. These patients sustained 1,195 fractures and 231 subluxations or dislocations. The distribution of fractures is listed in Table 1. C2 (including the odontoid) was the most common site of fracture, accounting for 23.9% of all injuries, whereas the C3 vertebra was the structure least likely to be injured. As shown in Table 2, dislocations occurred most commonly at the C5 to C6 and C6 to C7 levels, and atlanto-occipital and C7 and T1 dislocations occurred infrequently.

A total of 240 (29.3%) patients met predefined criteria for clinically insignificant injuries, and the remaining 578 (70.7%) patients had injuries that were deemed potentially unstable (464 [56.7%] patients) or otherwise clinically significant (13.9%).

Table 1.
Distribution of fractures by cervical spine level.

Spine Level	No. of Fractures	% of All Fractures
Occipital condyle	20	1.67
C1	105	8.79
C2 (nonodontoid)	194	16.23
Odontoid	92	7.70
C3	51	4.27
C4	84	7.03
C5	179	14.98
C6	242	20.25
C7	228	19.08
Total	1,195	100.00

Table 2.
Distribution of dislocations and subluxations by cervical spine level.

Spine Interspace Level	No. of Injuries	% of Injuries
Atlanto-occipital	5	2.16
C1–C2	23	9.96
C2–C3	21	9.09
C3–C4	23	9.96
C4–C5	38	16.45
C5–C6	58	25.11
C6–C7	54	23.37
C7–T1	9	3.90
Total	231	100.00

A summary of injuries by age (Table 3) shows that 67.7% of injuries occurred in patients younger than 50 years and 32.3% occurred in patients older than 50 years, whereas the age of the patient was unknown in 216 injuries. Patients older than 50 years sustained 177 fractures to the atlantoaxial complex. These injuries represent 42.9% of all fractures seen in this age group and 45.3% of all atlantoaxial injuries found in the study.

The distribution of injuries within individual vertebrae is shown in Tables 4 through 7. Injuries to the first cervical vertebra involved the anterior arch in 53 (50.5%) patients and the posterior arch in 58 (55.2%) patients. Overall, 72 (68.6%) injuries involved either the anterior or posterior arch. Injuries to the lateral mass and facets were seen in only 22 (21.0%) patients. The odontoid was the most frequent site of injury to C2, occurring in 92 individuals (32.2%), with type II injuries being the most common. Type I odontoid fractures were seen infrequently, and a single patient sustained a coronal odontoid fracture. Fractures to the second vertebral body occurred in 75 (26.2%) patients, and traumatic spondylolisthesis was diagnosed in 27 patients.

In the lower spine (C3 to C7), vertebral body fractures were seen in 235 (29.9%) patients, making this the most frequent site of injury. Injuries to the pedicles were relatively rare, occurring in only 46 (5.9%) patients.

DISCUSSION

Previous studies of cervical spine injury have been limited by the methods used to identify patients. Studies completed on the basis of chart review from a single institution,[3] hospitalized patients,[3,4] or the elderly[7,11-13] all contain selection biases that limit their external validity and make it difficult to generalize results to larger populations.[14] In contrast, the prospective data collected in the current study come from a diverse group of institutions and contain data on all cervical spine injuries, irrespective of patient admission status. These characteristics increase the reliability of the study findings and make the results representative of overall injury patterns. Furthermore, the data presented in this article present the largest prospective analysis of the spectrum of cervical spine injuries to date.

Table 3.
Distribution of injury levels by patient age.

	Age (y)									
Location	**<20**	**20–29**	**30–39**	**40–49**	**50–59**	**60–69**	**70–79**	**>80**	**Unknown**	**Total**
Cord	5	5	16	20	6	2	2	6	7	69
Occipital	1	3	2	2	0	1	1	0	10	20
C1	9	10	15	15	8	5	11	14	18	105
C2 (nonodontoid)	6	33	22	28	27	11	29	17	21	194
Odontoid	3	8	9	10	8	11	19	17	7	92
C3	2	9	13	5	11	1	3	3	4	51
C4	5	20	17	9	8	6	4	1	14	54
C5	18	43	37	24	11	7	9	3	27	179
C6	13	48	44	38	17	14	14	4	50	242
C7	15	42	48	41	15	9	17	5	36	228
O–C1	2	0	1	1	0	0	0	0	1	5
C1–C2	1	0	7	3	1	1	4	5	1	23
C2–C3	3	6	2	4	0	1	1	1	3	21
C3–C4	4	4	5	3	2	1	0	3	1	23
C4–C5	5	5	8	7	3	2	3	1	4	38
C5–C6	10	15	11	8	2	0	6	0	6	58
C6–C7	2	12	5	13	3	5	4	4	6	54
C7–T1	1	4	1	0	2	1	0	0	0	9
Totals	105	267	263	231	124	78	127	84	216	1,495
Fractures	72	216	207	172	105	65	107	64	187	1,195
Interspace	28	46	40	39	13	11	18	14	22	231
Noncord	100	262	247	211	118	76	125	78	209	1,426

A previous review of cervical spine injuries found that injuries to C2 accounted for nearly one quarter of all fractures, making this the most likely vertebra to be injured. Although this number is similar to the frequency of C2 injuries seen in this study, it is interesting to note that the earlier study failed to document any C2 injuries other than traumatic spondylolisthesis and odontoid fractures. The relatively high rate of C2 injuries, particularly among the elderly, has been documented by others.[4,7,13]

Injuries to C3 and C4 appear to be relatively uncommon, accounting for only 11.3% of all injuries, and injuries to C6 and C7 make up the bulk of lower cervical spine injuries. Other investigators have reported a lower rate of injury to C7 and the C7 to T1 interspace.[3,15] It is unclear whether these differences reflect referral bias (patients with trivial injuries, such as spinous and transverse process fractures, are unlikely to be referred for specialized care) or an increased effort on the part of clinicians participating in this study to adequately visualize the cervicothoracic junction.

Fractures of the vertebral body and odontoid account for the largest fraction of injuries to specific parts of the vertebrae. These fractures are important because of their frequent association with spinous instability. These are also the types of injuries most likely to be transferred to referral centers for specialized care. In contrast, injuries to the spinous and transverse processes often represent clinically insignificant injuries and are unlikely to be associated with spinous instability. As a result, these injuries are rarely referred for additional evaluation and probably account for the different injury patterns seen in referral centers.[3]

In summary, this study confirms the previously reported high incidences of atlantoaxial and lower cervical spine injuries but suggests that other levels of injury are much more common than previously appreciated. Differences between the current report and prior reports likely reflect the referral bias and single institution spectrum bias of the earlier studies.

Author contributions: WG, CM, EAP, ST, JRH, and WRM participated in the project development, data collection, interpretation, authorship, and critical review. WG and WRM take responsibility for the paper as a whole.

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Table 4.
Location of fractures to the C1 vertebra.

Location	No. of Injuries
Isolated posterior element	19
Isolated anterior element	14
Lateral mass/articular process	22
Comminuted arch fractures/combined posterior and anterior elements	39
Other	11

Table 5.
Distribution of nonodontoid fractures to the C2 vertebra.

Location	No. of Injuries
Body	75
Pedicle	9
Traumatic spondylolisthesis	27
Other lateral mass/articular process	23
Lamina	28
Transverse process	15
Spinous process	10
Other	1

Table 6.
Distribution of odontoid fractures.

Type	No. of Injuries
Type I	5
Type II	53
Type III	33
Other	1

Table 7.
Location of fractures to the C3 through C7 vertebrae.

Location	C3	C4	C5	C6	C7	Total
Body	19	26	74	57	59	235
Pedicle	2	7	10	11	14	46
Lateral mass/articular process	8	13	21	45	30	117
Lamina	10	14	36	46	23	129
Transverse process	3	4	5	17	43	72
Spinous process	6	16	28	59	54	163
Other	2	4	5	7	5	23

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APPENDIX 1

Radiographic cervical spine injuries categorized as not clinically significant.[*†]

1. Spinous process fractures
2. Simple wedge compression fracture[‡]
3. Isolated avulsion fractures[§]
4. Type I odontoid fractures
5. End-plate fractures
6. Isolated osteophyte fractures[||]
7. Trabecular fracture
8. Isolated transverse process fractures

[*]Failure to identify them would be extremely unlikely to result in any harm to patients (and if they required no specific treatment).
[†]Only if isolated, without evidence of other bony, ligamentous, or cord injuries.
[‡]Without loss of at least 25% of body height.
[§]Without associated ligamentous injury.
[||]Not including corner fractures or teardrop fractures.

APPENDIX 2

The following centers and investigators collaborated in this study.
Principal Investigator: W. Mower
Coinvestigator: 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. Siegmann; Cedars-Sinai Medical Center (Los Angeles): J. Geiderman and B. Pressman; Crawford Long Hospital (Atlanta): S. Pitts and W. Davis; Egleston Children's Hospital (Atlanta): H. Simon and T. Ball; Emory University Medical Center (Atlanta): D. Lowery and S. Tigges; Grady Hospital (Atlanta): C. Finney and S. Tigges; 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 Hospital (Decatur): W. Watkins and E. Hadley; State University of New York at Stonybrook (Stonybrook): P. Viccellio and S. Fuchs; 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. Hendey and R. Lesperance; University of Maryland Medical Center (Baltimore): B. Browne and S. Mirvis; University of Pittsburgh Medical Center (Pittsburgh): A. Wolfson and J. Towers; University of Texas Health Sciences Center/Hermann Hospital (Houston): N. Adame, Jr., and J. Harris, Jr.