Spinal Cord (2001) 39, 589–594
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Original Article

Epidemiology of extraspinal fractures associated with acute spinal cord injury

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Study design: A descriptive study of concurrent extraspinal fractures collected prospectively during initial hospital care.
Objectives: To examine the frequency and related characteristics of concurrent extraspinal fractures among patients with a new onset of spinal cord injury (SCI).
Setting: Model SCI care systems throughout the United States.
Methods: A consecutive sample of 5711 subjects admitted to the National SCI Database between 1986–1995 was recruited to estimate the incidence of extraspinal fractures associated with acute SCI, stratified by anatomic sites, demographics, and injury related characteristics.
Results: Of 5711 subjects, 1585 (28%) patients had extraspinal fractures; 580 (37%) patients had more than one fracture site. The most common region of fractures was chest, followed by lower extremity, upper extremity, head, others, and pelvis. The overall incidence rate was higher for women than men, for whites than non-whites, for paraplegics than tetraplegics, and for those injured in motor vehicle crashes than others. Compared with patients having single fracture, those who had multiple fractures were likely to be white, paraplegic, and injured in motor vehicle crashes. There was no age difference in the incidence of concurrent fractures, single or multiple.
Conclusions: Extraspinal fractures are not uncommon at the same time as SCI. The fracture occurrence varies by gender, race, injury level, and etiology of injury. The knowledge of these associated factors will aid in early recognition of fractures, preventing complications, and facilitating rapid mobilization and rehabilitation outcomes among persons with SCI.
Spinal Cord (2001) **39,** 589–594

Keywords: spinal cord injury; extraspinal fractures; epidemiology

Introduction

The spine is a well-protected and strongly reinforced structure, and one might expect that the high forces that contribute to spine trauma with spinal cord injury (SCI) could also produce multiple trauma. Extraspinal fracture is one of the common associated injuries with SCI.[1,2] Fractures of face or mandible may be accompanied by head injury; fractures of ribs or pelvis may relate to internal visceral organs injury, which can lead to critical or fatal complications.[3] Fractures of long bones may be associated with peripheral nerve injury, compartment syndrome, malunion, nonunion, or deformity, which could delay functional recovery and increase impairment. SCI should not be dealt with as an isolated problem.

Diagnosis of concurrent extraspinal fractures in acute SCI patients may be difficult and overlooked in the absence of pain, because of sensory impairment from neurological deficit. A close examination for crepitus, hematomas, or bony deformity must be made to discover a fracture. Awareness of the frequency, location, and related characteristics of extraspinal fractures is thus important for early effective evaluation, diagnosis, and proper management among persons with acute SCI.

The importance of classifying fractures as being acute (occurring at the time of injury) or pathological (low-energy break) has been emphasized in patients with SCI to assist in decision-making and further management.[4] From our literature review,[5–10] most studies concerned treatment of long-bone fracture in chronic SCI patients, while only a few articles focused on concurrent fractures or associated injuries in acute

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SCI patients. These studies, however, were based on small sample sizes. SCI associated with non-long-bone extraspinal fractures is a very neglected group.

To address this dearth, the present study was conducted to examine the incidence of concurrent extraspinal fractures among persons with acute SCI and to clarify the associated factors. As the combination of extraspinal fractures and SCI poses special problems of management, the treatments for extraspinal fractures in acute SCI patients were also reviewed.

Methods

The National SCI Database contains standardized data contributed by federally funded Model SCI care systems throughout the United States since 1973. Data have been prospectively collected on sociodemographic characteristics, injury-related information, medical complications, and functional status of all eligible subjects at admission to and discharge from the model systems, as well as annually thereafter. The inclusion and exclusion criteria, data collection process, quality control, and collaborating centers of the database have been previously described in detail.[11] For the present study, we limited the analyses to participants enrolled in the database between 1986 and 1995, aged 15 to 80 years at injury, and discharged alive from initial hospital care. A total of 5711 SCI patients were eligible for the present study.

Concurrent extraspinal fracture was defined as a break of a bone, including open and closed fractures, occurring at the same time as spinal injury. Primary or secondary spinal fractures were excluded. Six regions and 14 different anatomic sites were recorded, head (skull, face/mandible), chest (clavicle/scapula, rib/sternum), pelvis, upper extremity (humerus, radius/ulna, hand), lower extremity (femoral neck, other parts of femur, tibia/fibula, ankle, foot), and other (fracture at a site not listed above (e.g., knee)). Fractures occurring in two or more anatomic sites were classified as multiple fractures.

The associated factors with extraspinal fractures were assessed in three domains: demographics, etiology of injury, and neurological status. Demographic variables included gender, age, and race. Race was coded as Caucasian, African American, Hispanic, or other. The etiologies of injury were grouped into motor vehicle accident, violence, falls, sports, and other. Neurological status obtained at discharge, rather than at admission, was used in this study, because this variable was expected to contain more accurate and reliable information. According to the extent of neurological impairment, individuals were classified into five groups, complete tetraplegia, incomplete tetraplegia, complete paraplegia, incomplete paraplegia, and minimal deficit. The American Spinal Injury Association (ASIA) Impairment Scale was used to assess the completeness of injury.

Frequencies and percentages were computed for clinical and demographic characteristics of individuals. Student's *t*- and Chi-square tests were used to indicate the statistical significance of differences in demographics, etiology of injury, and neurological impairment, stratified by the presence and number of fractures.

Results

Subject characteristics

As summarized in Table 1, 82% of study participants were males and 57% were Caucasians. Motor vehicle accident was the leading cause of injury (39%), particularly automobile accident (31%). Act of violence was second at 26% (gunshot wound 23%). Overall, 48% of patients enrolled in this study were classified as having paraplegia, 46% tetraplegia, and 47% neurologically complete injuries.

Incidence of extraspinal fractures

Of 5711 study subjects, 1585 (28%) had extraspinal fractures at the same time as SCI, 1005 (63%) occurring in a single anatomic site and 580 (37%) occurring in multiple sites. There were 359 (23%) patients with two, 158 (10%) patients with three, and 63 (4%) patients with four or more fractures.

Categorized by anatomic regions (Figure 1), fractures most frequently involved chest (52%), followed by lower extremity (25%), upper extremity (24%), head (17%), other (11%), and pelvis (9%). The most common five anatomic sites of fractures were rib and/or sternum (43%), clavicle and/or scapula (17%), radius and/or ulna (14%), face and/or mandible (12%), and tibia and/or fibula (12%; Figure 2).

Associated factors

Clinical and demographic factors in relation with extraspinal fractures are summarized in Tables 1 and 2. Age was not significantly different between those with or without fractures (33 ± 15 vs 33 ± 14, $P=0.29$), single or multiple fractures (33 ± 14 *vs* 33 ± 13, $P=0.39$). Females were more likely to have fractures than males (31% *vs* 27%, $P=0.02$), but there was no significant gender difference between single and multiple fractures ($P=0.46$). Caucasians tended to have a higher fracture incidence ($P<0.0001$) than other races, and were more likely to have multiple fractures as well ($P=0.004$).

We observed a significant difference between fracture incidence and traumatic etiology ($P<0.0001$). Persons injured in motor vehicle crashes were at greatest rate of extraspinal fractures (38%), followed by falls (30%), violence (17%), and sports (5%). The group of other etiologies (32%) included medical and surgical complications, thus making it not a purely traumatic origin. Etiology of injury was also significantly associated with the number of fractures ($P<0.0001$). Motor vehicle crashes were most likely to

Table 1 Characteristics of study subjects and corresponding incidence of extraspinal fractures ($N = 5711$)

Characteristics	n	(%)	n	*Extraspinal fractures Incidence* (%)	P
Age (years),					
mean ± standard deviation	33 ± 15				
Gender					
Male	4702	(82)	1275	27	
Female	1009	(18)	310	31	0.02
Race					
Caucasian	3240	(57)	1010	31	
African American	1645	(29)	361	22	
Hispanic	675	(12)	167	25	
Other	151	(2)	47	31	<0.0001
Etiology of injury					
Motor vehicle accident	2199	(39)	835	38	
Violence	1490	(26)	259	17	
Falls	1283	(23)	386	30	
Sports	483	(8)	22	5	
Other	256	(4)	83	32	<0.0001
Neurological Status					
Minimal injury	332	(6)	58	17	
Paraplegia, complete	1584	(28)	600	38	
Paraplegia, incomplete	1139	(20)	411	36	
Tetraplegia, complete	1112	(19)	218	20	
Tetraplegia, incomplete	1534	(27)	293	19	<0.0001
Unknown	10	(0.2)			
ASIA grade					
A	2696	(47)	818	30	
B	588	(10)	153	26	
C	754	(13)	225	30	
D	1631	(29)	375	23	
E	19	(0.3)	3	16	<0.0001
Unknown	23	(0.4)			

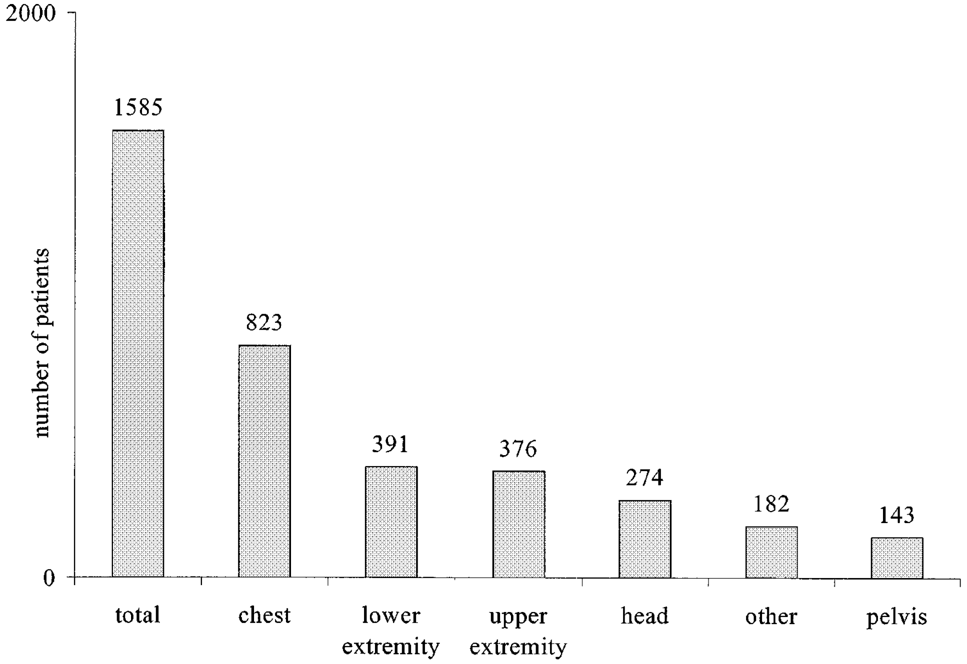

Figure 1 Distribution of extraspinal fractures, stratified by anatomic regions

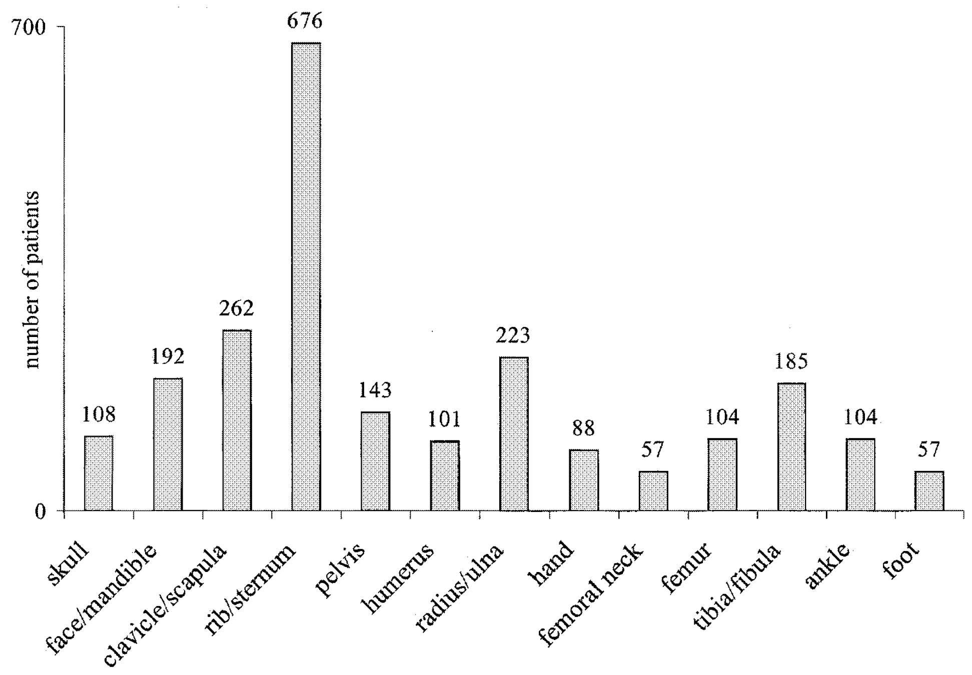

Figure 2 Distribution of extraspinal fractures, stratified by anatomic sites

Table 2 Related characteristics for single and multiple fractures

Characteristic	*Single* n	*Single* (%)	*Multiple* n	*Multiple* (%)	P
Gender					
Male	814	(64)	461	(36)	
Female	191	(62)	119	(38)	0.46
Race					
Caucasian	613	(61)	397	(39)	
African American	256	(71)	105	(29)	
Hispanic	103	(62)	64	(38)	
Other	33	(70)	14	(30)	0.004
Etiology of injury					
Motor vehicle accident	469	(56)	366	(44)	
Violence	212	(82)	47	(18)	
Falls	260	(67)	127	(33)	
Sports	17	(77)	5	(23)	
Other	47	(57)	36	(43)	<0.0001
Neurological status					
Minimal injury	39	(67)	19	(33)	
Paraplegia, complete	392	(65)	208	(35)	
Paraplegia, incomplete	229	(56)	182	(44)	
Tetraplegia, complete	149	(68)	69	(32)	
Tetraplegia, incomplete	193	(66)	100	(34)	0.005
ASIA grade					
A	541	(66)	277	(34)	
B	92	(60)	61	(40)	
C	139	(62)	86	(38)	
D	222	(59)	153	(41)	
E	3	(100)	0	(0)	0.09

cause multiple fractures (44%), followed by falls (33%), sports (23%), and violence (18%).

The fracture incidence significantly differed by neurological status ($P<0.0001$). Extraspinal fractures (both single and multiple) were more common among persons with paraplegia than tetraplegia. Persons with incomplete ASIA impairment scale D injuries were significantly less likely to have fractures than those with ASIA impairment scales A, B, or C injuries. There was no significant association between occurrence of multiple fractures and ASIA Impairment Scale ($P=0.09$).

Discussion

In a study of associated injuries,[1] Silver and colleagues found that 27 out of 100 acute SCI patients had concurrent fractures, with most of them involving ribs, sternum, and clavicle, which was consistent with our findings. The frequency of multiple fractures, nevertheless, was higher in Silver's series (20 out of 27), which might be partly explained by the difference in the definition of multiple fractures.

In a series of 508 individuals with spine trauma (with or without neural deficit),[2] Saboe *et al* classified associated injuries by anatomic site and its content, including, but not limited to, fractures. Two hundred and forty patients were reported with associated injuries, most commonly involving head (26%), chest (24%), and long bone (23%). Categorized by the etiology of injury, motor vehicle accidents and occupational injuries (falls account for a substantial portion) were leading causes of associated injuries. Persons with thoracic and lumbar fractures had more associated injuries compared with those having cervical fractures. Age, gender, and type of neural deficit were not significantly in relation to the occurrence of associated injuries. Related characteristics specifically for extraspinal fractures, however, were not thoroughly elucidated in this study and other studies of SCI-associated injuries as well.

The present study is the largest series to date of extraspinal fractures among 5711 SCI patients, with or without spinal fracture. We observed that the incidence of concurrent extraspinal fractures was significantly greater for females, Caucasians, paraplegia, and persons injured in motor vehicle crashes.

The size, shape, and architecture of the bone and related breaking strength might partly contribute to the variation in fracture rate between gender and races.[12] Long bone strength is likely to be size dependent, rather than dependent on bone mineral density. Perhaps, because of a greater periosteal expansion during growth, males and African Americans tend to have wider long bones, greater bone strength, and consequently lower fracture risk, compared with females and Caucasians.

Because cervical spine is comprised of small vertebrae and provides a large range of motion, it is susceptible to fractures with less force and fewer accompanying injuries.[3,13] In contrast, thoracic spine has good anatomic stability offered by rib articulations. This stability, however, will be compromized with multiple rib fractures, dislocations, or both. Lumbar vertebrae are large and strong. Subsequently, a tremendous force required to produce SCI contributes to associated fractures. These may explain to some extent why the paraplegics with thoracic or lumbar injury had more associated fractures than tetraplegics with cervical lesion.

A greater risk of concurrent fractures among persons injured in motor vehicle crashes might be explained by the high velocities and impacts involved.[3,14] When the vehicle decelerates, the unrestrained body continues to move forward, the chest impacts the steering wheel, the head impacts the windshield, and the legs hit the dashboard, which lead to multiple injuries. Falls from a height, the second leading cause of associated fractures, often involve a feet-first landing. This axial loading contributes to lumbar spine, long bone, and pelvic injuries. Other types of falls, including tipping backward in a chair or slipping and falling, cause fewer associated fractures with SCI.

It is still not clear whether both extraspinal fracture and SCI are the total result of high impact force, or extraspinal fracture is a protective mechanism that absorbs the impact force from more severe injury on spinal cord. Information and evidences from the scene of the accident may help clarify these issues. Nevertheless, motor vehicle accident is the leading cause of SCI and associated multiple fractures. Prevention efforts should be targeted toward this injury etiology. Our data could also serve as a baseline against which future information may be compared, demonstrating the change in injury and fracture rates from education, improving vehicular design, or other prevention strategies.

There is a paucity of literature concerning the treatment of SCI-related extraspinal fractures, although it is not an uncommon associated injury. For persons with acute SCI, after initial resuscitation, all potentially injured extremities have to be appropriately splinted, because immobilization reduces further soft tissue damage even if no fracture is present.[3] Every obviously or potentially fractured area should be examined radiographically, including the adjacent proximal and distal joints. Physicians need to follow patients with associated fractures closely. It is not unusual for blood loss to continue secondary to closed fractures. Pulmonary contusion may not be apparent on initial physical or radiographic examination, but may become evident within a few hours of rib and/or sternum fractures. Similarly, subdural or epidural bleeding may evolve after an initially lucid interval.

Spine injuries and dislocations of hip and knee demand priority treatments.[3] Delay in reduction of hip dislocations has been reported to increase the risk of avascular necrosis. Likewise, because knee dislocations are often associated with major vascular injury, prompt reduction is an essential management.

The overall goal of fracture management is to preserve maximal joint function with as close to normal range of motion as possible. For patients with acute SCI, to facilitate rehabilitation programs is also an important goal. Thus, early internal stabilization of fractures is favored in this population.[15–20] Intramedullary rodding or open reduction with internal fixation are the treatment modalities most commonly preferred. External fixation, nevertheless, need be considered for closed fractures with marked communication and for open fractures with significant contamination or soft tissue loss. In contrast, for chronic SCI patients, who usually have abnormal mineral content of bone, external splintage with soft padded or pillow splints for fractures should be considered first. External fixation will be considered only when patients' functional level significantly decreases, including the ability to use a wheelchair, drive a car, and return to work and the ability for self care.[19]

Conclusion

This report is one of the first discussions of the extraspinal fractures that take place at the same time when spinal paralysis occurs. Our results demonstrate a significant association of concurrent extraspinal fractures with gender, race, injury etiology, and injury level. Among patients with acute SCI, extraspinal fracture often occurs as one facet of multisystem injuries. Awareness of extraspinal fractures with careful physical and radiographic examination in SCI patients may be a significant aid in early recognition and in the prevention of complications, as well as facilitate rapid mobilization to permit rehabilitation. These reaffirm the importance of early admission to a coordinated SCI center for the proper management of SCI and associated fractures and early rehabilitation.

Acknowledgements

This work was supported in part by grant #H133N50009-96A from the National Institute on Disability and Rehabilitation Research, Office of Special Education and Rehabilitation Services, United States Department of Education, Washington DC, USA.

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