Pediatric spinal injury: review of 174 hospital admissions

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Injury to the spinal column and spinal cord occurs relatively infrequently in the pediatric population. A review of 174 pediatric patients is presented, representing 5.4% of all patients admitted with spinal injury. Spinal cord injury was present in 45% of patients. A distinct injury profile, explained by anatomical and biomechanical features, distinguishes the young patient with an immature spine from older adolescents with a more mature, adult-like spine. The younger patients, while less likely to have spinal injury, had a higher incidence of neurological injury, in addition to a higher frequency of both spinal cord injury without radiological abnormality and upper cervical cord injury. In addition, younger patients with spinal cord injury and no radiological abnormality were more likely to have complete or severe cord injury. Prognosis was determined by the severity of spinal cord injury. Patients with complete cord injuries showed little improvement, while patients with incomplete injuries generally fared much better, with 74% showing significant improvement and 59% experiencing a complete recovery of neurological functions. There were six deaths, but none was attributed solely to spinal injury. The authors conclude that outcome is quite good after pediatric spinal cord injury that does not produce a physiologically complete cord deficit.

KEY WORDS: pediatric spine - spinal fracture - spinal cord injury - children

Injury to the spinal column and spinal cord is relatively uncommon in the pediatric population. It is speculated that the pediatric patient has unusual anatomical spinal differences that offer significant protection from trauma and result in a unique injury profile when injury does occur. We present a review of spinal trauma occurring in 174 pediatric patients who were admitted to three hospitals over a 14-year period in southern Alberta. This large population confirmed the existence of distinct differences between the young child (aged 0 to 9 years) and the older adolescent (aged 15 to 17 years), and gave additional insight into both the epidemiology of the phenomenon of spinal cord injury without radiological abnormality (SCIWORA) and the prognostic factors relating to the pediatric patient with spinal cord injury.

Clinical Material and Methods

This retrospective series of pediatric patients were admitted with spinal injury between January, 1975, and December, 1988. The medical records of the three University of Calgary hospitals (Alberta Children's Hospital, Calgary General Hospital, and Foothills Hospital), which provide neurosurgical care for all southern Alberta (estimated population 1.25 million in 1988), were reviewed if the discharge diagnosis included spinal injury in a pediatric patient (aged 1 day to 17 years). Birth injuries were excluded. Specific details concerning the etiology of the injury, the presenting neurological examination, the radiological findings, the treatment administered, and the patients' hospital course were documented. Follow-up information was obtained for all patients from hospital and clinic records.

The patients were divided into three age groups: aged 0 to 9 years; aged 10 to 14 years; and aged 15 to 17 years. This separation allowed a comparison among the various age groups and the identification of distinct age-dependent injury profiles. Standard chi-squared statistical methods were employed to analyze the differences found among these groups. Severity of myelopathy was classified according to Frankel, et al.

Results

Overview

The 174 patients in this study ranged in age from 3 months to 17 years (mean 14 years). There were 19 patients aged 0 to 9 years, 36 patients aged 10 to 14 years, and 119 patients aged 15 to 17 years. Boys were more commonly injured than girls, with 115 (66%) male and 59 (34%) female patients. The ratio of boys to girls was smallest in the 0- to 9-year age group (11:8), increased marginally in the 10- to 14-year age group (21:15), and was markedly increased in the 15- to 17-year age group (83:36).

Motor-vehicle accidents were the most common cause of patient injury, accounting for 52% of the total (Table 1). The etiology of injury varied according to patient age. Falls and pedestrian/motor-vehicle accidents accounted for 79% of the injuries in the 0- to 9-year age group while 63% of the injuries in the 15- to
TABLE 1
Etiology of spinal injury related to age in 174 children*

<table>
<thead>
<tr>
<th>Source of Injury</th>
<th>No. of Cases</th>
<th>Age Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-9 Yrs</td>
<td>10-14 Yrs</td>
</tr>
<tr>
<td>motor-vehicle accident</td>
<td>91 (52%)</td>
<td>23 (14%)</td>
</tr>
<tr>
<td>sports-related</td>
<td>32 (18%)</td>
<td>10 (6%)</td>
</tr>
<tr>
<td>fall</td>
<td>21 (12%)</td>
<td>7 (4%)</td>
</tr>
<tr>
<td>pedestrian/motor</td>
<td>12 (7%)</td>
<td>8 (5%)</td>
</tr>
<tr>
<td>vehicle accident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorbike accident</td>
<td>8 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>bicycle accident</td>
<td>5 (3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>miscellaneous</td>
<td>5 (3%)</td>
<td>2 (1%)</td>
</tr>
</tbody>
</table>

* The difference in injury profile among the age groups was statistically significant (p < 0.005, χ² = 83.21, df = 12).

17-year age group occurred in motor-vehicle accidents (p < 0.005).

Injury Profile

The cervical level was injured in 73 patients (42%), followed by the thoracic level in 54 patients (31%) and the lumbar level in 47 (27%). The 10- to 14-year age group had less overall cervical injury (25%) when compared to the other two age groups, which had 46% to 47% cervical injury, but this difference was not statistically significant (p = 0.068). The level of cervical injury did vary significantly across the age groups, however; the upper cervical region (occiput to C-2 level) was injured in 32% of those aged 0 to 9 years (representing 67% of the cervical injuries in this age group), but this region was injured in only 6% of those aged 10 to 14 years and in 7% of those in the 15- to 17-year age group (representing 22% and 16% of the cervical injuries in these age groups, respectively) (p < 0.005). There were no significant differences in the incidence of thoracic or lumbar injuries. In 19 patients (11%), multiple levels of the vertebral column were injured.

Spinal injuries were classified into four categories on the basis of radiological criteria (Table 2): 1) fracture of the vertebral body or posterior elements without subluxation (56% of patients); 2) fracture with subluxation (29%); 3) subluxation without fracture (2%); and 4) SCIWORA (13%). These patterns of spinal injury varied significantly across the age groups; 42% of the patients in the 0- to 9-year age group sustained SCIWORA compared with only 8% of the patients in the 15- to 17-year age group (p < 0.0005).

Eighty-eight patients (51%) were neurologically intact at the time of injury. All patients with SCIWORA, by definition, had neurological compromise. Neurological function was graded according to the Frankel classification scheme. The 86 patients with neurological injury were subdivided into those with spinal cord injury (78 patients) and those with radiculopathy (eight patients). A total of 47 patients (27% of the total patients, 55% of those with neurological injury) had incomplete neurological impairment. The 39 patients with spinal cord injury (22% of the total patients, 45% of those with neurological injury) had complete loss of neurological function (Grade A). There was a significant trend toward a higher incidence of neurological injury in the 0- to 9-year age group (74%) compared with the 10- to 14-year age group (28%) and the 15- to 17-year age group (52%) (p < 0.005), but no difference was found in the degree of completeness of neurological injury among the different age groups (p = 0.18). A comparison of injury type with neurological deficit identified significant differences: 77% of patients with fracture were neurologically intact compared with only 20% of those patients with fracture and subluxation (p < 0.005). Furthermore, the severity of neurological injury varied significantly among the different injury types: spinal cord injury was physiologically complete in 68% of those with fracture and subluxation compared with only 27% of those sustaining fracture without subluxation (p < 0.005).

The severity of neurological injury in patients with SCIWORA varied significantly across the different age groups (Table 3). The incidence of physiologically complete spinal cord injury in patients aged 0 to 9 years with SCIWORA was 50% compared to 11% of patients aged 15 to 17 years (p = 0.062). Furthermore, the severity of incomplete spinal cord injury in patients with SCIWORA varied significantly across the age groups (p = 0.002). The onset of neurological symptoms was delayed in 23% of patients with SCIWORA (range 6 to 72 hours, mean 27 hours).

Treatment

Treatment was classified as surgical or nonsurgical. Surgery was performed on 26% of patients, but with significant differences in the frequency of surgery among the different injury types. Surgical treatment was performed in only 13% of the patients sustaining fracture without subluxation and in 57% of the patients with fracture and subluxation (p < 0.005). One patient with SCIWORA was treated surgically on a delayed basis to explore the injury level; this revealed necrosis of the conus. All other surgery was completed for the purpose of stabilization. The specifics of nonsurgical treatment were not detailed for this review.

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TABLE 3
Summary of patients with spinal cord injury without radiological abnormality (SCIWORA)

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Cases</th>
<th>Age Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0–9 Yrs)</td>
<td>10–14 Yrs</td>
</tr>
<tr>
<td>total cases</td>
<td>22 (13%)</td>
<td>8 (42%)</td>
</tr>
<tr>
<td>degree of neurological injury*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete†</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>incomplete</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>severe‡</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>mild</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>mild or severe disability</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>no deficit</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>died</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Neurological status classified according to Frankel, et al.†
† The difference in the number with physiologically complete neurological injury among the different age groups was not statistically significant (p = 0.062, χ² = 5.55, df = 2).
‡ The difference in the number with severe physiologically incomplete neurological injury among the different age groups was statistically significant (p = 0.002, χ² = 12.79, df = 2).

Outcome

Of the 88 patients who were neurologically intact at the time of admission to the hospital, 87 experienced no neurological deterioration. The other patient, with a fracture of the lumbar spine but no evidence of neurological injury, died from the effects of a severe head injury. There was no evidence of spinal cord deterioration in this patient. The 86 patients with neurological injury had a mean follow-up period of 15 months (range 0.5 to 144 months). All eight patients with radiculopathy experienced complete resolution of their deficit. The only significant determinant of outcome after neurological injury was the neurological status of the patient at the time of admission: specifically, whether the patient had a physiologically complete or incomplete spinal cord deficit (p < 0.005). Of the 39 patients with an incomplete myelopathy on admission, 29 improved either one or two grades (as classified by Frankel, et al.) and 10 were unchanged (with one death). Twenty-three (59%) of these 39 patients experienced a complete recovery of their deficit (Grade E). Of the 39 patients with a physiologically complete spinal cord injury (Grade A), four improved either one or two grades and 35 remained unchanged (with four deaths). This pattern of outcome held true even in patients with SCIWORA. The five patients with SCIWORA and physiologically complete spinal cord injury remained unchanged or died, while 14 of the 17 patients with SCIWORA and incomplete spinal cord injury showed improvement, with 13 of these 14 experiencing a complete resolution of their deficit (Table 3). No difference in outcome could be discerned on the basis of injury type (p = 0.073).

Six of the 174 patients died, although no deaths were attributed solely to spinal injury. Five of the six had complete cord injuries (Grade A). The Office of the Chief Medical Examiner of Alberta identified 55 additional pediatric patients who died in the period spanning 1975 to 1987 (13 years) after having sustained spinal injury. Details concerning patient deaths are reviewed elsewhere.11

Discussion

Overview

Spinal injury is relatively uncommon in the pediatric population.1–3,10,16 Estimates of 21 injuries/million individuals 19 years of age or younger/year can be compared to 68 injuries/million individuals/year in the 20- to 24-year-old age group.1 Kewalramani, et al.,16 reported the incidence of spinal cord injury in children to be 18.2 cases/million population/year compared with an overall incidence of 53.4 cases/million population/year.7 Pediatric spinal cord injury accounted for 9.4% of all spinal injuries. Our series of 174 pediatric patients, including six who died, represented 5.4% of all spinal injury admissions at our institutions during the 14-year period. This frequency is in the midrange when compared with other series of hospital-based populations, which report frequencies ranging from 1% to 10%,1,2,5,10,13–14,24 However, our population represents the total experience of a large geographic region where all neurosurgical care is completed at one of our three centers. In addition, the size of our patient series has only been approached in the report by Hadley, et al.,16 which described 122 patients, representing 5.0% of their spinal injury population treated over 14 years. The large size of this general pediatric population, which is believed to be representative of a large area, provides a unique opportunity to comment on previous observations regarding the injury profile and outcome of the pediatric spine-injured patients. We have also reviewed an additional group of 55 pediatric patients who died after sustaining spinal injury.11 The total of 61 deaths represents a 28% mortality rate for this pediatric population compared to an 11% mortality rate noted for adults during this period: a pediatric-to-adult mortality ratio of 2.5:1. Thus, while the incidence of spinal injury in the pediatric patient is lower than in the adult, it appears to be associated with a much higher mortality rate.

Injury Profile

Our pediatric spinal injury population confirmed the unique injury profile that has been reported for the child with an immature spine (aged 0 to 9 years) compared with the older adolescent; this includes a higher incidence of injury to the upper cervical spine, a higher incidence of SCIWORA, and a higher frequency of neurological injury.10,18,19,24 The differences in the spinal injury incidence rate and the injury profile noted for the pediatric population can be partially explained by certain anatomical and biomechanical factors: increased mobility secondary to

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ligamentous laxity, underdevelopment of neck and paraspinal musculature, shallow horizontal orientation of the facet joints, incompletely ossified wedge-shaped vertebrae with incompletely formed and flattened uncinate processes, and a larger head-to-torso ratio. These features offer protection from injury but also lead to the unique pattern of injury described. The child aged up to 9 years has an immature spine that does not completely resemble the adult spine until late adolescence (15 to 17 years of age). Pediatric patients in the 10- to 14-year age group represent an intermediate stage of development.

**Spinal Cord Injury Without Radiological Abnormality**

The 22 patients with a diagnosis of SCIWORA represented 13% of this patient series. This is slightly lower than the 16% frequency reported by Hadley, et al., but much lower than the 67% frequency reported by Pang and Wilberger and the 36% frequency referred to by Choi, et al. The two patient series reporting a frequency of SCIWORA ranging from 13% to 16% are probably more representative of general pediatric spinal injury populations, while the higher figures may represent a referral-based population bias. Osenbach and Menezes reported a 35% frequency of SCIWORA among pediatric spinal cord-injured patients. This is similar to the 28% frequency in our patient series and the 33% frequency reported by Hadley, et al. The mean age of our patients with SCIWORA was 10.7 years. This is significantly older than the mean age of patients in the series reported by Pang and Wilberger, Osenbach and Menezes, and Walsh, et al. (7.1, 5.1, and 2.6 years, respectively), but is similar to the mean age of 12 years reported by Hadley, et al. The reasons for this difference are most likely based in the different types of patient populations.

The frequency of SCIWORA in our 0- to 9-year age group was 42% compared with only 8% of the 10- to 17-year age group (p < 0.005). Furthermore, a significant difference existed in the severity of neurological injury across the different age groups (Table 3). All eight children aged 0 to 9 years with SCIWORA had complete or severe spinal cord injuries, while only two of nine children aged 10 to 17 years experienced a similar severity of spinal cord insult (p = 0.003). This pattern of injury distribution and injury severity, with SCIWORA occurring more frequently and with a greater degree of severity in young patients, was similar to the descriptions reported in other patient series.

In our series, 23% of the patients with SCIWORA had a delayed onset of neurological deficit ranging from 6 to 72 hours after injury (mean 27 hours). This is much less than the 52% delay frequency initially reported by Pang and Wilberger. However, Pang and Pollack later expanded their patient series and reported that delay occurred in only 27% of patients, with a delay range of 30 minutes to 4 days (mean 1.4 days). Our 23% delay frequency was very similar to the 22.5% delay frequency reported by Osenbach and Menezes. However, Hadley, et al., failed to document any neurological deterioration in their patients with SCIWORA. The reasons for this marked discrepancy are not evident. It is important that the physician be aware that about 25% of patients who develop SCIWORA have no neurological deficit after the accident. It would seem, therefore, that patients who are at high risk for SCIWORA require careful observation. Unfortunately, it is not currently clear what criteria can be used to identify this subgroup of patients at risk for neurological deterioration. In our patient population, there were no features of this group with delayed onset of neurological deficit that distinguished it from the remaining patients with SCIWORA. It has also been suggested that the delayed onset of neurological deficit is consistent with an ischemic pathophysiology in patients with SCIWORA. While it is not possible in this review to answer this hypothesis directly, it is noteworthy that the one child in this patient series with SCIWORA who underwent surgery was found to have necrosis of the spinal cord.

All children with SCIWORA undergo a complete radiological evaluation including dynamic x-ray studies and thin-section computerized tomography of the affected spinal level (with or without intrathecal contrast medium administration). Computerized tomography has generally replaced tomography at our institutions, and recently we have started performing magnetic resonance imaging in all suspected patients. The management protocol for patients with SCIWORA is in accordance with that outlined by Pang and Wilberger. No patient in our series has experienced recurrent cord injury as described by Pollack, et al.

**Treatment**

Only 26% of our patient series underwent surgery. There was a significant difference in the incidence of surgical treatment across the various injury types. Given that all operations but one were performed to achieve stability, this is not surprising. Among patients with fracture and subluxation or subluxation alone, surgery was carried out in 57% and 50%, respectively, compared with only 13% of those with fracture only (p < 0.005). One patient who presented with SCIWORA and complete paraplegia early in this series (1976) underwent surgery on a delayed basis to explore the affected site; no recovery of function occurred. No patient who underwent surgery deteriorated neurologically as a consequence of surgical intervention. Also of great importance to the physician was the high frequency of non-contiguous spinal fractures. This was found in 11% of the patients in our series. Hadley, et al., reported a frequency of 16%. Therefore, the neurosurgeon must be alert for injury at multiple levels of the vertebral column.

**Outcome**

The outcome in pediatric patients surviving with...
spinal injury was in general quite good, with the admission neurological status being the determining prognostic feature. A significant change in neurological function occurred in 74% of patients with an incomplete spinal cord injury, and 59% of these patients experienced a complete resolution of their neurological deficit. Only 10% of patients with a physiologically complete cord injury experienced a significant improvement of function (p < 0.005), and no patient in this group enjoyed complete recovery of function (p < 0.005). The outcome in patients with SCIWORA was also directly related to the degree of neurological injury (Table 3). This association between outcome and admission neurological status has been reported by other authors.1,2,6,21

No significant relationship was noted between patient outcome and injury type (p = 0.073). The previous suggestion that SCIWORA heralded a worse prognosis was not substantiated.22 The mean follow-up period for patients with neurological injury was 15 months, which is less than the median 44 months reported by Hadley, et al.10 While there was no dramatic difference in the outcome trends of their patient population, they did demonstrate a slightly more optimistic outcome, with significant recovery occurring in 89% of patients with incomplete spinal cord injury and 20% of patients with physiologically complete spinal cord injury. We believe that the majority of the factors involved in outcome determination occur early after injury,3 but agree with Hadley, et al., that a longer follow-up period will identify a small number of children who undergo remarkable changes in their neurological examinations at periods quite remote from their initial trauma. Children with a physiologically complete spinal cord injury generally have a poor prognosis, while those with an incomplete cord injury have excellent prospects for significant or complete recovery. It has been hypothesized that the outcome experienced by pediatric patients with incomplete spinal cord injury may be secondary to an enhanced plasticity of the nervous system that exists in young patients,10 however, no specific evidence to explain this phenomenon is currently available.

Six patients in this review died. Further details about these six patients and 55 other pediatric patients with spinal injuries who died are reviewed elsewhere.11

References

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