Pediatric neck injuries

A clinical study

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This review of pediatric neck injuries includes patients admitted to Children’s Hospital of Columbus, Ohio, during the period 1969 to 1979. The 122 patients with neck injuries constituted 1.4% of the total neurosurgical admissions during this time. Forty-eight patients had cervical strains; 74 had involvement of the spinal column; and 27 had neurological deficits. The injuries reached their peak incidence during the summer months, with motor-vehicle accidents accounting for 31%, diving injuries and falls from a height 20% each, football injuries 8%, other sports 11%, and miscellaneous 10%.

There is a clear division of patients into a group aged 8 years or less with exclusively upper cervical injuries, and an older group with pancervical injuries. In the younger children, the injuries involved soft tissue (subluxation was seen more frequently than fracture), and tended to occur through subchondral growth plates, with a more reliable union than similar bone injuries. In the older children, the pattern and etiology of injury are the same as in adults. The entire cervical axis is at risk, and there is a tendency to fracture bone rather than cartilaginous structures.

KEY WORDS • spinal injury • spinal cord injury • pediatric injury • cervical spine

STUDIES of cervical trauma in the pediatric population have usually focused on particular anatomical regions, or on the associated spinal cord injury that may also occur. This type of trauma is not common, but its true incidence is not well documented. It has been estimated that 2% to 8% of spinal cord lesions occur in children, but incidence figures for less serious trauma are not widely reported.

The anatomical and biomechanical features of the immature cervical spine make the upper segments at C1–3 especially susceptible to injury. General reviews of these features and the characteristics of pediatric spine lesions exist, as do studies of the radiological subtleties of congenital anomalies and true injuries of the incompletely ossified cervical spine.

The upper segments are susceptible to traumatic subluxations at the atlanto-occipital, atlantoaxial, 4,16,20,24,33, 44,47,67 and C2–3 levels, but the most common injury to the spinal column itself is probably fracture of the odontoid with or without cruciate ligament incompetency and atlantoaxial dislocation. Other high cervical fractures have been reported, but are rare. The remainder of the pediatric cervical spine is less prone to injury in young patients. Most of these cases involve missile injuries or penetrating wounds, or are in teenage patients.

Our retrospective analysis was designed to allow us to examine the community experience in neck injuries of all degrees (including simple strains) that required hospitalization during the 11-year period 1969 through 1979. We were interested in the nature of the precipitating violence, the seasonal variations in occurrence, the age and sex distributions, the anatomical level of the injury, the presence of other injuries caused by the trauma, and the occurrence of neurological deficit due to the neck injury. These features and their relationship to the inpatient population as a whole are the subject of this report.

Clinical Material and Methods

Patients admitted to the hospital within 24 hours of injury during the years 1969 through 1979 were eligible for inclusion in this study, if the clinical and radiological records were complete. Standard case review techniques were used, and Student’s t-test was employed in tests for statistical significance. Patients older than 18 years...
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FIG. 1. Relationship between age and pathology, showing the total group of pediatric neck injuries (left), patients with cervical strains with plain x-ray findings (center), and patients with spinal column injury (right).

were excluded from this study despite admission to the Children's Hospital, as were children transferred after treatment or surgery at other institutions. Thus, 122 patients were included under these conditions.

During this time period, Columbus Children's Hospital had a total of 159,617 admissions, an average of 14,510 per year. Of these, 8988 patients were admitted to the neurosurgical service (average 817 per year), which alone is responsible for spinal trauma. This is equivalent to 5.6% of the total hospital admissions, a figure that varied by only ± 1% during this study.

Lesions were classified by the extent of the injury. "Cervical strain" was defined as acute trauma-related neck pain and tenderness, with limitation of movement, muscle spasm, rapid recovery with conservative treatment, absence of neurological deficit, and absence of radiological evidence of injury to the spinal column (aside from transient reversal of the normal cervical lordosis). Radiologically demonstrable lesions of bone, such as fracture, fracture dislocation, or sprain (subluxation diagnosed from slippage on dynamic films), were grouped together as "spinal column injuries." Care was taken to exclude children whose x-ray films showed only pseudosubluxation of the C2–3 joints.14,59,68 A third subgroup consisted of patients who at some time during their course exhibited neurological deficit due to their cervical trauma.

Results

Table 1 gives the mean age for the population as a whole (12.7 ± 3.4 years) and for each subgroup. There was no statistical difference among the mean or median ages, with the exception of the group with neurological deficits, which was significantly older than all other groups (p < 0.001). The ages ranged from 2 to 18 years for the entire study, and the male:female ratio was roughly 2:1.

Figure 1 shows the spread of cases by age. In all, 48 patients proved to have cervical strains (mean age 11.3 ± 4.4 years), and 74 children suffered injuries to the cervical spine which were radiologically demonstrable (mean age 13.5 ± 4.1 years). This second group is stratified by age into those 8 years of age or under, whose injuries were exclusively upper cervical spinal in location, and those older than 8 years, whose injuries spanned the entire cervical axis (Fig. 1 right).

The distribution of injuries by calendar month is shown in Fig. 2. There was a seasonal peak in the summer months, and the otherwise smooth curve was interrupted in late December and early January by a recurring incidence of neck injuries in the 2 weeks following Christmas when the children were on holiday.

A wide variety of insults were responsible for the injuries. For the series as a whole, motor-vehicle accidents were most frequent (31%), with diving accidents and falls from a height next most common (20% each). The remainder were distributed among football injuries (8%), other sports injuries, such as tumbling, judo, and wrestling (11%), and miscellaneous causes, such as assaults, gunshot wounds, and sledding crashes, and even an accident with a thrown shotput (10%). If only trauma that resulted in spinal column damage is considered, then motor-vehicle accidents (45%) and diving (23%) remain prominent, while falls (11%), football (5%), gymnastics (7%), and miscellaneous causes (8%) are less important, presumably because of lesser violence.

TABLE 1
Mean age for patient population studied, 1969–1979

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Mean Age (yrs)</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>all injuries</td>
<td>12.7 ± 3.4</td>
<td>122</td>
</tr>
<tr>
<td>cervical strain</td>
<td>11.3 ± 4.4</td>
<td>48</td>
</tr>
<tr>
<td>spinal column lesion</td>
<td>13.5 ± 4.1</td>
<td>74</td>
</tr>
<tr>
<td>neurological deficit</td>
<td>16.1 ± 1.9</td>
<td>27</td>
</tr>
</tbody>
</table>
During this period, 27 children were left with a neurological deficit (Table 2). Two had brachial plexus avulsions, and the remainder suffered cord section injuries. One patient (a 15-year-old boy involved in a car crash) suffered a permanent C-4 level quadriplegia without any radiological evidence of spinal injury. The characteristics of this subgroup change drastically from those of the above-mentioned groups. The male:female ratio was nearly 6:1 (Table 2), and the mean age was 16.1 years, a significant increase from the other groups. With the exception of a 10-year-old child who fell from a tree and a 12-year-old child who was struck by a car, all cases involving neurological deficit were in patients of high-school age. Motor-vehicle trauma and diving mishaps were responsible for 75% of these cases; not surprisingly, they were most common (75%) in the warm months of May through October (Fig. 2D).

Neck injuries constituted 1.4% (122) of the total 8988 neurosurgical admissions during 1969 to 1979. Neurological deficit was rare (27 cases, 0.3%), as was the overall incidence of neck injury among these hospitalized patients (122 cases, 0.08%). The Columbus Children’s Hospital receives essentially all of the pediatric trauma cases for the Columbus, Ohio, area, so these estimates for the occurrence of cervical trauma are probably representative for the community as a whole.

Treatment of cervical strains was conservative in all cases, and consisted of bedrest with or without a soft collar, with or without analgesics. Flexion and extension films were routinely repeated prior to discharge to detect occult subluxations in this group, and one patient was reclassified to the skeletal injury group as a result.

For spinal injuries the treatment varied with the extent of the injury (Table 3). Almost half of the patients with structural injury underwent initial spinal stabilization with Vinke, Crutchfield, or Gardner-Wells tongs. For stable compression fractures and slight subluxations, external bracing was usually successful. A variety of devices were used, and for 40% of the patients with spinal injury this was sufficient. Children with spinal instability or major anatomical disruption were candidates for surgical fusion; 12 anterior fusions and 20 posterior fusions were performed, including two posterior operations after attempts at anterior fusion by the Cloward technique had failed.

Emergency laminectomy and cord cooling was carried out in the period prior to 1975, and nine patients with immediate and complete cord injuries underwent this type of procedure. In the early 1970’s, an additional 11 patients (15%) were treated with bedrest until spontaneous fusion occurred or until the patient died. Three patients died prior to any definitive treatment. The five deaths in this series were related to pulmonary complications in four cases, and erosion of the aortic arch by a tracheostomy device in one instance.

Associated injuries were found in 29 (24%) of the 122 patients at the time of admission. In six patients (13%) a cervical strain was complicated by a concus-
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TABLE 2
Causes of injury in 27 cases with neurological deficit

<table>
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<tr>
<th>Cause of Injury</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>motor-vehicle accident</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>motorcycle injury</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>diving</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>trampoline</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>fall, tumbling</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>assault</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>gunshot wound</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>sledding accident</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>total cases</td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>

* Five patients died.
† Vinke, Crutchfield, or Gardner-Wells tongs.

TABLE 3
Primary treatment in 74 cases of structural spinal injury*

<table>
<thead>
<tr>
<th>Primary Treatment</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>tongs†</td>
<td>35</td>
</tr>
<tr>
<td>soft collar only</td>
<td>8</td>
</tr>
<tr>
<td>bracing</td>
<td>22</td>
</tr>
<tr>
<td>anterior fusion</td>
<td>12</td>
</tr>
<tr>
<td>posterior fusion</td>
<td>20</td>
</tr>
<tr>
<td>bedrest until stable</td>
<td>11</td>
</tr>
</tbody>
</table>

* Five patients died.
† Vinke, Crutchfield, or Gardner-Wells tongs.

Discussion

Injuries of the cervical region in the pediatric population have usually been addressed in the greater context of trauma to the entire spinal axis, although a few authors have reported series limited to cervical spine trauma. The epidemiology of our series parallels that of other institutions. Motor-vehicle accidents, falls and diving accidents, and athletic mishaps are the major causes of these injuries.

In the younger age group, the violence is sustained in the home environment, including local playgrounds, basement steps, and upstairs window ledges. Adolescents and high-school students have a pattern that merges with that of the adult: increasing violence of the trauma, a greater distance from home, and more likelihood of neurological deficit.

The clear definition of our patients into a group aged 8 years and less with exclusively upper cervical injuries and an older group with pancervical injuries is shown in Fig. 3. A similar bimodal age distribution has been found by McPhee. Other authors have also observed a tendency for young children to suffer a disproportionately large percentage of high cervical injuries.

The reasons for both the bimodal age spread and the preponderance of atlas and axis injuries in infants and young children are related to the developmental anatomy of the high cervical region. First, a relatively heavy head on a small body results in high torques being applied to the neck with acceleration stress. Second, the ligaments and joint capsules in small children are unusually lax and stretchable in this region. Third, the facet joints in the upper three vertebrae are nearly horizontal for the first several years of life, and never become as oblique as the lower cervical facets. Fourth, there is a possible contribution by immature unco-vertebral joints at C2-4 to the general looseness of the area. Finally, the fulcrum of cervical movement may be located higher in young children than in adolescents and adults.

Because the immature spine ossifies progressively throughout childhood, injuries in the younger ages tend to be avulsions or epiphysial separations rather than true fractures. This is true for all spinal injuries, but is seen most commonly in odontoid fractures, where the line of separation is routinely through the basilar synchondrosis, into the body of C-2, and below the level of the superior facets, in children too young to have an ossified union of C-2 and odontoid. These injuries, essentially splits in the cartilaginous end-plates, routinely heal well with spontaneous fusion, unlike the adult-type odontoid-waist fracture where surgical fusion is often necessary.

The suppleness of the upper cervical ligamentous framework is lost with the assumption of an adult ossification pattern. Prior to this, there is sufficient play in the structures at C2-3 and C3-4 that anterior gliding of the superior vertebral body occurs, up to 4 mm in magnitude; this is referred to as pseudosubluxation. This situation can be found in as many as 40% to 50% of normal uninjured asymptomatic children up to the age of 8 years, and must be distinguished from true subluxation at these levels, which is quite rare.

The treatment of cervical strain was conservative and expectant. Patients were observed until asymptomatic, when lateral flexion-extension radiographs were repeated to assure the diagnosis. One 15-year-old girl injured in a high-speed automobile crash demonstrated gross instability at C5-6 (that is, sprain) on her repeat films, which had previously been masked at admission by cervical muscle spasm. No other cases had their initial diagnosis changed.

Where possible, closed reduction and external bracing is the treatment of choice for spinal column injuries, particularly for cartilaginous injuries of the upper cervical spine in young children.
Although some authors take an aggressive approach and recommend an early surgical fusion for their patients, most recommended operation only for penetrating wounds, deformity, non-union, or inability to achieve a closed reduction. In this 11-year series a distinct change in management philosophy occurred about midway. The aggressive surgical care of patients with cord injury, which characterized the earlier 5-year period, has given way to a more restrained approach. Immediate laminectomy with cord-cooling is no longer practiced; the four operative deaths in this series all occurred in the first 5 years of the study, in patients with complete cord injuries subjected to exploratory operation. Except for those patients with progressive neurological deficit, the decision to operate is now based on orthopedic rather than neurological considerations. Now unstable fractures and dislocations are operated on for internal fixation when the patient’s overall condition permits, the aim being earlier ambulation and rehabilitation, especially in older children with adult-pattern injuries.

The child who sustained a permanent tetraplegia without radiological evidence of spinal injury was unique in our series, but is an example of a pediatric phenomenon that has been recognized by other authors. Estimates of the frequency of this occurrence range from 15% to 70%, and the 4% rate in our series is unusually low compared to previous reports of this entity; this might be because it has attracted only anecdotal attention outside areas of high prevalence. The reported pathology from autopsied cases is an ischemic infarct of the central cord and the anterior gray matter, and the lesion has been compared to the acute central cord syndrome of adults with severe cervical spondylosis. The biomechanics of this lesion have been attributed to a combination of interference with microvascular blood supply, longitudinal traction on the cord, acute reversible disc prolapse, and compression or spasm of the vertebrospinal artery system.

In the remainder of our cases with spinal cord injury, the etiology of the deficit was clearly due to the vertebral column injury sustained. Our experience with these devastating lesions is identical with that reported elsewhere; cord injuries which are instantaneously complete do not remit. In very young children, mild degrees of cord injury have a subjectively better prognosis for return of function, even to normalcy, than in adults, but any progression of partial deficit is a very ominous occurrence and heralds cord necrosis. In our series, 27 (36%) of 74 cases of spinal injury included neurological deficit (that is, 19% of the entire population).

Conclusions

Our 11-year series confirms most observations of spinal injuries in the pediatric age group. Cervical strain was the dysfunction causing almost 40% of the admissions for neck injury at our institution, and had the same features as seen in adults. In younger children, spinal injuries tended to be predominantly in the upper cervical segments, were caused by falls and playground accidents, and were relatively benign in their course. They involved soft tissue (subluxation more frequently than fracture) and tended to occur through subchondral growth plates, with more reliable union than similar bone injuries.

In children over the age of 8 years, the pattern and etiology of injury were similar to those in adults. The traumatic insults became progressively more severe...
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with age, surgical repair was more commonly required, and neurologi
cal deficit was a frequent concomitant, especially in high-school aged
victims. The entire cervi
cal axis was at risk, and there was a tendency to
fracture bone rather than cartilaginous structures. The etiology shifted to accidents involving great violence, especially with the increased social mobility of senior
high school, when diving accidents, assaults, and vehicu
lar trauma parallel the adult pattern.

Many of these injuries would seem to be preventable,
or at least could be ameliorated, by such common-sense
measures as use of seatbelts, realistic use of vehicles,
and home safety education. The correlation of the
adolescent and teenage periods with cervical trauma
make this in part a disease of social progress. Whether
the usual social adjustments of education and legisla
tion will aid or hinder the control of this disease is proble
matical, in view of the recent tendency of state legisla
tures to repeal laws requiring motorcycle helmets to be
worn, and to lower legal alcohol-drinking ages. The
utilization of available restraint systems in automobiles,
such as infant seats and ordinary seatbelts with shoulder
harness, can markedly reduce the incidence of spinal
cord injury.

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