ORIGINAL ARTICLE

ACUTE SPINAL-CORD LESIONS IN A PEDIATRIC POPULATION: EPIDEMIOLOGICAL AND CLINICAL FEATURES*

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Abstract. The occurrence of acute spinal-cord lesions in children has been reported to be rare, comprising from less than one to 3.3 per cent of all cases of spinal-cord injuries (Audic & Maury, 1969; Burke, 1971; Melzak, 1969).

To our knowledge, the epidemiological features of all cases of acute spinal-cord lesions in a pediatric population have not been previously reported. The objective of this communication is, therefore, to describe the incidence and selected epidemiological and clinical features of acute spinal-cord lesions in children, aged 1 to 15 years.

Key words: Acute spinal cord lesions in a pediatric population.

Methods and Materials

THE complete details of the methods used in case ascertainment have already been presented elsewhere (Kraus *et al.*, 1975). For completeness, this report recapitulates certain important methodologic considerations.

Definition of spinal cord injury and criteria

A spinal cord lesion was defined as an acute, traumatic lesion of the spinal cord, including trauma to nerve roots resulting in some degree of sensory or motor deficit or both. The diagnosis of spinal cord injury and description of the resulting deficits were accepted as recorded by an attending physician in the hospital admission or discharge record, autopsy protocol, or other medical record.

For inclusion as an incidence case, the injury must have occurred in 1970 or 1971 to a resident of one of the 18 prespecified Northern California counties (regardless of place of occurrence or place of treatment of the injury). The years 1970 and 1971 were selected to utilise 1970 U.S. Census data as a denominator in deriving incidence rates according to sociodemographic factors.

Reference population and geographic region

The population at risk is thus defined as those, aged 1 to 15, who were usual residents of one of 18 Northern California counties (Fig. 1). According to the 1970

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FIG. 1

The 18 counties of California in the spinal cord study area.

United States Bureau of the Census the population of this area was slightly more than 1.68 million persons (29 per cent of the state's population in this age group). As illustrated in Figure 1, the counties included Shasta, Tehama, Nevada, Placer, El Dorado, Butte, Yuba, Sutter, Yolo, Sacramento, San Joaquin, Solano, Contra Costa, Alameda, Marin, San Francisco, San Mateo and Santa Clara.

Method of case ascertainment

Case ascertainment included an exhaustive, systematic review of records, files, and reports from all hospitals and coroner's offices in each county and records of the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation). There were three phases to case ascertainment: (1) review of all hospital admission records (the

principal method of ascertainment); (2) examination of all autopsy protocols¹ for evidence of spinal cord lesions; and (3) review of all records on file with the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation) to identify spinal cord injuries possibly missed in the previous two phases.

Preliminary to case ascertainment through examination of hospital admissions, indexing rubrics were examined to determine which could best identify hospital admissions having a potential spinal cord injury. All hospitals utilized the International Classification of Diseases, Adapted (ICDA) (United States Department of Health, Education and Welfare, 1967), the hospital adaptation of ICDA (Commission on Professional and Hospital Activities, 1968), or, to a lesser extent, the Standard Nomenclature of Diseases and Operations (Thompson & Hayden, 1961). Tests of potential rubrics at hospitals led to adoption of a final list of nine hospital admission/discharge rubrics (Table I). The medical record of each potential case with one or more of these rubrics was examined to determine conformance with the definition of spinal cord injury and whether the incidence criteria were met.

Case ascertainment was begun in October 1972 and completed in January 1974. Several months were devoted to case ascertainment outside the 18-county region to identify persons with a spinal cord injury who were usual residents of the 18-county region, but injured elsewhere. For this purpose, admission records of major hospitals in counties on the periphery of the 18-county study region were used (*i.e.* the remainder of California, western Nevada, and southern Oregon). A complete search was made of the files of the State of California Crippled Children's Service, Department of Rehabilitation and Workmen's Compensation, to identify all possible cases which met the criteria of incidence. Autopsy protocols were reviewed from 30 of the most populous counties in California, western Nevada, and southern Oregon.

TABLE I

Hospital admission indexing code numbers and rubrics used for spinal cord injury case ascertainment*

Rubric No.*	Rubric
349	Other diseases of spinal cord (mono, hemi-, para-, quadriplegia)
725	Displacement of intervertebral disk
772.1	Birth injury without mention of cause
805	Fracture and fracture dislocation of vertebral column without mention of spinal cord lesion
806	Fracture and fracture dislocation of vertebral column with spinal cord lesion
839	Other dislocation: spine
958	Spinal cord lesion without evidence of spinal bone injury
959	Other nerve injury
03	Surgical operations: operations on spinal cord structures

* International Classification of Diseases, adapted (8th revision).

¹ California law requires that all persons who sustain an unexpected, sudden, violent, or unattended death shall have a post-mortem examination and a coroner's investigation (Section 27491, California Government Code).

The 1976 version of the Abbreviated Injury Scale (1976) was used to assign numerical values to each injury identified from hospital records and/or coroner reports. The AIS codes and their descriptions are given in Table II.

TABLE II
Abbreviated injury scale code descriptions

Code	Description	Code	Description
0	No injury	5	Critical (survival uncertain)
1	Minor	6	Maximum (currently untreatable)
2	Moderate	9	Unknown
3	Severe (not life-threatening)		
4	Serious (life-threatening, survival probable)		

Results

Incidence

A total of 58 children, aged 1 to 15, with an acute spinal cord lesion which occurred in 1970 or 1971, were identified among the usual residents of the 18-county region, producing an average annual age-group-specific incidence rate of 18.2 per million population. The 58 cases represented 9.4 per cent of the total of 619 persons with a spinal cord injury of all ages identified. The percentage occurrence of incidence cases in children was about the same for each of the 2 years under study. Incidence rates were 1.7 times higher for males than for females. Age-sex-specific incidence rates are given in Table III. Children in the general population at greatest risk were males aged 10 to 15 years. In all age groups (1-4, 5-9, 10-15 years) incidence was higher for males than for females.

There were no children of Asian extraction identified with a spinal cord injury: 3.2 cases were expected based on their percentage representation in the general population. Incidence for those with a Spanish surname was 7.2 per million population. Risk of spinal cord injury was 2.5 times higher in whites (excluding those with a Spanish surname) and 5.7 times higher in blacks than for those with a Spanish surname. The 10 cases identified in black children was significantly higher than the 4.2 cases expected based on their percentage representation in the general population.

Thirty-eight of the 58 cases (65.5 per cent) were from a motor vehicle collision. In this group, 17 (45 per cent) were pedestrians, 12 (32 per cent) were passengers in an automobile or pickup truck, 7 (18 per cent) were bicyclists, and 2 (5 per cent) were passengers on a motor-cycle. Spinal cord injuries from falls and firearms each accounted for four cases and ten children were injured in recreational activities (seven from diving, two from high school football and one from wrestling). One child sustained a spinal cord injury from a plane crash and one was injured as a 'battered child'.

There were too few cases for statistical test of the relation between external cause of the spinal cord injury and age (Table IV). It should be noted, however, that all children injured from falls and firearms and half of the children injured in motor vehicle related incidents were between 10 and 15 years of age. Eight of 17 injured pedestrian children were under 5 years of age.

TABLE IV

Number of acute spinal cord lesions by age and external cause—18 Northern California counties

External cause	Age			All ages
	Under 5	5-9	10-15	
Motor vehicle	12	7	19	38
<i>Auto crash*</i>	4	3	5	12
<i>Pedestrian</i>	8	3	6	17
<i>Auto-bike</i>	0	1	6	7
<i>Motor-cycle†</i>	0	0	2	2
Falls	0	0	4	4
Firearms	1	1	2	4
Recreation	0	0	10	10
Other	1	0	1	2
Total	14	8	36	58

* Includes crashes involving a single or multiple automobile or pickup.

† Passengers.

There were too few cases for statistical test of the relation between sex and external cause of the spinal cord injury. As shown in Table V, the ratio of male to female cases was higher than unity for all causes except the general category of motor vehicle collisions. Within this category, however, more males were injured in auto-bicycle collisions than females.

Case fatality rates and injury severity

Case fatality rates (CFR) for external causes of spinal cord injuries are given in Table V. Overall, the CFR was 59 per cent. All children injured in auto-bicycle collisions or motor-cycle crashes died. Eighty-three per cent of children involved

TABLE V

Number of acute spinal cord lesions by sex and external cause—18 Northern California counties

External cause	Sex		Both Sexes	Ratio Male to Female
	Male	Female		
Motor vehicle	21	17	38	1.2
<i>Auto crash</i>	6	6	12	1.0
<i>Pedestrian</i>	8	9	17	0.9
<i>Auto-bike</i>	5	2	7	2.5
<i>Motor-cycle</i>	2	0	2	2.0
Falls	4	0	4	4.0
Firearms	3	1	4	3.0
Recreation*	7	3	10	2.3
Other†	2	0	2	2.0
All causes	37	21	58	1.8

* Includes 7 from diving, 2 from football, 1 from wrestling.

† Includes 1 from an air crash and 1 as a battered child.

TABLE VI

Case fatality rates (CFR) for children with an acute spinal cord lesion according to external cause—18 Northern California counties

External cause	No. injured	No. deaths	CFR%
Motor vehicle	38	32	84
<i>Auto crash</i>	12	10	83
<i>Pedestrian</i>	17	13	76
<i>Auto-bike</i>	7	7	100
<i>Motor-cycle</i>	2	2	100
Falls	4	0	0
Firearms	4	0	0
Recreation	10	0	0
Other	2	2	100
All causes	58	34	59

in automobile or pickup truck crashes and 76 per cent of those struck by a motor vehicle as pedestrians died. All children who sustained a spinal cord injury from falls, firearms, or recreational activities were alive 4 years following the date of the injury. Thirteen of 34 deaths occurred within 20 minutes of the injury. Nine additional deaths occurred from 20 to 60 minutes and another seven deaths occurred 1 to 24 hours after the injury (Table VII).

The number of spinal cord injuries, according to anatomic region, severity (using AIS) and external cause is given in Table VIII. With one exception, all AIS grade 6 (currently untreatable) cervical spinal cord injuries were from motor vehicle collisions. Twelve of 14 children injured while an occupant in a motor vehicle (automobile or motor-cycle) crash sustained an AIS grade 6 cervical spinal cord injury. One-half of the children injured in automobile-pedestrian or bicycle

TABLE VII

Survival among children with an acute spinal cord lesion according to external cause—18 Northern California counties

External cause	Survival time following injury						
	No. injured	< 20 min.	20-59 min.	1-23 hrs.	1-30 days	Late death	Alive at 4 yrs.
Motor vehicle	38	12	9	7	3	1*	6
<i>Auto crash</i>	(12)	2	3	4	1	—	2
<i>Pedestrian</i>	(17)	5	4	2	2	—	4
<i>Auto-bike</i>	(7)	3	2	1	—	1	0
<i>Motor-cycle</i>	(2)	2	—	—	—	—	0
Falls	4	—	—	—	—	—	4
Firearms	4	—	—	—	—	—	4
Recreation	10	—	—	—	—	—	10
Other	2	1	—	—	1	—	0
All causes	58	13	9	7	4	1	24

* Died 953 days post injury.

TABLE VIII

Number of acute spinal cord lesions graded by the abbreviated injury scale (AIS) by anatomic region of the injury and external cause—18 Northern California counties

External cause	Anatomic region and AIS									
	Cervical			Thoracic		Lumbar		All regions		
	6	5-4	≤3	5-4	≤3	5-4	≤3	6	5-4	≤3
Motor vehicle	24	5	2	6	—	1	—	24	12	2
(<i>Pedestrian,</i>	(12)	(5)	(2)	(5)	(—)	(—)	(—)	(12)	(10)	(2)
(<i>bicyclist</i>)										
(<i>Auto,</i>	(12)	(—)	(—)	(1)	(—)	(1)	(—)	(12)	(2)	(—)
(<i>motor-cycle</i>)		2		1		1		—	4	—
Falls				3	—	—	1	—	3	1
Firearms	—	4	6	—	—	—	—	—	4	6
Recreation	1	—	—	—	1	—	—	1	—	1
Others										
All causes	25	11	8	10	1	2	1	25	23	10

collisions had a grade 6 cervical spinal cord injury. All of the non-lethal spinal cord injuries from recreational activities were in the cervical region. Thirty-one of 38 (82 per cent) spinal cord injuries from motor vehicle collisions were located in the cervical region.

The most severe injury found in each of the major anatomic regions (*i.e.*, head, neck, chest, abdomen and extremities, including pelvis) was graded using the AIS. With the exception of 7 of the 17 pedestrians, the spinal cord injury was the *most* severe injury sustained. In the pedestrian group, the spinal cord injury (all located in the cervical region) was the most severe injury for ten and for five other children, the most severe injury was in an organ other than the spinal cord (brain injury in four and in one severe trauma to the heart/lungs). One child had equally severe injuries to the cervical spinal cord and the heart/lungs and one child had a thoracic spinal cord and brain injury of equal severity.

With one exception, all children with an AIS grade 6 injury of the spinal cord (22 children) and/or another anatomic region (5 children) died. (One 3-year-old with a complete transection of the cervical cord at C1-C2 was alive four years after the time of the injury.) Of 17 children with an AIS grade 4 (survival probable) or grade 5 (survival uncertain) injury to the spinal cord (in the absence of an AIS grade 5 or 6 injury in other anatomic regions), 16 were still living four years after the date of the injury. The single death occurred 953 days post-injury, from causes described as 'respiratory paralysis'.

An injury severity score (ISS) was derived for the 30 children who were admitted to a hospital. The ISS was obtained by adding the squared AIS score for the three highest scored body regions (Baker, O'Neil, Haddon, Jr. & Long, 1974). It should be noted that the ISS was developed to evaluate severity of injury for those with multiple injuries. For 12 of the 30 children admitted to a hospital, the spinal cord injury was the *only* injury sustained but these 12 are included nonetheless for purposes of this report.

Baker and her colleagues (1974) suggested an ISS score of 50 as pivotal above which survival becomes doubtful. In the group of 30 children on whom an ISS

score was derived, 22 of 24 survivors had an ISS of less than 50 (Table IX). One survivor from a fall had an ISS of 50 and one child is still living with an ISS of 86 (one AIS grade 6 and two AIS grade 5 injuries). In the six children who died after hospital admission, four had ISS scores of 50 or greater and two had scores of less than 50 (these were late deaths 18 and 953 days post-injury).

Autopsy findings

Twelve of 14 children injured in a single or multiple motor vehicle crash (including motor-cycles) were dead at the scene (four cases), died within one hour from the time of the crash (three cases), or died within 1 to 24 hours post-injury (four cases). There was one death two days post-injury. Eleven of these 12 fatalities had fracture/dislocation at the atlanto-occipital and/or atlanto-axial region of the spinal canal. One child had spinal lesions at C2-3 and one at C3-4 level. The spinal cord was lacerated/transected in all 12 children. Eight children had severe (AIS grade 4-5) intracranial injuries, and three of these children also had severe trauma to thoracic or abdominal organs. Multiple fractures of the extremities were common.

Thirteen of 17 pedestrians died, nine at the scene of the collision or were DOA at the hospital. One died 2 hours and one died 18 days respectively, post-injury. Nine had injuries to the cervical spinal cord at the atlanto-occipital and/or atlanto-axial level with laceration/transection of the cord. Seven of the pedestrian fatalities had AIS grade 4 or 5 injuries to the cerebral cortex and/or brain stem including fracture of the skull. Five of these seven cases had severe intrathoracic or intra-abdominal injuries.

Five of seven children involved in an automobile-bicycle collision were DOA at the hospital. Basal skull fracture, atlanto-occipital dislocation and lacerations/transections of the cervico-medullary junction was found in three of these children. AIS grade 5 or 6, intracranial injuries were present in all five. One patient had a fracture/dislocation of C4 on C5 with spinal cord transection and another patient

TABLE IX

Mortality by injury severity score (ISS) and external cause for children with a spinal cord lesion—18 Northern California counties

External cause	Injury severity score				Total injured
	Deaths	< 50 Survivors	Deaths	≥ 50 Survivors	
Motor vehicle	2	5	3	1†	11
Pedestrians and bicyclists	2*	3	2	1	8
Auto, motor-cycle	—	2	1	—	3
Falls	—	3	—	1‡	4
Firearms	—	4	—	—	4
Recreation	—	10	—	—	10
Others	—	—	1	—	1
All causes	2	22	4	2	30

* Deaths 18 and 953 days post-injury.

† ISS of 86.

‡ ISS of 50.

had transection of the spinal cord without evidence of fracture of the vertebral bodies. Three children in this group also sustained severe intrathoracic and/or intra-abdominal injury.

One child had massive multiple injuries as a result of a plane crash and one child died in the hospital with a grade 6 intracranial injury as well as multiple haemorrhages in the spinal cord with a fracture/dislocation of C7 on T1.

Clinical findings

Of 38 children involved in a motor vehicle crash only six survived 4 years. One child survived with an AIS grade 6 injury to the C1–C2 level of the spinal cord and a grade 5 injury to T1–T3 level. Another three patients showed no life-threatening (AIS grade 5) injuries to other organ systems. One child who had clinical evidence of a lesion below C8 with atrophy of the interossei, spooning of the fingers and sensory loss below the C8 dermatome had no evidence of osteoarticular injury on radiographs. The air myelogram was normal. Another child was tetraplegic with irregularity of the T7 vertebral body. This patient also had clinical evidence of brain stem injury and remained tetraplegic with sensory loss below T4. One patient with fracture of the pedicle of C2 vertebra and subluxation of the atlanto-axial joint who had clinical features of central cervical cord syndrome did not show any neurological improvement.

There were four patients who sustained injuries from falls; two patients sustained injury to cervical spine and two had injuries to the thoraco-lumbar region. One patient with a teardrop fracture of C4 vertebral body had minimal neurological deficit, and one child with a skull fracture, fracture of C3 lamina and subluxation of C3 on C4 was completely tetraplegic. The neurological status of this child remained unchanged although the cervical spinal cord was reported to be normal on laminectomy. One patient with fractures of T11, T12, and L3 vertebral bodies and jumped facet at T11–12 has a clinical picture of a cauda equina lesion. On laminectomy the conus medullaris was found to be swollen. Another patient with fractures of the occipital bone and T12 vertebral body was found to have maceration of the spinal cord and remained completely paraplegic below the T12 level.

Three patients sustained injury to the thoracic region and one patient had an injury to the lumbar region from firearms. All had radiographic evidence of osseous injury. Two patients had laceration of the spinal cord. Three of the four patients were paraplegic below T3, T5 and T10 levels and their neurological status remained unchanged. One patient with injury to the cauda equina showed some neurological return.

There were seven patients who sustained injury from diving. All injuries were to the cervical spine at the C3–C6 level with moderately severe neurological deficit. One patient was tetraplegic below C5 and one below C6 level. The latter patient showed functional improvement and was ambulatory with long leg braces and crutches. Four patients with a neurological picture of central cervical cord syndrome had good neurological improvement. One patient with a fracture of the C3 vertebral body and subluxation of C3 on C4 had paresthesias only and recovered completely.

Three children were injured while playing football or wrestling. All three sustained a cervical spinal cord lesion with radiographic evidence of osteoarticular injury at C4 and C5 levels. Two patients showed complete sensory-motor tetraplegia at admission to the hospital and their condition remained unchanged. The third patient, who had a clinical picture of cervical central cord syndrome, showed good neurological recovery and was ambulatory on hospital discharge.

Radiologic findings

In the group of 25 patients surviving one year, 20 had radiographic evidence (Table X) of osteoarticular injury to the spine on plane X-rays or tomography while, in the remaining five patients, plane X-rays were interpreted to be normal. One of these five patients was found to have a block at the T2 level on the myelogram which was confirmed on laminectomy (dislocation T2-3). The spinal cord was reported to be macerated in this patient. Thus, 21 of 25 patients had radiologic abnormalities.

TABLE X

Radiographic evidence of osteo-articular injuries (Surviving group)

Level of injury	Fractures		Level of injury	Luxations/Dislocations	
	Vertebral body	Neural arch		Luxations	Dislocations
C1 & C2		1	C1/2	1	
C3	3	1	C2/3		
C4	5	1	C3/4	4	
C5	5		C4/5	3	
C6	2		C5/6	2	
			C7/T1		1
T1-T6		2			
T7-T12	3	2	T7-T12	1	
L1-L5	3	1	L1-L5	1	
	21 (14)*	8 (5)*		12 (11)*	1 (1)*

* Number of patients.

Discussion

The impact of permanent paralysis in an otherwise normal child may result in severe psychological trauma to the child as well as the parents (Matson, 1969). Although the occurrence of acute spinal cord lesions in children is uncommon, the consequences of complete paralysis in a child elicits feelings of tragedy in our society, more so than for adults. Some investigators have reported an 'incidence' of spinal cord lesions in children of less than 1 to 3.3 per cent of all spinal injuries in the population. As mentioned previously, the term incidence referred only to those admitted to a hospital and often to only those with permanent complete paralysis. In this study, 9.4 per cent of all incidence cases occurred among children, aged 1 to 15 years. Of the total number of 58 cases identified, only 30 were admitted¹ to a hospital while others were either dead on arrival or died prior to admission. Using this latter figure, the incidence of hospital-admitted cases of spinal cord injury was 8.9 per million children, aged 1 to 15 years or 4.8 per cent of all cases of all ages identified in the 18-county region.

The average annual incidence of acute spinal cord lesions in the age group under study in this report was 18.2 per million population. Projected nationally, this rate indicates about 1065 children sustain an acute lesion of the spinal cord each year. About 550 of these children are admitted to a hospital and 80 per cent

¹ In most hospitals, emergency room treatment does not imply a hospital admission.

of those admitted survive with varying degrees of neurological deficit, most with permanent and complete paralysis.

Motor vehicle collisions were the cause of two of every three spinal cord injuries in children. This percentage (66 per cent) is much higher than the proportion (56 per cent) of spinal cord injuries identified in the total population as caused by a motor vehicle (Kraus *et al.*, 1975). Pedestrian and automobile-bicycle related injuries are relatively more frequent in the pediatric age group than in older persons. For example, 45 per cent of motor vehicle related spinal cord injuries in children resulted from motor vehicle-pedestrian collisions whereas only 18 per cent of adults injured in motor vehicle incidents were pedestrians. Also, 18 per cent of children injured by a motor vehicle were bicyclists compared to only 2 per cent for those over age 15. The differences in percentages between children and adults with respect to pedestrian or bicyclist involvement probably reflects differential exposure to risk of injury between these two broad age groups. Nonetheless, reduction in the occurrence of acute spinal cord injuries in children will only come about with more energetic and extensive efforts at reducing motor vehicle collisions or the degree of human damage sustained in them or, more optimally, both. Since present treatment offers little hope for restoration of neurologic function, prevention of spinal injuries augmented by limitation of sequelae is presently the best solution to this devastating injury. It is noteworthy to recall that the occurrence of another paralyzing condition in children (poliomyelitis) prompted widespread social demand for prevention. Yet, the annual incidence of paralysis from acute spinal cord injuries in the United States is greater than that from the annual incidence of paralytic polio during the period 1962-73 (United States Department of Health, Education, and Welfare—Center for Disease Control, 1974). A national determination to eliminate this form of childhood (or, for that matter, adult) catastrophic disability appears to be lacking.

In published accounts on spinal cord injured children, there is a variation in the upper age limit used. Most investigators chose an upper age limit of 18 years. In this study, the upper limit was 15 years because (1) inpatient pediatric services use this age as the limit for admission to this service and (2) skeletal maturity of the spine and fusion of the epiphyseal ring begins at about 14 to 15 years of age.

Hubbard (1974) reported a higher incidence of trauma in females than males and a greater susceptibility of thoracic and thoraco-lumbar spine in children and adolescents aged 1 to 17 years. In the present study, there was a higher incidence of injury in males and much greater susceptibility of cervical spine compared to thoracic and lumbar regions. Hubbard (1974) also reported that the clinical course of injuries to the spine in children and adolescents was benign and long term sequelae were absent suggesting that the treatment for a period longer than one month was not required. This finding has not been the experience of other investigators (Burke, 1971, 1974; Glasauer & Cares, 1973; LeBlanc & Nadell, 1974). Some investigators (Burke, 1974; LeBlanc & Nadell, 1974) believe that the clinical features and operative findings in children with spinal cord injuries are quite similar to those seen in adults with some minor exceptions. Burke (1974) reported that 86 per cent of the patients (aged 1-13 years) had complete spinal cord lesions and their status remained unchanged. According to Sharrard (1971), prognosis for recovery in this patient population is usually very poor. But, in the present study of 25 surviving patients, 15 had complete motor and sensory loss below the level of lesion and 13 of these (86 per cent) remained completely paraplegic or tetraplegic at the time of discharge from the hospital. Beatson (1963) and Hubbard (1974) surmised that the younger patients had better prognosis than the

adults following spinal cord trauma, but the findings in the present study suggest that the clinical picture and prognosis for neurological return following spinal cord injury in children is no different than that for adults. Often, the prognosis is worse in children since the diagnosis is delayed and neurological deficit augmented because of the absence of any radiographic abnormalities.

Melzak (1969) reported that only 45 per cent of children with traumatic lesions of spine had demonstrable fractures or malalignments of their vertebral columns. Since then, Audic and Maury (1969), Burke (1971, 1974), Glasauer and Cares (1973), and Sharrard (1971) have reported 'minimal' or very often total absence of radiographic abnormalities in most of the cases. In the present series, 20 of 25 surviving patients were found to have evidence of osteoarticular injury on plane radiographs. One of the five patients with no evidence of osteoarticular injury on plane radiographs was found to have a block at T2 level on myelography, which was confirmed on laminectomy (T2-3 dislocation). Thus, only four patients of 25 did not show abnormality on radiological examination. We agree with LeBlanc and Nadell (1974) that children with only radiographic abnormalities should not be subjected to surgical treatment unless there is history of sufficient injury and the clinical examination supports the possibility that these are pathological findings, but we do caution that there should be a high suspicion index and these patients with or without radiographic abnormalities should be observed very carefully until such time when affirmative decisions could be made by appropriate studies. Glasauer and Cares (1973) suggested that after carefully considering the patient's radiographs, myelography should be performed if questions or inconsistencies exist and we believe that this procedure could provide considerable information in those difficult cases.

Conclusions

The epidemiological and clinical features of 58 children with acute spinal cord lesions is given. This group represents all new cases of spinal cord injury in children, aged 1 to 15, while a resident of one of 18 Northern California counties. The incidence cases represent 9.4 per cent of the total of 619 persons with a spinal cord injury of all ages identified. Children in the general population at greatest risk were males aged 10 to 15 years, and, in all age groups, incidence was higher for males than for females. Almost 66 per cent of the cases were from motor vehicle collisions. Case fatality rates were from 76 to 100 per cent for various subcategories of motor vehicle causes. Significant reduction in the incurrence in the acute spinal cord injuries in children will only come about with more energetic and extensive efforts at reducing motor vehicle collisions or the degree of human damage sustained in them. The pathological, clinical, and radiographic features for this group of children is also reviewed.

RÉSUMÉ

Cet article présente une description clinique et épidémiologique de 58 enfants ayant subi une lésion aiguë de la moelle épinière. Ce groupe représente tous les cas nouveaux de lésions de la moelle chez des enfants âgés de 1 à 15 ans durant une résidence dans un des 18 comtés de la Californie du Nord. L'incidence est de 9.4 % du groupe total de 619 personnes de tous les âges, identifiées comme ayant subi une lésion de la moelle épinière. Les enfants présentant le plus grand risque étant les garçons de 10 à 14 ans. De tous ces groupes, il y avait plus de mâles que de femelles. Presque 66 % des cas étaient dûs à une collision de véhicules à moteur. Les cas de fatalité étaient de 76 % à 100 % pour les sous-catégories variées des causes d'accident de véhicules à moteur. On ne pourra obtenir une réduction de

l'incurrence des lésions de la moelle épinière qu'avec des efforts extensifs et énergiques pour réduire les collisions des véhicules à moteur et le degré de dommage humain qu'ils apportent. Les traits pathologiques, cliniques et radiographiques pour ce groupe d'enfants sont également récapitulés.

ZUSAMMENFASSUNG

Die epidemiologischen und klinischen Merkmale von 58 Kindern mit Rückenmark Verletzungen sind beschrieben. Diese Gruppe representiert alle neuen Fälle von Rückenmark Verletzungen in Kindern im Alter von 1 bis 15, wohnhaft in 18 Bezirken in Nord Californien. Dieses Vorkommen stellt 9.4 % von 619 Fällen mit Rückenmark Verletzungen in allen Altersgruppen dar. Die Kinder mit dem grössten Risiko in der allgemeinen Bevölkerung waren Knaben im Alter von 10 bis 15 Jahren und das Vorkommen in allen Altersgruppen war grösser in der männlichen als in der weiblichen Bevölkerung. Beinahe 66 % der Fälle waren durch Zusammenstösse von Motorfahrzeugen verursacht. Die Sterblichkeitsziffer war 76 % bis 100 % in verschiedenen Untergruppen der Motorunfälle. Eine bedeutsame Verminderung des Vorkommens von akuten Rückenmark Verletzungen in Kindern kann nur durch energische und ausgedehnte Bemühungen von Fahrzeugzusammenstösse oder die Schwere der Verletzung zur Verminderung menschlichen Schadens erzielt werden. Die pathologischen, klinischen, und roentgenologischen Merkmale für diese Gruppe von Kindern ist ebenfalls diskutiert.

REFERENCES

- AUDIC, B. & MAURY, J. (1969). Secondary vertebral deformities in childhood and adolescence. *Paraplegia*, **7**, 10-16.
- BAKER, S., O'NEIL, B., HADDON, W., Jr., & LONG, W. (1974). The injury severity score: a method for describing patients with multiple injuries and evaluating emergency cases. *J. Trauma*, **14**, 187-196.
- BEATSON, T. (1963). Fractures and dislocations of the cervical spine. *J. Bone and Joint Surg.*, **45B**, 21-35.
- BURKE, D. (1971). Spinal cord trauma in children. *Paraplegia*, **9**, 1-14.
- BURKE, D. (1974). Traumatic spinal paralysis in children. *Paraplegia*, **11**, 268-276.
- Commission on Professional and Hospital Activities (1968). Hospital Adaptation of the ICDA. Ann Arbor, Michigan.
- GLASAUER, F. & CARES, H. (1973). Biomechanical features of traumatic paraplegia in infancy. *J. Trauma*, **13**, 166-170.
- HUBBARD, D. (1974). Injuries of the spine in children and adolescents. *Clinical Orthopedics Related Research*, **100**, 56-65.
- KRAUS, J., FRANTI, C., RIGGINS, R., RICHARDS, D. & BORHANI, N. (1975). Incidence of traumatic spinal cord lesions. *J. Chron. Dis.*, **28**, 471-492.
- LEBLANC, H. & NADELL, J. (1974). Spinal cord injuries in children. *Surg. Neuro.*, **2**, 411-414.
- MATSON, D. (1969). *Neurosurgery of Infancy and Childhood*, 2nd edition. Charles C. Thomas, Publisher, Springfield, Illinois, p. 934.
- MELZAK, J. (1969). Paraplegia among children. *Lancet*, **2**, 45-48.
- SHARRARD, W. (1971). *Pediatric Orthopedics and Fractures*, J.B. Lippincott, Publishers, U.S.A.
- The Abbreviated Injury Scale (AIS), 1976 revision developed by a joint committee of the American Medical Association, the Society of Automotive Engineers, and the American Association for Automotive Medicine.
- THOMPSON, E. & HAYDEN, A. (eds.) (1961). *Standard Nomenclature of Diseases and Operations*, 5th edition. New York, McGraw-Hill.
- United States Department of Health, Education and Welfare (1967). Eighth revision of International Classification of Diseases, adapted for use in the United States. Public Health Services Publication No. 1693.
- United States Department of Health, Education and Welfare, Public Health Service, Center for Disease Control (1974). Neurotropic Diseases Surveillance, Poliomyelitis. Annual Summary 1972. DHEW Publication No. (CDC) 75-8214.