Spinal Injuries Due To Hockey

Charles H. Tator, Chris E.U. Ekong, David W. Rowed, Michael L. Schwartz, Virginia E. Edmonds and Perry W. Cooper

SUMMARY: Although many types of sports and recreational activities have been identified as common causes of acute spinal cord injury, hockey has been a rare cause of acute cord injury in Canada or elsewhere. For example, from 1948 to 1973 there were no patients with cord injuries due to hockey in a series of 55 patients with acute cord injuries due to sports or other recreational activities admitted to two Toronto hospitals. In contrast, between 1974 and 1981, the Acute Spinal Cord Injury Unit, Sunnybrook Medical Centre treated six patients with cervical spinal injury due to hockey, five of whom were seen during a 13 month period from September, 1980 to October, 1981. Five of the six sustained a severe acute cervical spinal cord injury, and one a cervical root injury. The cord injury was complete in two cases, while three had complete motor loss but incomplete sensory loss below the level of the lesion. All were males aged 15 to 26 years. Of the players with cord injury, four struck the boards with the neck flexed, and one struck another player with the neck flexed. The one player without cord injury struck the boards with his neck extended. The commonest bony injury was a burst fracture of C5 or C6. One of the patients with a complete cord injury died three months later of a pulmonary embolus, and the other patients with cord injury showed some recovery of root function, but little or no cord recovery. The reasons for the increase in spinal injuries in hockey are unknown.

RÉSUMÉ: Malgré le fait que les sports et autres activités récréatives sont souvent mentionnés comme cause d'injures aiguës à la moelle épinière, il faut noter que le hockey en est une cause rare, au Canada comme ailleurs. Ainsi, de 1948 à 1973, sur 55 patients avec lésion aiguë de la moelle secondaire au sport, aucune n'était due au hockey. Cependant, de 1974 à 1981, l'unité de soins pour lésion aiguës de la moelle (Sunnybrook Medical Centre) a eu à soigner six patients avec un traumatisme cervical dû au hockey, dont 5 pendant la période de september 1980 à octobre 1981. Cinq des six avaient des lésions aiguës de la moelle cervicale, et une atteinte des racines cervicales. Dans deux cas la lésion de la moelle était complète, chez trois autres il y avait préservation partielle des sensations sous le niveau atteint, mais perte motrice complète. Il s'agissait de mâles de 15 à 26 ans. Quatre des joueurs avaient frappé la bande avec le cou en flexion, l'autre avait frappé un autre joueur avec le cou également en flexion. Le sixième joueur, sans atteinte de la moelle, avait frappé la bande le cou en extension. La lésion osseuse la plus fréquente était une fracture par éclatement au niveau de C_5 ou C_6. Un des patients avec lésion complète de la moelle est mort 3 mois plus tard à la suite d'une embolie pulmonaire. Chez les autres, la fonction radiculaire s'est légèrement améliorée, mais non le déficit de la moelle. On ne sait pas pourquoi il y a une augmentation des lésions spinales au hockey.

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In a series of 55 patients with acute spinal cord injuries treated at two Toronto hospitals from 1948 to 1973, sports and recreational accidents were frequent causes of acute cord injury ranking third (15.4%) after traffic accidents and those due to accidents at work (Tator and Edmonds, 1979). In the sports-recreational group diving was the commonest type of accident, and accounted for 38 of the 55 cord injuries (Tator et al., 1981). Not one of these injuries was due to hockey. No case reports of cord injury due to hockey have been found in the English literature including a recent review of sports injuries to the neck (Torg, 1982). Indeed, Kalchman's recent book on hockey safety (Kalchman, 1981) which describes numerous types of hockey injuries, does not include any references to spinal injury. In contrast, during the five year period from 1977-81 inclusive, six patients with spinal injuries due to hockey were treated at the Sunnybrook Medical Centre, Toronto. During the same period, approximately 300 patients with spinal injury (two-thirds with cord injury) were admitted to this Unit. Although diving continued to be the most common sports-recreational activity causing acute cord injury (Tator and Palm, 1981), hockey was the second most common cause in this group. Indeed five of the six hockey injuries occurred in the 13 month period from September, 1980 to October, 1981. This paper describes these six patients and analyses the mechanisms of injury.

Clinical Material

Case 1: This 26 year old was injured while playing in an adult hockey league. He struck the boards head first with his neck flexed and was immediately unable to move his legs. He was wearing a helmet without a face mask. He was brought to Sunnybrook within 3 hours of the accident, and was found to have a complete cord injury at the C5-6 level. Cervical spine x-rays (Figs. 1a & b) showed burst fractures of C4 and C5. The body of C5 showed a major compression fracture and it was displaced 8 mm posteriorly into the spinal canal. There was also a major kyphotic deformity at C4-5 with reversal of the cervical lordosis.

Improved alignment of the cervical spine was achieved with skull tongs and 10 pounds traction. Traction was continued for one month and then a halo ring and vest were used. He was then mobilized and transferred to Lyndhurst Hospital for further rehabilitation. Three months after the injury he had a sudden respiratory and cardiac arrest from which he could not be resuscitated. At autopsy a large pulmonary embolus was found. There had been no clinical recovery of cord function prior to this event.

From the Acute Spinal Cord Injury Unit, Division of Neurosurgery and Department of Radiology, (Dr. Cooper), Sunnybrook Medical Centre, University of Toronto
Received August 9, 1983. Accepted October 3, 1983
Reprint requests to: Charles H. Tator, M.D., Acute Spinal Cord Injury Unit, Sunnybrook Medical Centre, 2075 Bayview Avenue, Toronto, Ontario M4N 3M5

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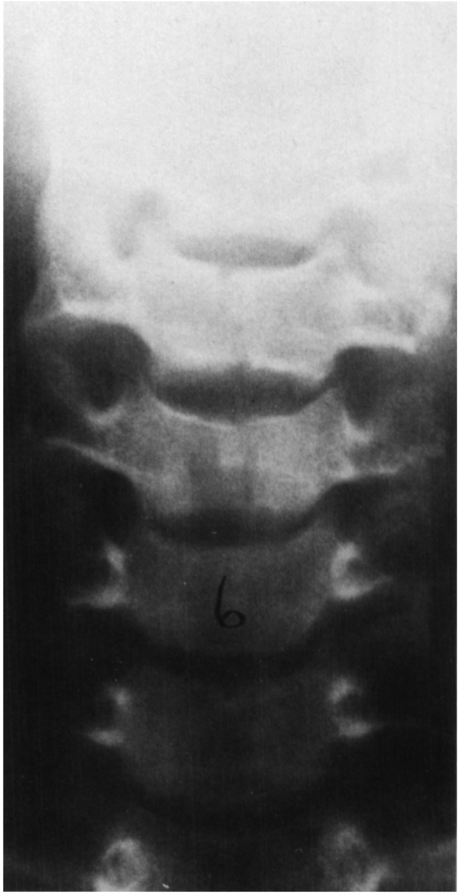

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Figure 1 — a) Case 1. Lateral view of major burst fracture of C5 with 8 mm posterior protrusion of C5 into the spinal canal. Reversal of normal cervical lordosis. b) AP tomogram shows sagittal fractures through the bodies of C4 and C5.

Case 2: This 17 year old student was injured while playing hockey in an organized league game. He was wearing a helmet and a face mask at the time of the accident. With his neck slightly flexed, his head struck another player. He immediately felt an "electric shock" go through him and was unable to move his arms and legs after which he fell to the ice. He was transferred to Sunnybrook several hours later, and was found to have a complete spinal cord injury at C6 with no motor or sensory function below this level. The cervical spine x-rays (Figs. 2a & b) showed a burst fracture of C5 with 5 mm posterior displacement of C5 into the spinal canal. Tomograms showed a sagittal fracture of the body of C5 and vertical fractures through both laminae and the right pedicle of C5.

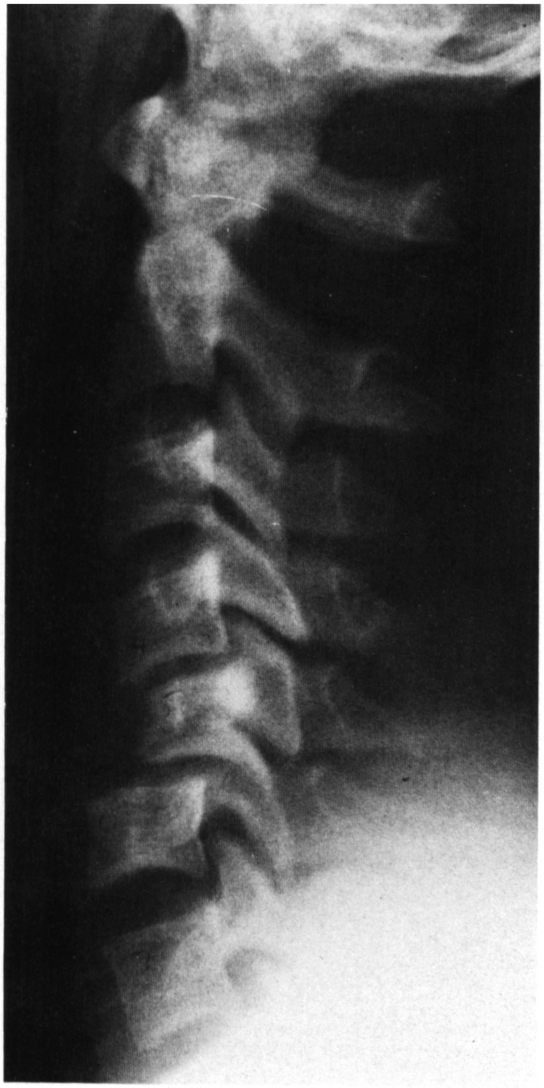
He was treated in a halo ring and vest for 3 months, at the end of which time cervical spine x-rays showed mild kyphosis at the fracture site with reversal of the cervical lordosis. The flexion-extension views showed that spinal stability had been achieved. Although there was no recovery of cord function, there was some recovery of C5 and C6 root function.

Case 3: This 22 year old man was injured while playing hockey in an adult hockey league. With his neck flexed, his head struck the boards. He immediately lost strength and sensation in his legs, and then he fell to the ice. He was wearing a helmet but no face mask.

He was transferred to Sunnybrook within 4 hours of the injury at which time neurological examination showed a complete spinal cord injury at C6. Cervical spine x-rays showed a burst fracture of C5 with posterior displacement of C5 7 mm into the spinal canal. There was also marked compression of the body of C5 with loss of approximately one-half its height, bilateral laminar fractures of C5, and a tiny fracture of the antero-superior corner of the body of C6. Halo traction was instituted and an acceptable, though not complete reduction was achieved with 35 lbs. during the next 48 hours. A halo vest was applied, and after 35 days, he was transferred to Lyndhurst Hospital for further rehabilitation. There was some improvement in his neurological status in that there was a return of deep pressure sensation in the lower limbs and sacral region. After 90 days in the halo device, flexion-extension views of the cervical spine showed slight instability at the C5-6 level. A four-poster brace was worn for six weeks at which time stability was achieved. His neurological status however did not show further improvement.

Case 4: This 24 year old university student was injured while playing hockey for a school team. He lost his balance and was pushed into the boards with his neck maximally flexed such that he hit the boards with his occiput. He was wearing a helmet but no face mask. He lost movement in his arms and legs and fell backwards on to the ice. He was taken to a nearby hospital where a complete cord injury at C5 was diagnosed. Cervical spine x-rays showed a burst fracture of C5 into the spinal canal (Figs. 3a and b). The C5 vertebra showed a marked loss of height anteriorly, several fractures of the body, and bilateral laminar fractures. He was treated with tongs and traction and transferred to Sunnybrook three weeks later. On admission he was found to have no voluntary motor function below C6, but there was some appreciation of deep pressure in the legs. The skull tongs were replaced with a halo ring. A metrizamide myelogram and CT scan (Figs. 3c and 3d) demonstrated marked cord compression, widening of the cord and a small syrinx. Anterior cervical decompression and fusion were performed five weeks after the injury. Several weeks later he was discharged to Lyndhurst Hospital in a halo vest for further rehabilitation. Although there was some improvement in upper limb function, there was no recovery of motor function in his legs.

Case 5: This 18 year old student was injured while playing hockey in an organized league game. While wearing a helmet and a face mask he tripped on the ice and struck the boards with his neck hyperextended. He experienced severe neck pain but no paraesthesiae or limb weakness. When first seen at Sunnybrook a few hours after the accident, the only neurological deficit was slight weakness of dorsi-flexion of the left



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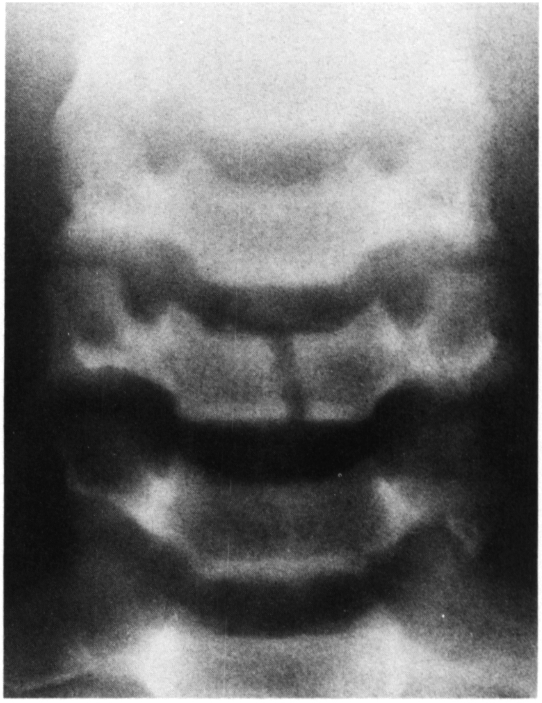

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Figure 2 — a) Case 2. Lateral view showing marked posterior protrusion of the compressed C5 vertebral body into the spinal canal. b) AP tomogram shows sagittal fracture through C5 body with flattening of body, increased interpedicular distance, and a fracture of the right pedicle.

wrist. Cervical spine x-rays showed a burst fracture of C7 with slight loss of height of C7 and 8 mm posterior displacement of part of the body of C7 into the spinal canal.

He was treated in a halo and vest and discharged after one month. At the time of discharge, there was almost normal power in the dorsiflexors of the left wrist. After three months in the halo vest, stability was confirmed with flexion-extension views, and the neurological examination was normal.

Case 6: This 15 year old boy sustained a neck injury while playing hockey in an organized league game. He was checked into the boards and recalls that his chin struck his chest when his head struck the boards. He immediately lost strength in his arms and legs and then fell to the ice. He had been wearing a helmet and face mask. He was initially assessed in a nearby hospital, and then transferred to Sunnybrook eight hours after the accident. He showed an incomplete cervical cord injury with a motor level at C6. There was preservation of deep pressure and touch distally. Cervical spine x-rays revealed burst fractures of C5 and C6 with posterior protrusion of C5 into the spinal canal by 4 mm. There was a reversal of the cervical lordosis at C5-6 (Figs. 4a and b). The CT scans showed saggittal fractures of C5 and C6, narrowing of the spinal canal and bilateral fractures of the laminae of C5 (Figs. 4c-4e).

He was treated in a halo ring and traction and later placed in a halo vest. After 35 days, he was transferred to Lyndhurst Hospital for further management. His deltoid and biceps power improved but he continued to have complete motor loss below C6. At three months, flexion-extension x-rays of the cervical spine showed stability at the injury site. He recovered grade 1 strength (MRC) at his hips and toes.

Analysis of Clinical Material

1. *Age and Sex of Patients*

Table 1 shows the ages of the six players with spinal injuries due to hockey. All were young males ranging in age from 15 to 26 with a mean age of 20.3.

2. *Level and Type of Bony Injury*

All six patients had burst fractures of the mid or lower cervical spine. The vertebrae with burst fractures were C4 and C5 in one patient, C5 alone in three patients, C5 and C6 in one patient, and C7 alone in one patient. All patients also had fractures of the laminae at the same level and showed posterior protrusion of the fractured bodies into the spinal canal.

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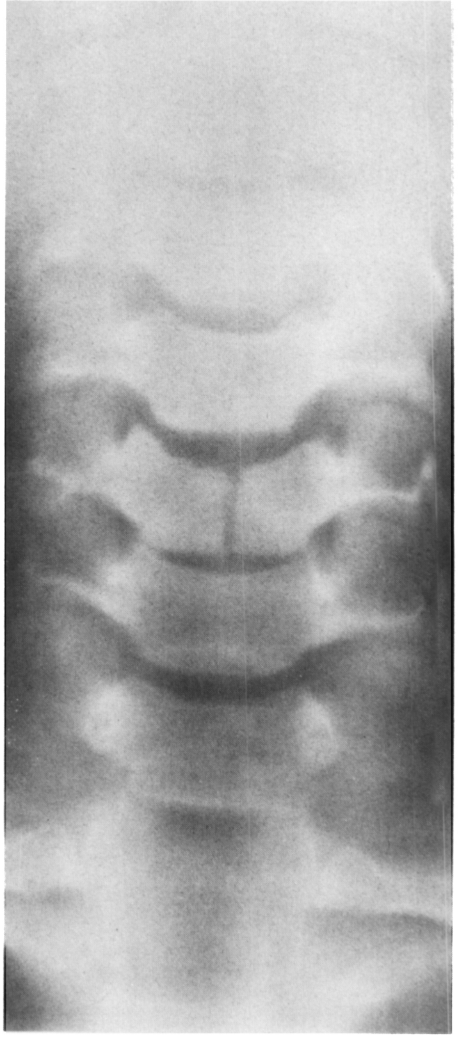

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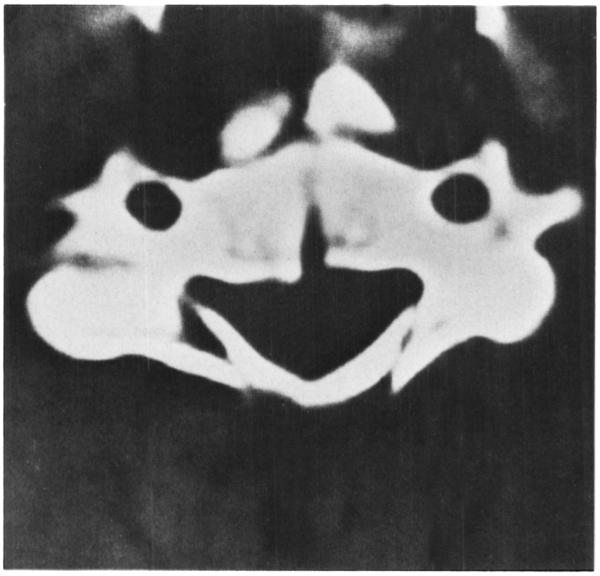
Figure 3 — a) Case 4. Lateral views shows burst and compression fracture of C5 with posterior protrusion into the spinal canal. b) AP tomogram shows sagittal fracture through the body of C5 with increased interpedicular distance. c) CT scan of cervical spine at C5 shows narrowing of spinal canal, bilateral laminar fractures and sagittal fracture of C5 body. d) CT at C4 shows a normal sized spinal canal.



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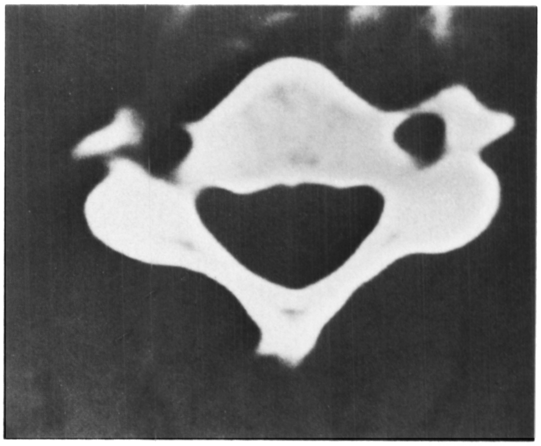

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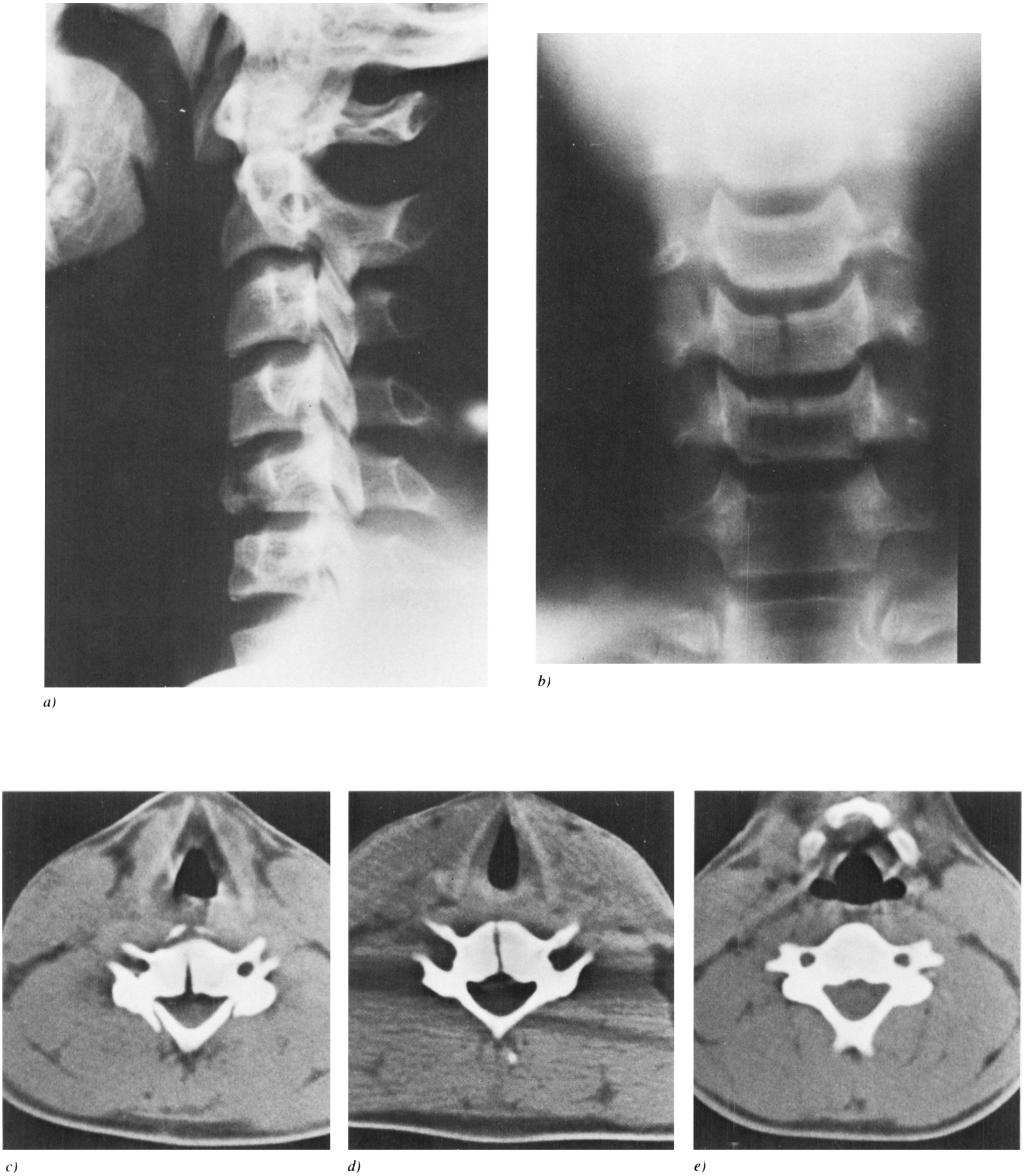

Figure 4 — a) Case 6. Lateral cervical spine x-ray shows burst fracture of C5 with posterior protrusion into spinal canal. There is marked compression of C5. b) AP tomogram shows sagittal fractures of C5 and C6 with increased interpedicular distance. c) CT scan of C5 showing sagittal fracture of the body and bilateral fractures of the laminae. There is narrowing of the spinal canal. d) CT scan of C6 showing sagittal fracture of the body. e) CT scan of C4 showing normal spinal canal and no fractures.

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Table 1: Spinal Injuries due to hockey

Case	Age	Bony Injury	Neurological Deficit	Mechanism of Injury
1	26	C4 and C5 Burst Fractures	Complete Cord Injury	Struck Boards in Flexion
2	17	C5 Burst Fracture	Complete Cord Injury	Struck Player in Flexion
3	22	C5 Burst Fracture	Incomplete Cord Injury	Struck Boards in Flexion
4	24	C5 Burst Fracture	Incomplete Cord Injury	Struck Boards in Flexion
5	18	C7 Burst Fracture	Root Injury	Struck Boards in Hyperextension
6	15	C5 and C6 Burst Fractures	Incomplete Cord Injury	Struck Boards in Flexion

3. *Neurological Status and Result*

Two patients had complete spinal cord injuries with complete motor and sensory loss distal to the level of injury. Neither recovered any distal motor or sensory function. Three patients had complete motor loss and partial loss of sensation distal to the level of injury. One of these patients recovered a minimal amount of distal motor function. One patient did not injure the spinal cord but had a unilateral C7 root injury which recovered completely.

4. *Treatment and Bony Result*

As shown in Table 2, all the patients were ultimately treated with the halo vest, although two patients had skull tongs applied elsewhere initially. One patient died of a pulmonary embolus three months after injury before stability could be assessed radiologically. In four others stability was accomplished by immobilization in the halo vest. One patient with a complete cord injury continued to have movement at the fracture site after three months. He was treated with a 4-poster brace for a further six weeks and stability was ultimately achieved. The sixth patient had an incomplete cord injury and underwent anterior decompression and operative fusion, with achievement of stability after immobilization in the halo vest.

Table 2: Spinal Injuries due to hockey: type of treatment and result of spinal injury

Pat.	Treatment	Result of Spinal Injury
1	Tongs for 39 days Halo vest for 54 days	Died of pulmonary Embolus at 3 months
2	Halo vest for 3 months	Stable
3	Halo vest for 3 months	Stable
4	Tongs for 25 days Anterior decompression & fusion at 36 days Halo vest for 3 months	Stable
5	Halo vest for 3 months	Stable
6	Halo vest for 3 months	Stable

5. *Circumstances and Mechanisms of the Injuries*

All six injuries occurred in games being played in organized leagues, and none occurred during practice or in unstructured games (shinny). All six players were wearing helmets, and three wore face masks.

Based on reports from the players and observers, and on the radiographs, it was concluded that major axial loading to the head was a mechanism of injury common to all six patients. Flexion of the neck was considered to be a major additional mechanism in the five players with spinal cord injuries. In four of these five, the player's head struck the boards with the neck flexed, and in one, the player's head struck another player with the neck flexed. The head of the patient who sustained only a nerve root injury struck the boards with the neck in hyperextension.

Discussion

From 1974 when the Sunnybrook Acute Spinal Cord Injury Unit opened until 1980 we admitted only one spinal injury due to hockey (Case 1). In contrast, five patients with spinal injuries due to hockey were admitted in the 13-month period from September, 1980 to October, 1981. The reasons for this major increase are unknown, but merit study in view of the seriousness of these tragic injuries.

There are several notable epidemiological features. All injuries occurred in organized hockey leagues in Ontario, five in Southern Ontario and one in Northern Ontario. All the injured players were young, three teenagers and three in their 20's. None was a professional hockey player. All six were wearing helmets, and collisions of the helmeted head against the boards caused five of the six injuries. Axial loading on the helmeted head with the neck flexed was the mechanism of injury in the five players with spinal cord injuries. Indeed, the head of the player who escaped cord injury struck the boards with the neck in extension.

It is possible that these young, non-professionals playing in organized leagues are sustaining these serious injuries because of lack of conditioning of the neck muscles, lack of care or training with respect to how to sustain an impact, and lack of concern for prevention of collision of the helmeted head with unyielding structures such as the boards. It was apparent that there was a lack of knowledge on the part of the players concerning the potential seriousness of the injuries that might be sustained by impact of the helmeted head.

In this small series axial loading plus flexion proved to be much more damaging to the cord than axial loading plus extension. The mechanical basis for this difference may be related to the anatomical structures in the line of action of the axial loading forces depending on the position of the neck. An axial loading force applied to the vertex with the neck in the neutral position or in extension would be distributed between the vertebral bodies and discs anteriorly, and the facet joints posteriorly. Conversely, an axial loading force applied in flexion would be concentrated mainly on the bodies and discs which would cause burst fractures with more marked posterior protrusion of the fractured vertebral body. However, it should be noted that in Case 5 with an extension injury there was 8 mm of posterior protrusion of the burst vertebral body although there was no cord injury.

The halo vest device has been exceptionally useful in the treatment of acute injuries of the cervical spine (Tator et al., 1982; Edmonds and Tator, 1982). In the present series it was the principal method of management for achieving spinal stability, and as shown here it has proven to be useful for both complete and incomplete cord injuries.

In the United States, football has been the most common type of body contact sport leading to major cord injury. Schneider et al. (1961) were the first to record the spinal injuries in football and determined that major injuries occurred in the upper cervical cord and cervical-medullary junction as a result of violent hyperextension. Schneider subsequently documented many more cases and reviewed the subject extensively in his excellent monograph (Schneider, 1973). Others have shown that hyperflexion is a more common mechanism of injury in football (Alley, 1964; Funk and Wells, 1975; and Kewalramani and Krauss, 1981). However, in Alley's series of 59 high school football players with neck injuries, only three had fractures and none had a neurological deficit. On Kewalramani's 40 cases, most had severe neurological deficits and most were hyperflexion injuries. It is of interest to note that many of the hyperflexion football injuries resulted in fracture-dislocation, whereas the hockey injuries were burst fractures.

Some consideration should be given to the issue of helmets now worn by virtually all young hockey players. Helmets were introduced to reduce the risk of serious head injury, and they have been successful in this regard. The contribution of helmets to the production of neck injuries is unknown. As noted above all six players in the present series were wearing helmets at the time of injury. There has been some concern that certain helmets have been a factor in cervical injuries in football players. Schneider et al. (1961) pointed to a possible "guillotine" effect caused by the posterior rim of the helmet striking the cervical spine and advocated that the posterior rim of helmets should be cut higher to avoid this mechanism. Recently, there has been controversy about this mechanism, and indeed, the studies of Carter and Frankel (1980) suggest that the safest design is with the helmet extending lower so that the posterior rim of the helmet would strike the shoulder pads. In a cineradiographic study of modern football helmets and the cervical spine, Virgin (1980) showed that no contact existed at any time between the posterior rims of all five types of helmets tested and the cervical vertebral spinous processes during movements from fully flexed to fully extended positions, and concluded that the posterior rim of the modern helmet could not injury the cervical spine in hyperextension. The relevance of this to the role of helmets in the current hockey injuries is uncertain, since five of the six hockey injuries occurred in flexion. Clarke and Powell (1979) studied the relationship between the type of football helmet and the incidence of spinal injury in high school and college football players in the U.S.A. from 1975-1977. Although a total of 5361 players were studied annually, they identified only six cervical fractures during the 3 years, only one of which, a hyperflexion injury, resulted in quadriplegia. It is of some interest that four of the six cases were wearing one particular manufacturer's helmet, although this helmet was the most frequently used helmet. Since so few neck injuries were identified the results of this study must be considered inconclusive with respect to the relationship between helmet type and incidence of neck injury.

Ill-fitting helmets were considered to be a factor in head injuries in football players, perhaps due to the lack of cushioning effect if the helmet did not fit the head snugly (Alley, 1964). The same lack of cushioning effect from a helmet that was too loose or too lightly padded might fail to reduce the forces on the neck resulting from a collision.

Other hockey equipment factors which should be considered include the face masks and the skates worn by the players. Melvin et al. (1965) were concerned that the protruding face mask might predispose football players to neck injuries. The importance of this in hockey players is unknown. There is no definite evidence that skate failure caused any of the injured hockey players to trip and collide.

Torg et al. (1979) studied head and neck injuries among high school and college football players from 1971-1977 and concluded that head injuries had decreased and neck injuries had increased as compared with earlier studies, especially that of Schneider (1973). They attributed these changes to the better protection of the head afforded by the newer helmet-face mask unit, which at the same time may have increased neck injuries because it "has encouraged the use of the head as the primary point of contact in blocking, tackling and head butting". Whether or not in hockey a similar increase in the use of the head as an offensive or defensive weapon has occurred, is unknown.

As a result of the knowledge gained about football injuries, training programs for football players have recently stressed the development of strong neck musculature through isometric and resistance exercises and the wearing of light-weight sponge rubber collars to prevent the extremes of flexion, extension and lateral flexion (Funk and Wells, 1975). There is some evidence that rule changes in U.S. football in which "spearing" and "clotheslining" have been made infractions have contributed to a recent reduction in spinal injuries. "Spearing" is the use of the head as an offensive weapon to strike the opponent and "clotheslining" is the use of the outstretched arm under the opponent's facemask to stop his progress.

There are several other factors which might account for the increased incidence of spinal injuries in hockey players. It is possible that because of helmets and other protective equipment, hockey players feel invincible and are taking more chances. Many observers feel that the professional game has become more violent and that this has influenced amateurs. The speed of the game has also increased and this may cause an increase in the forces at impact. An increase in the size of the players would also increase the forces at impact.

The five players with spinal cord injury had little or no recovery of motor function below the level of the lesion indicating that the prognosis for recovery of function in hockey-related spinal cord injury is poor. Thus, it is important to study the epidemiology of these injuries with a view to discovering preventable factors. Efforts at prevention might include rule changes or enforcement to reduce collisions with the boards. Increased awareness of players about the risks of head first collisions might reduce the incidence. Training to develop stronger

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neck musculature by appropriate isometric and resistance exercises should be encouraged. The use of collars to prevent extreme flexion, extension, or lateral flexion of the neck should be considered. The role of the helmet requires further study, including biomechanical investigation. Further epidemiological studies are necessary to determine the true incidence of these injuries. In this regard, a study is currently underway to document all spinal injuries due to hockey in Canada.

Conclusions

The reasons for the apparent increase in serious neck injuries in hockey are unknown. It is possible that the game has become more violent with an increased likelihood of player-boards and player-player collisions. The professional game has certainly featured more violence, and the amateurs may be following their professional role-models. However, the professionals undergo stringent conditioning which would strengthen the cervical musculature. There is a possibility that lack of neck muscle strengthening exercises among amateurs is a causative factor. It is possible that wearing "protective" equipment produces a feeling of invincibility which increases the likelihood of collision. The increased violence and aggressiveness of the game may reflect the same tendency in society in general. It is also possible that the increase in height and weight which characterizes the present generation may be producing an increase in the forces generated by collisions.

All six players in the present series were wearing helmets, and three were wearing facemasks. The role of the equipment in producing the injuries in the present series is unknown.

Acknowledgements

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