National survey of spinal injuries in hockey players*

CHARLES H. TATOR, MD, PH D, FRCS[C]
VIRGINIA E. EDMONDS, RN

There has been an alarming increase in the number of spinal injuries in hockey players. Between 1976 and 1983, 42 were reported to the Committee on Prevention of Spinal Injuries due to Hockey. The median age of the injured players was 17 years. Of the 42 players 28 had spinal cord injuries, and 17 of them had complete paralysis below the vertebral level of the injury. Strikes from behind and collisions with the boards were common mechanisms of injury. Many of the players had suffered a burst fracture of the cervical spine following a blow to the top of the helmet when the neck was slightly flexed. The committee studied a number of possible etiologic factors and made several recommendations regarding prevention. League officials, coaches, players and equipment manufacturers can all play a role in prevention.

On constate une augmentation alarmante du nombre de blessures de la colonne vertébrale chez les joueurs de hockey. Entre 1976 et 1983, 42 cas ont été signalés au Comité sur la prévention des blessures de la colonne vertébrale dues au hockey. L'âge médian des joueurs blessés était de 17 ans. De ces 42 joueurs 28 avaient des blessures de la moelle épinière; 17 d'entre eux étaient complètement paralysés sous le niveau de la vertèbre touchée. Les blessures sont survenues surtout lorsqu'un joueur était frappé par en arrière ou lorsqu'il venait en collision avec la bande. Plusieurs joueurs ont subi une fracture par éclatement de la colonne cervicale à la suite d'un coup porté au sommet du casque protecteur alors que le cou était légèrement fléchi. Le comité a étudié plusieurs facteurs étiologiques possibles et a émis plusieurs recommandations quant à la prévention. Les arbitres, les entraîneurs, les joueurs et les fabricants d'équipement peuvent tous jouer un rôle dans cette prévention.

From the acute spinal cord injury unit and the division of neurosurgery, Sunnybrook Medical Centre, University of Toronto

*Conducted by the Committee on Prevention of Spinal Injuries due to Hockey: chairman, Dr. Charles H. Tator; secretary, Ms. Virginia E. Edmonds; members, Dr. Patrick J. Bishop (biomechanics impact laboratory, department of kinesiology, University of Waterloo), Dr. Chris E.U. Ekong (neurosurgeon, Regina General Hospital), Mr. Robert Firth (technical director, trainer's program, Hockey Ontario Development Committee, Toronto), Mrs. Lois Kalchman (hockey writer, Toronto), Dr. J. Guy Morissette (executive member, Canadian Amateur Hockey Association, Hull, PQ), Dr. Thomas J. Pashby (chairman, committee on protective equipment for hockey and lacrosse players, Canadian Standards Association, Toronto), Mr. Michael Ryan (executive director, Canadian Paraplegic Association, Toronto), and Mr. Daniel Smith (assistant technical director, Canadian Amateur Hockey Association).

Presented June 23, 1983 at the XVIII Canadian Congress of Neurological Sciences, St. John's

Reprint requests to: Dr. Charles H. Tator, Division of neurosurgery, Sunnybrook Medical Centre, 2075 Bayview Ave., Toronto, Ont. M4N 3M5

Recently there has been an increased incidence of spinal injuries in hockey players. Between September 1980 and October 1981 five hockey players with major spinal injuries, four of which were injuries to the cervical spinal cord, were treated at the acute spinal cord injury unit at Sunnybrook Medical Centre, Toronto.[1] In contrast, between 1974, when the unit opened, and 1980 only one hockey player with a spinal injury was treated at the unit. Similarly, none of the 358 spinal cord injuries studied at two Toronto hospitals between 1948 and 1973 were hockey-related,[2] and previous reports of hockey injuries included no cases of spinal cord injury.[3-6]

The Committee on Prevention of Spinal Injuries due to Hockey was formed to investigate the increase in the incidence of hockey-related spinal cord injuries. Our first task was to determine the national incidence of hockey-related spinal injuries. In this paper we describe the results of our national survey.

Methods

We collected information on all patients with hockey-related major injuries of the spine with or without injuries to the nerve roots or spinal cord. We excluded those with minor spinal injuries such as sprains, strains, flexion–extension injuries and whiplash.

We had initially intended to perform the study over an 18-month period, from July 1, 1980 to Dec. 31, 1981. However, since many injuries that occurred before or after these dates were reported to the committee, we extended the study period to include these cases.

In the winter of 1982 we sent a questionnaire to all the neurosurgeons, orthopedic surgeons, and physical medicine and rehabilitation specialists practising in Canada. The questionnaire asked for the date and place of the injury and the initials and age of each player so that duplication of responses could be detected. There were also questions about the circumstances of the accident, the equipment worn by the player, and the nature of the bony and neurologic injuries. One of us (C.H.T.) had used this method to study spinal injuries due to diving in 1979[7,8] and had found it to be very accurate because virtually every case of spinal or spinal cord injury in Canada is referred to at least one of the types of specialists mentioned above. Pashby and associates[9] used a similar technique in their survey of eye injuries in hockey players.

Media accounts of the committee's work were helpful in bringing forth reports from injured players or their families, and letters and announcements in medical journals and at medical meetings helped encourage reporting of cases by physicians. We used up to three mailings 2 months apart; thus, each physician or

surgeon could have received two copies of the questionnaire and one reminder. When a case was reported to the committee the physician or surgeon was asked to obtain the player's permission for an interview with a committee member. When permission was granted we telephoned the player to obtain precise details about the circumstances of the injury, the equipment used and so forth. When permission was not granted we asked the reporting physician or surgeon to obtain this information.

Results

Of the 891 questionnaires we sent out, 360 were returned, for a response rate of 40%. The responses were analysed geographically to ensure that reports had been received from every major centre in Canada. If we had no reports from a particular city we telephoned specialists in that city to confirm the absence of injuries. Ontario had the highest return rate (50%).

By Jan. 31, 1983 the committee had received information about 42 hockey-related spinal injuries and had interviewed 32 of the 42 players, 1 of whom was a female. The youngest player was 11 and the oldest 45 years of age. The median age was 17 and the average age 20 years.

Most of the injuries occurred in Ontario (Table I). Table II shows the year of the injuries and suggests a continuing increase in their incidence. As we expected, the injuries were much more frequent in the winter months, although only May and July were free of injuries.

Of the 42 injuries 34 occurred during hockey games in organized leagues, and only 1 occurred during a practice; this information was not available for the other 7 injuries. The organized leagues varied from province-wide organizations such as the Ontario Hockey Association to adult leagues. No injury occurred in a "pick-up" game or "shinny" (an unorganized game). One of the 42 players was a professional hockey player.

The event leading to the injury was a push or a check in 17 instances (in 13 instances from behind), a trip on the ice in 7, an intentional slide in 4, a trip by another player in 1, a combination of two or more of these factors in 7 and unknown in 6. All the injuries resulted from a blow to the head, from the boards in 25 instances, other players in 6, a combination of the boards and other players in 4 and a goal post in 1; in 6 instances the object struck was unknown. In no instance was the blow directly to the neck. At the time of impact the neck had been flexed in 21 players, extended in 6 and neutral in 3; its position was unknown in 12.

Of the 42 players 37 were known to have been wearing a helmet. In addition, 20 players were known to have been wearing a face mask and 14 to not have been; we did not have this information for the other 8 players.

The principal vertebral level of the injuries is shown in Table III. All but three were in the cervical region,

Table I—Geographic distribution of 42 hockey-related spinal injuries

Location	No. of injuries
Canada	
Ontario	26
Quebec	3
Saskatchewan	3
Manitoba	3
Nova Scotia	2
Alberta	1
British Columbia	1
Prince Edward Island	1
Yukon Territory	1
United States	1

Table II—Year the injuries occurred

Year	No. of injuries
1976	2
1977	2
1978	4
1979	1
1980	8
1981	13
1982	10
1983 (up to Jan. 31)	2

Table III—Principal vertebral level of the injuries

Vertebral level	No. of injuries
C1	1
C1–2	1
C2	–
C2–3	–
C3	–
C3–4	1
C4	2
C4–5	6
C5	9
C5–6	9
C6	1
C6–7	4
C7	4
C7–T1	1
T12	1
L1	1
L2	1

Table IV—Types of vertebral injury

Type of injury	No. of injuries
Fracture–dislocation (including burst fractures)	27
Fracture	9
Dislocation	2
None	4

Table V—Types of neurologic injury

Type of injury	No. of players
Incomplete spinal cord injury	16
Complete motor loss, incomplete sensory loss	5
Incomplete motor loss, incomplete sensory loss	10
Incomplete sensory loss	1
Complete spinal cord injury	12
Nerve root injury	5
None	9

and the most frequent levels were C5 and C5–6. Table IV shows the types of vertebral injury, the commonest being fracture–dislocation, and approximately half of these being burst fractures (Figs. 1 and 2). Although four players had no radiologic evidence of a bony injury they all had spinal cord injuries.

The types of neurologic injury in the 42 players are shown in Table V. Twenty-eight players had an injury to the spinal cord: 17 had total paralysis below the vertebral level of the injury; in 10 players with incomplete motor loss the type of deficit was not indicated on all the questionnaires, but 5 players had insufficient power for ambulation. Thus, 22 of the 42 players were confined to wheelchairs. Five other players had injuries to one or more of the cervical nerve roots. Nine had no neurologic deficits, but they all had a vertebral fracture or fracture–dislocation.

One of the patients with a complete spinal cord injury died of pulmonary embolism 3 months after the injury. No other deaths had been reported to the committee up to the time of writing.

Discussion

Forty-two cases of major spinal injuries related to hockey had been reported to the committee by Jan. 31, 1983. We have since received information on several more cases, which indicates that such injuries are continuing. We believe that the occurrence of such a large number of hockey-related spinal injuries is a recent phenomenon, since the older clinicians we consulted could not recall any cases in former years. The first hockey-related spinal cord injury treated at the acute spinal cord injury unit was in 1977; since then the numbers have risen dramatically. Indeed, five players were admitted in the 13-month period between Septem-

Fig. 1—Burst fractures of C4 and C5 with 8-mm posterior protrusion of portion of body of C5 into spinal canal in hockey player with complete spinal cord injury. (Reproduced with permission from reference 1.)

Fig. 2—Burst and compression fracture of C5 with posterior protrusion into spinal canal in hockey player with incomplete spinal cord injury. (Reproduced with permission from reference 1.)

ber 1980 and October 1981. These six cases have been reported elsewhere.[1] A search of the English-language literature revealed no other reports of spinal cord injuries related to hockey, although there have been several reported studies of major spinal injuries related to sports.[10,11] Feriencik[4] reported the occurrence of hockey-related injuries to the lumbar vertebrae in Czechoslovakia, but the number of injuries was not stated.

Our study was subject to some biases, including those that favour the reporting of positive responses and more recent cases. However, we feel that the study identified virtually every case of hockey-related spinal injury since 1976 because of the large number of reporting channels, including the medical profession, the hockey leagues, the players and their families, and the media. This broad source of data also served to reduce the effect of any regional differences in the rate of reporting by the medical profession.

The evidence strongly suggests that the game of hockey is faced with a new problem. The ultimate purpose of our study was to document the national incidence of hockey-related injuries in Canada in order to identify common etiologic factors that might lead to preventive measures. We therefore examined several factors as possible causes of the increased incidence of spinal injuries in hockey players.

Our study has shown that the individuals at risk of spinal injuries are young men, usually in their teens or early 20s, who play hockey in organized leagues. That there were no injuries during unorganized games or "shinnies" and only one during practice is striking. The marked preponderance of injuries in Ontario contrasts sharply with the relative paucity of injuries in Quebec. The reasons for this difference are unknown, but this feature merits intense study of whether there are differences in play or organization between these provinces. Several studies of hockey injuries have indicated a relation between coaching and refereeing and the incidence of injuries.[4,5] We did not find any evidence that pooling of the better players in the same league had any effect on the incidence of spinal injuries.

A blow to the head from a push or check into the boards was the commonest injury event. Indeed, 13 of the 17 players who had been pushed or checked had been struck from behind, which strongly suggests that an alteration in the rules or enforcement of existing rules against attack from behind would be an important preventive measure. The unexpected impact does not allow the player to tense his muscles to resist the force of the impact.[12]

It is not known if poorly fitting helmets contributed to any of the injuries in our series, although a poor fit might favour flexion of the neck after impact. It is unlikely that obscured vision or an alteration in spinal posture due to the wearing of a face mask was an important factor. We did not find any evidence of skate failure as a cause of spinal injury, although in several cases the cause of the trip or fall could not be determined. Thus, there does not appear to be any piece of equipment apart from the helmet, the role of which we will discuss later, that can be implicated in these injuries.

Hockey observers agree than today's players are taller and heavier and skate faster than those of previous years. These features generate greater impact forces. Professional hockey has become more aggressive and violent, and amateurs tend to emulate the professionals. Most of the injured players we interviewed claimed to be unaware of the risks of spinal cord injury. On the other hand, many players admitted to feeling invincible when they were wearing their protective equipment.

Most of the players had never done specific exercises to strengthen their neck muscles, and most claimed that they had never been advised by their coaches to do so. Most were also unaware of the added risk of impact in flexion, and none had been cautioned about the dangers of "spearing" (striking another player head first).

The boards in some rinks may have less cushioning or shock absorbancy than others, and there may be an increased likelihood of player–boards or player–player collisions in small hockey rinks. It is not known whether friction between the helmets and the boards is a factor.

That so many fracture–dislocations and burst fractures of the middle to lower cervical spine occurred when a player who had his neck flexed and was wearing a helmet was pushed or checked into the boards or was pushed by another player merits further discussion and investigation. Bishop and colleagues[13] reported that the use of a helmet or a helmet and face mask combination shifted the centre of mass and increased the mass moment of inertia of a standard headform. However, since the alterations were small they concluded that these changes probably did not contribute significantly to the likelihood of neck flexion at the time of impact. The results of Hodgson and Thomas's studies of impact on helmeted heads of cadavers[14] may be highly relevant to the situation with hockey players. They found that impact to the top of the helmeted head produced much greater strain on the cervical vertebrae when the neck was flexed, and that the least strain occurred when the body, cervical spine and head were in neutral alignment. They also showed that impact to the top of the head produced much greater strain on the cervical vertebrae than impact to areas farther forward on the head. Thus, in the hockey players in our series who struck the boards with the top of their heads while their necks were slightly flexed the cervical vertebrae were probably subjected to maximum forces. Indeed, in the first six cases at Sunnybrook Medical Centre this was the commonest combination of mechanisms leading to a burst fracture of the vertebral bodies.[1] This type of injury due to axial loading plus flexion is the same as the injury that occurs in shallow-water divers.[7,8] When the vertebrae are subjected to these maximum forces a burst fracture occurs, and fragments of the vertebral bodies are displaced posteriorly into the spinal canal, resulting in acute compression of the spinal cord.

To prevent brain injury[15,16] the use of improved hockey helmets was made mandatory by most nonprofessional hockey leagues in Canada during the 1970s; this has resulted in a substantial decrease in the incidence of severe head injuries. Similarly, after improved football helmets were introduced in the United States there was a marked reduction in the number of deaths due to football-related head injuries. Schneider and cowork-

ers[17-19] were the first to document large numbers of spinal injuries in football players, and they raised the possibility that helmets may have contributed to the problem. They postulated that in some hyperextension injuries the back of the helmet struck and injured the cervical spine, producing the so-called "guillotine" effect. However, the importance of this mechanism has been disputed since most spinal injuries in football are not hyperextension injuries;[10,20,21] the "guillotine" mechanism has thus been refuted.[22,23]

From an epidemiologic viewpoint it is useful to examine the occurrence of spinal cord injuries in football players in the United States. Although the incidence of head injuries was markedly reduced during the 1960s and 1970s owing to the use of helmets, the incidence of spinal injuries may have increased,[24] according to the results of excellent epidemiologic studies of injuries documented by two athletic injury reporting systems.[25,26] It was concluded that the helmeted head was being used as an offensive weapon to spear the opponent. Indeed, head-first tackling and blocking was being encouraged by coaches. As a result of these findings the rules were changed in the mid-1970s so that spearing became an infraction, and head-first tackling and blocking were disallowed. There has since been a marked reduction in the incidence of spinal cord injuries in football.[27] Indeed, in the late 1970s and early 1980s the annual number of cases of quadriplegia in football players decreased from about 30 to 10.[26] There are approximately four cases of quadriplegia a year in hockey players in Canada. Thus, on a per-capita basis, hockey in Canada now causes approximately three times as many cases of quadriplegia annually as does football in the United States. In terms of the risk of spinal injury to the participants, hockey appears to be much riskier than football, especially in Ontario, although we have not been able to obtain exact data on the numbers of participants.

Motorcycle helmets have also been studied with respect to their role in the production of spinal injuries.[28] While their use has markedly reduced the incidence of head injuries, their value in preventing spinal injuries is much less marked. In an extensive study of 900 motorcycle accidents in California Hurt and collaborators[28] found that there were significantly fewer minor spinal injuries in the riders who had been wearing a helmet than in those who had not; however, there was no significant reduction in the incidence of severe spinal injuries. Indeed, the reduction in the incidence of minor injuries occurred only in the riders with helmets that did not include full facial protection; thus, the authors concluded that "the lighter partial and full coverage helmets have a significant beneficial effect in reducing neck injury, and the full facial coverage helmet simply has no significant effect. The principal observation is that there is *no adverse effect* and *no vulnerability* to neck injury from helmet use."

It is interesting to compare the strength, shape, size and weight of football, motorcycle and hockey helmets. Motorcycle helmets have the strongest outer shell and the thickest inner padding and therefore probably the greatest shock absorbancy. However, they are large and heavy. Football helmets are intermediate in size but are stronger than hockey helmets, and motorcycle and football helmets tend to be round, whereas hockey helmets tend to have a flat crown. However, it is not known if any of these features is important with respect to the prevention of spinal injuries in hockey players.

Recommendations

Having examined numerous possible etiologic factors in the increased incidence of spinal injuries in hockey players, we believe we are dealing with a problem of multifactorial origin. Prevention must therefore involve several approaches by hockey leagues, players, equipment manufacturers, and health care professionals and researchers.

- The hockey leagues should enforce the current rules, especially those against boarding and cross-check-

ing, and should consider introducing new rules against pushing or checking from behind. They should also recommend muscle-conditioning programs to improve the strength of the neck muscles. They should avoid using small rinks and should maintain accurate statistics on the occurrence of severe injuries.

- The players should be educated about the possibility of major neck injuries. They should avoid spearing and impact, especially with the boards, when the neck is flexed. They should follow a neck-muscle-conditioning program and avoid using poorly fitting helmets.
- The equipment manufacturers should encourage and undertake research on helmet design, especially with regard to shape and shock absorbancy.
- Health care professionals and researchers should continue epidemiologic studies on the causes of spinal injuries in hockey players and on the effectiveness of preventive measures. Further research on the biomechanics of the injuries, including the influence of equipment design, is urgently needed.

An effort has been made to publicize our recommendations among hockey associations, the public, equipment manufacturers and the medical profession. As part of this continuing effort to prevent these injuries, we urge physicians and surgeons to continue to report such cases to the committee.

References

1. TATOR CH, EKONG CEU, ROWED DW, SCHWARTZ ML, EDMONDS VE, COOPER PW: Spinal injuries due to hockey. *Can J Neurol Sci* 1984; 11: 34–41
2. TATOR CH, EDMONDS VE: Acute spinal cord injury: analysis of epidemiological factors. *Can J Surg* 1979; 22: 575–578
3. HASTINGS DE, CAMERON J, PARKER SM, EVANS J: A study of hockey injuries in Ontario. *Ont Med Rev* 1974; 41: 686–692, 698
4. FERIENCIK K: Trends in ice hockey injuries: 1965 to 1977. *Physician Sportsmed* 1979; 7: 81–84
5. HAYES D: Reducing risks in hockey. Analysis of equipment and injuries. *Physician Sportsmed* 1978; 6: 67–70
6. DAFFNER RH: Injuries in amateur ice hockey: a two-year analysis. *J Fam Pract* 1977; 4: 225–227
7. TATOR CH, PALM J: The issue of spinal injuries due to diving and aquatic activities. In PIKE B (ed): *Aquatic Spinal Injuries, Proceedings of the Symposium,* R Life Sav Soc Can, Toronto, 1980: 9–12
8. Idem: Spinal injuries in diving: incidence high and rising. *Ont Med Rev* 1981; 48: 628–631
9. PASHBY TJ, PASHBY RC, CHISHOLM LDJ, CRAWFORD JS: Eye injuries in Canadian hockey. *Can Med Assoc J* 1975; 113: 663–666, 674
10. KEWALRAMANI LS, KRAUSS JF: Cervical spine injuries resulting from collision sports. *Paraplegia* 1981: 19: 303–312
11. TORG JS (ed): *Athletic Injuries to the Head, Neck and Face,* Lea & Febiger, Philadelphia, 1981
12. REID SE, REID SE JR: Football, neck muscles and head impact. *Surg Gynecol Obstet* 1978; 147: 513–517
13. BISHOP PJ, NORMAN RW, WELLS R, RANNEY D, SKLERYK B: Changes in the centre of mass and moment of inertia of a headform induced by a hockey helmet and face shield. *Can J Appl Sport Sci* 1983; 8: 19–25
14. HODGSON VR, THOMAS LM: Mechanisms of cervical spine injury during impact to the protected head. In *Proceedings of the Twenty-Fourth Stapp Car Crash Conference,* Society of Automotive Engineers, Warrendale, Pa, 1980: 15–42
15. FEKETE JF: Severe brain injury and death following minor hockey accidents: the effectiveness of the "safety helmets" of amateur hockey players. *Can Med Assoc J* 1968; 99: 1234–1239
16. FERIENCIK K: Case report: depressed skull fracture in an ice hockey player wearing a helmet. *Physician Sportsmed* 1979; 7: 107
17. SCHNEIDER RC, REIFEL E, CRISLER HO, OOSTERBAAN BG: Serious and fatal football injuries involving the head and spinal cord. *JAMA* 1961; 177: 362–367
18. SCHNEIDER RC: Serious and fatal neurosurgical football injuries. *Clin Neurosurg* 1964; 12: 226–236
19. Idem: *Head and Neck Injuries in Football. Mechanisms, Treatment and Prevention,* Williams & Wilkins, Baltimore, Md, 1973
20. ALLEY RH JR: Head and neck injuries in high school football. *JAMA* 1964: 188: 418–422
21. FUNK FF, WELLS RE: Injuries of the cervical spine in football. *Clin Orthop* 1975; 109: 50–58
22. CARTER DR, FRANKEL VH: Biomechanics of hyperextension injuries to the cervical spine in football. *Am J Sportsmed* 1980; 8: 302–309
23. VIRGIN H: Cineradiographic study of football helmets and the cervical spine. *Am J Sportsmed* 1980; 8: 310–317
24. TORG JS, TRUEX R JR, QUEDENFELD TC, BURSTEIN A, SPEALMAN A, NICHOLS C III: The National Football Head and Neck Injury Registry. Report and conclusions 1978. *JAMA* 1979; 241: 1477–1479
25. CLARKE KS, POWELL JW: Football helmets and neurotrauma — an epidemiological overview of three seasons. *Med Sci Sports* 1979: 11: 138–145
26. CLARKE KS: An epidemiologic view. In TORG JS (ed): *Athletic Injuries to the Head, Neck and Face,* Lea & Febiger, Philadelphia, 1982: 15–25
27. HODGSON VR: Reducing serious injury in sports. *Interschol Athletic Admin* 1980; 7: 11–14
28. HURT HH JR, OUELLET JV, THOM DR: *Motorcycle Accident Cause Factors and Identification of Countermeasures,* vol 1 (tech rep), national highway traffic safety administration, US Dept of Transportation, Washington, 1981