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Neurologic Injuries in Hockey

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What they worry about most is injuries,.[in] this combination of ballet and murder.

Al Purdy, Hockey Players, 1965

References to hockey injuries can be found not only in poetry but also in the medical literature, where authors have described the game as a combination of ‘‘finesse and controlled aggression’’.[1,2] Hockey players attain skating speeds of more than 30 miles per hour and may shoot the puck at more than 100 miles per hour, all in the setting of a contact sport played on an ice surface enclosed by unyielding boards and glass.[1] There is an understandable risk for injuries, and many of these affect the nervous system.

Epidemiologic studies of hockey have reported overall injury rates using heterogeneous methods that prevent direct comparisons.[1–7] A recent large study of United States college hockey revealed an injury rate of approximately 16 injuries per 1000 athlete exposures.[7] Injuries occur much more commonly during games than practices[1,2,4,6–8] and most injuries (80%–90%) are the result of direct trauma, including collisions with other players, the ice surface, the boards and glass, goal posts, sticks, and the puck.[1,7] Injury rates increase with age and level of play;[1,4,6,9,10] based on age, the number of hours of playing time per injury is reported as 100 hours per injury for 11 to 14 year olds, 16 hours per injury for 15 to 18 year olds, 11 hours per injury for 19- to 21-year-old college players, and 7 hours per injury for professional players.[4] Children and youths playing in leagues permitting body checking have higher injury rates than players in noncontact leagues.[5,6,11,12] A study of Canadian University hockey showed no significant difference in injury rates between male and female players;[13] however, more recent studies of United States college hockey showed female athletes to have game injury rates less than 60% that of male athletes.[7,14] Most female hockey injuries result from collisions, even though intentional body checking is not permitted in women’s hockey.[7,13,14]

Neurologic injuries seem to account for 5% to 25% of all injuries in these various epidemiologic studies, with concussions making up the majority of neurologic injuries.

This article presents an overview of neurologic injuries occurring in hockey. More common or serious injuries are given extra attention. The articles by Boden and Jarvis; Tator; Park and Levy; and Lovell specifically devoted to sports-related spinal injuries and sports-related head injuries elsewhere in this issue are also relevant for researchers and clinical personnel caring for injured hockey players.

Information used in this article was obtained from searches of the following databases: Medline, SportDiscus, Scopus, CINAHL, Health Reference Center Academic, and CSA Biological and Medical Sciences. The majority of pertinent, nonduplicate citations were found in Medline (MeSH ''Hockey'' AND [MeSH ''Brain Concussion1'' OR {(MeSH ''Trauma1'' OR MeSH ''Wounds and Injuries1'') AND MeSH ''Central Nervous System1''}]) and CSA Biological and Medical Sciences (keywords: Hockey AND [wound* OR injur* OR trauma*] AND [neuro* OR nervous system OR brain]). References within these citations were used to identify additional relevant articles.

A presentation of the injuries formally described in the medical literature does not provide a complete picture of neurologic injuries in hockey. For example, there are no articles describing lumbosacral disc disease/radiculopathy or the more rare thoracic radiculopathy in hockey, despite the fact that a perusal of public injury data from professional hockey teams shows diagnoses of back strain, back spasms, herniated disc in back, and surgery for herniated disc in back as among the most common injuries accounting for lost time from play (personal observations). This may reflect not only a difficulty in attributing this particular injury to any specific incident, but also an understanding that this injury is common and certainly likely to occur in active athletes playing a contact sport, such that there is no great interest or novelty in reporting on it in the medical literature. Uncommon injuries that could occur as a result of similar, non–sports-related trauma also are unlikely to be reported formally and, therefore, escape inclusion in this review.

Neurologic injuries that have been described in the scientific literature are discussed in a peripheral-to-central direction—considering muscle, nerve, plexus, root, cord, and brain—beginning with injuries affecting the peripheral nervous system and followed by injuries affecting the central nervous system. Additional points regarding diagnosis, investigation, and treatment are included if novel or unusual, and a section on injury prevention concludes this article.

INJURIES OF THE PERIPHERAL NERVOUS SYSTEM

Muscle

The broad category of ''muscle strain'' is discussed both for completeness and because ''muscle strain'' injuries of one sort or another make up a large percentage of overall hockey injuries.[1–5,7,8] Muscle strains may occur about the shoulder region but more common are strains about the region of the lower abdomen, upper leg, hip, and pelvis, especially the ''groin strain,'' likely the result of overuse of the hip adductors, which can be a cause of significant lost time from play.[1,7,15] It seems that the incidence of groin strains, abdominal strains, and ''sports hernias'' (with symptoms possibly related to iliohypogastric nerve compression) has increased in professional players in recent years; a history of previous similar injury and a less intense off-season sport-specific training regimen are identified as risk factors for injury occurrence.[15,16]

Peripheral Nerve

In the lower extremity, peroneal nerve lesions are described as resulting from direct blunt trauma or, in one case, laceration of the nerve with a skate blade.[17–19] A single case of a reversible plantar neuropathy was reported in a recreational hockey player, caused by compression from a skate boot fitted with an inflatable lining.[20]

In the upper extremity, axillary neuropathies are described as a result of direct trauma and compression and with shoulder dislocations.[17,21–23]

Plexus and Nerve Root

The so-called ''stinger'' or ''burner'' occurs acutely after trauma to the shoulder region and is associated with pain, numbness, or tingling radiating down one upper limb, sometimes associated with transient weakness, typically recovering over a period of minutes.[17,21,24] This injury is most common in American football but is also reported in hockey.[17,21,24] It is considered to represent upper cervical nerve root injury or transient dysfunction affecting the upper trunk of the brachial plexus.[17,21,24]

Traumatic spinal cord injury is probably the most devastating injury in hockey.[6] Although rare, the risk for catastrophic spinal cord injury is never absent from hockey and the possibility of incurring a sports injury resulting in permanent quadriplegia is a sobering consideration.

The vast majority of spinal cord injuries in hockey occur in the cervical spine region, especially between the C5 and C7 levels.[6,25,26] Collisions with the boards account for most spinal injuries, usually occuring when a player is body checked or pushed from behind into the boards head first.[6,25–29] The risk for catastrophic outcome is greatest if a player's neck is flexed in posture at the time of impact with the boards, a posture greatly increasing the risk for a vertebral burst fracture and associated cervical cord compression.[6,30,31] The sequence of images in the top row of Fig. 1 shows an example of this type of collision: in this case, the player suffered only a concussion with no associated cervical spine injury, likely protected by the slight neck extension apparent before impact.

Data from a Canadian registry suggests an increase in the incidence of hockeyrelated spinal injuries between 1981 and 1996 compared with the preceding 15 years, although this apparent increase may have been related to better diagnosis and reporting.[25] Encouragingly, subsequently reported data from the same registry suggest a decline in the number of spinal injuries in more recent years, especially those causing paralysis resulting from checking from behind.[32]

Another, less serious, spinal cord injury is the so-called ''cervical cord neurapraxia'' or ''transient quadriplegia'' phenomenon, wherein reversible four-extremity weakness and/or sensory loss occurs as a result of transient cord compression.[33–35] In adults, it is most common in individuals who have sagitally narrowed cervical canals;[33] however, cervical stenosis usually is not found in injured children, where the mobility of the pediatric spine is postulated as the most relevant anatomic risk factor.[36] Like the stinger, this injury is most common in American football but also can occur in hockey.[33,36] Recurrence is common in adult athletes who return to contact sports, and the risk for recurrence is correlated with the degree of cervical stenosis.[33–35]

Fig.1. Different mechanisms of injury causing concussion in hockey. (Top row) Deceleration impact as player moving at high speed collides head first into end boards and glass. Mild extension posture of neck before (left) and at impact (middle) affords protection against cervical spine injury. This type of collision with the neck flexed can result in catastrophic cervical spinal cord injury. (Second row) Rotational impact about vertical axis as player's head is struck by opponent's shoulder in open ice collision. (Middle row) Combination of deceleration and rotational impact about vertical and horizontal axes as player moving at high speed is body checked in an open ice collision. The rotational component of impact results from the opponent's shoulder hitting the player's head. (Fourth row) Rotational neck flexion/extension impact (whiplash injury) occurring without direct head contact. Before impact, neck posture is neutral (left). Impact occurs as player is body checked in the chest by opponent's shoulder (middle), resulting in rapid neck flexion (middle) and subsequent extension (right). (Bottom row) Rotational impact about horizontal axis occurs as player is struck under the jaw by an uppercut punch (middle).

Brain

Severe brain injuries, such as epidural or subdural hematomas and fatalities associated with skull fractures, are known to have occurred throughout the history of hockey, and occasional cases are reported in the scientific literature.[6,37–39] Such injuries, however, have become exceedingly rare as a result of the introduction of mandatory helmet use in recent decades.[40,41] There are two case reports describing extraordinary brain injury mortalities triggered by hockey trauma; in the first, a blow to the neck was followed by delayed embolization from a traumatic pseudoaneurysm of the common carotid artery, resulting in fatal cerebral infarction;[42] in the second, a man struck by a puck in the mastoid region just below his helmet suffered a fatal rupture of a vertebral artery berry aneurysm.[43]

In contrast to the few reports of severe sports-related brain injury, mild traumatic brain injury, or concussion, is without doubt the most written about neurologic sports injury of the past decade.[44–73] Most of the published information regarding diagnosis, management, investigations, neuropsychologic testing, return-to-play guidelines, concussive convulsions, second impact syndrome, and recent research into the poorly understood pathophysiology of concussion is not specific to hockey and is not summarized in this article. The high incidence of concussions in modern hockey, however, is now appropriately recognized as an important issue and certain hockey-specific aspects are discussed.

In parallel with increased recognition of sports-related concussions during the past decade, it is suggested that the incidence of concussions in hockey is increasing.[2,74] There are few data, however, validating this claim. A prospective study of Swedish Elite League hockey showed no change in concussion frequency over four seasons from 1988–1989 through 1991–1992.[40] Concussion incidence in a single Swedish Elite League team followed over a period of 17 years, however, suggests an increasing rate of concussion in recent years.[75] A study of reported concussions in professional National Hockey League (NHL) players between 1986–1987 and 2001–2002 found a tripling in the concussion rate around 1997, followed by a subsequent plateau.[76] This abrupt increase in reported concussions in the NHL occurred during a time of increased awareness of sports-related concussions and during the initiation of the NHL Concussion Program, a project developed to monitor the occurrence of concussions and help guide return-to-play decisions.[76,77] Therefore, much of this apparent increase in the NHL concussion rate is likely related to improved recognition and reporting.[62,76] Nonetheless, the high incidence of concussions across all levels of hockey remains cause for concern.

More than 10% of 9- to 17-year-old players sustain a concussion in a given season.[6,41] Different studies report concussion rates of up to 0.8 per 1000 player hours in 5- to14-year-olds, 2.7 per 1000 player hours in high school players, 4.2 per 1000 player hours in university players, and 6.6 per 1000 player hours in elite players.[6,37] The annual risk for concussion in professional players in the Swedish Elite League is approximately 5% per player.[40] Perhaps unexpectedly, recent studies of United States college hockey show female athletes to have a higher game concussion rate (2.72/1000 athlete exposures) than male athletes (1.47/1000 athlete exposures). This female preponderance of concussion could be related to a greater disparity in the abilities of individual female players or to a larger number of unexpected collisions, given that volitional body checking is not permitted.[7,14] Weighted by position, forwards are more likely to suffer concussions than defense players, and goalies are far less likely to suffer concussions than either forward or defense.[7,58] It also must be acknowledged, with respect to all of these published injury rates, that the true incidence of hockey concussions is almost certainly is higher because of under-reporting.[76,78,79]

Biomechanical studies show that concussion may result from either translational (linear) motion of the brain imparted by a direct head impact or from rotational mechanisms, where an impact rotates the brain in a circular motion about some axis.[80,81] Concussion-inducing rotational forces may be imparted to the brain without direct head impact (ie, with whiplash injury).[80–82] Hockey-related concussions may result from any of these mechanisms.[83,84]

A collision of some sort is invariably the cause of a concussion in hockey. Different studies report that 45% to 60% of concussions result from player-player collisions and that 26% to 34% result from collisions of players with the boards or glass. The remainder of concussions are the result of collisions with the ice surface or goal posts or direct impacts from sticks or the puck.[6,7,10] It is reported that fighting (in leagues that permit fighting) is not a common cause of concussion in hockey;[6,58] however, more recent evidence suggests otherwise,[84] and it seems that concussions related to fighting are particularly likely to be under-reported in the NHL (personal observation).

Representative examples of the different mechanisms of injury causing concussions in hockey are presented in Fig. 1, with detailed explanations given in the legend.

PREVENTION

Prevention of head and neck injuries is a paramount concern in hockey. The personal and social costs of chronic spinal cord and brain injury are extensive.[41,85] The absence of effective medical interventions to reverse the effects of spinal cord and mild traumatic brain injury, combined with the potential severity of the former and the great incidence of the latter, make prevention efforts for these two injuries crucial. Injury prevention methods are considered under different headings of equipment, rules, training, education, and environment.[85]

Equipment

The introduction of mandatory helmet use essentially eliminated catastrophic brain injury at all levels of hockey, and the later introduction of mandatory facial protection in youth hockey has virtually eliminated ocular, facial, and dental injuries.[41,86,87] Early concerns that the weight of the helmet and face mask combination might increase the risk for cervical spine injuries[86,88] are not supported by biomechanical studies,[89,90] although a hypothesis that the increased protection afforded to players by helmets and face masks has led to an increase in illegal and injurious behavior is not disproved.[86,88]

There is no available hockey equipment that protects against cervical spine injury. Helmet development and testing is a complex issue not discussed in this article.[89–94] There is a belief, however, that the continued modifications made to helmet designs in recent years have failed to have much, if any, effect on the incidence of concussions in hockey (personal observation). There is not a single study in the scientific literature documenting the efficacy of helmets in prevention of concussion.[85]

The effect of full facial or half facial (visor) protection on concussion incidence is reported by several investigators.[95–100] Neither form of facial protection has decreased concussion incidence; however, decreased severity of concussions in players wearing full-face shields, as reflected by time lost from play, is suggested in some studies.[95,96,99]

The potential for mouth guards to protect against concussions in hockey is also controversial. There is some evidence suggesting that mouthguard usage decreases concussion severity in hockey.[95] Most studies examining the effects of mouthguards, however, fail to demonstrate conclusively decreased incidence or severity of sportsrelated concussion.[101,102]

There is concern that the design of shoulder pads and elbow pads has changed over the years to incorporate harder materials that may increase the risk for concussion in players struck by these pieces of hard protective equipment. The NHL created an injury analysis panel in 2000, which recommended that manufacturers should cover exposed hard plastic surfaces with softer padding.[76]

Rules

Vigorous enforcement of existing rules and the introduction of stiffer penalties to prevent deliberate blows to the head have been advocated and instituted across multiple levels of hockey in recent years.[58,76,103]

There is some evidence that the introduction of new rules and stiffer penalties to eliminate checking from behind may be starting to have a beneficial effect on reduction of the number of catastrophic cervical cord injuries.[32,41]

Because of clear evidence of an increased incidence of concussion in youth minor hockey leagues that permit body checking,[5,6,11,12] recommendations have arisen from within the medical community for the further restriction of body checking in youth hockey.[104]

Training

It is suggested that sport-specific training programs might be able to limit the risk for concussion or spinal cord injury through neck strengthening or the improvement of avoidance skills.[85,105] The potential benefit of such training, however, has not been addressed formally.[85]

Education

There is some recent evidence that educational programs of various sorts may be beneficial in reducing the incidence of spinal cord injury and concussion by reducing players' tendencies to injurious behavior and by increasing their knowledge of personal safety.[106,107]

Environment

Given that most head and neck injuries are caused by collisions, changes in the playing environment that would decrease the frequency of collisions, or lessen the force of impact, could provide direct prevention against spinal cord injury and concussion. Fewer collisions of all sorts, including head impacts, occur in elite hockey played on the larger international ice surfaces, compared with the smaller NHL rinks.[108,109] Therefore, enlarging the playing surface could presumably decrease the incidence of concussions. The same effect of reduced collisions would presumably also accrue from reducing the number of players on the ice, for example, switching to four-on-four play, although this would alter the nature of the game significantly.[108]

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Text from the Al Purdy poem, Hockey Players, (courtesy of Harbour Publishing, Madeira Park, BC, Canada; with permission).

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