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INJURIES, PROTECTIVE EQUIPMENT AND STANDARDS IN ICE HOCKEY

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ABSTRACT

The mechanisms of typical hockey injuries to the head and cervical spine suggest various risk reduction strategies, including education and training, rule revisions, increased consistency in the enforcement of existing rules, and the development and acceptance of properly-conceived headgear design and manufacturing standards. This article reviews

the literature regarding neck and brain injuries with a particular focus on the risks presented by ice hockey. It addresses various risk reduction techniques and strategies including the adoption of universally-accepted headgear standards.

KEYWORDS: hockey, safety, neck, brain, helmet

Hockey is a contact sport which exposes players to serious risks, including potentially paralytic or fatal injuries to the brain and cervical spine. This paper will address the ways in which these risks can be mitigated by (I) education and training regarding injury-avoidance techniques; (II) consistent rule enforcement and appropriate management of injuries; (III) properly-designed protective equipment; and (IV) universally-accepted ice hockey equipment standards.

I. The Mechanisms of Neck and Head Injury and Limitations on Protection Available from Hockey Helmets

On October 20, 1995, just eleven seconds into his first university-level hockey game, Travis Roy, then a freshman at Boston University, crashed head first into the end boards, striking the top of his helmet. In an instant, he was paralyzed for life. Although Mr. Roy's injury may not have been preventable, an understanding of the mechanisms of typical hockey injuries to the head and cervical spine provides a basis for developing risk reduction strategies.

A. Injuries to the Neck and Cervical Spine

Hockey helmets are not designed to prevent cervical dislocation or fracture, either of which can result in spinal cord injury and possible paralysis. Proper instruction and training, however, can educate players and coaches about the risk of such catastrophic injury and the importance of avoiding the most dangerous types of blows -- those to the crown of the helmet while the player's head is in a lowered position.[14]

Serious spinal neck damage can occur from flexion (bending the neck forward), extension (bending the neck backward) injuries, and combined flexion-rotation injuries, but the principal mechanism of cervical fracture associated with paraplegia and quadriplegia in football and hockey players is a compression or burst fracture caused by vertical loading from a blow to the top of the head with the neck flexed.[4] In a "heads up" position, the normal lordotic curve of the cervical spine protects the neck by causing the force of an impact to the crown of the head to be transferred to and absorbed by the cervical muscles.[4] By contrast, with the head lowered, the cervical spine's natural lordosis is straightened, the vertebrae are aligned as in a segmented column, and the force of a blow to the same area is transmitted straight down the spine with little dissipation by the surrounding tissue. A compression fracture results where the blow is sufficiently forceful, and, if the vertebral body bursts or dislocates into the spinal cord, paralysis or quadriplegia may result.[4]

Although most cervical spine injuries are accompanied by head trauma, these injuries can occur independently and without the head sustaining any observable traumatic impact.[4] For example, flexion injuries can be caused by abrupt deceleration like that occurring from a forceful frontal body check delivered when two players skating in opposite directions collide. Similarly, an extension injury can occur in sudden acceleration, as when a player is checked forcefully and unexpectedly from the rear. Rotation injuries are associated with forces which cause the head to rotate suddenly on the neck.

Cervical fractures associated with these types of injuries occur relatively infrequently but always present a grave risk of permanent, catastrophic and potentially fatal injury. One study found that head and neck injuries accounted for 10.6% of all ice hockey injuries to participants in Canadian interuniversity games between 1979 and 1985.[17] Although the incidence of such injuries appears to have

risen from 1966, when only one major cervical injury was reported in Canadian ice hockey, to 1992, when 22 such injuries were reported, current data suggest a slight reduction in the rate of these injuries.[21] In youth hockey, where intentional body contact is prohibited, injury rates are low, but injuries increase with the allowance of more aggressive play and with the age (and size) of the players.[20]

B. Injuries to the Head and Brain

In addition to cervical neck injuries, a blow that involves a sudden accelerative force to the head may cause injuries ranging from a concussion to more severe brain injury. A hockey helmet cannot prevent all acceleration or any rotation of the brain within the skull. The extent and duration of head injuries which do occur, however, can be reduced by appropriately conservative management of suspected injuries.

Skull and brain injuries may be caused in a number of ways with differing relationships between the site of impact and the site of an associated brain injury. A forceful impact to an immobile but movable head usually results in a principal injury site at the point of cranial impact and is known as a *coup* injury. When a moving head suddenly decelerates, as when it hits a fixed object, the most serious injury usually is found on the opposite side of the brain from the external impact site. This type of injury is known as a *contrecoup* injury. An exception to these principles occurs where there is a skull fracture and the displaced (either transiently or permanently) skull bone injures brain tissue directly.[4]

These types of injuries can produce symptoms of concussion and sometimes postconcussion syndrome. The definition of concussion cited by Cantu as generally accepted is that proposed by the Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons: "a clinical syndrome characterized by immediate and transient post-traumatic impairment of neural function, such as

alteration of consciousness, disturbance of vision, equilibrium, etc., due to brain stem involvement."[4, 7] The American Academy of Neurology has recently developed a protocol for managing concussions in athletes which classifies concussions as follows:

Grade 1: no loss of consciousness, with symptoms lasting less than 15 minutes

Grade 2: no loss of consciousness, with symptoms lasting more than 15 minutes

Grade 3: any loss of consciousness [10]

The treatment protocols associated with these clinical symptoms are discussed in the following section relating to management of head injuries.

The principal cause of serious injury or death from brain injuries is intracranial hemorrhage, of which there are four main types: epidural, subdural, intracerebral and subarachnoid.[4] All of these conditions are potentially fatal, making quick and accurate diagnosis, treatment and follow-up critically important.

Epidural, or extradural hematoma results from a tear in the artery which supplies the brain's dura (covering) and allows blood to accumulate, often quite rapidly, inside the skull but outside the brain covering. If accurately diagnosed and promptly treated with surgery, full recovery is generally possible since the brain itself is usually free from direct injury. If this lesion is missed clinically, however, it is rapidly and universally fatal.[4]

Subdural hematoma, as its name suggests, is a hemorrhage occurring between the brain surface and the dura. Injury to the brain tissue is often involved, and Cantu identifies this as the "most common fatal athletic head injury." Although a rapidly progressing subdural hematoma, which is frequently fatal (usually because of associated brain injury not caused by the hematoma itself), produces loss of consciousness and obvious signs of acute

distress, the more slowly progressing and/or chronic subdural hematoma can be both more difficult to diagnose but also more effectively treated if properly identified.[4]

Head trauma sustained in hockey or other contact sports can also cause intracerebral and subarachnoid hemorrhages. The former involves bleeding into the brain tissue itself, usually caused by a torn artery or a congenital vascular lesion. Subarachnoid hemorrhage is confined to the surface of the brain, is similar to a bruise involving tiny surface brain vessels and does not usually require surgery. Whether or not, in a particular case, either of these types resulted from the rupture of a congenital (usually undiagnosed) lesion such as an aneurysm or arteriovenous malformation may only be determinable upon a complete autopsy, which potentially may demonstrate that any impact sustained was largely incidental to the end result.[4]

Second Impact Syndrome ("SIS") denotes a condition involving rapid brain swelling following a second (often very mild) impact, a condition which Cantu describes as "more common than previous reports in the medical literature have suggested."[4] It occurs most often after a concussion when the athlete sustains a second impact to the head before the symptoms from the initial concussion have fully resolved.[5] The latter paper reviews six cases of SIS fatalities, one involving hockey and five involving boxing injuries. In all cases, either surgery or autopsy revealed massive edema which produced greatly increased intracranial pressure and resulting brain stem collapse. They also all involved apparently relatively minor head trauma in the "second" and fatal impacts. Cantu warns that the second impact may be potentially fatal without even involving a direct impact to the head, as, for example, where a body blow snaps the head or neck and imparts accelerative forces to the brain. The etiology of this syndrome is described as a disruption of the brain's blood autoregulatory system with vascular engorgement leading to marked increases in intracranial pressure, and it

usually results in brain stem failure within two to five minutes after the second impact.[5] The implications of SIS for the treatment and management of head injuries is discussed more fully in the following section.

II. Coaches and Referees: The Role of Education and Training in Avoiding Brain and Spinal Injury

Although the mechanism of injury is different for injuries to the cervical spine than for brain injuries, the most obvious and best advice to players regarding the avoidance of brain and spinal injury is to avoid blows to their helmet or head. A practical approach, however, must recognize that such blows are an inherent part of hockey and seek to mitigate, to the extent possible, the risk of serious or catastrophic injury from them. The following discussion addresses the vital role coaches and referees can play in reducing the risk of brain and cervical spine injury through education -- regarding both risk-avoidance techniques as well as appropriate management of injuries which may occur -- and strict rule enforcement.

Despite the use of protective equipment, head and neck injuries occur. The critical significance of head position in increasing the risk of compression fractures of the cervical vertebrae underscores the vital preventive role of education and training regarding the mechanism of such injuries (as discussed above) and the importance of "heads up" play. Players should be drilled in avoiding lowering the head before head first contact with other players or the boards, and players, coaches and officials should be educated about the potentially catastrophic injuries that can result from illegal checking purposely designed to send opponents crashing head first into the boards.

In addition to teaching players to avoid head first collisions with their head lowered, the apparent increase in violence in ice hockey at all levels of play must also be addressed.[3, 24] The results of one study involving rules which

reward penalty-free play suggests that stricter enforcement of existing rules and modification of rules to more effectively discourage injury-inducing play could significantly reduce the rate of ice hockey injuries, including head and neck injuries.[20] The study involved a community-organized three-day tournament of high-school aged teams, with the qualifying round of games being played under "fair-play" rules and the championship round being played under regular rules. Under the fair-play rules extra points were awarded for completing a game with less than six penalties and points were subtracted from teams assessed more than twelve penalties.[20] Individual players with more than five penalties in a game were suspended from play for one game.[20]

The number and rate of penalties, as well as the rate of injury, were strikingly higher during play under the regular rules than they were in the fair-play games.[20] In commenting on their results, the authors observed, in particular, that checking from behind is associated with a greatly enhanced risk of injury, is "of grave concern" to ice hockey administrative bodies, should be more consistently penalized, and perhaps should be elevated to a game misconduct penalty.[20]

In addition to measures which might reduce the frequency and gravity of neck and head injuries in ice hockey, attention should also be given to assuring the availability of prompt and appropriate treatment when serious injuries do occur. The on-field evaluation of a possible cervical injury is the critically important first step in this treatment. It is estimated that 50% of all neurological deficits are caused in the course of events following the initial traumatic insult.[25]

An unstable fracture and potentially permanently paralyzing neck injury should be assumed following any impact which leaves the athlete unconscious, or, if awake, with numbness, neurological deficits, or neck pain.[25] The athlete's head and neck should be

moved as little as possible. Appropriate airway management techniques should be employed, and the helmet should not be removed although the mask may be cut away if necessary for airway access. The presence of a carotid pulse should be confirmed, and chest compressions should be started if necessary. After checking for respiratory and circulatory impairments, a motor and sensory assessment and a mental status exam should be performed to evaluate any disabilities. Unless a serious neck injury can be ruled out, a cervical collar and backboard should be used to immobilize the spine before moving the athlete to the sideline or to a medical facility. [25]

In the case of head injuries without associated neck or neurologic symptoms, the player's mental alertness, orientation, memory, attention span and ability to calculate should be assessed. If mental function seems normal, including the absence of any amnesia, and if there has been no loss of consciousness or complaints of headache, the player can usually return to play 5-15 minutes after any other symptoms have cleared.[1] Any athlete who complains of headache, light-headedness, visual disturbances or other neurologic symptoms should not return to play that day. [5]

The Centers for Disease Control and Prevention have reported that an estimated 300,000 sports-related brain concussions occur each year in the United States.[10] There is some dispute among experts in the field regarding how conservatively concussions should be managed, with the Colorado Medical Society's recommendations reflecting some of the most conservative approaches. For example, the American Academy of Neurology ("AAN") parameters discussed in the previous section would permit a return to play in the case of a second grade 2 or a first grade 3 concussion after the athlete has been asymptomatic for two weeks. The Colorado guidelines recommend that the player be sidelined for a month following the injury even if the symptoms resolved relatively

quickly. Even the less conservative AAN parameters have been criticized by Cantu for treating cases involving a brief loss of consciousness in the most severe category (grade

3) while treating posttraumatic amnesia, which Cantu viewed as possibly involving days of mental dysfunction, as less severe if not accompanied by a loss of consciousness. [10]

Although there is some difference of opinion regarding how long an athlete should be required to remain asymptomatic before being permitted to return to play, it is clear that any athlete who is symptomatic from a head injury should not be permitted to participate in any contact sports or other activities which involve a risk of even minor forces being exerted on the athlete's head.[4] The earlier-cited case review by Cantu indicates the importance of careful and thorough clinical evaluations in which the athlete and any coaches involved are made aware of the potentially fatal consequences of risking a second impact. Several of the cases appeared to involve players and coaches who denied the existence of continuing, albeit seemingly minor, symptoms.[5]

The severity of the symptoms usually make the need for neurosurgical evaluation obvious in conditions like a rapidly progressing subdural hematoma where the athlete usually does not regain consciousness. In such cases the immediate need for a high level of medical intervention and extreme caution in permitting *any* return to contact sports is readily apparent and undisputed. As the above discussion indicates, however, the head injuries which produce distinctly observable but less dramatic symptoms also require careful evaluation and educated management. This is particularly true with the dangers presented by second impact syndrome where, as noted above, a relatively minor subsequent impact can be quickly and irreversibly fatal.

III. The Role of Protective Helmets in Ice

Hockey

Protective headgear in contact sports such as ice hockey serves many purposes. The primary function of a helmet is to spread the impact forces over a wide area and provide some measure of energy attenuation. The typical helmet accomplishes this by employing a rigid outer shell and an internal flexible liner to suspend the outer shell away from the wearer's head. The helmet typically also provides a smooth surface which helps minimize injury by deflecting somewhat direct impacts that might result in high accelerations into glancing blows that result in much lower accelerations. Helmets also provide a convenient means to mount various types of facial protectors resulting in an integrated headgear that covers much of the head and facial area of the wearer.

Helmet use in contact sports has been very effective in reducing the incidence of laceration, abrasion and surface contusion to the area of the wearer's head that is covered by the headgear. The implementation of full coverage face protectors in Ice Hockey has greatly reduced eye injury and significantly reduced risk of dental and facial injuries to those players who wear full face protection as part of their headgear. [6, 16] Modern helmets that include a rigid shell and resilient liner provide effective protection from skull fracture. [23]

Helmets do not offer any protection from non-head impact injuries induced via rotation of the head about any axis of rotation. Helmets provide little or no effective protection from rotationally induced injury that involves direct head impact, managing only very small amounts of input energy (depending on impact vector) and thus are unable to prevent rotational head injury. [12] Helmets offer no protection to the cervical spine, [2] but helmet design considerations must include evaluation as to the potential risk of increasing the danger of cervical injury. [23]

Protective headgear has been cited as an enabling cause for the increasingly aggressive style of play.[22] It may be that helmets can lead to more aggressive play. Given the considerable injury and death reductions attributable to headgear, the appropriate remedy, however, lies not with the helmet but in significant rule changes, officiating to enforce those rules, and proper education/coaching such as the "heads up" program.[22]

IV. The Potential Benefits of Proper Helmet Standards

The benefits society reaps from good standards are well known and documented.[8, 13] Hockey headgear is covered by several standards depending on whether it is the facial protective portion, the helmet portion, or a combination such as for the goalie. This picture is further complicated by the country in which the products are produced and/or used. In addition there are several bodies that may pass judgment on the protective product including HECC (Hockey Equipment Certification Council), CSA (Canadian Standards Association) and CE (European Community).

Standards have been written by CSA, ASTM (American Society for Testing and Materials), ISO (International Standards Organization), SIA (Swedish Ice Hockey Association), and CE. Although these standards are similar, a review of them reveals significant differences.

Only the ASTM standard requires the helmet to sustain impact at elevated temperatures. This is significant, as hockey helmet performance typically deteriorates with temperature increases; yet the higher temperature is a reality of the game.[9, 11] The ASTM test protocol, however, falls short in that the impact test surface is somewhat soft.[15] The SIA and ISO standards require low headgear weight even though it has been documented that such concern is unfounded in the realm of modern headgear.[18, 19] This

mass limit is often at the expense of impact attenuation limits. Although harmonization is urged, more aggressive

performance standards should be considered in light of the current evidence that a somewhat heavier helmet does not pose a hazard.

Hockey helmet standards, in general, require remarkably little from the helmet in the way of impact management.[11] In addition, for products sold in the litigious environment of the US market the final decision regarding the required standards may be made, not by those who volunteer their time to create standards, but by a panel of 12, most likely inexperienced, laymen sitting as jurors in a civil action brought by or on behalf of someone injured while wearing a particular helmet. It is anticipated the decision will be that the most demanding requirements from competing standards-setting documents be combined and the product judged against them all. It is, therefore, urged that those involved in the standards process put aside any parochial issues that may exist and strive to improve the performance of the equipment used by our children and athletes. It can not be overemphasized that the actions of regulating bodies and coaching/educational efforts are likely to have a greater positive impact on injuries at this time than any other effort we could undertake.

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