A Review of Cervical Spine Injury Mechanisms in Athletics

From Management of Potentially Catastrophic Injuries in Athletics

By Michael J. Cendoma, MS, ATC
Director, Sports Medicine Concepts, Inc.

Introduction

Even with today's understanding of the mechanisms that lead to spinal cord injury in athletics, some are still inclined to present these injuries as "freak" accidents1,2. The physics and mechanics of injury to the cervical spine are well understood, investigated, and documented. There is nothing "freaky" about these injuries. Athletes who place themselves in positions known to be associated with spinal cord injury run a higher risk of spinal cord injury and paralysis. Sports health care professionals with an interest in reducing the incidence of spinal cord injuries must not only understand mechanism of injury to the point of being able to recognize them on-field, but also be able to demonstrate that in the majority of cases it is an athlete's decision to place him/herself in a compromising position that leads to injury. Covering these injuries with the "freak" or "unfortunate" accident blanket only minimizes the athlete's role and allows others to play under the false pretense that these injuries are total random occurrences.

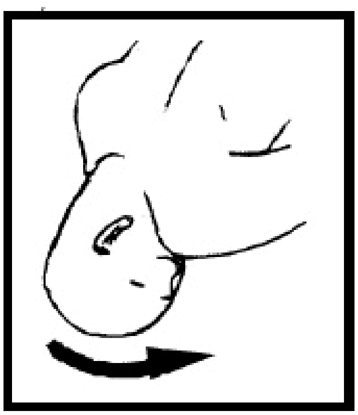

Figure 13. Flexion is often associated with rotation. The combination of the two is much more dangerous than any one individually.

Early theories implicating the helmet as a liability in catastrophic spinal cord injuries in football have not survived scientific scrutiny. These involved the face mask acting as a lever by encouraging flexion of the neck and the posterior rim of the helmet acting as a guillotine" 9. The majority of cervical spine injuries associated with athletics can be attributed to hyperflexion, hyperextension, excessive lateral bending, rotation, compression, or any combination of these movements.

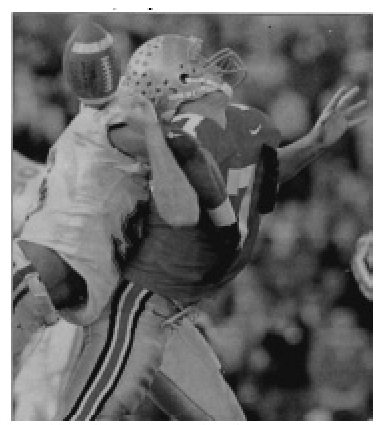

Figure 14. Hyperextension is a mechanism not often associated with injury to the spinal cord in athletics. However, the risk of severe injury does exist.

.Consideration of the mechanism of injury is an important first step in the on-field assessment of any athletic injury; however, perhaps in no other injury situation is initial determination of the mechanism of injury as vital. An athlete having suffered a significant spinal cord injury may not immediately present with emergent signs and symptoms. Mechanism of injury alone should indicate to the sports medicine team that the most conservative measures are indicated. As will be detailed later, "the most conservative measures" does not mean immediate transfer. Rather, it means that the sports medicine team should make a very thorough assessment of the injury situation regardless of a lack of any other significant signs or symptoms. This approach may uncover subtle signs and symptoms that otherwise could go undetected.

Soft-tissues surrounding the vertebral column play an important role in protecting the spinal cord and related structures from excessive movements. Muscle tone at the time of injury can have a major impact on the force required to produce spinal cord damage while ligamentous tissue provides stability throughout the vertebral column; in general ligaments and soft-tissue are most vulnerable to injury from rotational forces.

Hyperflexion and Hyperextension Injuries

The atlantooccipital joint permits 10° of flexion and 25° of extension. The atlantoaxial joint provides approximately 15° of flexion and extension. The remaining flexion and extension of the cervical region comes from the vertebral segments below. Overall, range of motion throughout the cervical region is greater in young adults than in older adults 7.

Hyperflexion injuries usually involve instability due to disruption of the supportive posterior longitudinal ligament. Often hyperflexion injuries are accompanied by some degree of rotation. Injuries involving a combination of hyperflexion and rotation can be exceptionally dangerous because the rotational forces more easily result in dislocation when combined with a hyperflexion component that disrupts the integrity of the supportive soft-tissues (Figure 13). Injuries involving hyperflexion and rotation frequently involve C5-C6 in the cervical region but may also involve T12-L1 segments.

Hyperflexion may also result in the lamina of a superior vertebra and the posterior aspect of an adjacent vertebra come together causing a rapid decrease in the diameter of the canal, compressing the spinal cord. This mechanism is frequently referred to as the “Pincers’ mechanism” 10.

Most spinal cord injuries resulting from hyperextension involve a fall. However, in athletics a common mechanism of injury involving hyperextension is whiplash. (Figure 14). These injuries frequently involve the anterior longitudinal ligament rather than the spinal cord. However, violent hyperextension may result in the posterior inferior aspect of a vertebral body comes together with the anterior-superior aspect of the lamina of an adjacent vertebra 10. This result in a pincer mechanism as the spinal cord is compressed and neurological signs and symptoms prevail.

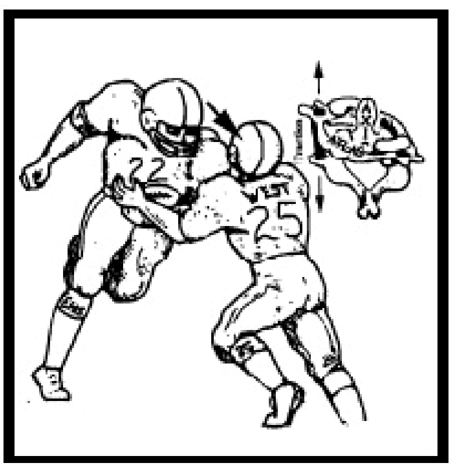

Figure 15. Excessive tractional forces places tractional forces on peripheral nerves as well important blood vessels.

Lateral Bending

Excessive lateral bending can place tractional or compressive forces on spinal nerve roots, peripheral nerves, and circulatory tissues (Figure 15). The meningeal outcropping (dorsal root sheath) that follows the ventral and dorsal nerve roots through the meningeal sheath helps resist lateral traction injury to the spinal cord and nerve roots as its cone shape becomes wedged within the sheath when greater tension is applied along the nerve roots. The connective tissue of peripheral nerves helps protect them from injury, but they are still susceptible to injuries resulting from excessive tractional forces. Recall that peripheral nerves are tethered to the periosteum of transverse processes by the perineurium. Tractional forces applied along a nerve are absorbed through taking up slack along the nerve, much like pulling on a loose rubber band. As the elastic limits of the nerve’s connective tissues are exceeded, disruption of neurological structures ensues. Neuropraxia, such as in a “burner” or “stinger”, is a prime example of a neurological injury resulting from excessive tractional forces applied to peripheral nerves. These injuries can also occur as a result of contralateral compression forces secondary to hyperextension and contralateral approximation of the head and shoulder.

Rotation
Lateral bending in the cervical region is necessarily accompanied by some degree of rotation due to the oblique orientation of the superior and inferior facets. During right rotation of the atlas on axis, the left transverse foramen of the atlas moves anteriorly while the right transverse foramen moves posteriorly relative to those of the subjacent axis. With excessive rotation, the increased distance between adjacent transverse foramen results in increased tensile forces applied to the vertebral artery and spinal nerves. Thus, brainstem and upper cord circulation can be affected in addition to resulting neuropraxia.

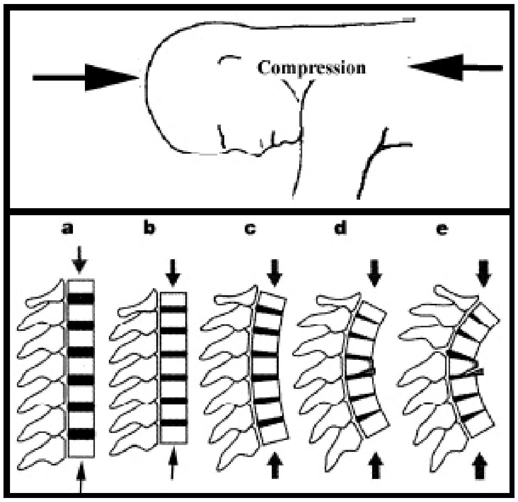

Figure 16. A) Lowering of the head takes away the absorptive properties of the cervical soft-tissue; b) contact made with the head lowered causes compression of the cervical segments; c) compressive energy is transferred to the segment as strain energy; d) failure occurs; e) further strain causes a large angulation that results in displacement of the fracture and instability.

Axial Loading
Fractures resulting from pure vertical compression generally involve C5-C6 or T12-L1 and tend to be the most stable fractures 5. Generally, it is necessary for an injury mechanism to include a rotational component to produce dislocation 6. Axial loading is quite similar to pure vertical compression as it does not involve a rotational component; yet, these injuries are associated with the greatest instability. In athletics, the mechanism that has received the most attention is that of axial loading (Figure 16 and Figure 17). Only 13% of the 209 football related injuries resulting in permanent cervical quadriplegia between 1971 and 1975 resulted from hyperflexion (10%) and hyperextension (3%), while 52% were attributed to axial loading 8. The most disturbing aspect of the axial loading mechanism is that often these injuries are avoidable. Too frquently, these injuries are brought about by a conscious effort to use the crown of the head as the initial point of contact. Proper technique and adherence to rule changes initiated as a result of the clinical findings relating spearing to SCI could have prevented many of the SCI in football. Still, it appears that spearing is as prevalent now as it was prior to rule changes and equipment improvements resulting from these significant clinical findings 6.

Cervical flexion resulting from lowering of the head results in a straight segmented vertebral column (Figure 16a). The normal lordodic curve disappears, taking with it the normal energy absorbing elastic component of this region that allows energy to be absorbed and dissipated through soft-tissue deformation and bending. When contact is made with the top of the head and the vertebral column is in the straight segmented position, kinetic energy is transferred to the vertebral column as strain energy (Figure 16 b, c). When strain energy exceeds the absorbing capabilities of the column, the result is failure in the form of intervertebral disk space injury, vertebral body fracture, disruption of ligamentous and other soft-tissues, or posterior element fracture 8 (Figure 16d). The location at which vertebral failure has occurred becomes the most unstable area in the column. Size and shape of vertebral bodies and disks, elastic capabilities of ligaments, and muscular preload influence where and to what extent failure will occur.

To this point, the physical characteristics of pure vertical compression and axial loading injuries are somewhat similar. However, with axial loading further compressive forces result in buckling at the most unstable segment of the column. This buckling produces a large angulation or hyperflexion as a means of releasing the additional strain energy. Hyperflexion at the failed vertebral level produces dislocation of the unstable segment, resulting in major neurological damage 8 (Figure 16e).

Compressive load limits of the cervical vertebrae have been calculated to be between 3,340 and 4,450 nt (750-1,000 lb). These limits are easily reached when the head is lowered and used as the initial point of contact. In fact, these limits can be reached with an impact velocity of 2.3 m/sec or the equivalent of a fast walk 8.

Dislocations and Subluxation
As previously stated, vertebral components are particularly vulnerable to dislocation or subluxation when the mechanism of injury involves rotation. A dislocation or subluxation typically results in the vertebrae becoming maligned due to significant trauma to the head or neck. In some cases the vertebrae may become locked on top of one another. These types of injuries cause intrusion of bone into the vertebral canal. Accompanying muscle and ligament damage may contribute to instability and, in themselves, compromise the vascular structures of the cord.

Pressure Gradient Injuries
Permanent cord damage can occur even if osseous- and soft-tissues remain intact. Normal range of motion of the head and neck results in both cord and canal diameter changes. Imagine the dural sac as a water filled balloon. As the balloon is bent or squeezed at the midsection, the diameter of the balloon at the site of the squeezing diminishes as water inside the balloon flows away from the site of increased pressure. As the water collects on either side of the restricted area, the balloon distends as increased water volume applies greater stress to the walls of the balloon.

Normal cervical motions apply standard pressure changes to the spinal cord that do not result in injury; but, when the neck is subjected to extreme ranges of motion at high speeds, excessive pressure is applied to neural tissues. If this stress exceeds the resiliency of the neural tissue, these structures may be compromised, much like an excessive or rapid squeeze of a water balloon may cause the balloon to rupture. Within the spinal canal these types of movements may also cause the smooth muscle controlling the vascular system to spasm, further compromising neurological function by disrupting blood flow to neural tissue.

Vertebral Fractures
A significant force transmitted through the vertebral column may cause one of the vertebrae to fracture. The different mechanisms of injury result in various types of fractures, all of which are of great concern to the sports medicine team because of the potential damage that may be inflicted on the neural tissue.

Vertebral fractures result in significant neural tissue damage when they are unstable and become displaced. The most apparent potential result of a vertebral fracture is the severing of the cord resulting in instant and readily observable neurological complications. Very rarely will any fracture within the vertebral column cause cutting or severing of neural tissue. Rather, the fracture penetrates the vertebral canal resulting in the initiation of mechanical, biochemical, and hemodynamic changes that lead to neurological complications.

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Cervical Spine Injury

1. It is particularly important to determine the mechanism of injury in a conscious and alert athlete who has potentially suffered injury to the spinal cord as.

A Mechanism of injury, alone, indicates the need for immediate transfer of the athlete.
B An athlete having suffered a significant SCI may not immediately present w/emergent signs & symptoms.
C Mechanism of injury, alone, should indicate the sports medicine team take the most conservative steps.
D Both B and C are correct

2. In educating athletes about the risks of SCI, it is important to ensure that they understand.

A That these are freak accidents that rarely occur, the risk is minimal, & that participation in sports is safe
B That the risk is minimal and sports participation is safe, but that athletes who use their head to make contact dramatically increases their risk of serious injury
C That rules regarding spearing have been implemented to protect them more that the athlete they hit.
D Both B and C are correct

3. Though injury to the cervical spine rarely results from hyperextension in athletics, a possible mechanism involving hyperextension may involve?

A. whiplash
B lateral bending
C Rotation
D Axial loading

4. Which of the following is susceptible to injury from hyperflexion?

A Anterior longitudinal lig
B Posterior longitudinal lig
C Subclavian lig
D Sternocleidomastoid

5. Injury to the spinal cord resulting from approximation of the posterior inferior aspect of adjacent vertebrae describes which of the following injury mechanisms?

A Axial loading
B Pressure gradient
C Pincer
D Compression

6 Injuries involving a combination of ___________ and __________can are exceptionally dangerous because these forces can more easily result in dislocation following disruption of supportive soft-tissue structures.

A Rotation and hyperextension
B Lateral bending and extension
C Flexion and Rotation
D Axial loading and compression

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