



Cervical Spine and Brachial Plexus Injuries

Return-to-Play Recommendations

Joseph S. Torg, MD

Julie A. Ramsey-Errhein, MEd, ATC

In brief

Great care is required in managing cervical spine and brachial plexus injuries. Athletes who suffer one or more burners (transient brachial plexus injuries) may return to contact activity when they are asymptomatic and neurologically normal and have full cervical motion. A vertebra displaced horizontally more than 3.5 mm or rotated more than 11° is an absolute contraindication to contact sports. Cervical cord neurapraxia is generally benign, but patients should be counseled about the probability of recurrence, depending on the spinal canal/vertebral body ratio. Unresolved spear tackler's spine is an absolute contraindication to collision sports, as are axial-load teardrop fracture and cervical spine fusion of more than three levels. Spinal cord resuscitation can include blood pressure maintenance and timely methylprednisolone.

All athletic injuries require careful attention, but evaluation and management of injuries involving the cervical spine and brachial plexus require particular caution. Possible nervous system involvement creates a high-risk situation with little room for error, particularly in athletes playing

continued



For CME credit, see page 107

Dr Torg is a professor of orthopedic surgery at Allegheny University for Health Sciences in Philadelphia; Ms Ramsey-Errhein is head athletic trainer at Dickinson College in Carlisle, Pennsylvania. Dr Torg is an editorial board member of THE PHYSICIAN AND SPORTSMEDICINE.

Illustrations: Mary Albery-Noyes

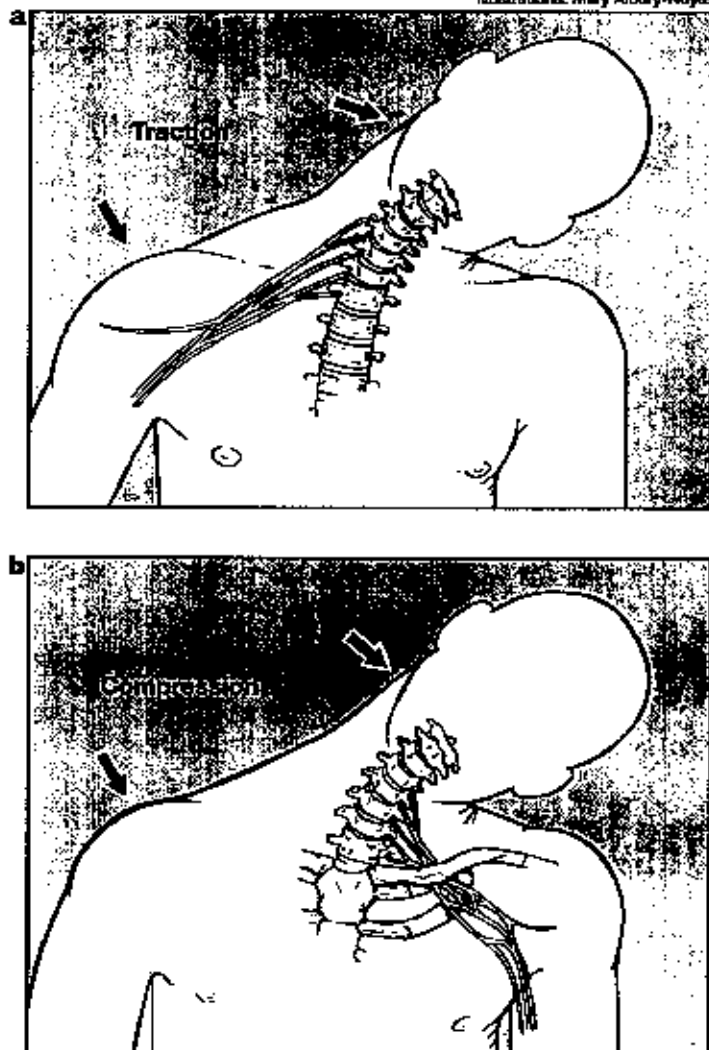


Figure 1. Acute brachial plexus injuries (burners) are typically traction neurapraxias (a) that occur when a blow to the head causes shoulder depression and lateral neck flexion away from the side of the blow. Lateral flexion of the neck may also compress the nerve roots in the intervertebral foramina (b), causing a burner on the side opposite the blow.

recognized injury mechanisms,⁴ and the authors' experience. The more common cervical spine conditions are discussed below, and a more complete list of conditions, classified by return-to-play recommendations, is presented in table 1.

Diagnostic Considerations

Most serious injuries to the cervical spine result from axial loading, as in spear tacking in football. Fortunately, few athletes have more than transient neurologic episodes, and even fewer incur permanent paralysis.

An athlete with a significant injury will usually have a slight torticollis (wry neck posture), limitation of cervical motion, and, if the condition is chronic, atrophy or decreased cervical paravertebral muscle bulk. A patient with torticollis, decreased range of cervical motion, and cervical muscle atrophy requires a complete neurologic examination and a radiographic study, including anteroposterior (AP), lateral, oblique, open-mouth, and lateral flexion and extension views. If the findings persist or if the patient presents acutely with neurologic signs and symptoms, a magnetic resonance imaging (MRI) study should also be performed.

Brachial Plexus and Nerve Root Neurapraxia

Acute, transient brachial plexus injuries, often called burners, are typically traction neurapraxias occurring in younger athletes as a result of shoulder depression and lateral neck deviation away from the side of injury (figure 1).⁵ Chronic recurrent root neurapraxia, typically occurring in older players, results from compression of the nerve root in the intervertebral foramina secondary to hyperextension and ipsilateral deviation of the head and neck.⁶ Frequently the symptoms can be reproduced by Spurling's maneuver (figure 2). Nerve root neurapraxia is characteristically associated with foraminal stenosis (figure 3) and/or degenerative disk changes (figure 4), often in combination with developmental cervical stenosis.

Athletes who experience one or more burners should wear a cowboy collar (figure 5) to prevent extreme hyperextension and lateral bending of the cervical spine and should undertake a year-round neck and shoulder strengthening program. They may return to collision activities when they are asymptomatic, have normal strength, are neurologically normal, and have a full range of painless cervical motion.

continued

Figures 2-7, 9, 10, 12: Courtesy of Joseph S. Torg, MD



Figure 2. Spurling's maneuver is performed by passively forcing the subject's head and cervical spine into extension and lateral deviation toward the symptomatic side. In a patient who has chronic recurrent brachial plexus injuries (burners), symptoms may be reproduced as a nerve root is compressed in the intervertebral foramen.



Figure 3. An axial MRI of an athlete with chronic burner syndrome demonstrates narrowing of the intervertebral foramina (arrows) with decreased space for the nerve root at the C4-5 level. These changes are due to degenerative disk disease.



Figure 4. A sagittal MRI scan of an athlete with chronic burner syndrome demonstrates disk bulges at C3-4 and C4-5 (arrows) and a disk herniation at C5-6 (arrowhead) indenting the spinal cord.

Recurrent burners do not increase the risk of a more serious neck injury.

Strains, Sprains, and Disk Injuries

Mild injuries to the ligaments, paravertebral muscles, and intervertebral disk are rarely associated with neurologic signs and symptoms. An injured player will initially complain of neck pain and have limited range of cervical motion. After appropriate treatment, these individuals may return to activity when they are asymptomatic, have normal muscle strength, and have a full range of pain-free cervical motion.

In individuals with injuries involving minor ligamentous laxity, the situation is less clear. Albright et al⁷ showed that 10% of freshman football recruits at the University of Iowa demonstrated "abnormal motion." This finding is consistent with our experience and suggests that some high school and college football players may have minor laxity without apparent adverse effects. The degree of acceptable instability or laxity is, of course, the question.

Though no available research sets the upper limits of instability clearly enough for clinical use, the work of White et al⁸ is helpful. Using lateral radiographs, they clearly demonstrated that a vertebra displaced horizontally more than 3.5 mm or rotated more than 11° relative to an adjacent vertebra represents spinal instability—certainly an absolute contraindication to further participation in collision activities. Less vertebral displacement or rotation can be considered a relative contraindication, depending on the athlete's level of performance, physical habitus, playing position, and results of imaging studies to rule out disk disease or occult fractures (figure 6). An experienced sports medicine orthopedist should be consulted to assist in deciding if participation is safe.

Acute cervical disk disease associated with limited cervical motion and/or neurologic signs and symptoms is an absolute contraindication. However, chronic degenerative disk changes (figure 7) in individuals who are neurologically normal and have full muscle strength and range of cervical motion are a relative contraindication.

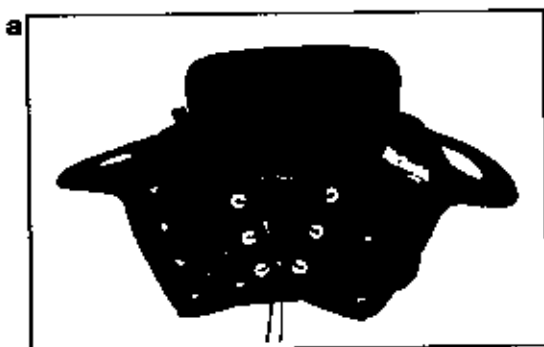


Figure 5. Frontal (a) and lateral (b) views of the cowboy collar. This device is worn under the shoulder pads and limits the extremes of extension and lateral bending of the cervical spine. The cowboy collar is believed to prevent burners more effectively than the traditional horse collar.

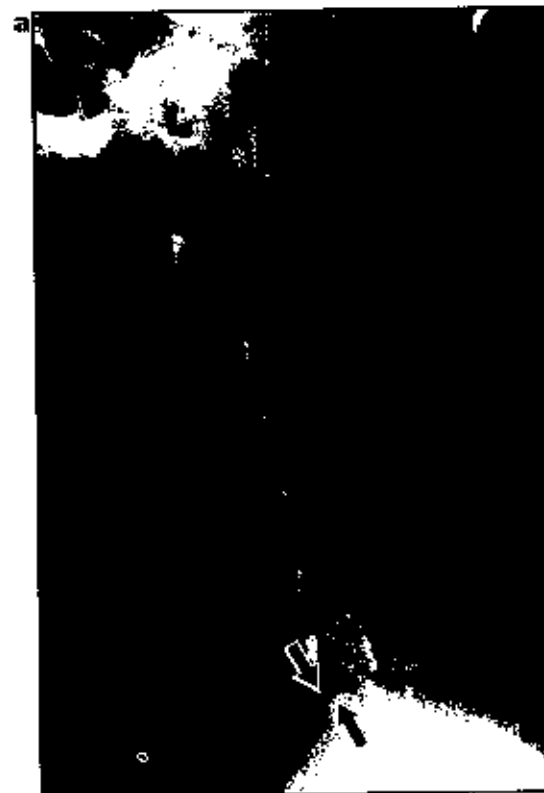


Figure 6. A lateral radiograph (a) of a 21-year-old college football player's cervical spine in the erect neutral position demonstrates anterior displacement of C-6 on C-7 of less than 3.5 mm (arrows). In the same patient, a computed tomography (CT) scan (b) of C-6 in the axial plane demonstrates a fracture to the lateral mass (arrow). Persistent displacement, despite healing of the fracture, would be an absolute contraindication to further participation in contact sports.

Figures 6, 7, 9a, 10, and 12a are reprinted with permission from Torg JS, Ramsey-Ehrlich JA: Management guidelines for participation in collision activities with congenital, developmental, or postinjury lesions involving the cervical spine. *Mod Sci Sports Exerc* 1997;29(7, clinical suppl), to be published.

Cervical Cord Neurapraxia

Our research has previously described cervical cord neurapraxia (CCN) as a distinct clinical entity and, using x-ray measurements, has identified the cause as developmental narrowing of the AP diameter of the cervical canal in combination with acute mechanical deformation of the spinal cord.⁹

The typical clinical case involves an athlete

who has an acute transient neurologic episode of cervical cord origin. Neurologic findings may include both arms, both legs, all four extremities, or an ipsilateral arm and leg. The symptoms may result in sensory changes with or without motor findings. Sensory changes include burning pain, numbness, or tingling; motor changes consist of weakness or complete paralysis. An episode usually lasts less than 15 minutes, al-

continued

Figure 7. Cervical spine MRI images—sagittal (a) and C4-5 axial (b)—of a 23-year-old professional football defensive back who had an episode of cervical cord neurapraxia with transient quadriplegia. He returned to professional football and had no recurrence despite spinal cord compression and deformity (arrows) at the C4-5 disk level.

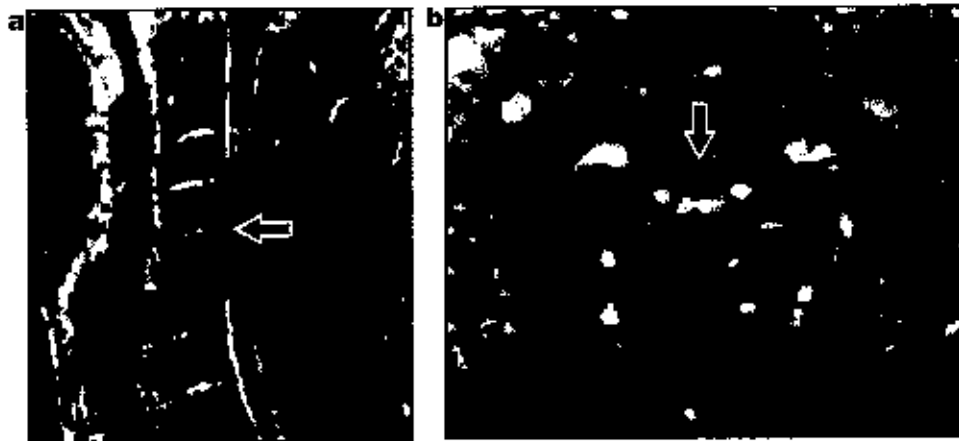


Figure 8. Schematic illustration

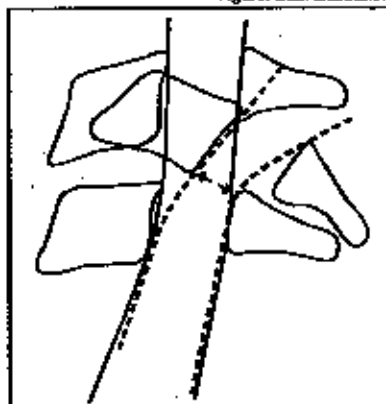


Figure 8. In the presence of cervical canal stenosis, a pincer-like mechanism can cause cervical cord neurapraxia. As shown here, this occurs when hyperextension of the cervical spine causes the posterior inferior aspect of one vertebral body and the anterior superior aspect of the lamina of the subjacent vertebra to come together. The mechanism also can occur in flexion when the lamina of the superior vertebra and the posterior superior aspect of the subjacent vertebral body come together. In both cases, the approximation causes a sudden decrease in the anteroposterior diameter of the canal, compressing the spinal cord.

though some cases may take up to 48 hours to resolve. Complete motor function and full, pain-free cervical motion normally return.

'Pincers' mechanism. The relationship between developmental cervical canal narrowing and CCN has been clearly established.¹⁶ In the presence of cervical canal stenosis, CCN results from cord compression due to a "pincers" mechanism (figure 8). This mechanism occurs when hyperextension of the cervical spine causes the posterior inferior aspect of the superior vertebral body and the anterior superior aspect of the lamina of the subjacent vertebra to come together; conversely, in flexion the lamina of the superior vertebra and the posterior superior aspect of the subjacent vertebral body come together. In both cases the approximation causes a sudden decrease in the AP diameter of the canal at that cervical level, resulting in compression of the spinal cord.

The relationship between temporary neurologic dysfunction and cord deformation has been explained through the study of a squid axon injury model. Torg et al¹⁷ correlated the clinical findings of reversible cord deficits with the histochemical response of isolated neural and vascular elements subjected to controlled mechanical deformation. Neurologic recovery from mechanical deformation is inversely proportional to a rise in the intracellular calcium ion concentration, which is directly proportional to the amount and rate of tension applied to the

continued on page 81

cervical cord. CCN appears to involve rapid cord deformation without loss of spinal stability or cell damage, and recovery of axonal function is not impeded by the deleterious effects of local anoxia from venous spasm.

A benign condition. In the absence of instability or structural deficiency of the cervical spine, CCN appears to be clinically benign. Torg et al,¹² in a study of a large group of football players who had cervical spine stenosis and episodes of CCN, found that 109 of 110 athletes had complete neurologic recovery and that no permanent morbidity occurred in the 63 patients who returned to contact sports. (The one case of irreversible neurologic injury was a direct complication of surgery.) Further, a study¹³ of MRI images of 25 professional football players who had CCN episodes with significant cervical canal stenosis and cervical spondylosis showed that all patients with actual cord compression from degenerative disks safely returned to contact activities. Thus, developmental or spondylitic stenosis, regardless of the degree of canal narrowing, does not result in irreversible cord injury.

Predicting recurrence. Though patients who have an episode of CCN are not at increased risk of permanent injury when they return to contact sports, they should be advised that they may have recurrent episodes. Thirty-five (56%) of the 63 aforementioned patients who returned to contact activities after a CCN incident had a recurrence. Participation in football and increased stenosis raise the risk of recurrence. MRI measurement of disk-level canal diameter was the best predictor of recurrence risk, followed by the ratio of the spinal canal diameter to the vertebral body diameter (figure 9a) and by the space available for the cord. Given the technical requirements for making an accurate MRI measurement, the ratio is the method of choice in general practice.

Although Herzog et al¹⁴ have suggested that the ratio is overly sensitive in diagnosing cervical stenosis, it is a reliable, accurate, and accessible method for quantifying the risk of CCN recurrence when used with the probability-of-recurrence graph (figure 9b). With the ratio and the

continued

the
physician
and
sportsmedicine

For inquiries about
your subscription to
THE PHYSICIAN AND SPORTSMEDICINE
you may call
the toll-free number
in your country:

Belgium	32-0800 71260
Denmark	45-8001 8934
Germany	49-0130 829 448
Holland	31-06022 4959
United Kingdom	44-0800 973 195
Italy	39-1678 79415
Spain	34-900 943539
Sweden	46-020 793386
Switzerland	41-155 24 18
France	33-0591 6068

An English-speaking operator will answer
your call.

If you wish to order a subscription, the
operator will request your VISA,
MasterCard, or American Express credit
card information.

You may also contact us by FAX,
phone, or mail at:

THE PHYSICIAN AND SPORTSMEDICINE
148 Princeton-Hightstown Rd.
Hightstown, NJ 08520-1450
U.S.A.

Phone: +1-609-426-7070
FAX: +1-609-426-7087

OR:

THE PHYSICIAN AND SPORTSMEDICINE
Post Office Box 85
Galway, IRELAND
Phone: 353-91-752792
FAX: 353-91-752793

In countries not offering toll-free numbers,
please contact

THE PHYSICIAN AND SPORTSMEDICINE
as shown above.

graph, a physician can counsel patients with CCN regarding their risk of recurrence. For example, a CCN patient with a spinal canal/vertebral body ratio of 0.5 has approximately a 75% risk of a recurrent episode. Because of the low specificity and low positive predictive value, however, the canal/vertebral body ratio should not be used as a screening test for athletes who have not had an episode of CCN.

Several investigators have observed an inverse relationship between increased posttraumatic myelopathy and sagittal diameter of the cervical canal in patients suffering fracture, dislocation, or instability of the cervical spine.^{14,15} In the series of Torg et al,¹¹ there was no correlation between the severity of the clinical manifestations of CCN and the degree of narrowing. But unlike patients in the other studies, the latter patients did not have loss of cervical spine stability.

Return-to-play recommendations. Though we believe that CCN is a benign entity, all patients should undergo a routine plain-film radio-

graphic and MRI examination. Patients with uncomplicated CCN may be advised that they can return to contact activities without increased risk of permanent neurologic injury. However, since the overall recurrence rate of 56%¹² is related to the degree of cervical canal narrowing, patients can be counseled regarding the risk of recurrence using the following recommendations:

- Asymptomatic patients with a canal/vertebral body ratio of 0.8 or less: no contraindication;
- Patients with a ratio of 0.8 or less who have had one CCN episode: relative contraindication;
- Patients with CCN episodes and degenerative changes and/or intervertebral disk disease: relative contraindication;
- Patients with a CCN episode and MRI indication of cord defect or edema: relative to absolute contraindication; and,
- Patients with a CCN episode, ligamentous instability, neurologic symptoms lasting more than 36 hours, and/or multiple episodes: absolute contraindication.

continued

Figure 9. Staff Illustrations

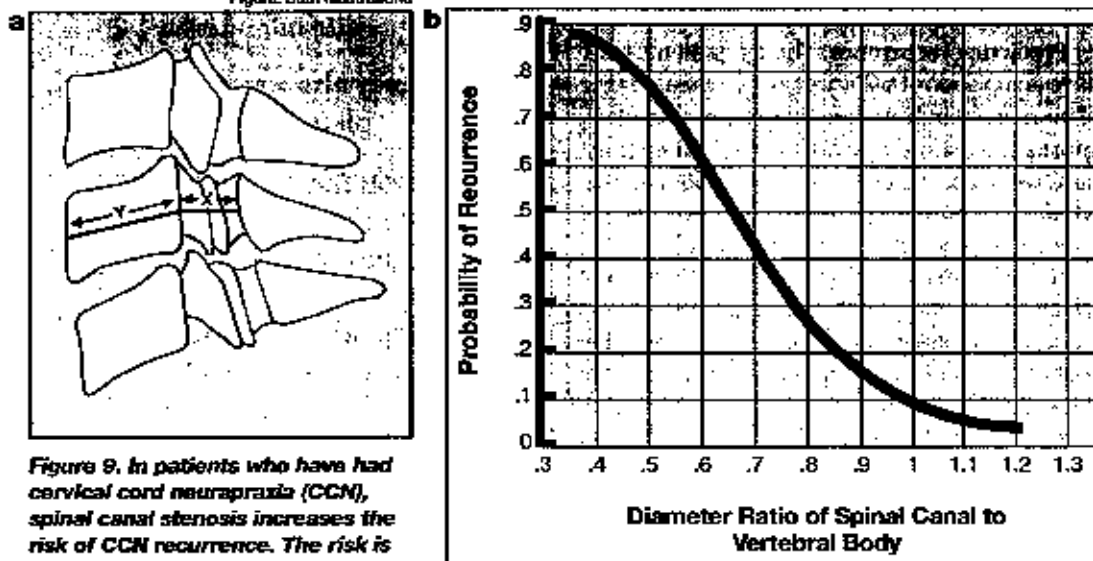


Figure 9. In patients who have had cervical cord neurapraxia (CCN), spinal canal stenosis increases the risk of CCN recurrence. The risk is inversely related to the ratio of the spinal canal diameter to the vertebral body diameter. This ratio (a) is the distance (x) from the midpoint of the posterior aspect of the vertebral body to the nearest point in the corresponding laminae, divided by the anteroposterior width (y) of the vertebral body. A graph (b) gives the approximate risk of recurrence as a function of the ratio, permitting appropriate counseling of CCN patients regarding return to play. The graph was derived by means of logistic regression analysis of data that showed the risk of recurrence to be inversely related to canal diameter.

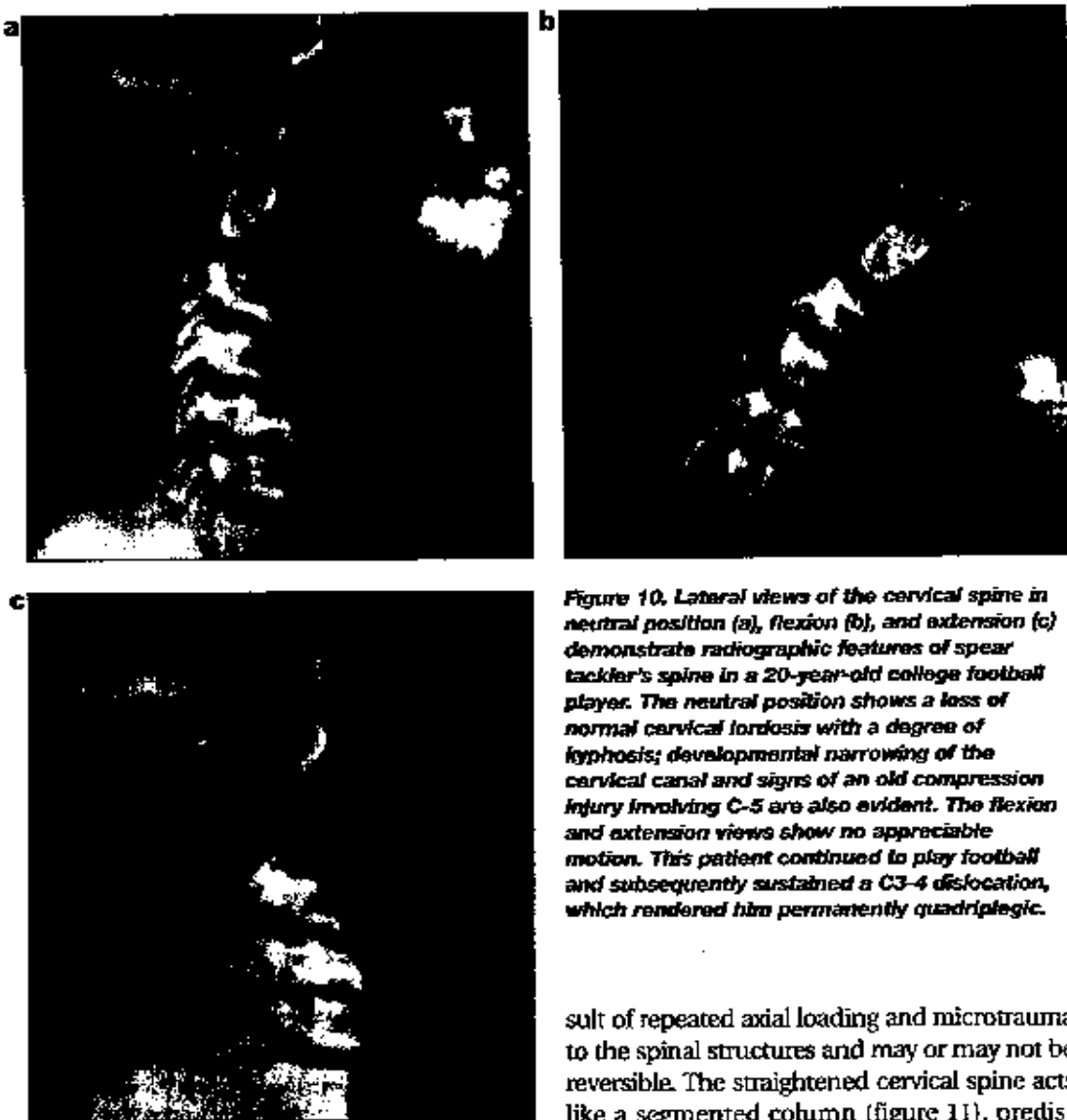


Figure 10. Lateral views of the cervical spine in neutral position (a), flexion (b), and extension (c) demonstrate radiographic features of spear tackler's spine in a 20-year-old college football player. The neutral position shows a loss of normal cervical lordosis with a degree of kyphosis; developmental narrowing of the cervical canal and signs of an old compression injury involving C-5 are also evident. The flexion and extension views show no appreciable motion. This patient continued to play football and subsequently sustained a C3-4 dislocation, which rendered him permanently quadriplegic.

Spear Tackler's Spine

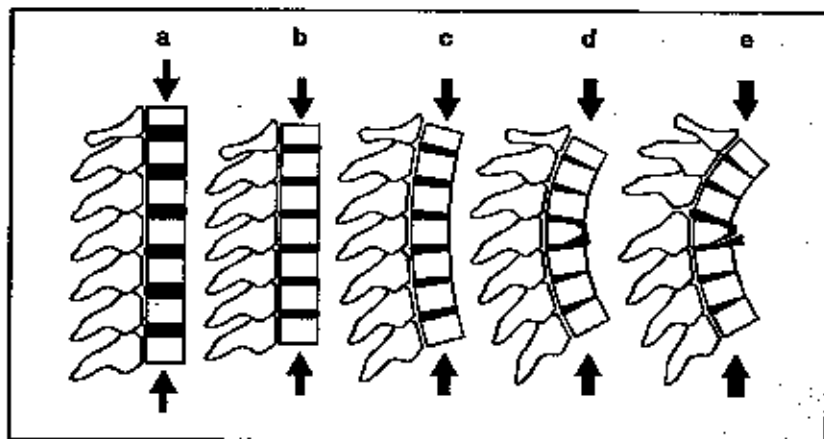
Spear tackler's spine is a condition that occurs in football players who habitually use the head as the initial point of contact.¹⁶ Plain radiographs (figure 10) of the condition show cervical stenosis, posttraumatic changes, and loss of the normal cervical lordosis. An erect lateral view of the neck in neutral alignment best shows the loss of the normal cervical lordosis. The straightening of the cervical spine is the re-

sult of repeated axial loading and microtrauma to the spinal structures and may or may not be reversible. The straightened cervical spine acts like a segmented column (figure 11), predisposing the spine to permanent neurologic injury with further axial loading; thus, the combination of spear tackler's spine and head-first tackling is extremely dangerous. Spear tackler's spine is therefore an absolute contraindication to further participation in contact sports.

In patients whose loss of cervical lordosis is reversible, a return to activity may be considered when the normal lordotic curve returns. Counseling regarding the perils of head-first impact is imperative, as is the teaching of safe tackling techniques.

continued

Figure 11. Spear tackler's spine involves loss of normal cervical lordosis. When subjected to an axial loading force, the straightened cervical spine behaves like a segmented column. The force first compresses the intervertebral discs (a and b). As maximum compression is reached, the spine flexes and buckles (c) with resulting fracture, subluxation, or dislocation (d and e). The combination of spear tackler's spine and head-first tackling is extremely dangerous.



Fractures

In a patient with or without ligamentous laxity, an acute fracture of either the vertebral body or the posterior elements is an absolute contraindication to participation. However, depending on the type and location of the fracture, healed lesions may or may not preclude further participation (table 1). Consultation with an experienced sports medicine orthopedist should be obtained to assist in deciding whether further participation is prudent.

The axial-load teardrop fracture. This fracture is a variant of the burst fracture and is different from the *isolated* tear-drop fracture.¹⁷ The latter (figure 12a) is a fracture of the anteroinferior corner of the vertebra and is not usually associated with permanent neurologic sequelae.

In contrast, the axial-load teardrop fracture (figures 12b, 12c, and 12d) is a three-part, two-plane fracture including a sagittal vertebral body fracture and a fracture of the posterior neural arch. It is caused by severe compression. Although the name focuses attention on the anteroinferior vertebral body fracture, the unstable fracture pattern is actually responsible for encroachment on the spinal cord, which results in the paralysis that frequently accompanies this injury.

Cervical Spine Fusion

A patient who has undergone spine fusion does not necessarily have to avoid contact activities, but recommendations vary according to

the individual's signs and symptoms and the level of vertebral fusion:

- No contraindication for patients with a stable, one-level anterior or posterior fusion at C-3 or below, so long as they are neurologically normal, are free of pain, and have a normal range of cervical motion.
- Relative contraindication for patients who have a stable, two- or three-level anterior or posterior fusion, are neurologically normal and asymptomatic, and have full, painless cervical motion. It appears that these patients should only rarely be permitted to return to contact activities, because stresses at the articulations of the vertebrae adjacent to the fusion will probably increase and may lead to degenerative changes.
- Absolute contraindication for those with anterior or posterior fusion of more than three levels.

Spinal Cord Resuscitation

Research over the past 20 years has clearly established the principles of brain resuscitation in the management of closed head injuries. The pathophysiologic and mechanistic phenomena causing morbidity in these head injuries are the same as those causing morbidity in acute spinal cord trauma.¹⁸ Specifically, secondary spinal cord injury caused by hypoxia, edema, and aberration of cell membrane potential is largely responsible for neurologic deficits. The methods of spinal cord resuscitation seek to minimize hypoxia, edema, and aberrations of cell membrane



Figure: Staff Illustration

Figure 12. A lateral radiograph of the cervical spine of an 18-year-old football player (a) demonstrates an isolated teardrop fracture (arrow) of C-5, which is rarely, if ever, associated with neurologic involvement. Diagram (b) shows an axial-load teardrop fracture—a three-part, two-plane vertebral body compression fracture consisting of an anterior inferior teardrop fracture with sagittal vertebral body fracture and associated lamina fracture. CT images (c and d) demonstrate the pattern of the axial-load teardrop fracture in a 17-year-old football player. This is a markedly unstable fracture and is characteristically associated with permanent quadriplegia.

potential in an attempt to reverse secondary changes and enhance neurologic recovery. These methods include the following:

Treatment of any aberrations of neurovascular function, with particular regard to maintaining blood pressure and respiration.

Prompt reduction of spinal deformity so as to relieve cord deformation.

Prompt stabilization of the injured segment of the cervical spine.

- Use of intravenous corticosteroids in recommended doses.¹⁹ Within 8 hours of injury, methylprednisolone, 30 mg/kg, should be given as a bolus, followed by an infusion of 5.4 mg/kg/hr for 23 hours. In a major trial, 19 patients who received methylprednisolone within 8 hours of injury improved significantly at 6 months compared with those who received a placebo. The steroid may suppress the breakdown of the cell membrane by inhibiting lipid peroxidation and

continued

hydrolysis at the injury site. When lipid peroxidation is inhibited, the vasoreactive products of arachidonic acid metabolism decrease and blood flow at the site of injury is improved.

• Use of cerebrogangliosides, such as Sygen (GM-1), in an attempt to facilitate the patient's neurologic recovery.

Individualized Advice

The proposed recommendations for managing cervical spine injuries are based on the best available information. As more data are gathered, however, changes may be necessary. In deciding whether or not an athlete can safely return to contact sports, the athlete's age, experience, ability, position, and level of participation

should be considered along with the recommendations. **RSM**

For more information on this subject, see Torg JS, Ramsey-Emrhein JA: Management guidelines for participation in collision activities with congenital, developmental, or postinjury lesions involving the cervical spine. Med Sci Sports Exerc 1997;29(7, clinical suppl), to be published.

Address correspondence to Joseph S. Torg, MD, Allegheny University Hospitals-Center City, Broad and Vine, Philadelphia, PA 19102-1192; send e-mail to torgmd@aol.com.

References

1. Torg JS, Truex R, Quendenfeld TC: The National Football Head and Neck Injury Registry: report and conclusions. *JAMA* 1979;241(14):1477-1479
2. Torg JS, Vegso JJ, O'Neill J, et al: The epidemiologic, pathologic, biomechanical, and cinematographic analysis of football-induced cervical spine trauma. *Am J Sports Med* 1990;18(1):50-57
3. Torg JS, Vegso JJ, Sennett B, et al: The National Football Head and Neck Injury Registry: 14 year report on cervical quadriplegia, 1971 through 1984. *JAMA* 1985;254(24):3439-3443
4. Otis JC, Burstein AH, Torg JS: Mechanisms and pathomechanics of athletic injuries to the cervical spine, in Torg JS (ed): *Athletic Injuries to the Head, Neck and Face*, ed 2. St Louis, CV Mosby Co, 1991, pp 433-456
5. Torg JS, Reilly PF: Injuries to the cervical nerve roots and brachial plexus in athletes. *Current Opinions in Orthopaedics*, 1994;5(2):79-84
6. Levitz CL, Reilly PJ, Torg JS: The pathomechanics of chronic, recurrent cervical nerve root neurapraxia: the chronic burner syndrome. *Am J Sports Med* 1997;25(1):73-76
7. Albright JP, Moses JM, Feldick HG, et al: Nonfatal cervical spine injuries in interscholastic football. *JAMA* 1976;236(11):1243-1245
8. White AA, Johnson RM, Panjabi MM, et al: Biomechanical analysis of clinical stability in the cervical spine. *Clin Orthop* 1975;109:85-95
9. Torg JS, Pavlov H, Genuario SE, et al: Neurapraxia of the cervical spinal cord with transient quadriplegia. *J Bone Joint Surg (Am)* 1986;68(9):1354-1370
10. Torg JS, Naranja J, Pavlov H, et al: The relationship of developmental narrowing of the cervical spinal canal to reversible and irreversible injury to the cervical spinal cord in football players. *J Bone Joint Surg (Am)* 1996;78(9):1308-1314
11. Torg JS, Thibault L, Sennett B, et al: The pathomechanics and pathophysiology of cervical spinal cord injury. *Clin Orthop* 1995; 321(Dec):259-269
12. Torg JS, Coocoran TA, Pavlov H, et al: Cervical cord neurapraxia classification, pathomechanics, morbidity and management guidelines. *J Neurosurg*, to be published
13. Herzog RJ, Wiens JJ, Dillingham ME, et al: Normal cervical spine morphometry and cervical spine stenosis in asymptomatic professional football players: plain film radiography, multiplanar computed tomography, and magnetic resonance imaging. *Spine* 1990;16(6 suppl):179-186
14. Eismont FJ, Clifford S, Goldberg M, et al: Cervical sagittal spinal canal size in spine injuries. *Spine* 1984;9(7):663-666
15. Maroon JC, Bailes JE: Athletes with cervical spine injury. *Spine* 1996;21(19):2294-2299
16. Torg JS, Sennett B, Pavlov H, et al: Spear tackler's spine: an entity precluding participation in tackle football and collision activities that expose the cervical spine to axial energy inputs. *Am J Sports Med* 1993;21(5):640-649
17. Torg JS, Pavlov H, O'Neill MJ, et al: The axial load tear-drop fracture: a biomechanical, clinical and roentgenographic analysis. *Am J Sports Med* 1991;19(4):355-364
18. Torg JS, Thibault LE: Spinal cord resuscitation, in *Current Therapy in Sports Medicine*, ed 3. Philadelphia, CV Mosby Co, 1995, pp 66-70
19. Bracken MB, Shepard MS, Collins WF, et al: A randomized controlled trial of methylprednisolone or naloxone with treatment of acute spinal cord injury: results of the second National Acute Spinal Cord Injury Study. *N Engl J Med* 1990;322(20):1405-1411