Thoracic Spine Sports-Related Injuries

Heather Menzer, MD; G. Keith Gill, MD; and Andrew Paterson, MD

Abstract
Although sports-related injuries to the thoracic spine are relatively uncommon, they are among the most feared due to the potential for catastrophic neurologic injury. The increased biomechanical support of the thoracic spine makes injuries in this region particularly rare compared with the cervical and lumbar spine. As a result, thoracic spine injuries can be missed easily, difficult to diagnose, and problematic to treat. Recognition of mechanism and awareness of injury patterns help physicians determine a diagnosis and create an index of suspicion for unstable thoracic spine injuries. Aggressive full-contact sports receive the most attention for spinal injury; however several sports with repetitive loading of the spine can cause severe injuries, including rowing, gymnastics, and golf. The goal of this article was to provide an overview of the unique anatomic and biomechanical features of the thoracic spine and to discuss some of the more common thoracic injuries that can affect athletes.

Introduction

The thoracic spine plays an important role in providing optimal biomechanics in a variety of sports, especially those that involve the use of upper extremities. Injuries to the thoracic spine in athletics are relatively uncommon, but they are among the most feared of all injuries due to the potential for catastrophic injury. The increased biomechanical support imparted on the thoracic spine by the thoracic cage, which includes the associated ribs, sternum, costal cartilages, and associated ligaments, makes injuries in this region particularly rare compared with those in the cervical and lumbar regions. As a result, thoracic spine injuries can be missed easily, difficult to diagnose, and problematic to treat. The goal of this article was to provide an overview of the unique anatomic and biomechanical features of the thoracic spine and to discuss some of the more common thoracic injuries that can affect athletes.

Epidemiology

Approximately 15% of all spine injuries occur in sport-related activities, making sports the fourth most common mechanism behind motor vehicle collisions, violence, and falls (7). Injuries to the spine are often predictable on the basis of mechanism and pattern recognition; this is also true regarding sports-related injuries. Certain injury patterns can be seen in specific sports, such as cervical spine injuries in diving. Awareness of these patterns can help physicians diagnose these injuries better and create an index of suspicion for unstable injuries. Although most common injuries occur in the cervical spine, followed by the lumbar spine, thoracic spine injuries can be potentially catastrophic and easily missed.

Advances in sport injury recognition have allowed parents, coaches, and physicians to help provide specialized equipment to prevent injury. Ironically however, in some sports such as hockey, improved protective gear for the head, face, and body has not decreased the incidence of catastrophic spine injuries (21). Aggressive full-contact sports, such as American football and rugby, receive the most attention; however, several other sports with repetitive loading of the spine can cause severe injuries, including rowing, gymnastics, and golf. Sports such as cheerleading, baseball, and wrestling all have lower incidence of injury, but the injuries tend to be more debilitating. Newer winter sports such as snowboarding and other adventure sports involve higher speeds and vertical heights and significantly have increased the incidence of catastrophic injuries to all spinal levels. These jumping events predominantly result in injuries to the thoracolumbar spine. In the thoracic spine specifically, compression fractures are the most common injury at 52%, followed by transverse process fractures at 37% (30).

Anatomy/Biomechanics

The anatomic morphology and biomechanical characteristics of the thoracic spine are distinct from the cervical and lumbar regions (Fig. 1). The thoracic region of the spine consists of 12 vertebrae with articulating ribs bilaterally at every level. The heads of the ribs from T2 to T10 articulate with two demifacets of the vertebral bodies, one superior demifacet of the same numbered vertebra and one inferior demifacet of the next adjacent vertebra above. For example, the T6 rib head articulates with the upper part of the T6 vertebra and the inferior aspect of the T5 vertebra.

Department of Orthopaedics, University of New Mexico, Albuquerque, NM

Address for correspondence: Andrew Paterson, MD, Department of Orthopaedics, University of New Mexico, Albuquerque, NM 87131; E-mail: APaterson@salud.unm.edu.

1537-890X/1401/34–40
Current Sports Medicine Reports

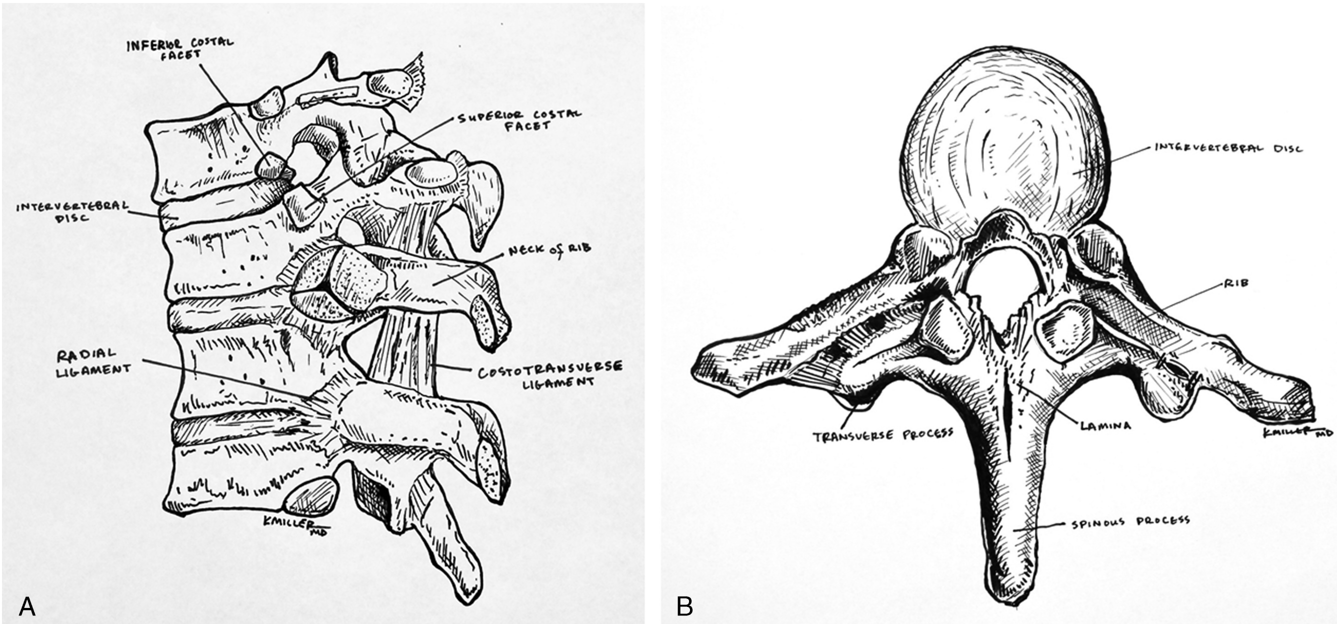


Figure 1: A. Sagittal view of the thoracic spine showing the costovertebral anatomy and articulations, including the facet joints. B. Axial view of a thoracic vertebra depicting the costovertebral articulation and orientation.

The tubercle of these ribs, just distal to the rib head, also articulates with the ventral portion of the transverse process of its similarly numbered vertebra. The ribs at T1, T11, and T12 only articulate with their respective vertebra. In addition to the costovertebral joint capsules, there are also several associated ligaments that secure the rib cage to the thoracic spine, which provide additional stability to the spine.

The zygapophyseal joints, or facet joints, make up the dorsal articulations at each motion segment. In the thoracic region, these encapsulated synovial joints are oriented vertically in the coronal plane, with slight medial angulation. This orientation limits flexion and extension but allows for lateral bending and especially rotation. As such, the thoracic region can provide a fair amount of powerful axial rotation, which can augment torsional maneuvers through the shoulder region, such as in tennis or pitching.

Denis (8) first described the concept of three columns of the spine, specifically regarding injuries of the thoracolumbar spine. This conceptual understanding is also applicable in the thoracic region. The anterior column includes the anterior vertebral body, anterior anulus fibrosus, and the anterior longitudinal ligament. The middle column consists of the posterior longitudinal ligament, posterior anulus fibrosus, and posterior wall of the vertebral body. The posterior column includes the laminae, pedicles, spinous processes, transverse processes, facets, ligamentum flavum, interspinous ligaments, and facet capsules. The anterior and middle columns of the spine bear much of the axial loads of the spine, which are balanced partly by the tensile constraints of the posterior column.

A so-called fourth column of the thoracic spine also has been described and is made up of the thoracic cage, which includes the ribs, sternum, and costosternal/costovertebral articulations (3). Thoracic spine injuries are generally uncommon due to the anterior biomechanical support provided by this fourth column compared with cervical and lumbar injuries. Studies report that a complete rib cage with intact sternum increases thoracic spine stability in flexion-extension, lateral bending, and axial rotation by up to 40% (14,26).

The thoracolumbar junction consists of the region from T9 to L3. In addition to the absence of true ribs in this region, the morphology of the facet joints transition from a coronal orientation in the lower thoracic spine to an oblique sagittal orientation in the lumbar spine. This more sagittal orientation permits increased mobility in flexion and extension and more limitation of rotation. The transition from a more rigid thoracic region to a mobile lumbar region renders it more prone to injury. Furthermore when standing upright, the sagittal alignment of the spine between T10 and L2 is relatively straight and in this position, the ideal center of mass is anterior to T10, resulting in a flexion moment at the thoracolumbar junction. This, too, creates greater risk of injury in the transitional region. The intervertebral discs of the thoracic spine have the same morphologic structure as that of other regions, with a central nucleus pulposus and a peripheral anulus fibrosus. The spinal cord terminates at the conus medullaris, which lies posterior to the body of the L1 in most individuals, below which is the collection of spinal nerve roots known as the cauda equina.

Clinical Evaluation

There are myriad scenarios when one might encounter a patient with a thoracic spine injury. These can range from an acute high-energy traumatic injury to a chronic, debilitating upper back overuse injury. In all spine-related injuries, clinical evaluation must begin with Advanced Trauma Life Support Protocol. Injuries to the thoracic spine may be concomitant with a pneumothorax, diaphragmatic rupture, or rib fracture affecting ventilation, and these must be addressed with priority. A complete history should include details about mechanism of injury, location, and character of pain, presence or absence of neurologic symptoms, bladder and bowel function, and history of preexisting symptoms (Fig. 2).

In an acute on-field setting, an injured athlete's equipment should be left in place during the initial assessment. Face masks may be removed to assess airway and breathing better. When transporting an athlete from the field, spinal precautions should be implemented using a rigid backboard and cervical immobilization. A focused history and physical examination should follow to evaluate neurologic status. Examination of the neck and back should be performed using the log roll technique to visualize skin for ecchymosis or deformity and palpating spinous processes to assess posterior tenderness. A neurologic examination also should be performed, including sensory and motor tests of the upper and lower extremities as well as an assessment of deep tendon reflexes. If a spinal cord injury (SCI) is suspected, it is imperative to maintain blood pressure and oxygenation during transfer to a trauma center (1,2).

In the event of a suspected SCI, a more detailed neurologic evaluation is necessary (Fig. 3). This includes a rectal examination to assess sacral-level neurologic function and to establish the presence or absence of the bulbocavernosus reflex. The absence of a bulbocavernosus reflex can indicate either the presence of spinal shock or an injury to the conus medullaris at the thoracolumbar junction.

Spinal shock is defined as a transient period of areflexia/hyporeflexia and autonomic dysfunction after sustaining an SCI; this includes loss of sensory and motor function. Return of bulbocavernosus reflex marks the end of spinal shock. Conversely neurogenic shock results from the loss of sympathetic tone from an SCI and will manifest clinically as hypotension and bradycardia. This also can be differentiated from hypovolemic shock, which presents with hypotension and tachycardia (12,27). Hypotension (systolic blood pressure, <90 mm Hg) in the patient with SCI should be corrected as soon as possible. Current guidelines recommend maintenance of mean arterial pressure between 85 and 90 mm Hg for the first week following acute SCI (19).

Radiographic workup initially should include dedicated plain radiographs of the spine and, secondarily, a computed tomography (CT) scan to evaluate for an occult fracture or whether there is evidence of a significant injury on x-ray. Magnetic resonance imaging (MRI) is recommended when there is concern for a neurologic injury, to evaluate a more severe or unstable injury, and occasionally to evaluate for soft tissue injuries. If a significant injury to the spine has been

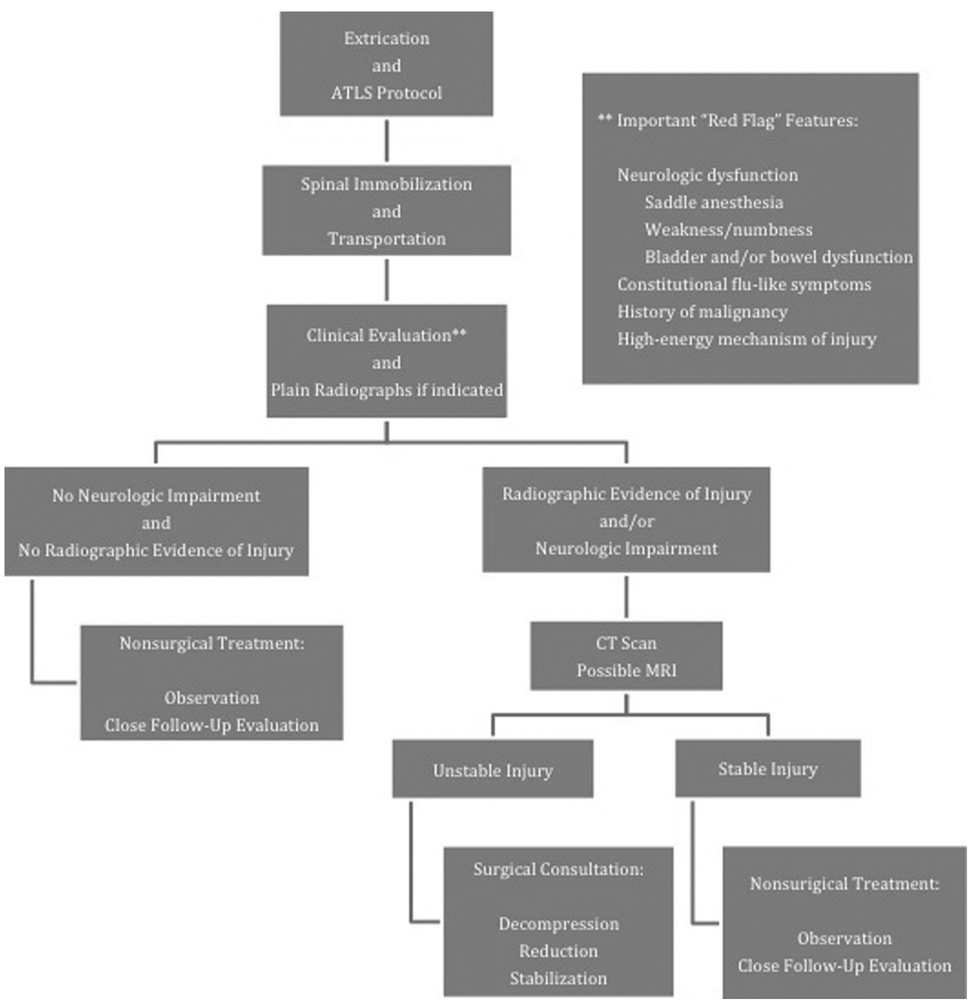
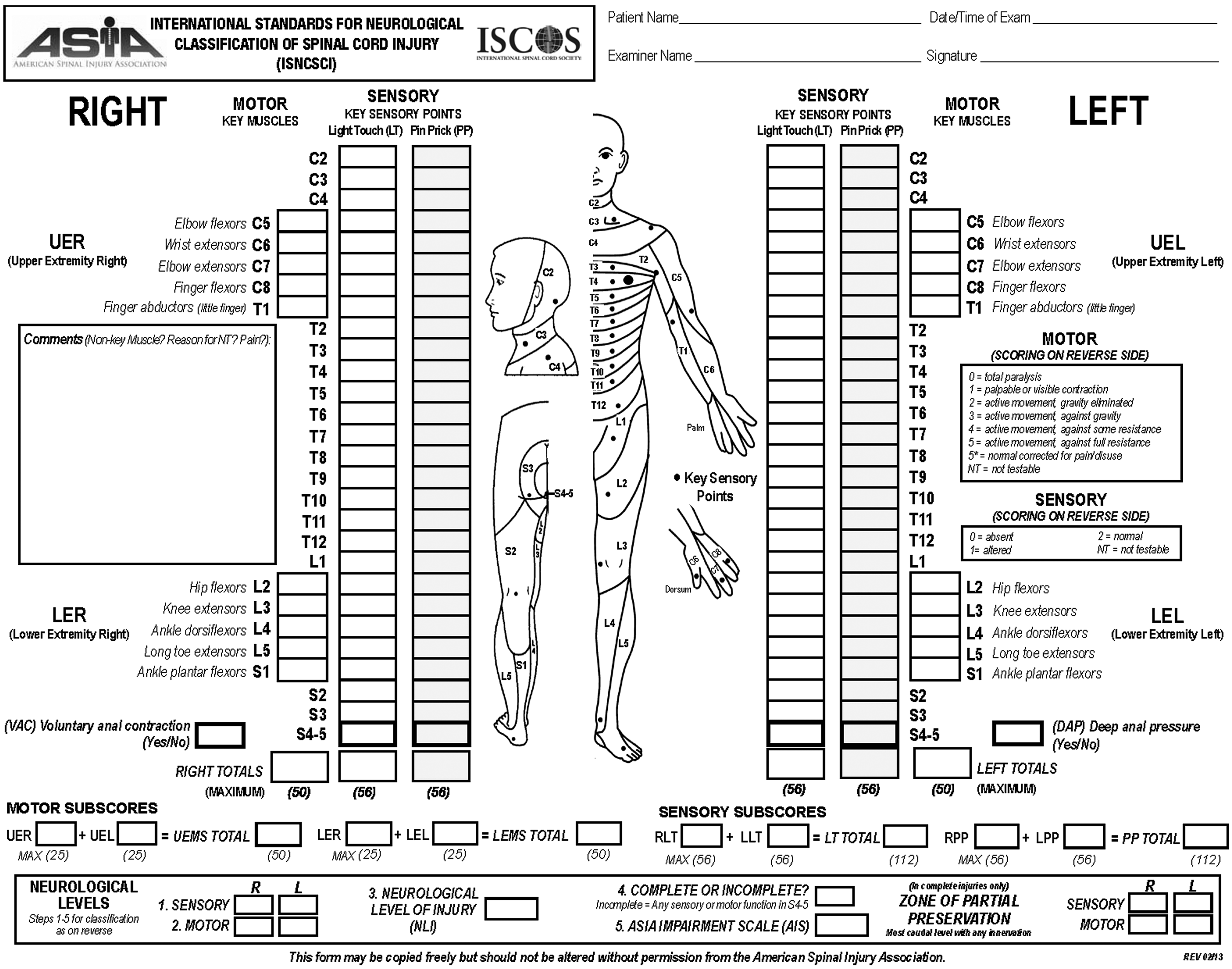


Figure 2: Treatment approach to a patient with a thoracic spine injury.


INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)

ASIA — AMERICAN SPINAL INJURY ASSOCIATION

ISCoS — INTERNATIONAL SPINAL CORD SOCIETY

Patient Name ______ Date/Time of Exam ______

Examiner Name ______ Signature ______

RIGHT

MOTOR — KEY MUSCLES

SENSORY — KEY SENSORY POINTS — Light Touch (LT) — Pin Prick (PP)

C2, C3, C4

UER (Upper Extremity Right): Elbow flexors C5; Wrist extensors C6; Elbow extensors C7; Finger flexors C8; Finger abductors (little finger) T1

Comments (Non-key Muscle? Reason for NT? Pain?):

T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1

LER (Lower Extremity Right): Hip flexors L2; Knee extensors L3; Ankle dorsiflexors L4; Long toe extensors L5; Ankle plantar flexors S1

S2, S3, S4-5

(VAC) Voluntary anal contraction (Yes/No)

RIGHT TOTALS (MAXIMUM) (50) (56) (56)

LEFT

SENSORY — KEY SENSORY POINTS — Light Touch (LT) — Pin Prick (PP)

MOTOR — KEY MUSCLES

C2, C3, C4

UEL (Upper Extremity Left): C5 Elbow flexors; C6 Wrist extensors; C7 Elbow extensors; C8 Finger flexors; T1 Finger abductors (little finger)

T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1

MOTOR (SCORING ON REVERSE SIDE)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
5* = normal corrected for pain/disuse
NT = not testable

SENSORY (SCORING ON REVERSE SIDE)

0 = absent; 1 = altered; 2 = normal; NT = not testable

LEL (Lower Extremity Left): L2 Hip flexors; L3 Knee extensors; L4 Ankle dorsiflexors; L5 Long toe extensors; S1 Ankle plantar flexors

S2, S3, S4-5

(DAP) Deep anal pressure (Yes/No)

LEFT TOTALS (MAXIMUM) (56) (56) (50)

• Key Sensory Points

Palm

Dorsum

MOTOR SUBSCORES

UER ☐ + UEL ☐ = UEMS TOTAL ☐ — MAX (25) (25) (50)

LER ☐ + LEL ☐ = LEMS TOTAL ☐ — MAX (25) (25) (50)

SENSORY SUBSCORES

RLT ☐ + LLT ☐ = LT TOTAL ☐ — MAX (56) (56) (112)

RPP ☐ + LPP ☐ = PP TOTAL ☐ — MAX (56) (56) (112)

NEUROLOGICAL LEVELS — Steps 1-5 for classification as on reverse — R L — 1. SENSORY — 2. MOTOR

3. NEUROLOGICAL LEVEL OF INJURY (NLI)

4. COMPLETE OR INCOMPLETE? Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS)

(In complete injuries only) ZONE OF PARTIAL PRESERVATION — Most caudal level with any innervation — R L — SENSORY — MOTOR

This form may be copied freely but should not be altered without permission from the American Spinal Injury Association.

REV 02/13

Figure 3: Neurologic examination recommended by the American Spinal Injury Association for each patient sustaining a spinal injury (International Standards for Neurological Classification of SCI (American Spinal Injury Association)).

identified, then formal consultation with spine surgery should be requested. Initial management of the patient with injury begins with preventing further damage. Unconscious athletes or those with neurologic symptoms and/or severe back and neck pain always should be considered unstable (22).

In the off-field clinical setting, it is important to identify the main focus of pain and the distribution of any associated radiating symptoms. Inspect the back to evaluate skin abnormalities or ecchymosis and overall spinal posture and alignment. Palpate for focal areas of tenderness to differentiate midline pain that could result from injury to the spinal column from paraspinal/lateral regions of tenderness that may signify musculoligamentous injury. Cervical spine conditions often manifest symptomatically in the thoracic region; therefore a detailed examination of the neck and cervical spine also should be performed. Provocative testing of the neck and upper extremities will help localize the etiology of symptoms in athletes with referred pain. A thorough neurologic evaluation including sensory and motor tests of the upper and lower extremities and assessment of deep tendon reflexes should be performed. Athletes with concerning neurologic abnormalities such as weakness, paresthesias, or severe radiculopathy should undergo a similar radiographic workup as stated previously regarding acutely injured athletes. Severe thoracic pain, in absence of neurologic examination findings, is an indication to obtain plain radiograph of the affected region first. The patient should be referred to a surgical spine specialist if a thoracic spine injury is identified on clinical examination and radiographic evaluation, especially if there is any concern for an unstable spinal injury or neurologic condition.

Injuries

Musculoligamentous Injuries

Thoracic musculoligamentous injuries can occur either with acute, high-energy mechanisms or with chronic overuse, high-repetition mechanisms. Acutely these injuries are caused by violent rotational or bending forces in a similar fashion to whiplash injuries in the cervical spine. The onset of symptoms often is delayed 12 to 24 h due to the inflammatory cascade and may be accompanied by paravertebral muscle spasm. Pain and tenderness are the most common symptoms. Injuries in the throwing athlete tend to involve excessive torsional stress. Interestingly though, these frequently are found to be on the contralateral side of the dominant throwing arm (25). No neurologic impairment should result from these injuries, and radiographs are usually normal. The presence of any accompanying neurologic symptoms or signs of neurologic dysfunction always should prompt a more extensive evaluation including an MRI.

Chronic overuse injuries from sustained high-repetition activities also can result in debilitating symptoms. Rowing, for instance, has 22% incidence of back injury and 9% of rib cage injury from continuous, repetitive motion. These athletes in particular also are susceptible to stress fractures usually involving the ribs. The posterior ribs are often where the fractures occur from the pull of the serratus anterior. This occurs most frequently after time off when endurance is not optimal. These specific injuries involve the kinematics of the thoracic spine, rib cage, and shoulder girdle interdynamics. Pull of the rhomboids, latissimus dorsi, and erector spinae at the T4-to-T7 junction is particularly susceptible to strains and stress fractures (25).

Although musculoskeletal strains and stress fractures are common in athletes, thoracic spine lesions must be ruled out always. If indicated, a CT scan can detect occult fractures and an MRI can identify both soft tissue injury and fracture. Treatment of musculoligamentous injuries includes rest, activity modification, stretching, physical therapy, nonsteroidal anti-inflammatory drugs (NSAID), and muscle relaxants. In some instances, selective injections also can be a helpful modality. With regard to physical therapy recommendations, the physician should request both passive and active modalities. Passive modalities, such as ultrasound, hot/cold compresses, and massage, can help alleviate acute painful symptoms and also facilitate a transition into active modalities, which include exercises for postural mechanics, core strengthening, and trunk stabilization.

Disc Herniations

The function of the intervertebral disc is to absorb axial loading, provide flexibility, and resist deforming forces. Injury to the disc results from axial loading and rotation on the flexed spine, resulting in traumatic herniation of the nucleus pulposus through an annular defect (13). The incidence of symptomatic thoracic disc herniation (TDH) in the general population is reported to be 1 in 1,000 to 1 in 1,000,000 (24,29). TDH usually presents in the fourth and fifth decade and occurs with a slight male predominance (20,24) Disc herniations are not associated commonly with sports injuries; however when they occur, they are diagnosed more frequently in the cervical or lumbar spine. Gray et al. (11) reported that TDH accounted for 2% of all disc herniations in the National Football League over the course of 12 seasons. The activity involved at the time of onset was reported to include blocking, tackling, and other modes of contact in running backs, defensive lineman, and linebackers. Although TDH was reported to be the least common location of herniation, it resulted in higher loss of playing time compared with herniation in the cervical and lumbar regions (11).

Disc herniation can occur at any level of the thoracic spine, but approximately 75% are reported to be below T8 (20,24). Symptoms often include a form of axial pain, radiculopathy, and/or myelopathy. Axial pain of varying intensities is the most common symptom of TDH and often is localized to the middle or low thoracic region near the level of injury. This differs from radicular pain, which often is described as a band-like discomfort that radiates in a dermatomal distribution. The most commonly reported distribution of radicular pain is in the T10 distribution, regardless of the disc level involved (24). Sensory changes such as paresthesias and dysesthesias also are reported in similar dermatomal distributions. Patients with myelopathy are most concerning, as this is indicative of thoracic cord compression. Myelopathic signs include muscle pain and weakness in the lower extremities as well as long tract signs such as a wide-based gait, spasticity, a positive Babinski reflex, and sustained clonus. Upper extremity symptoms can be present in high thoracic herniations and can mimic cervical disc disease. Middle and lower thoracic herniations can affect the lower extremities in a similar fashion to lumbar disc disease. Stillerman et al. (20) reviewed 82 patients with symptomatic TDH treated surgically and reported presentation of localized, axial, or radicular in pain in approximately 75% of patients. Approximately 60% of the patients had myelopathic signs, including motor impairment, hyperreflexia, spasticity, and sensory impairment. Bladder dysfunction was present in approximately 25% (20).

Although x-rays are not particularly helpful for the evaluation of TDH, they always should be obtained to rule out other osseous abnormalities such as fracture, infection, or other pathologic processes that can affect the bony anatomy. MRI is the imaging modality of choice for TDH and can confirm diagnosis if symptoms persist. MRI has a high sensitivity for detecting TDH; however the high prevalence of asymptomatic disc herniations makes it difficult to identify truly symptomatic disc herniations. It is important to correlate the finding of any TDH, as well as any other abnormal findings seen on MRI, with the clinical examination for diagnosis.

As with cervical and lumbar disc herniations, the vast majority of symptomatic TDH can be treated effectively with nonsurgical modalities, and symptoms usually will remit over the course of several weeks and even months. Radicular symptoms and axial pain can be treated with rest, physical therapy, and NSAID. Oral steroids and injections can be considered in the patient with more incapacitating or persistent symptoms. Directed epidural steroid injections can be quite helpful both from a therapeutic and a diagnostic standpoint. Surgical intervention is recommended in the early setting when there are signs of progressive neurologic deficits or myelopathy. Otherwise it should be considered a treatment option for those patients who have persistent debilitating symptoms that have been refractory to a course of nonsurgical treatment. There are a variety of approaches and technical aspects to consider regarding the surgical treatment of TDH, which are beyond the scope of this review.

Fractures

Sport activities can cause a variety of fractures in the thoracic spine that range from minor injuries such as isolated transverse or spinous process fractures to major injuries such as unstable vertebral body fracture-dislocations with potential for SCI. Stress fractures occurring in spinous processes, transverse processes, or ribs can result from overuse activities. Repetitive injury also may result in avulsion-type fractures in the lower cervical or upper thoracic spine, historically called the clay-shoveler fracture, caused by shear forces on the dorsal aspect of the neck. Several case reports document this injury in sports such as golf, rock climbing, baseball, and wrestling (6,16,28). Kang et al. (16) documented a case involving multiple spinous process fractures of the thoracic vertebrae in a beginner golfer. Symptoms of neck pain radiating to both shoulders were described for a 2-wk period. Although initial radiographs did not show any obvious fracture, a CT scan and MRI revealed multiple stress fractures. This injury was treated by immobilization in a cervical collar for 4 wk. The patient ultimately returned to playing golf 10 months after the initial onset of pain (16). Two similar cases involving a high school wrestler and baseball player were described by Yamaguchi et al. (28). Acute posterior neck pain was reported after participation in the sporting activities, and both patients reported a "pop" before the onset of pain. Soft tissue avulsion from the spinous processes in the low cervical and high thoracic region was seen on MRI. This was considered to be an equivalent injury to a clay-shoveler fracture. These two patients also were treated without surgery and returned to play in 4 months.

More severe injuries can be caused by higher-energy activities, such as skiing, rugby, and football. Forces resulting from axial loading and flexion of the thoracic spine may cause compression-type fractures. These are defined as failure of the anterior column of the spine while the posterior columns remain intact. They appear as acute anterior wedging of the vertebra on lateral radiographs. Compression fractures are generally stable without spinal cord compromise. Due to the inherent stability from the ribs and sternum, thoracic compression fractures rarely require operative treatment (14,26). An external orthosis, such as a Jewett brace or custom-made thoracic lumbar sacral orthosis (TLSO), may be used for comfort but is often unnecessary. These orthoses are helpful for stabilizing the mid- and lower-thoracic regions up to the levels of approximately T6, above which, a cervicothoracic orthosis is needed such as a Minerva brace.

Elattrache et al. (9) discuss a patient that sustained T8 and T9 compression fractures after a football tackling injury. The athlete described focal pain and tenderness to direct palpation of the spine at the affected levels. No neurologic symptoms were reported. Plain radiographs demonstrated 40% loss of vertebral height, and a CT scan demonstrated injury isolated to the anterior vertebral body. This patient was treated with an extension thoracolumbar spinal orthosis for 12 wk when walking. Three months after injury, radiographs showed no increase in vertebral collapse or kyphosis. He returned to football at that time (9).

Major thoracic spine fractures include burst, translation-rotation, and flexion-distraction fracture patterns. These often unstable injuries result from high-energy mechanisms and have significant potential to cause SCI. Burst fractures by definition involve the failure of the anterior and middle columns and usually result in the retropulsion of fracture fragments into the spinal canal. When assessing stability of burst fractures, a physician must consider loss of vertebral height, resulting kyphosis, posterior ligamentous complex injury, and neurologic deficits. The treatment goals are to prevent progression of the deformity, preserve neurologic function, facilitate fracture healing, and restore painless function. Translation-rotation fractures are much more unstable and more commonly result in compromise spinal canal alignment. They typically involve failure of all three columns with resultant subluxation through the vertebral segment. These injuries are more common in the thoracolumbar or lumbosacral region and almost always require operative treatment with open reduction and instrumented posterior fusion. Plain radiographs that show interspinous widening are highly suggestive of a distraction injury through the posterior column. The separation of elements results in destruction of the posterior osteoligamentous structures. Isolated bony distractions sometimes can be treated in extension orthosis, but soft tissue or hybrid injuries are likely to require surgical stabilization. Unstable injuries occur most commonly in the thoracolumbar region. The decision for nonsurgical versus surgical treatment is guided in part by the Thoracolumbar Spine Trauma Classification and Severity Score developed by Patel et al., (18) which integrates injury morphology, neurologic status, and integrity of the posterior ligamentous complex.

SCI

An SCI is the most feared aspect of any injury to the spine. The overall incidence of SCI varies drastically, depending on developed versus developing nations, but recent literature suggests 30 to 40 cases per million. Sports-related injuries are the second most common cause of SCI in patients less than 30 years of age, and 7% of new SCI cases involve sports (4,6,10,17). The sports most commonly cited are diving followed by football, skiing, and horseback riding. In the United States, it is estimated that more than 250,000 people are living with SCI. Recent data suggest that thoracic-level SCI account for 35.6% of the national SCI database (30). The demographics show that the majority of injuries occur in young, single males. With regard to sports-related SCI, 23.9% occurred in populations less than 15 years of age and then trending down with increasing age. Neurologically incomplete lesions account for 53%, and the trend is increasing, thought to be due to better on-scene emergency medical services (30)

The initial treatment and management of patients with SCI are outlined partly in the section on Clinical Evaluation. Historically the use of steroids, specifically methylprednisolone, was considered a fundamental component of the treatment for SCI. Current guidelines, however, no longer recommend the administration of methylprednisolone given the absence of Class I or Class II medical evidence supporting the clinical benefit of steroids. Furthermore there is good evidence that the use of high-dose steroids is associated with harmful adverse effects (15). There have been many other significant advances in the treatment of SCI over the past several decades. Many of these have involved prevention strategies, prehospital care, emergency department management, intensive care, and SCI rehabilitation. Nevertheless SCI entails significant morbidity and mortality including multisystem compromise, depression/suicide, and decreased life satisfaction. Life expectancy is normal in

90% of patients with paraplegia and 80% in quadriplegia, and treating physicians must be adept at recognizing secondary complications and orchestrating appropriate rehabilitation protocols. The young age of sports-related participants leads to a substantial burden of SCI on the patient-centered care team.

Return to Play

Important variables to consider in treating patients with sports-related thoracic spine injuries include injury prevention, appropriate supervision, medical protocols, game management, and return to play guidelines. The topic of return to play after spinal injury is complex and, at times, difficult to enforce. Burnett et al. (5) note that litigation concerns by physicians sometimes extend athlete restrictions, causing delay in return to a sporting activity. In their discussion, they suggest several injury-specific return to play guidelines and remind physicians not to lose sight of the significant financial and emotional burden surrounding spine related injuries experienced by the athlete (5). In addition, they mention the importance of optimizing health treatment plans while avoiding risk of devastating injury. Amateur and professional athletes must be treated equally.

There is paucity of literature to guide the decision for return to play with regard to spinal injuries in general. In the discussion of return to play criteria in cervical spine injuries, Vaccaro et al. (23) considered mechanism of injury, objective clinical and radiographic evaluation of the injury, and the athlete's recovery response. With regard to thoracic injuries specifically, current concepts recommend that the athlete should be able to return to preinjury level of play once painless range of motion and strength are achieved and in the absence of neurologic deficit. Injuries and operative treatment involving the transitional regions of the cervicothoracic and thoracolumbar injuries are far more likely to produce altered biomechanics; therefore these athletes should be limited further (5). Restrictions affecting return to play on midthoracic injuries are shortened compared with those in the junctional regions due to the 40% increased biomechanical stability provided by the rib cage, sternum, and paraspinal musculature (3,14,26). Burnett et al. (5) recommend that athletes who have undergone midthoracic decompression or fusion be released to sporting activities if they are pain free and neurologically intact and if the imaging correlates to successful surgical treatment.

Conclusions

The anatomical and biomechanical characteristics of the thoracic spine and thoracic cage are important in understanding and recognizing injury patterns involving the thoracic spine. Although the incidence of thoracic spine injuries in sports is less common compared with that of the cervical and lumbar spines, it is still a region that is vulnerable to injury. A thorough knowledge of biomechanics, anatomy, and mechanism of injury allows for the most successful medical care for athletes experiencing sports-related thoracic spine injuries.

All authors declare no conflicts of interest and do not have any financial disclosures.

References

1. Banerjee R. Catastrophic cervical spine injuries in the collision sport athlete, part 1: epidemiology, functional anatomy, and diagnosis. *Am. J. Sports Med.* 2004; 32:1077–87.
2. Banerjee R. Catastrophic cervical spine injuries in the collision sport athlete, part 2: principles of emergency care. *Am. J. Sports Med.* 2004; 32:1760–4.
3. Berg EE. The sternal-rib complex. A possible fourth column in thoracic spine fractures. *Spine*. 1993; 18:1916–9.
4. Boden BP, Boden MG, Peter RG, *et al*. Catastrophic injuries in pole vaulters: a prospective 9-year follow-up study. *Am. J. Sports Med.* 2012; 40:1488–94.
5. Burnett MG, Sonntag VK. Return to contact sports after spinal surgery. *Neurosurg. Focus*. 2006; 21:E5.
6. Cantu RC, Mueller FO. Catastrophic football injuries: 1977–1998. *Neurosurgery.* 2000; 47:673–5; discussion, 5–7.
7. Clarke KS. Epidemiology of athletic neck injury. *Clin. Sports Med.* 1998; 17:83–97.
8. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine*. 1983; 8:817–31.
9. Elattrache N, Fadale PD, Fu FH. Thoracic spine fracture in a football player A case report. *Am. J. Sports Med.* 1993; 21:157–60.
10. Gill SS, Boden BP. The epidemiology of catastrophic spine injuries in high school and college football. *Sports Med. Arthrosc.* 2008; 16:2–6.
11. Gray BL, Buchowski JM, Bumpass DB, *et al*. Disc herniations in the national football league. *Spine*. 2013; 38:1934–8.
12. Guly HR, Bouamra O, Lecky FE, Trauma Audit and Research Network. The incidence of neurogenic shock in patients with isolated spinal cord injury in the emergency department. *Resuscitation*. 2008; 76:57–62.
13. Hochschuler S. *The Spine in Sports*. Philadelphia (PA): Hanley & Belfus, Inc.; 1990, p. 342.
14. Horton WC, Kraiwattanapong C, Akamaru T, *et al*. The role of the sternum, costosternal articulations, intervertebral disc, and facets in thoracic sagittal plane biomechanics: a comparison of three different sequences of surgical release. *Spine*. 2005; 30:2014–23.
15. Hurlbert RJ, Hadley MN, Walters BC, *et al*. Pharmacological therapy for acute spinal cord injury. *Neurosurgery.* 2013; 72:93–105.
16. Kang DH, Lee SH. Multiple spinous process fractures of the thoracic vertebrae (Clay-Shoveler's Fracture) in a beginning golfer: a case report. *Spine*. 2009; 34:E534–7.
17. Molsa JJ, Tegner Y, Alaranta H, *et al*. Spinal cord injuries in ice hockey in Finland and Sweden from 1980 to 1996. *Int. J. Sports Med.* 1999; 20:64–7.
18. Patel AA, Vaccaro AR. Thoracolumbar spine trauma classification. *J. Am. Acad. Orthop. Surg.* 2010; 18:63–71.
19. Ryken TC, Hurlbert RJ, Hadley MN, *et al*. The acute cardiopulmonary management of patients with cervical spinal cord injuries. *Neurosurgery.* 2013; 72:84–92.
20. Stillerman CB, Chen TC, Couldwell WT, *et al*. Experience in the surgical management of 82 symptomatic herniated thoracic discs and review of the literature. *J. Neurosurg.* 1998; 88:623–33.
21. Stuart MJ, Smith AM, Malo-Ortiguera SA, *et al*. A comparison of facial protection and the incidence of head, neck, and facial injuries in Junior A hockey players: a function of individual playing time. *Am. J. Sports Med.* 2002; 30:39–44.
22. Swartz EE, Boden BP, Courson RW, *et al*. National athletic trainers' association position statement: acute management of the cervical spine-injured athlete. *J. Athl. Train.* 2009; 44:306–31.
23. Vaccaro AR, Klein GR, Ciccoti M, *et al*. Return to play criteria for the athlete with cervical spine injuries resulting in stinger and transient quadriplegia/paresis. *Spine J.* 2002; 2:351–6.
24. Vanichkachorn JS, Vaccaro AR. Thoracic disk disease: diagnosis and treatment. *J. Am. Acad. Orthop. Surg.* 2000; 8:159–69.
25. Watkins R. *The Spine in Sports*. St. Louis (MO): Mosby; 1996, xxi, p. 657.
26. Watkins R 4th, Watkins R, 3rd, Williams L, *et al*. Stability provided by the sternum and rib cage in the thoracic spine. *Spine*. 2005; 30:1283–6.
27. Winter B, Knight D. Spinal cord injury. *Anaesth. Intensive Care Med.* 2005; 6:315–7.
28. Yamaguchi KT Jr., Myung KS, Alonso MA, *et al*. Clay-shoveler's fracture equivalent in children. *Spine*. 2012; 37:E1672–5.
29. Yoshihara H. Surgical treatment for thoracic disc herniation: an update. *Spine*. 2014; 39:E406–12.
30. Zigler JE, American Academy of Orthopaedic Surgeons. *Spine Trauma*. 2nd ed. Rosemont (IL): American Academy of Orthopaedic Surgeons; 2011, xxiii, p. 792.