Chapter 3
Spinal Injury in Athletes: Prevalence and Classification

Gordon Mao and Nicholas Theodore

Abbreviations

AIS	ASIA Impairment Scale
ASIA	American Spinal Injury Association
CCN	Cervical cord neuropraxia
CSI	Cervical spine injury
MVA	Motor vehicle accident
NSCISC	National Spinal Cord Injury Statistical Center
SCI	Spinal cord injury
SLIC	Subaxial Injury Classification
TAL	Transverse atlantal ligament
TLICS	Thoracolumbar Injury Classification and Severity

Introduction

Athletic competition is a common cause of traumatic spinal cord injury (SCI). In fact, sports-related injuries contribute to 8.7% of SCI cases in the United States and are a leading cause of SCI only behind motor vehicle accidents, falls and violence [54]. Spinal injuries are common across all age groups, from high school athletics to collegiate- and professional-level sports. These injuries can be devastating and have long-lasting effects on athletes and their families.

G. Mao · N. Theodore (✉)
Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA
e-mail: theodore@jhmi.edu

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Sports-related spinal injuries are separated into cervical and thoracolumbar spine injuries. Cervical injuries include insults to the C1 vertebra as well as the craniocervical junction downward to the C7–T1 disc space and facet joints. Common causes of cervical spine injuries include both direct-contact sports such as American football, wrestling, ice hockey, and baseball; and non-contact sports such as diving, skiing, snowboarding, and cheerleading. Thoracolumbar injuries include those that occur from the T1 vertebra downward, through the lumbar and sacral spine to the coccyx. Thoracolumbar sports injuries are even more prevalent than cervical sports injuries, and frequently occur during both direct-contact sports such as football and hockey, as well as sports with frequent jumping and landing, such as basketball and downhill skiing or snowboarding.

The term “spinal injury” is broad and may be used to describe direct damage to the spinal column, the neural elements that make up the spinal cord, the 31 pairs of exiting spinal nerve roots, and the surrounding paraspinous muscles that allow for movement and maintenance of erect posture. The spinal column itself includes the boney vertebral elements, the intervertebral discs, and the surrounding stabilizing ligamentous structures that support the vertebral column against gravity and preserve normal, anatomic alignment during movement. Minor injuries to the spinal column generally affect the paraspinous musculature and fascia, which absorb the brunt of the trauma and spare the underlying spinal column and neural elements from severe injuries. Major spinal injuries from high-energy sports trauma can cause significant damage to the spinal column, leading to acute mechanical instability, or neurologic injury that causes different patterns of weakness and numbness in the torso and extremities. High-impact injuries can also result in epidural hematoma, angulated or comminuted vertebral fractures, or catastrophic fracture–dislocations—all of which can result in the violation of the spinal canal with resulting SCI and pronounced neurologic deficit. Of the 11,000 cases of SCI in the US per annum, the second leading cause of SCI in the young adults (ie, patients under the age of 30) is sports participation [66].

Cervical Spine Injuries

Incidence

The cervical spine supports the weight of the head and provides flexibility that allows extensive range of motion of the head. Cervical spine injuries can manifest in a wide spectrum of physiologic and neurologic symptoms, both transient and permanent. Mild injuries can present primarily with pain and spasm from soft tissue injury without structural instability or neurologic impairment. In other instances, non-catastrophic cervical injuries can include transient neurologic phenomena from radicular or plexus injuries, such as stingers or burners, and mild cord insult causing cord neuropraxia. Cervical cord neuropraxia (CCN) generally comprises transient sensory disturbance of the upper or lower extremities with resolution in 10 to

15 minutes [9], secondary to hyperflexion or hyperextension neck movements in individuals with existing spinal stenosis. Stingers, or transient unilateral or bilateral dysesthesia of the upper extremities, can also occur in patients with milder injuries secondary to brachial plexus traction. Less commonly, catastrophic cervical injuries can cause acute mechanical instability from disruption of osteoligamentous structures, as well as neurologic deficit from nerve root injury or acute SCI.

Because of the high range of motion in the cervical spine, injuries can occur in a variety of positions. Catastrophic injuries involving SCI or traumatic malalignment typically occur with axial impact to the top of the head with the neck in flexion. In the neutral (ie, lordotic) position, the impact energy is dissipated by both the paravertebral musculature and the intervertebral discs. However, at 30 degrees of flexion, the energy is transferred directly through the spinal column up to the failure point when a flexion injury (eg, flexion tear drop fracture, facet dislocation) or pure compression (eg, burst fracture, acute disc herniation) injury occurs [9].

A severe, sudden twist to the neck or a severe blow to the head or neck can cause a neck fracture. Sports involving violent physical contact (eg, football, ice hockey, rugby, and wrestling) carry a greater risk of neck fracture. Spearing an opponent in football or rugby can cause a neck injury, as can non-contact activities like gymnastics—for example, if the gymnast misses the high bar during a release and falls. Cervical spine injuries can range from subluxations and dislocations with or without neurologic symptoms to fractures with or without neurologic symptoms.

The US Consumer Product Safety Commission tracks product-related injuries through its National Electronic Injury Surveillance System. According to the Consumer Product Safety Commission, an estimated 23,720 neck fractures were treated at US hospital emergency departments in 2018. Of these, an estimated 3194 fractures (13.47%) were related to sports. Cervical injuries can occur both in contact sports, such as soccer and rugby, and in non-contact sports, such as gymnastics and cycling. Between 2000 and 2015, the number of sporting-related cervical fractures increased by 30%, driven primarily by a 300% increase in cycling-related injuries [75]. Gender-related differences also exist in SCI patients, due to the underlying differences in the popularity of various sports between men and women (Fig. 3.1). Cycling was the most common cause of cervical fractures in men, whereas horseback riding was the most common cause in women [18]. Nearly one-quarter of cervical spine injuries (CSIs) in young persons under 15 years of age are sport related, and 85% of sport-related CSIs result in tetraplegia [54]. More than 250 new sport-related CSIs occur each year [54].

The risk of injury varies among sports. Ice hockey players are among those at highest risk of CSIs [83]. American tackle football has the highest number of catastrophic cervical spine injuries among all sports played in the United States, due to the high level of participation, with more than 1.5 million active players ranging from middle school to professional levels [83]. American football does, however, maintain an overall low rate of cervical spine injuries [52]. Less than 1% of cervical spine injuries result in a serious fracture or SCI [48]. Just as the development of safer helmets reduced the incidence of traumatic brain injury in football in the 1970s, cervical spine injury rates likewise declined after the recognition and ban of

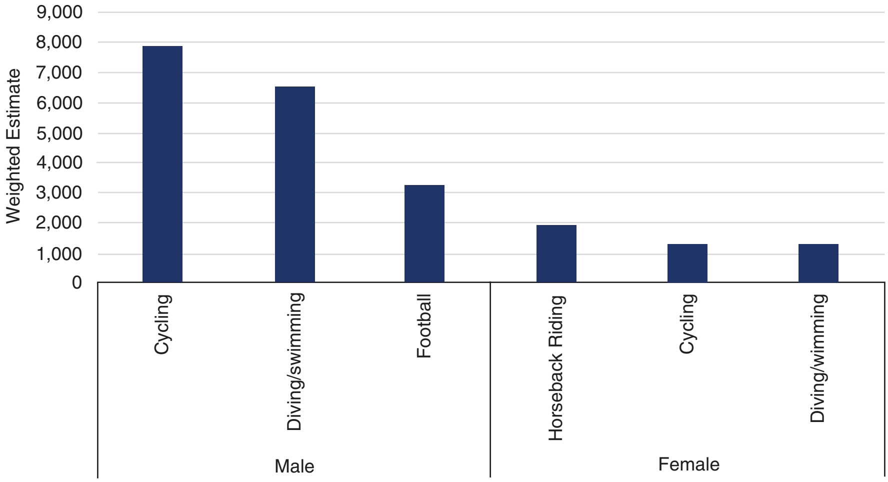


Fig. 3.1 Most frequent causes of cervical spine fractures in men versus women (Depasse [18])

dangerous maneuvers such as spear tackling in 1976, dropping the rate of quadriplegia by 80% over the subsequent decade [73]. CCN is estimated to occur in approximately 7 per 10,000 participants [72], and CSIs are estimated to occur in 10% to 15% of all football players—most commonly in linemen and defensive players. Similarly, rugby also has a high rate of cervical injury, particularly due to the lack of protective gear worn by the players and the aggressive style of play. During engagement, a rugby hooker player can sustain almost 0.75 tons of force. Overall, 10% of serious rugby injuries occur in the cervical spine, with SCI occurring in 25% of those cases [62].

Injuries are an inevitable consequence of horseback riding, as the rider's head may be up to 4 m (13 feet) from the ground and horses can travel at speeds up to 65 km/h (40 mph) [64]. In the US, as many as 30 million people will ride a horse each year [59], and a 1991 report of horseback riding injuries described 217 deaths in 10 states [14]. Horseback riding carries an injury rate of 1 per 350 hours of riding, which is 20-fold higher than the injury rate of motorcycling [29]. Unlike other sports in which the head often leads during movement, falls from horseback riding predominantly cause thoracolumbar injuries. Horseback riding accidents can be divided based on 2 methods of riding—the jockey style with the head forward, which presents a higher risk for cervical injury after a fall; and the classical style, where the head is held high and the rider lands on her buttocks [7].

Cervical spine sports-related injuries increased by 35% between 2000 and 2015, mainly due to an increase in cycling-related injuries. A 14-year Canadian study of severe cycling injuries identified spine injury as accounting for 45.7% of the 11,772 cases [60]. Studies in the US, Ireland, Australia, France, and Israel have all found evidence of increased cycling related-cervical spine injuries. During a 1-year period in Ireland, 70% of cycling-related spine trauma occurred in the cervical spine [13].

The authors of these studies attributed the increased popularity of cycling to its health benefits and the agreeable climate [18]. In a study specifically looking at off-road cycling, a similar 73% spine injury rate was seen, but off-road cycling was associated with higher relative rates of severe SCI (40% ASIA A) [21] compared with road cycling (12.5% overall) [13].

Cheerleading has evolved into a highly competitive sport that requires complex gymnastic maneuvers. At the high school and college levels, cheerleading is the leading cause of up to 50% of severe sports injuries, with the United States Consumer Product Safety Commission recognizing 1814 neck injuries occurring in collegiate cheerleaders in 2000 [10]. Collegiate cheerleading athletes sustain more injury proportionally than those at the high school level due to the increasing technical difficulty of the performances. The pyramid stunt and the basket toss are the most common scenarios for injury, mostly due to the high vertical distance reached by the participants, and the hard indoor gym surface [12]. In response to these risk factors, safety guidelines have been implemented to limit the maximum height of pyramids to 2 people at high school level and 2.5 body lengths at collegiate level, and to limit stunts such as the basket toss during wet conditions.

Although spinal injuries are infrequent in baseball, the relative rate of catastrophic cervical spine injuries remains high, as in cheerleading. A common scenario involves a base runner diving head-first toward the catcher and sustaining a compressive injury. Rules advise the runner to avoid the fielder, who has the right to base path [9], but this rule is not always followed. Little leagues have outright banned head-first sliding in favor of feet-first sliding.

Diving injuries in shallow water are another well-recognized cause of catastrophic cervical SCI. Although many recreational cervical spine diving injuries remain unreported, a European trauma center reported 7.7% of all cervical SCI to be from diving [63]. Both college and high school athletic associations now prohibit race diving in waters less than 4 feet in depth, and many community recreational pools are choosing to remove high-dive boards in favor of water slides to mitigate the risk of SCI.

Spine injuries in wrestling overwhelmingly occur in the cervical spine, notably when a wrestler lands directly on top of his head with his arms locked in a position unable to support his body weight, or when a wrestler attempts to roll but is landed on with the full weight of his competitor [9]. More injuries occur in the light- and middle-weight divisions frequently during a defensive posture during a takedown, followed by a kneeling or lying position. Vulnerable wrestlers in the defensive position often have their arms restrained, preventing protection of the neck [11]. Thus, the main safety mechanisms rely on both the referee and the coach maintaining vigilance, and a low threshold for stopping the match in dangerous circumstances.

Downhill skiing is another common cause of both cervical and thoracolumbar spine injuries. Although the rate of SCI is low—just 0.01 per 1000 ski days [51]—spinal injuries in downhill skiing actually appear to be increasing in the past 2 decades. Injuries tend to occur in younger male skiers, with risk factors including poorly groomed slopes, equipment failure, inclement weather, collision, high speeds, and overcrowded conditions. Injuries tend to occur at the end of the day, suggesting that fatigue is a major factor, and fatalities are typically from traumatic brain injury secondary to collision with stationary object.

Ice hockey is also a common source of cervical spine injury due to its high participation rate. Most injuries occur in the lower cervical spine, between C5–7, and do not result in SCI. Common mechanisms include axial loading to the top of the head from direct head contact with the boards after being checked from behind. A Canadian survey from 1966 to 1993 reported 241 cervical spine fractures from ice hockey [68].

Classification

Cervical spine injuries are generally classified based on a morphologic description of the fracture level and pattern, and traditionally divided into subaxial (C3–T1) and upper cervical (occipital condyle–C2) injuries. Traditionally, various common fracture patterns of the cervical spine have been described individually and attributed to eponymous physicians with specific grading systems attached in order to categorize fractures on a spectrum of severity, thereby guiding treatment practices. Since the 1980s, efforts have been made to create subaxial cervical injury classification schemes, but none of these early systems were widely adopted by spine surgeons due to their over-complexity in real-world application and lack of validation studies. More recently, in 2011, the Academy of Orthopedics has developed a more structured nomenclature system to describe upper cervical (Fig. 3.2) and subaxial spine injury (Fig. 3.3).

In a clinical context, cervical injuries resulting from participation in sports can be divided into the following syndromes:

- Acute cervical sprains/strains, including whiplash injury.
- Cervical spinal stenosis.
- Intervertebral disc lesions.
- Nerve root or brachial plexus injuries.
- Cervical fractures and dislocations.
- Transient or permanent quadriplegia from SCI.

Historically, upper cervical spine injuries have been considered a distinct entity due to the inherent anatomic differences in the morphology of the C1 and C2 vertebrae as well as the unique and high degrees of motion concentrated at the craniocervical junction and the C1–2 segment [20]. A significant degree of flexion–extension motion is contributed by the atlantooccipital joint between C1 and the cranium. The atlantoaxial joint between C1 and C2 is responsible for approximately 50% of cervical rotation. In particular, ligamentous structures are recognized for their high contribution to the stability of motion segments of the upper cervical spine. Upper cervical injuries are rare in sports and are more commonly seen in either a high-impact settings (eg, MVA, fall from height); however, they can occur with direct cervical trauma in sports such as diving and American football. We will describe

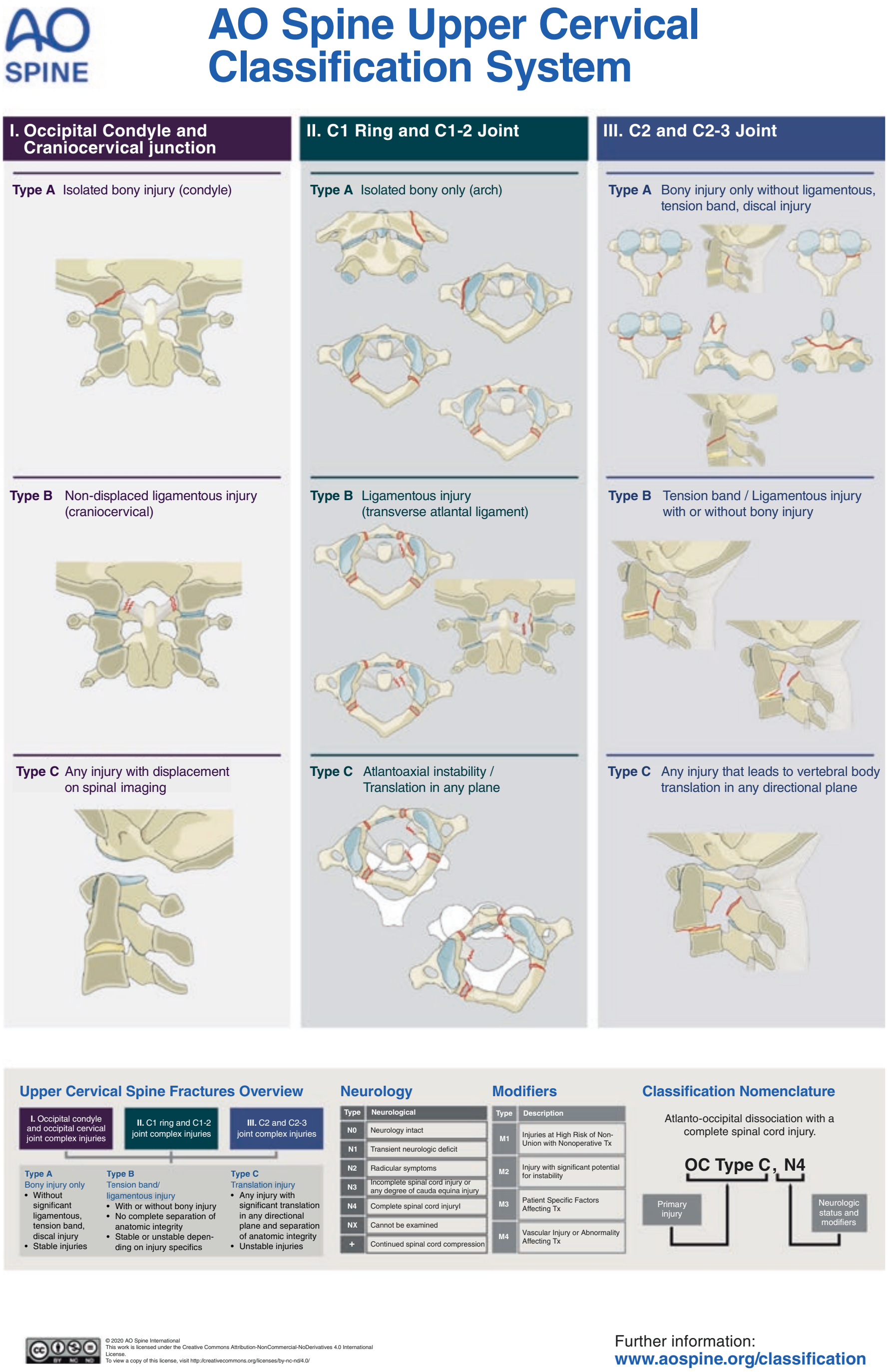


Fig. 3.2 Upper cervical spine classification. (Reprinted with permission from AOSpine International. © AOSpine International, Switzerland)

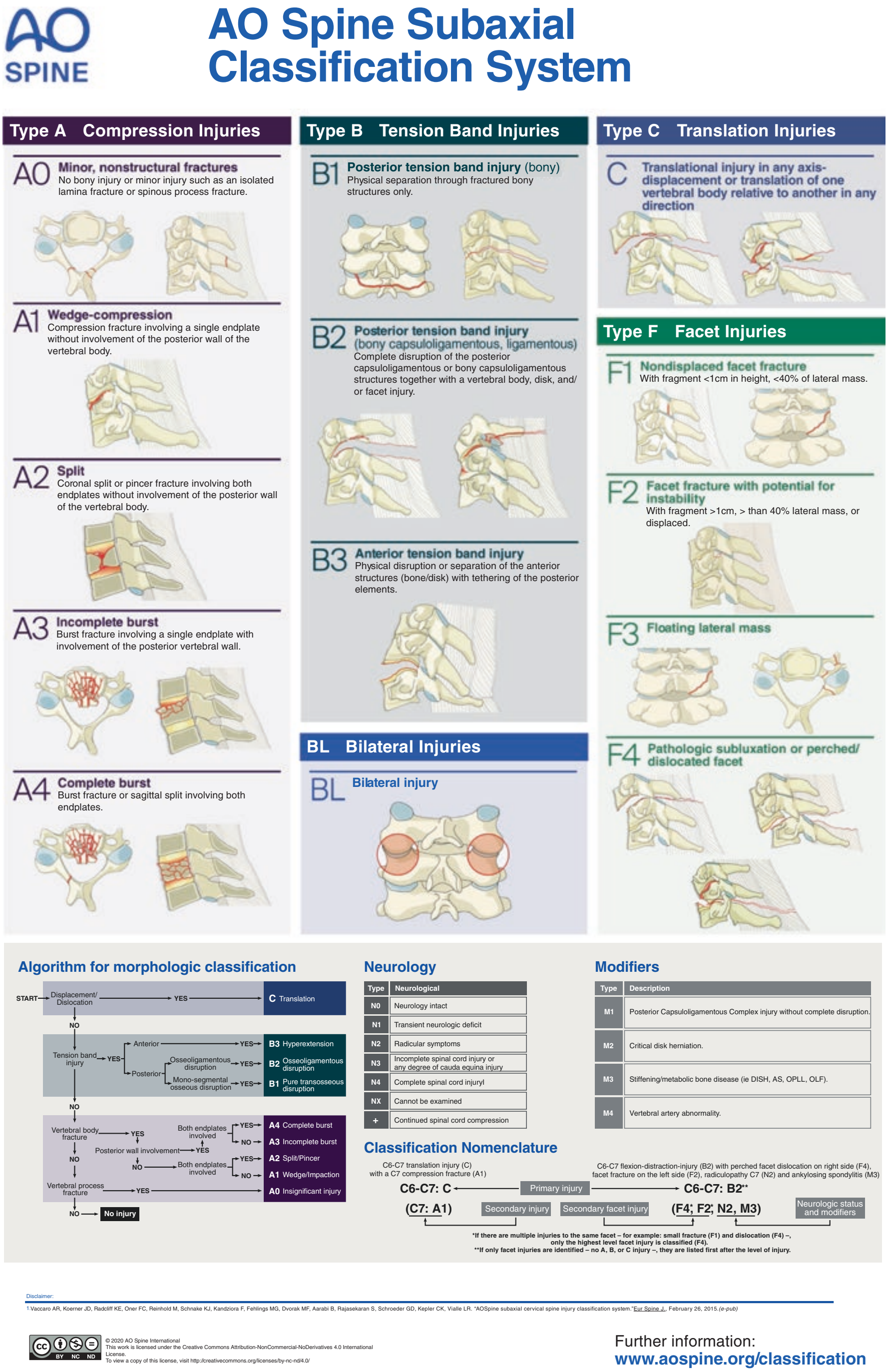


Fig. 3.3 Subaxial cervical spine classification. (Reprinted with permission from AOSpine International. © AOSpine International, Switzerland)

some of the older classification schemes as well as a new system developed by AOSpine.

Older classification systems of upper cervical spine injury are based on the specific level of injury as well as the morphology or potential for instability. Occipital condyle fractures are commonly described by the Anderson and Montesano system [4], which is based on the mechanism of injury and extent of fracture. Traumatic atlantooccipital dislocations are classified by the Traynelis system [74], which is based on direction of displacement, while the later Harborview system [8] graded the degree of displacement to predict stability.

Fracture of the C1 vertebra is classically referred to as a Jefferson fracture when it affects both the anterior and posterior rings. Jefferson fractures are described generally based on suspicion for transverse atlantal ligament (TAL) injury, which affects the stability of the C1–2 complex. Odontoid fractures are described morphologically by the Anderson and d'Alonzo system [3] based on involvement of the C2 body and location of the fracture line with respect to TAL. C2 pars fractures, known as Hangman fractures when occurring bilaterally, were described by 2 similar systems known the Francis and Effendi (modified by Levine-Edwards) systems. The Francis classification [30] separated fractures based on degree of fracture displacement (3.5 mm), C2–3 angulation (11 degrees), and C2–3 disc space involvement. The Effendi system [26, 45] divided fractures based on progressive degrees of ligamentous involvement, initially with posterior longitudinal ligament or disc disruption, and culminating in C2–3 facet capsule disruption.

The AOSpine upper cervical classification system was created in 2013 to unify and simplify existing classification systems. It divides injuries into 3 broad categories based on the spinal level affected—the occipital condyle and craniovertebral junction, the C1 vertebral body and C1–2 joint injuries, and C2 vertebral body and C2–3 joint issues. Each injury type is then subcategorized into 3 categories of increasing instability, beginning with isolated boney fracture, then additional ligamentous injuries, and finally, translational injuries. Additional case-specific "M" modifiers are available. M1 describes any ligamentous injuries with high potential for instability (eg, radiographic evidence of TAL disruption). M2 describes risk factors for nonunion, such as odontoid fracture with significant displacement (>5 mm) or angulation (>11 degrees). The M3 modifier describes patient comorbidities such as smoking, renal failure, or osteoporosis that would affect treatment. Finally, M4 describes any anatomic or vascular abnormality or injury that would affect treatment, such as the presence of vertebral artery injury.

The subaxial cervical spine is a region commonly affected by trauma. Various methods have also been proposed to classify these injuries. In isolation, these systems have been based on assumed mechanism of injury inferred from plain radiographs, ignoring the contribution of ligaments to stability and failing to account for underlying neurologic injury [76]. Allen and Ferguson [2] provided the first comprehensive description of such injuries based primarily on mechanism of trauma. This include the categories CF (compressive flexion), VC (vertical compression), DF (distractive flexion), CE (compressive extension), DE (distractive extension), and LF (lateral flexion). Each category was further subdivided into 2–5 severity stages to correlate with degree of neurologic risk. Although this was comprehensive, it has been difficult to apply clinically and lacks interobserver reliability [65]. Another classification system was later introduced by Harris [36]. Based on biomechanical, cadaveric, and pathological evidence that vector forces along the "central coordinating system" are fundamental determinants of cervical spine injuries, Harris and colleagues introduced yet another mechanistic classification based on the literature and clinical data [1]. Major vector forces in this system were flexion, extension, rotation, vertical compression, and lateral bending. Like the Allen method, this scheme was overly detailed and was never adopted into widespread use.

AOSpine developed a user-friendly unified subaxial classification system in 2016 [77]. By avoiding overly descriptive terminology often used in historical systems, injury morphology was used as the basis for recent algorithm-based systems instead of mechanism of injury. This comprehensive but simple classification system was developed with high intraobserver and interobserver reliability. It separates injuries broadly into compression injuries (type A), distraction injuries (type B), and translation injuries (type C), in a fashion similar to the AOSpine thoracolumbar injury classification (described below). Like thoracolumbar injuries, type A subaxial injuries are categorized on a continuum ranging from minor, nonstructural fractures to complete burst fractures, whereas type B injuries are split between anterior versus posterior tension band injuries. Unique to the subaxial classification is a fourth category (type F) specifically created to distinguish facet injury patterns from small, nondisplaced fractures affecting less than 40% of the lateral mass to true facet dislocations. Also similar to other AOSpine schemas, additional neurologic (N) and patient-specific modifiers (M) can optionally be added to capture the complete clinical picture of the spinal injury, ultimately assisting surgeons to select a treatment plan.

Management

Cervical spine injuries can be managed operatively or nonoperatively, depending on the biomechanical stability of the injury and the neurologic status of the patient. Different factors, such as the fracture pattern, suspected mechanism of injury, spinal alignment, and expected long-term stability will also help determine the treatment plan. Panjabi and White introduced the most widely accepted definition of clinical spinal stability: namely, the ability of the spine under physiology loads to limit displacement in order to prevent injury or irritation of the spinal cord and nerve roots, and to prevent major deformity or incapacitating pain due to structural changes [82]. In their seminal cadaveric biomechanical study, Panjabi and White systematically destroyed the facets and incrementally sectioned ligamentous structures in 8 cervical cadaveric specimens, and then examined behavior of the spine under physiologic bending moments. They demonstrated that overt instability occurred whenever displacement or listhesis progressed to 3.5 mm at rest or with any physiologic bending or 11 degrees of segmental angulation in the subaxial spine.

Milder cervical spine injuries without significant neurologic deficit or concerns for acute instability may be treated conservatively with symptomatic pain control, and sometimes serial imaging and follow-up, with or without a rigid orthosis. Cervical sprains isolated to paraspinous muscle and soft tissue injuries often require only physical therapy and pain control without imaging or rigid orthosis. Traumatic injury patterns typically involve either isolated ligamentous injuries without acute malalignment or deformity, or focal boney fractures of the vertebral body or posterior elements without significant fracture displacement, malalignment, or concomitant ligamentous injuries. These injuries will require a rigid collar for at least 4 to 6 weeks, followed by dynamic cervical spine radiographs to assess stability before the collar can be discontinued and the patient returned to certain activities.

Acutely or overtly unstable cervical injuries typically require surgical intervention. These are usually classified as AOSpine type B or C subaxial injuries, which involve both boney and ligamentous injuries, or more severe type F (facet) injuries with high risk for instability. Unstable injuries typically have greater involvement of ligamentous structures and higher risk of development of acute malalignment. Rigid bracing or application of a Halo vest can be alternatives to surgery in patients with unacceptably high medical risk from comorbidities or advanced age. However, many surgeons try to avoid prolonged bracing for unstable fracture patterns due to the long-term risk factors of braces, such as pressure ulcers or aspiration risks, as well as development of severe spinal deformity.

In general, acute cervical injuries that cause pronounced or progressive neurologic impairment require surgical intervention at the very least to relieve neural compression. Often times, neurologic injury is related to higher impact and severity mechanisms that are also associated with boney or ligamentous injuries that are chronically or acutely unstable. These circumstances often necessitate open surgery involving decompression of the neural elements with instrumentation and fusion of multiple segments.

These anatomic and neurologic considerations have been synthesized into a validated severity scoring system for subaxial cervical injuries. The Subaxial Injury Classification (SLIC) scoring system was developed by Vaccaro and the Spine Trauma Study Group in 2007. According to the SLIC system, patients with scores between 6 and 10 represent surgical candidates; those with scores between 1 and 3 are likely better candidates for immobilization by rigid orthosis (Table 3.1). Unlike older frameworks built on inferred injury mechanisms, the SLIC system is utilitarian in that it abandons these anatomic considerations for the 3 expert-consensus–determined major components of the injury. This scheme was validated by 20 spine surgeons across 11 cervical trauma cases, showing raters' agreement with treatment recommendations of the algorithm in 93.3% of cases [76].

Table 3.1 The Subaxial Injury Classification (SLICS) scale

Classification	
Injury morphology	No abnormality: 0 points
	Simple compression fracture: 1 point
	Burst fracture: 2 points
	Distraction (eg, perched facet joint, hyperextension cervical injuries): 3 points
	Rotation/translation (eg, facet dislocation, unstable teardrop or advanced flexion compression injury): 4 points
Discoligamentous complex	Intact: 0 points
	Indeterminate (eg, isolated interspinous widening, MRI signal change only): 1 point
	Disrupted (eg, disc space widening, facet perch or dislocation): 2 points
Neurologic status	Intact: 0 points
	Root injury: 1 point
	Complete cord injury: 2 points
	Incomplete cord injury: 3 points
	Incomplete with ongoing cord compression: 4 points

Thoracolumbar Spinal Injuries

Incidence

Between 75% and 90% of spinal injuries occur in the thoracolumbar spine, most commonly between T10 and L3 [37]. Low back pain is common in the general population, but almost 30% of athletes experience lumbar pain directly related to their sports participation [24]. Unlike cervical spine injuries, thoracolumbar injuries in athletes tend to separate into 2 distinct populations. The first is the acute, high-energy traumatic injury that typically occurs at the thoracolumbar junction with boney, and (often concordant) ligamentous injuries that can also be associated with SCI or root injuries. The second population comprises more chronic, degenerative stress injuries that occur in the lower lumbar spine secondary to the strenuous and repetitive flexion, extension, and loading activities involved in athletic training and competition [5]. In a study of collegiate athletes, just over 50% of lumbar injuries were found to be acute [40].

Age and anatomic considerations also influence the type of lumbar injury. Adolescent athletes experience more posterior-element injury secondary to skeletally immature spines [50], whereas adults tend to suffer from muscle strain and discogenic disease [25]. In general, sports involving repetitive hyperextension, axial loading (jumping), twisting, or direct contact carry higher risks of low-back injuries. In a study of 4790 collegiate athletes, the highest rates of lumbar injuries were seen in football players, gymnasts, and rowers, with an overall incidence of 7% among collegiate athletes [38]. Another study identified the setting of injury as predominantly during practice in 80% of cases, versus 14% during preseason, and 6% during competition [40].

American football is a common cause of thoracolumbar injuries, with 30.9% of all football injuries involving the lumbar spine [48] and 28% of lumbar injuries due to disc herniations at L4–5 and L5–S1 [33]. Axial loading is a common mechanism during heavy blocking and tackling maneuvers; therefore, defensive and offensive linemen are the players most commonly affected. Shear stress from sudden directional changes in non-contact scenarios can also lead to injuries. Pars fractures (spondylolysis) are also common affecting up to 50% of players [70], in part due to the inadequate locking of the lumbosacral spine that normally protects the spine since there are multiple concurrent forces on the athlete as they compete for possession of the ball [15].

Ice hockey players have a high prevalence for chronic low back pain—one study reported that 95% of players experienced chronic low back pain [39]. One long-term study over 15 years in players with a median age of 24 found that most athletes who developed back pain already had existing degenerative abnormalities on magnetic resonance imaging, and these abnormalities continued to progress throughout their careers. This study concluded that most back pain was the result of injuries sustained during adolescence that persisted through adulthood [6]. A study of Canadian hockey league players identified 18% of spinal injuries in the thoracolumbar spine, with the most common mechanism of injury as being checked from behind [69]. Furthermore, up to 44% of low back pain in youth hockey may be linked to spondylolysis [22].

The incidence of spinal injuries in snowboarding is almost 4 times higher than skiing. Most injuries are in the thoracolumbar spine [46] and secondary to overcrowded slopes and high-risk jumps. Jumping is estimated to be responsible for 80% of these injuries [67].

Basketball injuries are heavily concentrated in the lower extremities and lumbar spine due to the large amount of jumping and short sprints involved in the game. Lumbar injuries account for 10.2% of all National Basketball Association player injuries [23] based on a 17 year study. The majority of lumbar injuries were related to musculoskeletal strain and sprain, which accounted for 7.9% of injuries while disc disease accounted for another 0.9% [23].

Degenerative lumbar disease is also prevalent in baseball. One Major League Baseball study found a 11.7% injury rate between 2002 and 2008 [57], whereas a Japanese study showed a 60% prevalence of degenerative disc disease at the L4–5 and L5–S1 levels among professional players [34]. Indeed, 89.5% of baseball players report experiencing lower back pain during their lives [34].

Injury Classification

An understanding of the typical injury patterns in the thoracolumbar spine requires an understanding of the anatomic and biomechanical consideration of the thoracolumbar spine. The natural lumbar lordosis disperses axial loads both perpendicularly and horizontally through the disc space [25]. Flexion movements place the instantaneous axis of rotation at the center of the disc space, placing tension on the lumbodorsal fascia, erector spinae muscle groups, and gluteus maximus, whereas extension movements shift the instantaneous axis of rotation posteriorly within the disc space. The spinal column bears significant tensile and shear stress, as well as compressive loads, whereas the posterior soft tissues bears more resistive stress.

Minor and degenerative thoracolumbar injuries in athletes can be broadly classified into several patterns. Soft tissue injuries are the most common and divide into "sprains," which are ligamentous injuries, and "strains," which are injuries to the muscle, tendon, and musculotendinous junction [25]. These injuries typically present with localized paraspinous tenderness with superficial bruising and back pain exacerbated by bending or twisting at the waist. Pseudoradicular symptoms of radiation to the hip may be present, representing spasms extending to the fascia latae.

Disc herniations are also common. They can occur acutely during weight-lifting or strength training, or from a sudden twisting or pivoting movement. Athletes who are exposed to repetitive twisting, bending/flexion, or heavy lifting movements are vulnerable to lumbar disc herniations [25]. Bowling and collision sports both have higher risks of herniation [53]. Radicular symptoms typically occur in older athletes, while younger, adolescent, or collegiate athletes more often present with back pain and spasm likely due to the more viscous disc composition and lower chances of a large, sequestered disc free-fragment [32].

Minor fractures without any risk to spinal stability or neural elements also often occur. These injuries include thoracic and lumbar spinous process and transverse process fractures, as well as vertebral body endplate and wedge compression fractures. These fractures can occur after forceful rotation, flexion, compression, and direct blows. Athletes with these injuries typically report acute-onset localized pain, generally without any neurologic signs or symptoms.

More severe thoracolumbar injuries typically pose significant risk to mechanical stability and neurologic elements. Historically, various classification systems have been based on individual experience or retrospective series predicated on anatomic structures of the injury involvement as well as mechanisms of injury. Many systems were difficult to apply clinically, as they involved an impractical number of variables and were difficult to interpret. Serious efforts at creating a comprehensive morphology-based classification systems such as the Magerl system [47] were overly complex for clinical use and ultimately were never validated, revised, or updated. For many decades, there was a lack of a widely accepted universal classification system.

Kelley and Whiteside proposed the first biomechanical model of thoracolumbar stability in 1968, introducing the concept of the 2-column model—the anterior column (vertebral body) and the posterior column (neural arches) [41]. By the 1980s, McAfee et al. analyzed a series of 100 patients with unstable fracture complexes using modern computed tomography technology that offered insight into some of the important theoretical principles behind our current understanding of thoracolumbar stability, such as the integrity of the middle column osteoligamentous complex and the effects of translational injuries [49]. Another influential mechanical model, proposed by Francis Denis in 1983, is known as the 3-column thoracolumbar stability model. Denis became the first person to introduce a graduated system of instability rather than trying to clearly define each injury in a binary (ie, stable or unstable) fashion. The anterior column was composed of the anterior two-thirds of the vertebral body, while the middle column—often crucial in defining stability—was composed of the posterior longitudinal ligament and posterior one-third of the body. The posterior column was composed of the pedicles and other neural elements and dorsal ligamentous structures. Isolated violation of the anterior or posterior was therefore considered a more stable injury, while the addition each additional column increased the instability of the injury.

An international group of spine surgeons was assembled the American Academy of Orthopedics, known as the AOSpine Knowledge Forum, to formulate the current AOSpine thoracolumbar classification system (Fig. 3.4). This system takes into account morphological factors and other important clinical factors, such as neurologic status, with the goal of creating a simple but comprehensive classification scheme that could guide surgeons with treatment planning. This system was validated in a subsequent clinical study that found a moderate interobserver reliability coefficient (k = 0.56) and good intraobserver reliability coefficient (k = 0.68).

The AOSpine system separates injuries into 4 broad groups representing different injury mechanisms. Within each group, different subtypes are further delineated to distinguish severity or anatomic structures (eg, osseous vs ligamentous). Type A injuries involve various degrees of compression/axial-loading–related fractures. Type B injuries represent tension band injuries to key ligamentous structures anterior or posterior to the vertebral column. Type C injuries represent high-energy translational injuries in any plane or direction, and are considered uniformly structurally unstable. Additional modifier categories include neurologic status, which defines the degree of neurologic injury and presence of ongoing spinal cord compression, and patient-specific comorbidities that would affect surgical decision making or planning, such as presence of osteoporosis or ankylosing spondylitis.

Management Guidelines

Similar to the management of cervical spine injuries, traumatic thoracolumbar spine injury management is guided by the severity and stability of the injury complex, as well as the degree of neurologic impingement. Bracing, physical therapy, rest, and symptomatic pain relief are indicated with purely soft tissue paraspinous injuries that present with focal pain and back spasms that cause limitation of activity. Soft braces (ie, corsets) or no bracing can be used for injuries in which there is no concern for long-term chronic instability, whereas rigid (ie, clamshell) lumbar sacral orthosis or thoracic lumbar sacral orthosis braces can be used for more severe boney injuries, such as burst fractures, which have higher long-term risks for development of a focal kyphotic deformity.

Nonsurgical conservative management is reserved for injury complexes without pronounced or progressive neurologic injury or acute instability. Like cervical injuries, major neurologic compromise is typically an indication for urgent surgery for decompression and possible instrumented stabilization of the injury. Otherwise,

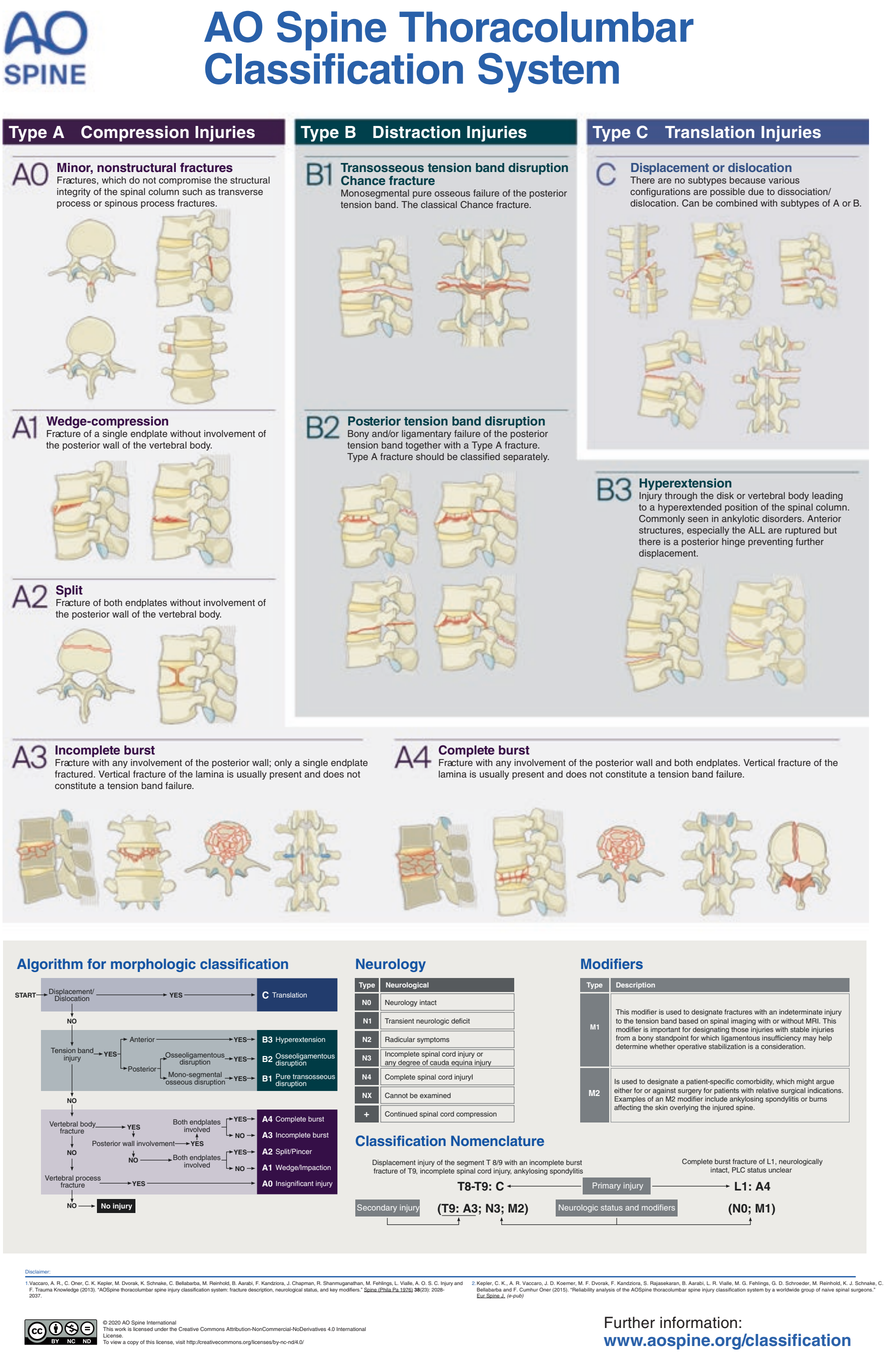


Fig. 3.4 Thoracolumbar classification. (Reprinted with permission from AOSpine International. © AOSpine International, Switzerland)

acutely unstable injuries without neurologic compromise will often also be surgical candidates for instrumented fixation or fusion procedures. Overtly unstable injuries typically involve at least 2 of the 3 columns [17] and represent AOSpine types B and C, especially with any translation or distraction noted on imaging.

Anatomic and neurologic considerations are similarly synthesized into a reproducible, valid, and easily performed scoring system known as the Thoracolumbar Injury Classification and Severity score (TLICS) score developed by Lee and the Spine Injury Trauma Group in 2005 [44]. TLICS was created based on an extensive review of the literature as well as consensus opinion from a diverse group of 40 spinal trauma surgeons from 15 trauma centers in the United States. This scoring system has been validated both retrospectively [78] and prospectively [79], with greater than 95% to 96% agreement with actual administered treatment.

This system combines point-based severity classification across 3 categories that serve as independent surgical indications for thoracolumbar injury. First, the immediate stability of the injury can be described by the morphology. Compression fractures with minimal instability are rated with 1 point, whereas high-energy distraction injuries are tallied at 4 points. Immediate and long-term stability also depend on the soft tissue ligamentous support around the spine that, in the thoracolumbar spine, is highly reliant on the integrity of the posterior ligamentous complex. Here a definite injury is given 3 points. Finally, neurologic compromise forms a distinct surgical decision-making branch point, so both the severity of the injury (ie, cord vs root injury) and responsiveness to intervention (ie, incomplete vs complete SCI) are given extra points. The total points from the 3 subcategories are summated for the final TLICS score (Table 3.2). Similar to the SLIC score, a score higher than or equal to 5 represents stronger surgical indication, whereas scores 0 to 3 represent evidence for conservative management. Often, magnetic resonance imaging is required to determine the posterior ligamentous complex score when the findings from computed tomography are indeterminate.

Table 3.2 Thoracolumbar Injury Classification and Severity Scale (TLICS)

Classification	
Morphology	Wedge compression fracture: 1 point
	Burst fracture: 2 points
	Translation/rotation: 3 points
	Distraction: 4 points
Posterior ligamentous complex	Intact: 0 points
	Suspected injury or indeterminate: 2 points
	Injured: 3 points
Neurologic involvement	Intact: 0 points
	Nerve root: 2 points
	Cord/conus medullaris (complete): 2 points
	Cord/conus medullaris (incomplete): 3 points
	Cauda equina: 3 points

Table 3.3 Top US Sports Contributing to SCI in 2019 (National Spinal Cord Injury Statistical Center 2019)

Sport	Male	Female	Total
Diving	1772	160	1932
Cycling	496	68	564
All-terrain vehicle/all-terrain cycle	218	37	255
Football	153	0	153
Skiing	170	19	189
Horseback riding	76	77	153
Surfing (including body surfing)	140	6	146

-Spinal Cord Injury

Incidence

Based on epidemiologic data from 2011, the global incidence of traumatic SCI is estimated at 23 million, or almost 180,000 new cases year each [43]. In the US, sports injuries account for 8.4% of all causes of SCI, ranking fourth behind MVAs, falls, and violence as contributors of traumatic SCI (Table 3.3) [55].

Rates of sports-related SCIs vary by country. A 2016 systematic review/meta-analysis of 54 studies identified wide variation in rates of traumatic SCI caused by athletics [16]. The 6 countries with the highest proportions of sports-related SCI were Russia (33%), Fiji (32%), New Zealand (20%), Iceland (19%), France (16%), and Canada (13%). Countries with the lowest proportion of SCIs caused by sports were Turkey (3%), Jordan (3%), Nepal (2%), Malaysia (2%), China (2%), and Nigeria (2%) [16]. Similarly, the popularity of different sports across the world affected their contributions to SCI, with skiing and winter sports causing 48% of sports related SCI in Scandinavian countries but only 1% of SCI in Ireland. The popularity of rugby in New Zealand contributes to its causing 74% of all sports-related SCI in that country, while it only contributes to 0.7% of sports-related SCI in Germany. The popularity of diving in China causes it to contribute to 65% of sports-related SCI in China, but just 8% in Germany. Similarly, horseback riding accounts for 42% of sports-related SCI in Ireland but only 1% in Japan.

Outcomes and location of SCI also vary based on pattern of activity and trauma from each sport. The cervical spine is the level most commonly affected across all sports—it is the cause of greater than 96% of SCI in diving and American football, but only 41% in snowboarding. Thoracic SCI is relatively more common in noncontact sports such as snowboarding and horseback riding, where it accounts for 25% to 30% of SCI cases with mechanism of injury more likely from falls rather than direct impact against another person or object [16].

Unfortunately, prognosis remains poor after sports-related SCI. NSCISC 40-year data from 1973 to 2013 show that only 1% of individuals who sustain sports-related SCI recover to neurologic baseline by discharge. The most common discharge neurologic examinations showed incomplete tetraplegia from incomplete cervical SCI (47%), followed by complete tetraplegia (37%), and incomplete and complete paraplegia (both 6%) [56].

Injury Classification

Traumatic SCI represents a wide range of pathology that can affect both presentation and prognosis. Classification systems have been developed to standardize the description of neurologic injury by qualifying the degree of residual neurological function and neurologic compromise based on sensory and motor functions below a specific spinal or neurologic level. They have been useful not only for reproducibility, but also for prognostication. Prior to the formation of the American Spinal Injury Association (ASIA) in 1973, the Frankel scale was the most commonly recognized SCI classification system. This scale (Table 3.4), developed in 1961, included 5 grades, from A to E, in decreasing severity. This legacy system posed several inherent limitations related to the lack of specificity in the grade descriptions. Specifically, the failure to define a distinct level of spine injury, and the ill-defined terms "motor-useful" and "motor-useless" in distinguishing grades C and D [61].

By 1982, ASIA created the ASIA Impairment Scale (AIS), which currently serves as the gold standard for evaluation of SCI both in clinical and academic setting (Fig. 3.5). This standardized exam is composed of a myotome-based motor examination, dermatome-based sensory examination, and an anorectal examination, the results of which are combined into a single neurologic injury level and an overall injury severity grade. The neurologic level is defined as the most caudal spinal level at which the sensory exam is normal, and the motor exam is at least 3/5 (ie, anti-gravity) on testing.

A notable and important distinction in the AIS is the delineation between complete and incomplete SCI. Many large retrospective registries have shown a

Table 3.4 Frankel Grading System

Grade	Injury
A	Complete neurological injury. No motor or sensory function detected below level of lesion
B	Preserved sensation only. No motor function detected below level of lesion, some sensory function below level of lesion preserved
C	Preserved motor, nonfunctional. Some voluntary motor function preserved below level of lesion, but too weak to serve any useful purpose. Sensation may or may not be preserved
D	Preserved motor, functional. Functionally useful voluntary motor function below level of injury is preserved
E	Normal motor function. Normal motor and sensory function below level of lesion, abnormal reflexes may persist

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

Patient Name________________ Date/Time of Exam ________________

Examiner Name ________________ Signature ________________

RIGHT — **MOTOR** KEY MUSCLES — **SENSORY** KEY SENSORY POINTS: Light Touch (LTR), Pin Prick (PPR)

SENSORY KEY SENSORY POINTS: Light Touch (LTL), Pin Prick (PPL) — **MOTOR** KEY MUSCLES — **LEFT**

	C2	
	C3	
	C4	
Elbow flexors	C5	*Elbow flexors*
Wrist extensors	C6	*Wrist extensors*
Elbow extensors	C7	*Elbow extensors*
Finger flexors	C8	*Finger flexors*
Finger abductors (little finger)	T1	*Finger abductors (little finger)*
	T2	
	T3	
	T4	
	T5	
	T6	
	T7	
	T8	
	T9	
	T10	
	T11	
	T12	
	L1	
Hip flexors	L2	*Hip flexors*
Knee extensors	L3	*Knee extensors*
Ankle dorsiflexors	L4	*Ankle dorsiflexors*
Long toe extensors	L5	*Long toe extensors*
Ankle plantar flexors	S1	*Ankle plantar flexors*
	S2	
	S3	
	S4-5	

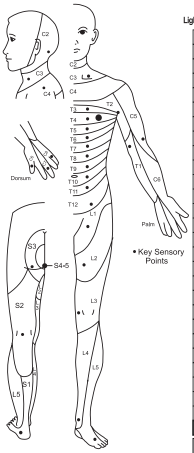
UER (Upper Extremity Right)

UEL (Upper Extremity Left)

LER (Lower Extremity Right)

LEL (Lower Extremity Left)

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



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
NT = Not testable
0, 1*, 2*, 3*, 4*, NT* = Non-SCI condition present*

SENSORY
(SCORING ON REVERSE SIDE)

0 = Absent *NT = Not testable*
1 = Altered *0*, 1*, NT* = Non-SCI condition present*
2 = Normal

(VAC) Voluntary Anal Contraction (Yes/No)

(DAP) Deep Anal Pressure (Yes/No)

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

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

MOTOR SUBSCORES

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

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

SENSORY SUBSCORES

LTR ___ + LTL ___ ***= LT TOTAL*** ___ — *MAX (56) (56)* **(112)**

PPR ___ + PPL ___ ***= PP TOTAL*** ___ — *MAX (56)* **(56)** *(112)*

NEUROLOGICAL LEVELS *Steps 1- 6 for classification as on reverse* — ***1. SENSORY*** R ___ L ___ ; ***2. MOTOR*** R ___ L ___

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 injuries with absent motor OR sensory function in S4-5 only) ***6. ZONE OF PARTIAL PRESERVATION*** *Most caudal levels with any innervation* — ***SENSORY*** R ___ L ___ ; ***MOTOR*** R ___ L ___

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Muscle Function Grading

0 = Total paralysis
1 = Palpable or visible contraction
2 = Active movement, full range of motion (ROM) with gravity eliminated
3 = Active movement, full ROM against gravity
4 = Active movement, full ROM against gravity and moderate resistance in a muscle specific position
5 = (Normal) active movement, full ROM against gravity and full resistance in a functional muscle position expected from an otherwise unimpaired person
NT = Not testable (i.e. due to immobilization, severe pain such that the patient cannot be graded, amputation of limb, or contracture of > 50% of the normal ROM)
0*, 1*, 2*, 3*, 4*, NT* = Non-SCI condition present [a]

Sensory Grading

0 = Absent **1** = Altered, either decreased/impaired sensation or hypersensitivity
2 = Normal **NT** = Not testable
0*, 1*, NT* = Non-SCI condition present [a]

[a] Note: Abnormal motor and sensory scores should be tagged with a '*' to indicate an impairment due to a non-SCI condition. The non-SCI condition should be explained in the comments box together with information about how the score is rated for classification purposes (at least normal / not normal for classification).

When to Test Non-Key Muscles:

In a patient with an apparent AIS B classification, non-key muscle functions more than 3 levels below the motor level on each side should be tested to most accurately classify the injury (differentiate between AIS B and C).

Movement	Root level
Shoulder: Flexion, extension, abduction, adduction, internal and external rotation **Elbow:** Supination	C5
Elbow: Pronation **Wrist:** Flexion	C6
Finger: Flexion at proximal joint, extension **Thumb:** Flexion, extension and abduction in plane of thumb	C7
Finger: Flexion at MCP joint **Thumb:** Opposition, adduction and abduction perpendicular to palm	C8
Finger: Abduction of the index finger	T1
Hip: Adduction	L2
Hip: External rotation	L3
Hip: Extension, abduction, internal rotation **Knee:** Flexion **Ankle:** Inversion and eversion **Toe:** MP and IP extension	L4
Hallux and Toe: DIP and PIP flexion and abduction	L5
Hallux: Adduction	S1

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.

B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments S4-5 by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body.
(This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3.

D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.

Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

AMERICAN SPINAL INJURY ASSOCIATION

INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

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Steps in Classification

The following order is recommended for determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
The sensory level is the most caudal, intact dermatome for both pin prick and light touch sensation.

2. Determine motor levels for right and left sides.
Defined by the lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5).
Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level, if testable motor function above that level is also normal.

3. Determine the neurological level of injury (NLI).
This refers to the most caudal segment of the cord with intact sensation and antigravity (3 or more) muscle function strength, provided that there is normal (intact) sensory and motor function rostrally respectively.
The NLI is the most cephalad of the sensory and motor levels determined in steps 1 and 2.

4. Determine whether the injury is Complete or Incomplete.
(i.e. absence or presence of sacral sparing)
If voluntary anal contraction = ***No*** *AND all S4-5 sensory scores =* ***0***
AND deep anal pressure = ***No****, then injury is* ***Complete.***
Otherwise, injury is ***Incomplete****.*

5. Determine ASIA Impairment Scale (AIS) Grade.
Is injury Complete? If YES, AIS=A
NO ↓
Is injury Motor Complete? If YES, AIS=B
NO ↓ (No=voluntary anal contraction OR motor function more than three levels below the motor level on a given side, if the patient has sensory incomplete classification)

Are at least half (half or more) of the key muscles below the neurological level of injury graded 3 or better?
NO ↓ AIS=C **YES ↓ AIS=D**

If sensation and motor function is normal in all segments, AIS=E
Note: AIS E is used in follow-up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact and the ASIA Impairment Scale does not apply.

6. Determine the zone of partial preservation (ZPP).
The ZPP is used only in injuries with absent motor (no VAC) OR sensory function (no DAP, no LT and no PP sensation) in the lowest sacral segments S4-5, and refers to those dermatomes and myotomes caudal to the sensory and motor levels that remain partially innervated. With sacral sparing of sensory function, the sensory ZPP is not applicable and therefore "NA" is recorded in the block of the worksheet. Accordingly, if VAC is present, the motor ZPP is not applicable and is noted as "NA".

Fig. 3.5 Asia Impairment Scale © 2020 American Spinal Injury Association. (Reprinted with permission) significant difference in functional motor and sphincter improvement between patients with complete and incomplete SCI. Van Middendorp et al. reported 91.7% negative predictive value in grade A patients for regaining ambulatory capability at 1 year, whereas grade D patients have a 97.3% positive predictive value for regaining independent ambulation at 1 year [80]. Similarly, others have shown a low probability for any significant improvement in grade A patients, as only 2.1% improved to grades B through E at 5 years [42]. In AIS, grade A, or complete SCI, is defined as the absence of all motor and sensory functions, including sacral roots, distal to the site of injury. Grades B through E are defined as incomplete injuries that retain some degree of motor or sensory function below the site of injury.

Nevertheless, the AIS scale does have some limitations that require attention. First, the injury level specified as a grade A lower lumbar injury could result in loss of bowel and bladder function and a foot drop, but the patient would still remain ambulatory; while a mid-cervical grade C or D patient could still be quadriparetic and dependent on significant assistance for activities of daily living and mobility. Second, AIS grades do not account for pain, spasticity, or dysesthesias that can still produce significant functional and mental disability for patients who are otherwise AIS grade E. Finally, no minimal clinically important difference has been defined in evaluation of patients in response to surgical or medical intervention, resulting in confusion with regard to defining thresholds for clinically significant changes for interventions.

Management Guidelines

Despite advances in protective safety equipment technology, an average of 7 catastrophic cervical spinal injuries with incomplete recovery and six quadriplegic events occurred in football alone in 2009 [66]. Surgical and medical treatments are available for the treatment of traumatic SCI, depending on the severity of injury, the anatomy of the structural spinal injury adjacent to the SCI, and the overall medical condition of the patient. Surgical intervention is generally indicated in the presence of ongoing spinal cord compression or unstable spinal fractures or ligamentous injuries. The exact timing of surgery and the effects of delays on neurologic outcome have historically been a point of controversy due to conflicting clinical [27] and animal data [31, 58]; however, more recent clinical data increasingly support the adoption of urgent or emergent surgical decompression paradigms based on both clinical series and prospective controlled trials [28].

Medical management begins with close monitoring for prevention of common cardiovascular and pulmonary complications of spinal shock, as well as optimization of various physiologic parameters for such perfusion, including maintenance of elevated mean arterial blood pressure. Neuroprotective or therapeutic agents for the treatment of acute spinal cord injury do not exist [81] and the use of high-dose steroids is contraindicated in these patients. Other potential treatments, such as induced hypothermia [19], stem cell therapy, biodegradable scaffolding [71], and endogenous growth factors, remain under active investigation [35]. For a full explanation of the current evidence-based medicine SCI recommendations, please refer to Chap. 5.

Conclusion

Athletics remains a common cause of spinal injuries worldwide, especially as sports participation increases. Although sports injuries often present with milder muscular strain or are nonstructural, they can also be a leading cause of catastrophic outcomes, such as acute SCI, depending on the activity. Early recognition of spinal injuries in various sports disciplines is vital to ensure proper medical and surgical management of both minor and more severe injuries. While minor issues mainly require symptomatic control and restriction from participation and activity limitation, major spine injuries should be approached in the same fashion as traumatic spinal injuries from other causes. Besides common clinical syndromes, standardized and validated systematic grading systems as well as severity scoring systems have been introduced for traumatic cervical, thoracic, and lumbar spinal injuries to assist the surgeon in deciding between initial medical vs surgical intervention.

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