Thoracolumbar spine trauma typically occurs when high-energy forces damage bony and ligamentous spinal structures and, in severe cases, the spinal cord. These injuries often cause considerable neurological deficits as a result of the damage. Computed tomography (CT) is the imaging method of choice for determining injury severity in most victims of multiple trauma. In addition to describing various types of thoracolumbar trauma, this article discusses the role of CT in emergency diagnosis and management of thoracolumbar injuries.

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rauma to the thoracolumbar spine can lead to neurological deficits, physical disability, and chronic pain. Estimates show that up to 90% of all spinal fractures occur in the thoracolumbar region, the portion of the spine that transitions from the relatively rigid cervical and upper thoracic vertebrae to the more flexible lumbar region. Approximately 160,000 new thoracolumbar fractures occur each year in North America. Peak incidence appears in adults aged 15 to 29 years and those older than 65 years. As many as 30% of traumatic injuries to the thoracolumbar spine also damage the spinal cord. Motor vehicle collisions and falls cause more damage to the spinal cord than any other type of trauma.

Early and accurate assessment of thoracolumbar spine injuries is critical to trauma triage and care. Detecting injuries rapidly improves patient stabilization and reduces risk of new or worsened neurologic deficits. Despite advancements in spinal injury management and treatment, such as the 1978 introduction of Advanced Trauma Life Support principles and courses, injuries continue to be missed in trauma patients around the world.

Evaluation of spinal injuries can involve several medical imaging modalities, including radiography, sonography, magnetic resonance (MR) imaging, and nuclear medicine technology. Computed tomography (CT) is the primary imaging modality, however, largely because of its ability to display bony details on images. Use of CT for multiple trauma has been shown to reduce mortality, speed diagnosis, reduce the time patients spend in the emergency department, and improve diagnostic accuracy.

The advent of multidetector computed tomography (MDCT),
introduced clinically in the early 21st century, has significantly improved evaluation of spinal injuries.\textsuperscript{14}

Despite the clinical advantages of CT to evaluate trauma, its increased utilization is of concern. CT use in the emergency setting has risen dramatically since 2005, leading to worries about increased radiation exposure and costs. Researchers continue to investigate optimal management for trauma patients, including appropriate and effective CT utilization.\textsuperscript{15,16}

**Thoracolumbar Spine Anatomy**

Thirty-three vertebrae comprise the vertebral column. The vertebrae are divided into 5 sections: cervical, thoracic, lumbar, sacral, and coccyx (see Figure 1).\textsuperscript{17} The presacral vertebrae are classified as:\textsuperscript{18}
- Cervical – 7 vertebrae (C1-C7).
- Thoracic – 12 vertebrae (T1-T12).
- Lumbar – 5 vertebrae (L1-L5).

In addition, the sacrum is made up of 5 fused vertebrae, and the coccyx is made up of 4, often-fused, vertebrae.\textsuperscript{18}

The entire vertebral column supports the body, helps maintain posture, and protects the vital and delicate spinal cord and associated nerves.\textsuperscript{17} The thoracolumbar region, comprising vertebrae from T1 to the border of L5, is the middle portion of the column.\textsuperscript{19,20} The thoracolumbar junction involves the adjoining vertebrae, T11 through L2.\textsuperscript{1} The anterior and middle columns of the spine support up to 80% of the body’s total weight.\textsuperscript{19}

Looking at the spine laterally, 3 distinct columns are identified on medical imaging:\textsuperscript{20,21}
- **Anterior** – the anterior longitudinal ligament and anterior two-thirds of the vertebral body and disk.
- **Middle** – one-third of the posterior portion of the vertebral body and the annulus fibrosis, including the posterior longitudinal ligament.
- **Posterior** – the pedicles, lamina, facet joints, and posterior ligamentous complex.

The makeup of vertebral bodies varies along the column, but most vertebrae have a body (anterior element) and an arch (posterior element). A vertebral endplate of compact bone appears on superior and inferior surfaces of each vertebral body. Intervertebral disks separate vertebral bodies. Each disk has a gelatinike nucleus pulposus and a more solid outer ring known as the **annulus fibrosus** (see Figure 2).\textsuperscript{17}

Projections called *pedicles* and *laminae* meet to form the spinous process. The transverse processes project from the junction of the pedicles and laminae, and the articular processes project from the same junction to form the facet joints.\textsuperscript{17} Intervertebral facet joints provide stability.\textsuperscript{4} The joints, which have cartilaginous surfaces, are located between and posterior to adjacent vertebrae.\textsuperscript{22}

Structures in the lumbar spine differ from those of the cervical and thoracic spine. The size, shape, and orientation support the functional requirements of these lower vertebrae.\textsuperscript{23} Paired facet joints and the disks between joints also provide support for motion in the form of extension, flexion, lateral bending, and limited rotation.\textsuperscript{20,22} The lumbar facet joints are oriented differently than are those that support the thoracic spine. Lumbar joints are oriented in an anteroposterior plane.\textsuperscript{20}

The thoracic area of the spine is somewhat limited in movement; the thoracic bodies attach to the ribs and...
Other spinal anatomy components provide stability and help prevent the mechanical damage, typically from forces of traction and compression, that contributes to spinal cord injury.

**Supporting Ligaments**

Ligaments form the basis for dynamic stabilization of the spine. These elastic structures adhere to anatomy to support movement and load. Capsular ligaments facilitate facet joint stability based on ligament orientation and shape and spinal column level. Similar to bones, ligaments are subject to long-term stress from chronic loads. When trauma occurs, the ligament responds to tensile forces.

Ligaments vary within the 3 columns that make up the thoracolumbar spine. The spine’s anterior column includes the anterior longitudinal ligament. The anterior longitudinal ligament extends from level C1 down to the sacrum, connecting vertebral bodies along the anterior. The anterior column is responsible for axial loading. The middle column...

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To view a short video about spinal anatomy, visit asrt.org/as rt7xTV.

Aside from protecting the spinal cord, the spine transmits loads and is flexible enough to support movement, even for simple tasks such as bending over. The spine acts as a single functional unit, rather than in sections or as individual vertebrae. Each vertebra functions with, and is affected by the health of, the 2 vertebrae adjacent to it, the disk between it and adjoining vertebrae, and soft tissue structures that surround or support the spine. The vertebra’s size and shape work in concert with the facet joints to provide passive stabilization. For example, the facet joints allow typical spinal motion for everyday activities and help protect delicate nerves from strain. The disks between vertebrae absorb shock and resist forces such as tension, shear, compression, and torsion.
is closest to the spinal canal and neural structures and contains the posterior longitudinal ligament.25 The posterior longitudinal ligament is not as thick or as strong as the anterior longitudinal ligament, and it runs inside the vertebral canal from level C2 down the entire vertebral column. It attaches at intervertebral disks and their margins.17

The posterior column comprises the facet joint capsules and the posterior ligamentous complex. This region, or complex, houses the supraspinous ligament, interspinous ligament, and ligamentum flavum.25,26 The posterior column resists axial loading; injuries to the posterior ligamentous complex typically indicate severe instability in the thoracolumbar spine.25,26 Although forces can damage any of these columns, long-term thoracolumbar stability depends on the posterior ligamentous complex.25,26 In the lower lumbar spine, iliolumbar ligaments provide significant stability to the caudal lumbar vertebrae.27 Spinal stability refers to the ability to prevent deformity or neurological damage within normal loads or ranges of movement.28

**Muscular Attachments**

The muscles that attach to and control the spine provide active, voluntary stabilization. They absorb force to spare the bones and ligaments, allowing the spine to sustain normal loads without damage. A mechanically stable thoracolumbar spine must have intact musculature.23 However, muscles only contract and relax. Under force, attached muscle pulls on vertebral structures and causes the structures to move.29

A superficial layer of muscle is located on the upper thoracic spine’s lateral and posterior aspects. The flat, oblique splenius muscles attach to the spinous processes from level C7 to T6. An intermediate layer of muscle includes the erector spinae muscle group, which extends along the vertebral column in layers. At the thoracic level, the longissimus muscles run superiorly and insert into processes of the thoracic region. The spinalis group is narrower and inserts into the spinous processes of the lower thoracic and lumbar regions.17

**Other Soft Tissue Spinal Structures**

Other parts of the spinal column support or protect structures. The spinal meninges hold the spinal cord and cerebrospinal fluid. At the thoracolumbar junction, the spinal cord tapers into the conus medullaris, the most interior location of the nerve. Bundled nerves continue from the spinal cord’s termination point to the lumbosacral foramina. Of the 31 pairs of spinal nerves that connect to the spinal cord, 12 correspond to the thoracic region and 5 to the lumbar.17 Both the bony morphology and neural structures differ among vertebrae as they extend from the top of the thoracic region to the lower lumbar spine.27

The anterior spinal artery, 2 posterior arteries, and branches of these supply blood to the spinal cord. Segmental arteries that arise from the descending aorta supply the cord and vertebral column. In the thoracic region, these segmental arteries are called intercostal arteries; those in the lumbar region are lumbar arteries. Other branches, called radicular arteries, feed into the spinal artery. The great anterior radicular artery is the largest of these vessels and is located in the thoracolumbar region (between approximately T12 and L3).17

**Biomechanics**

Biomechanics relates to the body’s function and structures and how internal or external motion and forces act on the body. The spinal anatomy absorbs energy through a complex connection of structures. The components fail at nearly the same level of force. Up to the point of failure, the vertebral anatomy allows normal range of motion.28 Injury occurs on impact, or when a high-magnitude force or energy acts on the anatomy. The force causes structures and tissues to exceed their normal range of motion, leading to damage.28,30 The area affected by the force varies depending on the cause and how a load transmits to the body.31 Spinal injuries tend to occur at regions of the spine that have the greatest mobility.12

During a motor vehicle accident, the most common cause of thoracolumbar injuries is a sequence of forces. Following a high-energy impact, a series of other movements happens, such as when the head of a driver who is restrained by a seat belt whips forward and back at decelerating force before stopping. The main damage occurs at the initial high-energy impact, even in instances of repetitive force, such as tumbling across a road if ejected from a car. A range of 2000 to 4000
newtons of force typically is required to fracture the cervical spine, for example.\textsuperscript{30}

Newton’s laws of motion are important concepts in physics and biomechanics. Force is equal to momentum changes (or mass × acceleration).\textsuperscript{30,33} A force either changes the motion of a free body or deforms a fixed body.\textsuperscript{28} Along with force is motion over distance; together they create energy. The velocity of an object changes when subjected to an outside force. In vehicle crashes, the occupant’s head, neck, and body decelerate at different velocities, which causes kinetic energy, or energy resulting from the object’s motion.\textsuperscript{30} The energy is transmitted to an injured area and the external force causes internal stress in the spine’s structures.\textsuperscript{29,30}

\textbf{Mechanisms of Injury}

Many forces can affect and injure the spine either singly or in combination. Typically, 1 or 2 forces act on the thoracolumbar spine to damage bone and ligaments.\textsuperscript{34} Flexion, extension, and rotations likely lead to fractures.\textsuperscript{35} The pattern of injury and likely force can contribute to the resulting injury classification and severity.\textsuperscript{35} Although the injury patterns follow fairly predictable morphology, the injuries still can vary depending on factors such as center of rotation of the spine during injury and specific combinations of forces (ie, flexion/distraction or extension/tension).\textsuperscript{34,36} Five forces most often contribute to thoracolumbar spine injuries: axial compression, flexion/distraction, hyperextension, rotation, and shear.\textsuperscript{34}

\textbf{Axial Compression}

Force acting along the spine’s axis compresses spinal anatomy. Axial loading causes endplate failure and can result in incomplete or complete burst fractures, mostly in the more rigid regions of the thoracolumbar spine. Upward motion compresses, and spinal stretching produces tension. Axial load compression flattens disks and vertebrae; tension elongates them. Compression primarily affects the vertebral body, and tension damages ligaments and osseous elements.\textsuperscript{29,34} The most common causes of axial compression injuries are motor vehicle crashes, falls from heights, violence, and sports injuries.\textsuperscript{34}

\textbf{Flexion/Distraction}

Flexion, or bending, of the spine can produce unusual patterns of vertebral compression. The force compresses disks and vertebral bodies and leads to tension in the posterior region of the spine. Distraction is when tension causes the vertebral bodies to separate. The forces combine to move the axis of flexion toward the anterior region, creating tension on the entire spinal column and potentially damaging ligaments, disks, and pure osseous structures.\textsuperscript{34} Posterior elements can fail to withstand high-energy distractive forces. Their failure can disrupt the posterior tension band, the muscles and ligaments that normally stabilize the trunk and vertebrae.\textsuperscript{29,37} Distraction causes a horizontal disruption to anterior spinal elements and potentially to posterior regions, causing a fracture that extends through bone (Chance fracture). Flexion-distraction injuries typically occur in motor vehicle crashes when the occupant is wearing a lap seat belt and is subjected to a whiplash force.\textsuperscript{34}

\textbf{Hyperextension}

When the upper trunk is thrust backward, the hyperextension force can cause the opposite injury pattern of flexion. Hyperextension places tension on anterior structures and can injure anterior ligaments and the anterior portion of the annulus fibrosus. The force disrupts the vertebral anatomy from anterior to posterior. Resulting injuries include fractures to the facet joint, lamina, and spinous processes.\textsuperscript{34} In a rear-end vehicle accident, for example, the neck is subjected to severe hyperextension if no head rest is in place, but the thoracolumbar area is more protected from hyperextension because of the support of the seat and seat belt.\textsuperscript{36}

\textbf{Rotation}

When compressive or flexion-distraction forces combine with rotational forces, rotational fracture dislocations can occur. Also called torque, rotational forces act perpendicular to the spine but not in its plane, which causes vertebral components to rotate around their axis.\textsuperscript{34} Transverse process fractures and fracture/dislocations can result from rotation; fracture/dislocation is an unstable injury that often causes spinal cord compression.\textsuperscript{35} Increasing rotational
force can cause the ligaments and facet joints to fail. Examples of rotational forces include being hit with a heavy object or being thrown against an object. Damage from rotation can occur in both anterior and posterior regions.34

Shear

Shear occurs when opposing, unaligned forces act perpendicularly to the vertebral column. A shearing force slides the anatomy away from the normal axis. With great enough force, shearing causes severe disruption of ligaments and can lead to vertebral displacement. A frequent type of vertebral displacement called anterior spondylolisthesis usually causes a complete spinal cord injury when 1 vertebra slips anteriorly over another.29,34 Shear lesions also can occur at multiple spinal levels.27

Thoracolumbar Trauma

In thoracolumbar trauma, injury can occur because of stress concentrations. Stress can be caused by33:

■ Spinal loading.
■ Existing spinal degeneration or imperfections.
■ Abrupt changes to anatomy such as facet orientation.
■ Differences between the spine’s rigidity and physiological ranges of motion of the thoracic and lumbar regions.

Spinal injuries are uncommon but can lead to mortality or substantial morbidity.24 Up to 3% of all blunt trauma patients have injury to the spinal cord. An unstable fracture involves 2 to 3 vertebral columns. Unstable fractures lead to spinal cord injury by subjecting the spinal cord to traction and compression. These forces cause ischemia and swelling of the cord.24 Box 1 outlines common thoracolumbar fracture types. Thoracolumbar spine injuries typically result from compression and flexion forces.11

Nearly half of spinal injuries are isolated to the cervical spine.32 Injuries to the thoracic spine exclusively are uncommon,11 and those that are seen in the thoracic area often are associated with multiple injuries, or polytrauma.4 Approximately 25% of patients with spinal injuries have brain or chest injury, or major injuries to extremities.32 Most thoracic fractures occur at T4 through T6, an area that makes up the middle of the spine’s curve and is farthest from the torso’s center of gravity.11 Studies vary on incidence of thoracolumbar junction injuries, which might be as high as 62% of all spinal injuries; most occur at L1, L2, and T12.14

Causes

Blunt trauma accounts for most thoracolumbar injuries; motor vehicle collisions are the primary cause, followed by falls. Other causes include violence and sports injuries.23 Geyer et al reviewed records of 581 patients who had multiple trauma and were admitted to a level 1 trauma center in Munich over 2 years. Motor vehicle accidents accounted for 56% of multiple trauma injuries, and falls from heights made up 21%. Nearly 10% of the patients had injury to the thoracic spine, and 14% to the lumbar spine.41

Reconstructions of motor vehicle collisions have shown that nearly 78% of significant thoracolumbar fractures and 73% of spinal cord injuries occur as a result of frontal collisions.4 Other factors increasing the severity of injury included speed (>31 mph, or 50 kph) and absence of safety restraints. Speed and magnitude of crash contribute to forces that act on the body’s tissues. When speed suddenly declines on impact, energy transfers to occupants’ bodies. In addition, more severe crashes can cause greater damage within the passenger portion of the car, increasing risk of spinal injury.4

The highest risk of thoracolumbar trauma was attributed to collisions in which the occupant was not restrained and the air bag deployed. Air bags deploy at speeds of up to 211 mph (340 kph), which suddenly decelerates the thoracic cage and can injure the spinal column of drivers and front-seat passengers. Occupants protected by both seat belts and air bags have the lowest risk of thoracolumbar injury from a motor vehicle collision. Occupants restrained with 3-point seat belts and protected by air bags were as likely as unrestrained occupants to have an injury to the thoracic spine, and 14% to the lumbar spine.41

Although seat belts typically save occupants from serious injuries, they can cause injury, particularly when used incorrectly. Onu et al reported on a case of an unstable Chance fracture to L2 (see Box 2).42 A Chance
Military personnel have experienced increasing incidence of spinal injuries from blasts under motorized vehicles. The device’s detonation produces a shock wave and thrusts a massive amount of ground toward the underside of the impacted vehicle. The floor generally gives way or deforms, transferring the load to the vehicle’s occupants. As a result, lower extremity and spinal injuries are common from these vehicle explosions. It is possible that the legs of seated passengers are forced upward when the floor deforms, which causes flexion of the lumbar spine against the restrained upper torso. Research on vehicle modifications to minimize injuries and fatalities from under-vehicle detonations suggests spacing the wheels further from the center of the vehicle body and adding blast deflectors to wheels to aim forces away from the vehicle. In addition, reshaping the hull of military vehicles into a “V” helps direct force around the vehicle.

Spurrier et al studied the effects of under-vehicle blasts using CT scans performed on live and deceased casualties of explosions who had spinal injuries. Of the 78 casualties studied, 42 had thoracic vertebral fractures and 55 had lumbar fractures. Although most of the 21 cervical fractures involved compression and often extension, the majority of the fractures to the thoracolumbar vertebrae resulted from compression and flexion. The association of midthoracic spine fractures with adjacent injuries to the spinous processes at the same spine level suggested tension as the cause of compressive fractures. Other possible causes of injuries include falls from heights or being struck by a falling mass. A lumberjack fracture-dislocation is a type of hyperextension injury named for incidents such as timber striking a worker in the back. If the mass strikes near the midportion of the spine, it can disrupt anterior ligaments and destabilize the vertebral column.

Classification
Although a classification system helps guide treatment and ensures better consistency among treating physicians and researchers, thoracolumbar spine and spinal cord injuries are complex and vary markedly in clinical and structural presentation, making consistency

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Box 1

**Types of Thoracolumbar Fractures**

- **Compression** – severe compression of the vertebral body in the anterior portion of the spine. Compression injuries can cause delayed instability of the spine.
- **Wedge-compression** – single endplate fracture with no involvement of the posterior vertebral body.
- **Split** – a compression fracture involving both endplates but no posterior vertebral body involvement.
- **Burst** – severe compression of the vertebral body that spreads the margins in all directions and results from a high-energy force. An incomplete burst involves only 1 endplate but disruption of the posterior wall. A complete burst involves the posterior wall and both endplates. A burst fracture with little posterior element disruption might cause delayed instability of the spine. One that completely disrupts the posterior elements can cause immediate instability.
- **Chance** – typically, a transverse split in the spinal column in the posteroanterior direction, beginning with the spinous process and extending through the pedicles and vertebral body. A Chance-type fracture involving ligaments can cause malalignment and immediate spinal instability; if the Chance fracture is of a bony element and no malalignment is present, instability can occur but is delayed.
- **Fracture dislocation** – along with a fracture, 1 or more vertebrae are moved significantly. Typically involves all spinal columns and leads to extreme spinal instability.
- **Translation** – displacement or dislocation of the vertebral column.
- **Major** – break in the pedicles, lamina, or part of the vertebral body. Major fractures can cause instability of the spine and risk of spinal cord injury.
- **Minor** – fracture restricted to posterior elements of the spine, such as spinous processes and facet joints.
- **Stable** – cause no deformity or neurologic damage.
- **Unstable** – cause disruption of 2 to 3 vertical columns and make it difficult for the spine to handle loads.
in classification challenging. 

44,45 Early identification of thoracolumbar spine injuries can prevent problems associated with missed or delayed diagnosis, such as long-term pain and reduced quality of life. However, emergency assessment can be complicated by neurological deficits or, at times, high blood alcohol levels in patients with potential thoracolumbar spine injury. 

46 In addition, some patients do not report pain, which can be an effect of morphine administration or, less often, the fact that no pain is associated with an injury.

Several iterations of classification systems have been developed to assess thoracolumbar spine injury. 27 Over
The Spine Trauma Study Group developed the Thoracolumbar Injury Severity Score in 2005. Although more comprehensive than previous systems, researchers found that physicians’ interpretations when assigning scores varied. More recent versions have attempted to address limitations of early systems, but according to Chhabra et al, more work needs to be done to ensure reliability of the systems and agreement among clinicians using them.

Classification System

The Spine Trauma Study Group adopted the Thoracolumbar Injury Classification and Severity (TLICS) score in 2013. By assigning injury severity according to an algorithm, physicians could make more informed decisions regarding conservative or surgical management of thoracolumbar spine trauma. Assigning scores helps physicians identify features that indicate spinal stability, potential future deformity, and progressive neurologic concerns. The TLICS system includes 3 categories for scoring and classifying injuries:

- Injury morphology.
- Posterior ligamentous complex status.
- Neurologic status.

Scores are assigned based on severity within each category, with the lowest number indicating least severe injury or neurologic involvement, and the higher number representing more severe injury or poorer neurologic status. For example, an intact posterior ligamentous complex represents 0 points, one that is likely injured or indeterminate equals 2 points, and a clearly injured complex is assigned 3 points. Generally, a total score of 3 points or less indicates the patient needs no surgical management, and a score of 4 or more points typically indicates surgery is required.

The purpose of the TLICS score is to help clinicians better predict spinal stability, deformity resulting from injury, and progressive neurologic deficits. Physicians rely heavily on CT scans to assign injury classifications under the TLICS method. Both CT and MR imaging can provide important information for assigning a severity score to thoracolumbar images. Development of the new injury scoring system placed a greater emphasis on the role of imaging in determining injury
location, severity, and treatment options. Injury severity scoring systems and sound clinical judgment are essential to treatment decision-making.²

**AOSpine System**

In 2013, Vaccaro et al published a new spine classification system that incorporated elements of the Magerl and TLICS systems. The Arbeitsgemeinschaft für Osteosynthesefragen Spine (AOSpine) classification system was developed as a treatment algorithm that could be accepted around the world. After publishing the system, the authors sought feedback regarding possible problems with the classification to improve acceptance and effectiveness.⁴⁸

Three major types of injuries make up the AOSpine injury classification system⁶⁵:
- A – compression injuries.
- B – tension band injuries.
- C – translational injuries.

Subtypes further define injuries based on fracture location, disruption, and other subcategories. Scores are assigned based on severity; for example, distraction injuries are assigned 4 points (more severe), and compression injuries typically receive 1 point.⁴⁸ The AOSpine system also considers a patient’s neurological status and patient-specific modifiers, such as comorbidities and multiple injuries.⁴⁸

**Management**

Despite advancements in imaging and classification of thoracolumbar injuries, health care professionals face challenges in diagnosing and managing spinal trauma.¹⁴⁴ For example, determining current or future spinal instability can be made difficult by lack of a standard definition or prediction model for instability.¹ The goal of treatment for thoracolumbar injuries is to stabilize the patient and improve neurological status or prevent further neurological damage.¹,²⁶

**Prehospital Care and Triage**

Clinical assessment of neurologic involvement can include verbal questioning for alert patients and physical examination to assess spinal cord-related deficits. Multiple and distracting injuries such as skull, rib, or pelvic fractures complicate clinical examination.⁷ Intra-abdominal injuries are associated with seat belt use during motor vehicle accidents.⁴⁵

Although a small percentage of patients evaluated for spinal trauma are later found to have injuries, the potential for serious complications and long-term disability for patients makes emergency providers particularly vigilant. As a result, patients with suspected spinal injuries are immobilized immediately according to most standard protocols.⁵⁰ Typically, these patients arrive at an emergency department or trauma center on backboards, and often with a cervical collar. The patient’s spine is immobilized at the accident scene in most cases, and immobilization continues—including the time spent in CT examinations³²,⁴⁹—until physicians are certain the spine is stable. The boards on which patients arrive are designed for speedy and safe extrication of injury victims from the site and not for comfort and long-term use. Tissue ischemia can develop rapidly in areas of the body in contact with the board.⁵⁰

Most patients are immobilized during their hospital stay, but studies report that patients who are at low risk for spinal cord injury can be identified and the spine protected with alternative methods. In some patients, restricting movement is adequate, making complete immobilization unnecessary. Motion restriction requires attentive and informed decision-making on the part of paramedic and emergency department providers. Studies of potential neurological injury from motion restriction assess the cervical spine only. Still, a systematic review by McDonald et al revealed no instances of neurological damage or deterioration from studies investigating motion restriction vs immobilization.⁵¹

Intoxicated and uncooperative patients might receive sedating medications to keep them still. Protocols for emergency neurological life support also call for immediate airway stabilization. Emergency personnel check breathing and circulation before conducting a brief neurological examination. Patients who are not cleared clinically typically have imaging before further assessment.⁷ Most trauma centers use CT scanning as the initial imaging examination for thoracolumbar spine injuries.⁷

In the primary survey, emergency responders or emergency department staff often identify clinical
indications of other injuries. Traumatic brain injury and hemorrhage are examples of life-threatening injuries that take precedence over thoracolumbar trauma assessment.22

**Conservative Treatment**

Modern equipment and techniques improve the success of surgical treatment of thoracolumbar spine injuries, but many patients fare better with conservative management. Improved classification and imaging are needed to better support thoracolumbar injury management decisions. Reasons for conservative management include similar clinical outcomes for both approaches in patients whose injuries leave them in a gray area between indications for surgery and conservative management, and lower complication rates for conservative management.20

Most compression fractures can be managed conservatively. The patient might receive an external hyperextension brace or orthosis. Flexion-distraction injuries such as an osseous Chance fracture can be treated conservatively with extension bracing. Burst fractures are managed conservatively in some cases and operatively in others. Signs such as less than half of anterior compression and absence of neurological deficit suggest that the spine is stable.20 Meta-analyses of the literature show that surgery for burst fractures with no neurological deficit results in higher complication rates and costs with no improvement in patient outcome.20

Jaffray et al reported success with early mobilization following fracture evaluation and confirmation of neurological status with radiography, CT, or MR imaging.42 Early mobilization included encouraging patients to log-roll on their own as soon as possible upon hospital admission. Patients who could sit erect comfortably in bed were considered stable enough for supervised ambulation. External orthotic support was supplied when needed. As a result, patients were discharged sooner.52

**Operative Treatment**

When thoracolumbar spine instability is diagnosed, the management approach varies depending on the presence of other injuries or comorbidities in a patient. For patients who have multiple life-threatening injuries and unstable spines, minimally invasive surgery can temporarily stabilize the spine until open surgery can be performed.3

Typically, surgery is indicated in patients who have progressive neurological deficits, unstable fractures, and complete spinal dislocation with a partial spinal cord injury. Fracture dislocations cannot be managed conservatively; they are unstable injuries that require a posterior approach to fixation in most cases and an anterior approach in others, such as when a large ventral fragment compresses neural structures or when posterior stabilization and fusion fail.20

Operative or conservative management decisions are based on several factors, such as injury location in the spine. For example, when the injury is between levels T1 and T10, the rib cage provides anterior support. Injuries closer to the thoracolumbar junction can be stabilized with surgery. Injuries to the spinal cord either do not exist or are complete; neither situation indicates operative management.20 A flexion-distraction injury that causes significant ligament damage typically involves fusion and posterior fixation.20

Surgery for thoracolumbar fractures requires precision because of the proximity of vital anatomy, such as large vessels, the spinal cord, and nerves.53 Minimally invasive techniques reduce patient recovery time and decrease risk of damage to paraspinal muscles. One such approach is transfuraminal lumbar interbody fusion using 3-cm longitudinal incisions; the surgeon places pedicle screws using a guidewire under fluoroscopic guidance.14

The primary surgical goals for thoracolumbar injuries are to decompress the spinal cord and restore vertebral column stability.30 Surgery can facilitate earlier patient mobility and decrease time the patient spends in bed; bed rest often is associated with complications such as skin damage and the risk of deep vein thrombosis.30 Spinal fixation instruments have biomechanical characteristics that make them suitable for stabilizing a particular section of the vertebral column until the structures fuse.51 Physicians can implant rods, hooks, sublaminar wiring, or pedicle screws to stabilize the thoracolumbar spine.28 Interlaminar hooks are most effective when placed 3 levels above and 2 levels below the injured segment.28
Modern instrumentation allows the use of more rigid techniques while also using shorter fixation implants to reduce future effects on spinal movement. These systems are tested on cadavers or plastic models to determine their stability and their effect on spinal movement. Nonfusion instrumentation helps restore motion to an injured segment; these devices also provide long-term load tolerance and functional stability.

Short-segment fixation involving the vertebrae just above and below the fracture level has become the most common operative method. For example, pedicle screws can be inserted along the fewest number of motion segments necessary to achieve stability. Success of placement improves when the screws are placed in quality bone vs bone with low mineral density. Patients might have single or dual rods with attachment screws at each vertebra. Rods and metal plates can fail over time from repeated loading.

The surgical approach to thoracolumbar spine anatomy can be posteriorly, anteriorly, or both. Surgeons have relied on various methods to increase the accuracy of pedicle screw placement, including fluoroscopic guidance. Fluoroscopy is limiting, however, in that it displays thoracolumbar anatomy well only below the upper thoracic vertebrae. Cone-beam CT with a C-arm and computer assistance also are used in spinal surgery.

Traumatic spinal cord injury management has been evaluated in numerous clinical trials since the late 20th century. The primary goal of management is to recover a measure of voluntary motor function for patients. Pharmaceutical, medical, surgical, and rehabilitative therapies are under investigation, but little progress has been made in identifying clinically effective treatments for spinal cord injury.

**Role of Computed Tomography**

When patients arrive at an emergency department with multiple injuries, staff must prioritize injuries that are life threatening and treat them accordingly. The next step is to complete a diagnostic workup of the patient that includes imaging so that health care providers can formulate an interdisciplinary approach to further prioritize and treat the injuries.

CT scanning is a reliable and fast modality for early trauma care, and it is better than radiography for identifying and classifying spinal injuries. Drawbacks to CT scanning for trauma include exposure to ionizing radiation, cost, and incidental findings. Therefore, referral for CT scanning should follow established institutional protocols or specialty guidelines.

**CT in the Trauma Chain**

MDCT is the imaging method of choice to evaluate trauma and possible thoracic and lumbar injuries. An increasing number of trauma centers are using whole-body MDCT as the primary imaging examination to assess patients with multiple trauma, and CT scanners often are located in emergency departments. The technique provides high-resolution images that are superior to radiography in helping physicians classify chest, abdomen, and spine injuries. MDCT can be reconstructed in multiple planes. In addition, for trauma cases, replacing modalities such as radiography and focused abdominal sonography with CT scanning minimizes patient time in imaging and patient transfer and movement.

Whole-body CT first was described in 1997, following advancements in helical scanning. Use of whole-body CT during trauma resuscitation has been associated with lower patient mortality. In particular, patients who have unstable hemodynamics require no repositioning for whole-body CT examinations. The examination also results in faster and more accurate diagnoses in patients who have multiple trauma, as well as reduced time in the emergency department.

**Value of CT Scanning for Spinal Injury Assessment**

MDCT assessment of thoracolumbar fractures has been reported as superior to radiography in identifying thoracolumbar fractures. CT scanning is essential in evaluating spinal trauma. A CT scan can better display features such as location of fracture fragments in the spinal canal than can a radiograph. MDCT has shortened scan times and can be the only imaging examination required for initial assessment of thoracolumbar fractures in patients who have severe trauma, including those with intubation. MR is the modality of choice for follow-up imaging to evaluate suspected...
spinal cord injury related to a thoracolumbar spine fracture. However, MR scans are not required to evaluate possible unstable ligament injury in patients who have normal thoracolumbar spine results on CT scans. Both MR and CT can detect hematomas associated with spinal injury. Increased confidence in the thoracolumbar spine injury classification systems has increased the significance of CT to assess and manage spinal injuries. Integrity of the posterior ligamentous complex is 1 of 3 primary variables used in treatment decision-making. Imaging can identify injury to the complex by determining reasons for spinal instability, such as osseous element dislocation. Barcelos et al found that although CT can result in misdiagnosis of a small number of injuries to the posterior ligamentous complex, MR could lead to overestimating instability. MR is more sensitive for subtle injuries to the complex, but subtle injuries have little significance in predicting instability or determining prognosis. The authors reported that CT scanning identified posterior ligamentous complex injuries in more than 90% of patients who had thoracolumbar spine injuries type B and C according to AOSpine classification. Type B injuries involve the tension band; type C are translational injuries.

**Indications**

Research on thoracolumbar imaging indications is limited compared with evidence from similar studies of cervical spine imaging. However, systematic triage using injury classification systems and trauma protocols can ensure that clinicians use CT effectively for trauma and thoracolumbar spine injuries. In addition, knowledge of a patient’s injury mechanism helps surgical staff correctly identify injuries to the spine. The Eastern Association for the Surgery of Trauma guidelines for screening thoracolumbar injury contain indications for CT. Specifically, these indications include back pain and focal tenderness, altered mental status, neurological deficit, and the presence of multiple and distracting injuries. Organ-specific CT scans are included in Advance Trauma Life Support evaluation recommendations for multiple trauma patients. Other tools such as the American College of Radiology (ACR) Appropriateness Criteria can assist physicians with imaging decisions. The ACR rates CT as the top imaging examination for patients who have blunt trauma consistent with criteria for thoracic and lumbar imaging. Despite its availability, the appropriateness criteria have not been widely adopted in the clinical setting. According to an ACR panel, distracting injuries such as lacerations and contusions indicate the need to screen for thoracolumbar fractures. In general, indications for thoracolumbar spine CT include:

- Back pain or midline tenderness.
- Local signs, such as pain and bruising, indicating thoracolumbar spine injury.
- Cervical spine fracture.
- Abnormal neurological signs.
- Glasgow coma score of less than 15.
- One or more major distracting injuries.
- Intoxication from drugs or alcohol.

The ACR recommends radiography for evaluating patients with suspected cervical spine injury or for patients with a low risk of thoracic and lumbar injury. Use of CT to guide pedicle screw placement has reduced significantly the rate of misplaced screws (see Figure 4). The technology is expensive, however, requiring a carbon fiber table, 3-D C-arm, and the navigation system.

**Imaging Considerations**

When radiography is used to assess the thoracic spine, the examination typically begins with the lateral projection, followed by an anteroposterior projection. The anterior angle is particularly helpful to the radiologist in determining the 12th rib for numbering vertebral bodies on the image. For patients who have multiple spinal injuries, the ACR states that images of the thoracolumbar spine derived from thoracic-abdominal-pelvic CT examinations suffice, with no need for primary spine imaging.

**Radiation Dose**

CT, particularly whole-body CT, is associated with a higher radiation dose than conventional radiography. Use of whole-body CT should negate the need for site-specific radiography and CT examinations.
emergency department. Research on CT use in emergency departments indicates that many of the patients who have minor trauma and receive whole-body CT scans are aged 18 to 24 years. These patients are at the greatest risk for cumulative radiation effects.\textsuperscript{15,16}

Efforts to reduce CT dose include investigation of iterative reconstruction and low-dose CT scanning.\textsuperscript{13,62}

Alshamari et al compared lumbar spine radiography with low-dose lumbar spine CT. According to the study, past research showed low-dose CT scans in patients with cervical spine trauma were of diagnostic quality when compared with scans performed with regular doses. The investigators performed standard lumbar spine digital radiography and low-dose CT examinations on the same day for participants, and found that low-dose CT improved display of most anatomy over radiographs (see Figure 5). However, the authors cautioned that their study participants were referred mostly from primary care providers for low back pain and that findings could differ in trauma imaging.\textsuperscript{62}

The iterative reconstruction technique rebuilds the image with a focus on reducing noise in scans, lowering radiation dose, and improving scan quality. Physicians have hesitated to implement iterative reconstruction in CT as a primary imaging assessment because of concerns about missing subtle injuries such as vertebral fractures. Kahn et al studied the use of adaptive statistical iterative reconstruction and a

and, therefore, reduce total dose. In addition, whole-body CT must not be used indiscriminately, such as for minor trauma.\textsuperscript{57} Although evidence suggests value in using CT to evaluate patients who have multiple trauma, it might not be advisable in patients with only minor symptoms.\textsuperscript{69} One study reported that use of CT to assess minor injuries doubled from 2005 to 2013.\textsuperscript{12} The increase in CT examinations to evaluate minor injuries could be the result of more convenient access to the modality, decisions based on defensive medicine, or pressure to decrease patient time in the

Radiation dose for spine CT has been estimated at 6 mSv.\textsuperscript{11} Thoracoabdominal CT scans are associated with a high dose as well, potentially 16.1 mSv, according to van Vugt et al.\textsuperscript{14} A 2008 study assessing total radiation dose to patients in emergency departments who had severe trauma found that the total dose from all imaging in the first 24 hours of care was 40.2 mSv.\textsuperscript{15} Radiologists should review the spines of blunt trauma patients in torso CT scans to minimize total scans performed and to reduce dose.\textsuperscript{14}

Decisions to use modalities that do not involve ionizing radiation must be tempered by their disadvantages, such as time spent in MR imaging and relative isolation of MR suites, which involves patient transfer. Research continues on the harms and benefits of whole-body CT scanning vs a combination of radiographs and site-specific CT scanning.\textsuperscript{16} All radiology personnel should adhere to ALARA (as low as reasonably achievable) principles in thoraco-lumbar spine trauma imaging.\textsuperscript{10}

**Technique**

Classification systems such as TLICS rely on morphology descriptions by the radiologist and surgeon following trauma imaging.\textsuperscript{26} According to ACR practice parameters, CT imaging of the thoracic and lumbar spine should involve a slice thickness no greater than 3 mm and a small enough field of view to improve geometric resolution.\textsuperscript{10} In CT imaging of adults with blunt trauma that meets the criteria for thoracic and lumbar examinations, including the presence of neurological signs, the practice parameters recommend dedicated noncontrast

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Figure 5. Low-dose CT scan with good image quality of a 27-year-old woman of normal weight, which demonstrates the sharp reproduction of different anatomical structures of the lumbar spine. Reprinted with permission from Alshamari M, Geijer M, Norrman E, et al. Low dose CT of the lumbar spine compared with radiography: a study on image quality with implications for clinical practice [published online ahead of print]. Acta Radiol. 2015 pii:0284185115595667.
images with sagittal and coronal reformatting unless diagnostic information on the spine can be derived from a thoracic-abdominal-pelvic scan. MR should be added when the patient shows signs of neurologic abnormalities. Other parameters are used to evaluate spinal fusion integrity, including 1-mm to 2-mm contiguous slices of the involved segments.

Adequate positioning and technique are critical in examining trauma patients. Radiology staff must be aware of devices such as respirator tubing and central venous lines when performing trauma CT scans of the thoracolumbar region. Removing artifact-causing objects that are not essential to patient and spinal stability can improve image quality.

**Patient Care**

A value of using whole-body CT as the primary imaging examination is the ability of emergency personnel to perform life-saving procedures without moving the patient from the CT table. According to Hauswald, advanced airway management techniques exert force across the cervical spine, causing it to move. When resuscitation is necessary, trauma patients’ vital signs must be monitored continuously during CT scans. When acquiring images on patients who have spinal injuries, radiologic technologists might have to delay starting the scan until the patient is stabilized. Patient monitoring equipment should be available immediately and include cardiopulmonary resuscitation supplies, vital signs monitoring equipment, an emergency crash cart, and support equipment.

Support for the use of immobilization for all suspected spinal trauma patients might be shifting, largely because of rapid injury assessment with diagnostic imaging. Criteria for low risk of injury from movement include the absence of neurological deficits, midline tenderness, or distracting injuries; immobilization also might be unnecessary for patients who are alert and sober. Imaging staff should follow physician instructions and institutional policies regarding moving a patient or removing an immobilization device such as a cervical collar. Staff also should be familiar with the log-rolling technique per their institutional policy.

**Pediatric Patients**

Spinal fractures are rare in children; they make up approximately 5% of all pediatric fractures. As with adults, motor vehicle collisions cause most thoracolumbar spine injuries, including injuries from automobile lap belts. Children can have transient pain from these injuries; spinal trauma signs in children are more easily missed by imaging than in adults.

Biomechanics and anatomy of the spine differ in children compared with adults. A lower center of gravity in children can cause injury patterns to be slightly different than in adults. Children’s heads are disproportionately large compared with adults’ heads, and children require backboard support for their necks when transported for spine trauma.

Compression fractures are the most common fracture to the thoracolumbar spine in children. The fractures are caused by flexion and axial loading. Most are stable and can be treated with braces, but the presence of multiple fractures can indicate posterior fusion. Burst fractures occur because of high-energy axial loading. Children can have neurological deficits from these fractures because of fracture fragments in the lamina. CT scanning can demonstrate loss of vertebral body height and kyphosis. If no neurological deficits are found, children can be treated with a molded cast or brace. Unstable thoracolumbar fractures require operative stabilization.

Chance fractures usually are caused by a lap belt and can be associated with intra-abdominal injury. When the child’s injury involves only bone, it can be treated with a cast or brace. Fusion with spinal instrumentation is warranted for Chance fractures involving ligaments. Fracture-dislocations are unstable and often cause spinal cord injury in children. When patients are neurologically intact, surgical stabilization can protect the spinal cord. Children recover from severe spinal cord injuries much better than do adults, but children aged younger than 10 years nearly always develop paralytic scoliosis, which contraindicates bracing.

An additional type of fracture that occurs only in pediatric patients and most often in adolescent lumbar spine trauma is the apophyseal injury. Caused by flexion, an apophyseal injury is marked by fracture and displacement of the endplate into the spinal canal. Patients who have this injury face chronic pain; those
with severe pain and neurological signs require surgical stabilization.\textsuperscript{43}

In general, children with thoracolumbar trauma should be assessed with radiography\textsuperscript{44}; however, imaging is not necessary when the child is younger than 14 years, alert, free of pain, and has a supple neck and no distracting injuries.\textsuperscript{30} Children experience more soft tissue injuries than bony fractures from spinal trauma, and the soft tissue injuries can be demonstrated on radiographs and MR scans.\textsuperscript{32} CT and MR might be indicated in Chance fractures to evaluate the child’s ligaments for disruption and in apophyseal fractures.\textsuperscript{44} CT also is used for preoperative planning in children; surgeons use the scans to measure areas of the spinal column, such as pedicles, to plan instrumentation placement.\textsuperscript{44} Children are prone to multiple compression fractures in adjacent vertebrae, necessitating imaging of the entire spine when investigating possible thoracolumbar injuries.\textsuperscript{44}

Dose is a critical consideration in imaging pediatric thoracolumbar trauma patients because of their remaining life span in which stochastic radiation effects can arise. Swanson et al concluded that doses could be reduced to as low as 25% of standard CT doses in preoperative imaging of the spine without affecting accuracy or precision of spinal measurements.\textsuperscript{66}

\textbf{Elderly Patients}

The spine becomes more porous with age, and vertebral body strength declines. This reduced strength is seen as kyphosis in elderly women and men.\textsuperscript{33} Decline in bone mineral density from osteoporosis is progressive and increases the risk of spinal fracture.\textsuperscript{67} Along with fractures to the wrist and proximal femur, vertebral fractures are among the most common types of osteoporotic fractures in people 55 years and older. Most vertebral fractures in the elderly occur in the thoracolumbar spine.\textsuperscript{68} Fractures related to osteoporosis and low-energy forces differ from those caused by high-force acute trauma.\textsuperscript{3}

Falls cause the most trauma in older patients. The elderly are more likely than other populations to experience serious consequences from falls, including fractures and traumatic brain injury, even from falls from standing heights.\textsuperscript{64,67} Mukherjee et al reported a high rate of neurological injury in elderly people with thoracolumbar spine injuries from motor vehicle collisions.\textsuperscript{3} The thoracic cage is less tolerant of force and injury, as demonstrated by decreased elasticity of bone and a rib angle that is more perpendicular to the vertebrae than in younger adults. It takes less force to fracture an osteoporotic vertebra than a normal one. Stenosis in the thoracic region of the spinal canal, which occurs as people age, increases the risk of neurological deficits. Central nervous system tissue in older patients also can degenerate more rapidly in response to mechanical forces.\textsuperscript{3}

Elderly patients with thoracolumbar fractures can have high morbidity and mortality from their injuries.\textsuperscript{68} Immobilization in this population can lead to serious adverse effects such as pneumonia.\textsuperscript{68} Skin breaks down in as little as 1 hour when patients are left immobile on backboards, and tissue injury is more likely in elderly patients.\textsuperscript{32} Conservatively managing thoracolumbar injuries in the elderly has been shown to provide the same level of mobility as when the fractures are managed operatively.\textsuperscript{32}

In addition to standard classification information to determine treatment, physicians must consider comorbidities and other operative risk factors compared with potential benefits of surgery in elderly patients with spinal trauma. Fusion with instrumentation in particular is associated with higher risk of complications and longer hospital stays.\textsuperscript{3} Research has shown that pedicle screws can loosen more easily in spines with low bone mineral density, which reduces torque, and instrumented fusion is less secure for spinal fixation than is fusion surgery.\textsuperscript{3} Early ambulation can reduce complications and generally is not associated with higher risk of neurological damage.\textsuperscript{66} It is likely that bones take longer to heal following spinal fracture, but no large studies outline the specific time or complications associated with fracture healing in older trauma patients.\textsuperscript{3}

The use of CT scanning, including spinal CT, has increased for elderly patients who have fallen. Roudsari et al found a 15% increase in spinal examinations in the Medicare population between 1996 and 2006.\textsuperscript{61} Older age has been identified as a significant factor in CT use. The reason could be provider awareness of potential for injury from low-energy mechanisms.\textsuperscript{315}
Conclusion

Thoracolumbar spine stability is essential and relies on a complex interaction of bones and ligaments to provide physical and neurological support. CT imaging is key to identifying traumatic injury to the spine rapidly and accurately. Interpretation of CT scans can provide important information about thoracolumbar injury patterns, injury morphology, vertebral body and facet joint integrity, kyphosis, and other signs to help guide injury management and preserve function.

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1. The thoracolumbar region of the spine includes which vertebrae?
   a. C12 through L1
   b. T1 through L1
   c. T1 through L5
   d. T3 through L3

2. Long-term thoracolumbar stability depends on the:
   a. capsular ligaments.
   b. posterior ligamentous complex.
   c. anterior longitudinal ligament.
   d. posterior longitudinal ligament.

3. Compression **primarily** affects:
   a. the vertebral body.
   b. ligaments.
   c. osseous elements.
   d. disks.

4. Hyperextension causes tension on which portions of the spine?
   a. posterior
   b. anterior
   c. medial
   d. superior

5. Anterior spondylolisthesis occurs as a result of ______ forces.
   a. compression
   b. flexion
   c. shear
   d. rotation

6. The **most** common spinal injury for vehicle occupants with seat belt syndrome is the ______ fracture.
   a. burst
   b. Chance
   c. wedge-compression
   d. translation

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**QUICK QUIZ**

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   d. translation

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**continued on next page**
7. Which of the following scoring and classification categories are included in the Thoracolumbar Injury Classification and Severity score?
   1. injury morphology
   2. neurologic status
   3. mechanism of injury
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

8. Which of the following injuries cannot be managed conservatively?
   a. compression fracture
   b. osseous Chance fracture
   c. fracture-dislocation
   d. burst fracture with no neurological deficit

9. Interlaminar hooks for spine stabilization are most effective when placed ______ the injured segment.
   a. directly in
   b. into segments adjacent to
   c. 2 levels above and 3 levels below
   d. 3 levels above and 2 levels below

10. Which of the following statements is false regarding the use of computed tomography (CT) for trauma imaging?
    a. CT is reliable and fast.
    b. Physicians should base CT indications on injury mechanisms, regardless of severity.
    c. Drawbacks include costs and incidental findings.
    d. CT scanning is better than radiography for identifying and classifying spinal injuries.

11. ______ is the modality of choice for follow-up imaging to assess suspected spinal cord injury from thoracolumbar spine damage.
    a. Site-specific CT
    b. Whole-body CT
    c. Magnetic resonance imaging
    d. Sonography

12. Indications for thoracolumbar spine CT include:
    1. local signs of injury.
    2. abnormal neurological signs.
    3. cervical spine fracture.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

13. Which of the following statements is true about iterative reconstruction?
    a. It reduces noise on CT scans and contributes to lower dose.
    b. It reduces noise on CT scans but adds to dose.
    c. Physicians have embraced the technique because of its high sensitivity.
    d. Image quality is reduced markedly in the reconstructed images.

14. Which type of fracture to the thoracolumbar spine is most common in children?
    a. burst
    b. major
    c. compression
    d. fracture-dislocation