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A Simplified Approach to Imaging Thoracolumbar Spine Injuries with TLICS

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Abstract: ***Background**: Thoracolumbar (TL) spine injuries are one of the common entities contributing to morbidity post - trauma. Major complications include transient or permanent neurological damage, spinal cord injury, malunion causing deformities that may further lead to early onset of spondylosis and chronic pain syndrome. TL injuries distinguish themselves from other musculoskeletal injuries by virtue of their unique anatomical configuration. Hence, similar mechanisms of injury can lead to a range of different injury patterns. **Aim**: This study illuminates the comprehension of the anatomical biomechanics of the thoracolumbar spine, the significance of CT & MRI in conjunction with visual examples of different injuries based on the TLICS score, and an encompassing methodology for scoring these injuries. **Methods**: A descriptive study involving patients with suspected TL spine injury referred for imaging (CT and /or MRI), a detailed clinical history and examination for neurological status were recorded and TLICS system was applied to manage the patient. Patients with past history of spine surgery, radiotherapy or chemotherapy were excluded. **Conclusion**: The assessment of TL spine injuries starts with a clinical neurological evaluation, patient immobilization and imaging. Computed tomography (CT) and magnetic resonance imaging (MRI) play pivotal roles in assessing TL spine injuries, ultimately guiding management decisions and prognosis. None of the existing classification systems for spine injuries emphasize on posterior ligamentous complex and neurological status. The Spine Trauma Study Group devised the Thoracolumbar Injury Classification and Severity (TLICS) score, incorporating factors like fracture morphology, injury to the posterior ligamentous complex, and clinically evaluated neurological status. It is both a classification and scoring system, helps identify surgical candidates including surgical approach. Hence, the TLICS score stands as a thorough, rapid, dependable, and precise scoring system that every radiologist should integrate into their reports.*

Keywords: Thoracolumbar spine, traumatic spine injuries, MDCT, MRI, TLICS

1. Introduction to Imaging in Thoracolumbar Spine Injuries

Traumatic injuries to thoracolumbar (TL) spine are one of the commonest causes of morbidity most of which are contributed by disabling neurological deficits, spinal deformities, chronic pain syndromes and need for prolonged hospitalization despite surgical intervention. Risks of these complications can be minimized by early and prompt treatment of spine injuries which employs both clinical assessment and imaging to ensure better quality of life.

Traumatic spine injuries are managed primarily as per ATLS guidelines which includes assessment of spine trauma after initial resuscitation. Few principles of the guidelines are assessing the neurological status with respect to sensory, motor status, reflexes, sphincter tone and stabilization of spine [1]. Indications for imaging of traumatic cervical spine has been well sought with criteria such as National Emergency X - radiography Utilization Study (NEXUS) [2] and Canadian c - spine rules [3]. However, indications in the setting of TL spine injury mainly remain clinical. Commonly performed imaging techniques are plain radiography, multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI).

Plain radiography used to be the initial imaging modality in the evaluation of spine injuries with both anteroposterior and lateral views. They commonly reveal spinal misalignment and obvious fractures [4]. In the acute setting, up to 30% of the examinations were limited due to the inadequate motion affecting their diagnostic utility [5]. Presence of ligamentous injuries often are masked by extensive muscle spasm and pain. With this background, some institutes may rely on radiographs as a screening modality due to its availability in cost limited settings.

MDCT is the preferred imaging modality in blunt spine trauma. Some of the indications [6] are outlined in Table 1.

Table 1: Indications for MDCT in TL trauma [6]

1.	Back pain or midline tenderness
2.	Local signs of TL injury
3.	Abnormal neurologic signs
4.	Cervical spine fracture
5.	Glasgow Coma Score (GCS) less than 15
6.	Major distracting injury
7.	Alcohol or drug intoxication

MDCT is sensitive for spine fractures, evaluation of displaced bone fragments, bone loss, acute hematoma, osteoporosis and invariably have an overview of the whole thoracoabdominal structures that is included in the field of view. Availability of 3D reconstruction algorithms, windowing options and a relatively quick contrast study can be performed to rule out vascular injuries. Related conditions associated with fractures like fused vertebrae, ankylosing spondylitis and DISH are also detected with ease. Disadvantages of MDCT are exposure to ionizing radiation and inadequate evaluation of soft tissue and neural structures [4] of the spine such as ligaments, discs, spinal cord and nerve roots. When there is neurological deficit and / or signs that could indicate injury of posterior ligamentous complex on MDCT, MRI is indicated. Therefore, MDCT is the preferred initially modality and also a screening modality in TL spine trauma who require imaging [6].

MRI is the imaging modality of choice for assessing soft tissue injuries, spinal cord injury, intervertebral disc integrity and ligamentous complex. Table 2 outlines the indications for MRI in TL spine injures.

Table 2: Indications for MRI in TL trauma [5]

1) Signs of myelopathy or radiculopathy 2) Progressive neurologic deficit 3) Signs of spinal cord injury 4) Unexpected level of signs above the level of the radiographically seen injury 5) Negative MDCT (or radiographs) and suspected ligamentous injury

It's also the only method of directly visualizing and differentiating spinal cord hemorrhage and edema which greatly contributes to prognosis [7]. Some institutes often perform MRI in patients with unreliable physical examinations (e. g., obtunded or impaired) even when the CT is negative [4]. Protocol at our institute for spine trauma is described in Table 3. Limitations of MRI include higher cost and availability where the benefits of superior contrast resolution and sensitivity to detect subtle acute fractures outweighs the risks in an appropriate clinical setting.

Table 3: MRI protocol for traumatic TL spine

1. T1 - weighted imaging in sagittal and axial planes.
2. T2 - weighted imaging in sagittal and axial planes at the disco vertebral junctions.
3. STIR in sagittal and coronal planes.
4. T2 - weighted imaging in thin sections (3 mm) in the region of spine trauma.
5. GRE in axial plane.

Anatomy & Biomechanics of Thoracolumbar Spine

The spinal motion segment comprises of two consecutive vertebrae with intervertebral disc and the connecting soft tissues [8]. This serves as the primary functional unit of the spine. They are classified into anterior and posterior portions of functional unit. Anterior portion consists of aligned consecutive vertebral bodies with intervertebral discs (IVD), anterior (ALL) and posterior longitudinal ligaments (PLL). Posterior portion includes vertebral arches, facet joints and posterior elements.

The primary support for axial loading comes from the vertebral bodies and IVD. Vertebral bodies withstand compressive loading, while IVD feature a central nucleus pulposus that absorbs and distributes compressive loading hydrostatically. Additionally, they have an annulus fibrosus that counters circumferential tensile stress resulting from the loading [8, 9].

The posterior portion of motion segment contains the posterior ligamentous complex (PLC) which is the most critical in providing stability. It is composed of

1) Supraspinous ligament: Strong cord - like ligament connects the tips of spinous processes from C7 to the sacrum. High collagen content contributes to high tensile strength making it effective to limit flexion of the spine [8, 9, 12].
2) Interspinous ligaments: Weaker, thin membrane - like ligaments that connect the adjacent spinous processes also limits spine flexion.
3) Ligamentum flavum: A thick band connecting the laminae of adjacent vertebrae. High elastin content in this ligament is responsible for exerting contractile force on the vertebral arches. This keeps the vertebrae together keeping them aligned [9, 10]. The ligament elongates in flexion.
4) Articular facet joint capsule: Made of hyaline cartilage primarily act against rotatory stress. The capsule acts as a fulcrum in active extension, thereby reducing the load on the anterior column [10, 11].

Anterior portion therefore bears axial compressive loading whereas the posterior portions guide the type of spinal movement which is determined by the plane of facet joint orientation.

Concept of tension bands: The osseous and ligamentous structures responsible for averting distraction, hyperextension, and hyperflexion of the thoracolumbar spine are termed tension bands [6]. The anterior tension band limits hyperextension and is formed by ALL and anterior disc annulus. Posterior tension band limits hyperflexion and is formed by posterior bony arch and PLC. Injury to these tension bands causes gross displacement of the injured segment and deformities.
The axis of rotation for TL spine is just anterior to the anterior half of the vertebral bodies in erect posture, this is counterbalanced by PLC and erector spinae muscle forces [14].

Thoracolumbar spinal segments per se are functionally categorized into thoracic spine (T1 - 10), thoracolumbar junction (T11 - L2) and lumbar spine (L2 - 5).

Kyphotic thoracic spine (T1 - T10) communicates with the first 10 ribs making it the most rigid part of the TL segment. They have coronally oriented facet joints limits extension (more than flexion) but allows rotation and relatively have smaller intervertebral discs and narrow spinal canal.

Thoracolumbar junction (T11 - L2) is the segment where a rigid thoracic spine articulates with flexible lumbar spine. The facet joints are intermediately oriented. These anatomical details are what makes this unit is the most commonly injured segment in TL spine.

Lordotic lumbar segment (L3 - 5) have larger IVD, spinal canal and sagittal orientation of facet joints limits lateral bending & rotation, allowing flexion and extension.

2. Historical Review of Classification Systems

The concept of fracture stability plays a crucial role in guiding surgeons to decide whether surgical intervention or nonoperative treatment is the most suitable approach.

White and Panjabi proposed a widely referenced and comprehensive definition of stability as "a loss in the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve roots. In addition there is no development of incapacitating deformity or pain due to structural changes" [13]. Assessing stability remains a topic of debate, with over a dozen classification systems proposed to evaluate injuries to the TL spine. Few notable examples are Denis [15], McAfee [16], and AO - Magerl classification systems.

Arguably, the most familiar one amongst radiologists is the Denis three column system which is based on morphology and mechanism of injury. This system emphasizes fracture involvement of the middle and posterior columns, considering them unstable injuries. However, subsequent modifications indicated that burst fractures with an intact posterior ligamentous complex (PLC) could be effectively managed without surgery. This introduced a new category of "unstable - stable" fractures [16], causing confusion. It does not offer prognostic insight or take into account the neurological status of patients. Ultimately, these factors render the Denis classification theoretically relevant, as it fails to provide guidance for surgeons in practice [17, 18].

The next significant advancement in spinal injury classification came with the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification [19]. It classifies injuries into group A (compression), B (distraction) and group C (translational or rotational), with up to nine subtypes in each category. One of its main principles is that groups A through C represent a spectrum of escalating injury severity and instability, correlating with a higher probability of requiring surgical stabilization. It emphasizes importance of injuries to soft tissue structures (PLC, IVD and ALL). Due to its intricate subclassifications, the AO system demonstrates minimal interobserver variability. However, it failed to consider the patients neurological status. In 2016, Keppler and colleagues [20] added neurological status and clinical modifiers to the above classification. Although the AO classification demonstrated interobserver reliability similar to that of the TLICS classification [21], the assessment of the PLC, a crucial component of the classification, was notably less reliable. Consequently, this limitation hindered its practical application.

TLICS Categories

The Thoracolumbar Injury Classification and Severity Score (TLICS) was formulated by the Spine Trauma Study Group to address the inadequacies of prior classification systems, which were found to have limited prognostic value and generally lacked treatment guidance. It is both a scoring and a classification system which relies on three injury categories, each independently crucial and complementary in aiding the determination and management of spine injuries. Within each category are the subcategories arranged from least to most significant, with a numerical value [21] alongside. These values from each category are summed up to provide a severity score.

Injury morphology

Different mechanism of spine injury can result in similar injury patterns. Retrospectively inferring the injury mechanism from imaging findings may lead to errors [22]. TLICS relying on morphology of the injury rather than the mechanism of injury makes it simple and straightforward for both the surgeons and radiologists. Compression fractures are caused when the vertebral body gives away under axial loading. They appear as a visible loss of vertebral body height or disruption of the vertebral endplate [23]. Less severe compression injuries involve only anterior portion of vertebral body and are termed as simple compression (1 point). Severe forms of compression which involve both the anterior and posterior vertebral body with varying degrees of retropulsion are called burst compression fractures (2 points). Compression fracture with a coronal plane deformity of more than 15^o is assigned a score of 2 points [24].

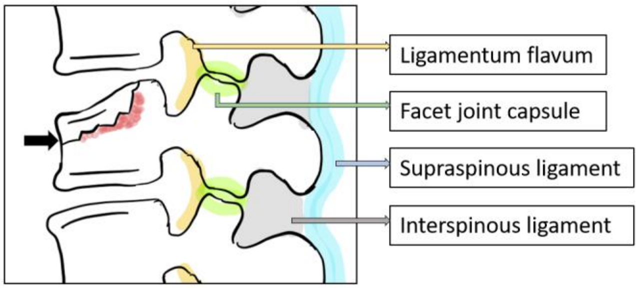

Figure 1: Horizontally oriented fracture line involving the anterior cortex of vertebral body, a simple compression fracture (1 point)

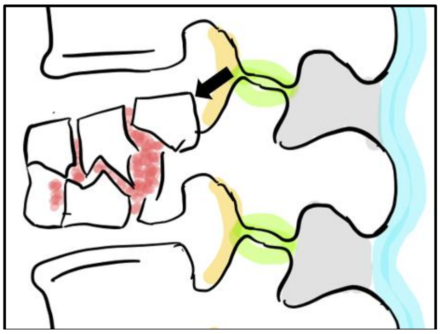

Figure 2: Fracture line involving anterior and posterior cortices with retropulsion of the fracture fragment, a burst compression fracture (1 point)

Rotational / translational injuries (3 points) occur as a result of torsional and shear forces of higher magnitude. They cause rotation of spinous processes, facet fracture - dislocation and subluxation of vertebra [21]. They are detected on imaging as horizontal displacement or rotation of one vertebral body with respect to another. Sagittal images are best to detect anteroposterior translation whereas coronal images are best suited for assessing mediolateral translations.

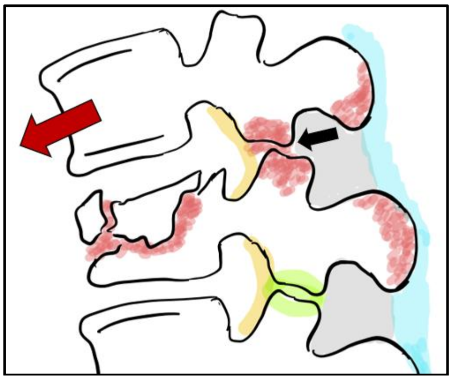

Figure 3: Fracture of the vertebral body with facet joint dislocation (black arrow) and subluxation of the vertebra (red arrow), can be associated with spinous and transverse processes fractures. This is a translational injury (3 points)

Distraction injuries (4 points) occur secondary to disruption of both posterior and anterior elements leading to separation of rostral and caudal components of the spinal column often associated with angulations [21]. They are rightly regarded as the unstable injury as there is circumferential disruption of the spinal column.

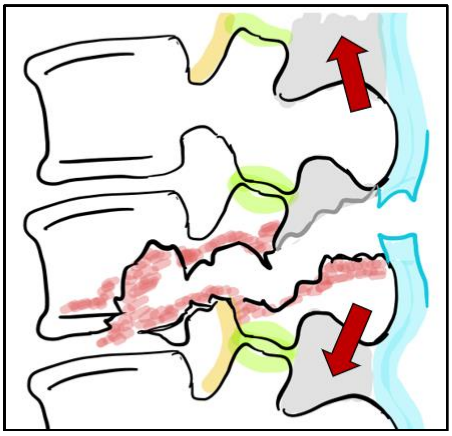

Figure 4: Disruption of posterior elements extending anteriorly causing the spinal column to separate into unstable superior and inferior components which is consistent with distraction injury (4 points)

In complex fractures, multiple injury morphologies may coexist at a single level, it is advisable to use both the terminologies while reporting for classification purposes. However, injury with the largest score is what contributes to the final TLICS [21].

Table 4

Injury morphology	Points
Compression	1
Burst	1
Translational / rotation	3
Distraction	4

Integrity of posterior ligamentous complex

PLC is the important stabilizer of spine acting as a posterior tension band protecting against excessive flexion, rotation, translation, and distraction. The integrity of the PLC is classified as intact, indeterminate, or disrupted. After disruption, surgical intervention is typically necessary for the injured segment of the PLC due to its limited ability to heal [21]. It's often characterized by splaying of the spinous processes (widening of the interspinous space), diastasis of the facet joints, and facet perch or subluxation. If the evidence of disruption is subtle, it is labelled as indeterminate / suspected. Rarely, a palpable gap between the spinous processes maybe an evidence of PLC disruption [21].

Disruption of PLC is seen as fluid in any of the constituting ligaments on fluid sensitive MRI sequences. In diagnosing traumatic PLC injuries, studies have reported an overall sensitivity and specificity of 91% and 100% respectively, with 100% accuracy in identifying surgical fractures [25].

Table 5

Integrity of PLC	Points
Intact	0
Suspected / indeterminate	2
Injured	3

Neurological status

Neurological function serves as a crucial indicator of the severity of spinal column injury. Incomplete neurologic injury and cauda equina injury are indication for surgical intervention.

Table 6

Neurologic status	Points
Intact	0
Nerve root involvement	2
Complete involvement of spinal cord / conus	2
Incomplete involvement of spinal cord / conus	3
Cauda equina involvement	3

TLICS Treatment Guidelines

A TLICS total score of 3 or lower typically suggests nonsurgical management involving brace immobilization and active patient mobilization. A score of 5 or higher indicates the need for surgical intervention, which may involve deformity correction, neurologic decompression if necessary, and stabilization. A score of 4 falls within an intermediate zone where both surgical and nonsurgical treatments may be equally appropriate [9].

Table 7: Treatment guidelines

TLICS score	Management
0 - 3	Medical
4	Medical or surgical
≥ 5	Surgical

TLICS guides not only identifies candidates for surgery but also determines the appropriate surgical approach. As far as the surgeon's perspective, the two most important factors deciding the surgical approach are PLC and neurological status. There is no treatment algorithm that can supersede a surgeon's intuition in prioritizing and integrating a multitude of complex clinical and biomechanical issues [21].

Table 8: Preferred surgical approach

Neurological status	Intact PLC	Disrupted PLC
Intact	Posterior approach	Posterior approach
Nerve root involvement	Posterior approach	Posterior approach
Complete involvement of spinal cord / cauda	Anterior approach	Combined approach
Incomplete involvement of spinal cord / cauda	Posterior (anterior) approach	Posterior (combined) approach

Checklists For Reporting Spine Injury

Computed Tomography

Midline Sagittal images	Parasagittal images	Coronal images	Axial images
Vertebral lines to be assessed: anterior, posterior vertebral lines, spinolaminar lines	Facets	Lateral vertebral lines	Vertebral bodies
Vertebral bodies	Articular processes	Spinous processes	Pedicles
Spinous processes	Pedicles	Transverse processes	Laminae
Interspinous distances	Pars interarticularis		Facets
Perivertebral soft tissues			Spinous processes
Spinal canal			Spinal canal
			Prevertebral soft tissues

MRI

Osseous injury
Soft tissue injuries
PLC status 1. Supraspinous ligament 2. Ligamentum flavum 3. Interspinous ligaments: Facet capsule, discs, anterior and posterior longitudinal ligaments
Neurological injuries 1. Spinal cord or conus medullaris injury 2. Cauda equina 3. Nerve root injury 4. Epidural hematoma

Approach to TLICS scoring

Step I: Assess Osseous Structures

1. Facet joint disruption or dislocation. 2. Anterior or lateral vertebral body component fracture. 3. Fractures of transverse or spinous processes (posterior ribs). 4. Oblique linear array of bone fragments on CT.
✓ Yes, to any of the above? Classification: Translational - rotational type. Score: 3. PLC is mostly involved, proceed to step II.
✓ None of the 4 features present? ○ Anterior cortex involved with intact posterior cortex and horizontal orientation of the fracture. Classification: Translational - rotational type. Score: 3. Proceed to step II. ○ Coronal orientation of the compression with angulation > 15º Describe the fracture with a score of 2 and proceed to step II. ○ Anterior and posterior cortex involved? ➢ Retropulsed fracture fragment / sagittal orientation of fracture involving vertebral body or posterior element / increased interpedicular distance. Classification: Burst compression. Score: 2. Proceed to step II. ➢ Severe vertebral body compression / horizontal fracture of posterior elements / separation of posterior elements. Classification: Distraction. Score 4. Proceed to step II.

Step II: Assess PLC injury

CT features that could indicate PLC injury: 1. Increased interspinous distance. 2. Fractures of transverse or spinous processes. 3. Facet joint disruption / dislocation. 4. Translational – rotational morphology. If any of the above present, correlate with neurological status and assess further with spine MRI.
MRI Spine: • Fluid signal intensity / edema in any of PLC structures with loss of ligamentous low signal intensity on T1WI, T2WI & STIR – indicative of disruption. Classification: Definitive injury. Score: 3. Proceed to step III. • Fluid signal intensity / edema in any of PLC structures without evidence of ligamentous disruption. Classification: Indeterminate for PLC injury. Score: 2. Proceed to step III. • No fluid / edema in any of PLC structures. Classification: Intact PLC. Score: 0. Proceed to step III.

Step III: Neurological status assessed clinically.

Completion of TLICS score and surgical approach is decided.

Step IV: Additional mention of

1. Epidural hematoma (site, extent, maximum thickness and signal). 2. Spinal cord injury. 3. Bony fragments within the spinal canal.
In case of multiple fractures score each level separately.

Clinical Scenarios

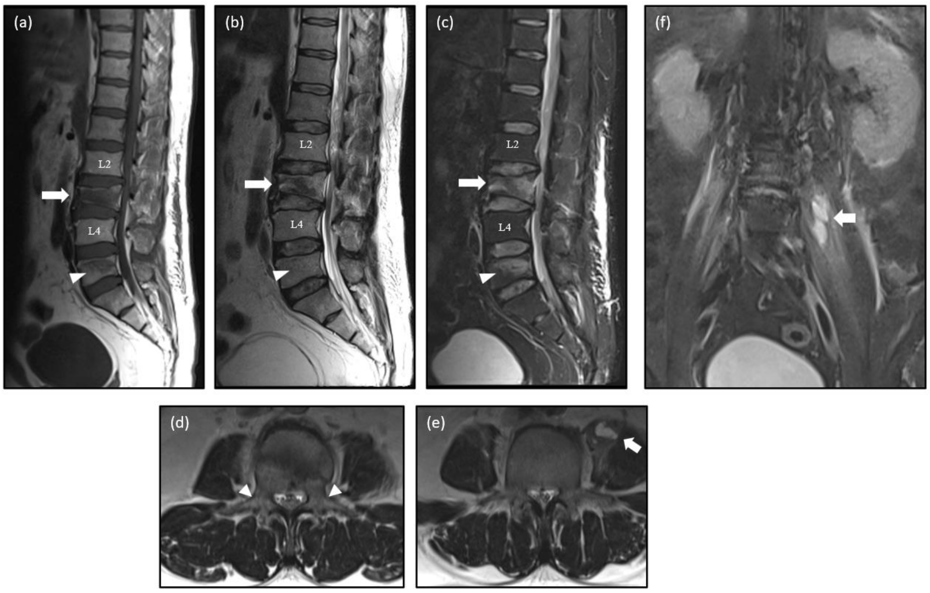

Figure 5: 60 - year - old male with acute traumatic low back ache. No neurological abnormality**.**

Sagittal (a) T1 - weighted, (b) T2 - weighted, (c) STIR images; (d, e) axial T2 - weighted and coronal (f) STIR images. Anterior wedge compression of L3 vertebral body. The body (arrow in a, b, c) and the pedicles (arrowhead in d) show fluid signal intensity (T1 hypointense, T2 hyperintense without suppression on STIR) within, which is suggestive of edema. No retropulsion. No evidence of PLC injury.

L5 vertebral body shows fluid signal intensity (arrowhead in a, b, c) in the superior half associated with subtle reduction in vertebral body height measuring 18.8 mm as compared to 22.4 mm of L4 vertebral body.

Fluid collections noted in the left psoas muscles (arrow in e, f) at and distal to the L3 vertebral body in keeping with hematomas.

Classification: Simple compression type. TLICS score: 1.

Management: Recovery with conservative management.

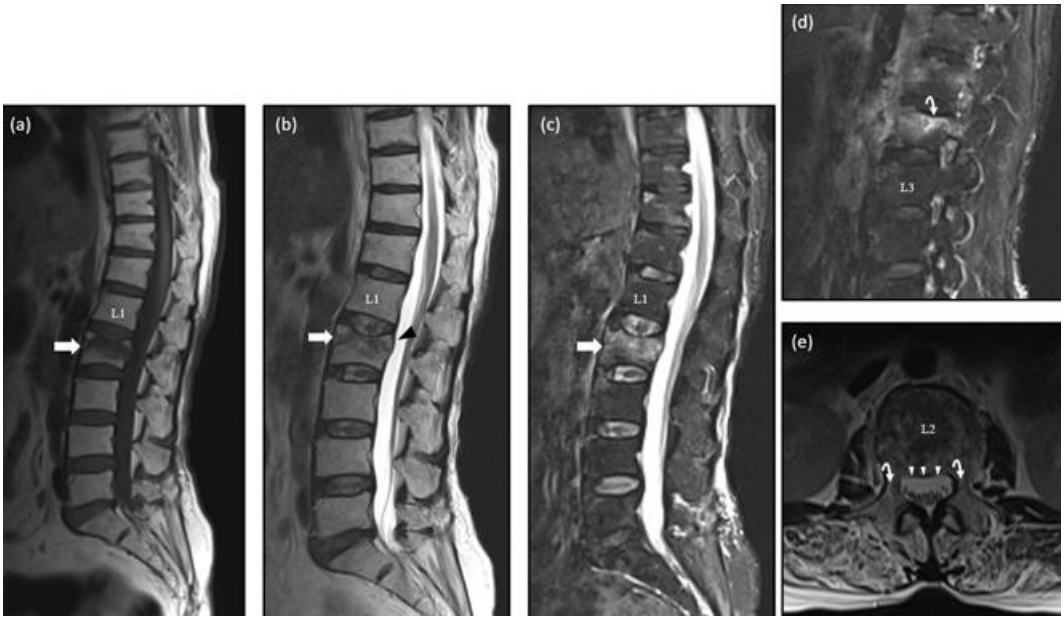

Figure 6: 60 - year - old female with fall from height. No neurological deficits.

Sagittal (a) T1 - weighted, (b) T2 - weighted, (c) STIR; parasagittal (d) STIR and axial (e) T2 - weighted images. Compression fracture of L2 vertebral body. The body (arrow in a, b, c) and the pedicle (curved arrow in d, e) show fluid signal intensity suggestive of edema. Posterior convex bulge of the vertebral body (arrowheads in b, e) is indenting the thecal sac. No posterior ligament complex injury.

Classification: Simple compression type with indentation of thecal sac. TLICS score: 1.
Management: Conservative management.

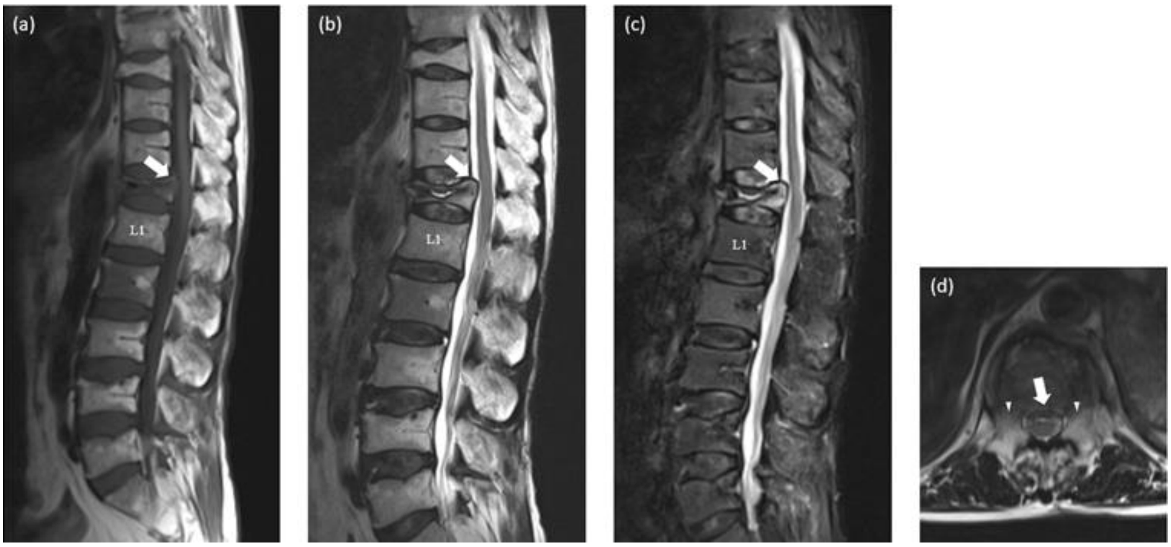

Figure 7: 70 - year - old male with acute low back ache after lifting heavy object. No neurological deficits

Sagittal (a) T1 - weighted, (b) T2 - weighted, (c) STIR; axial (d) T2 - weighted images. Burst compression fracture of D12 vertebral body showing retropulsion of the vertebra body (arrow in a, b, c) causing spinal canal narrowing (arrow in d). No posterior ligament complex injury. Edema within the posterior vertebral elements (arrowheads). Degenerative changes in the visualized spine.

Classification: Burst compression type. TLICS score: 2.

Management: Conservative treatment.

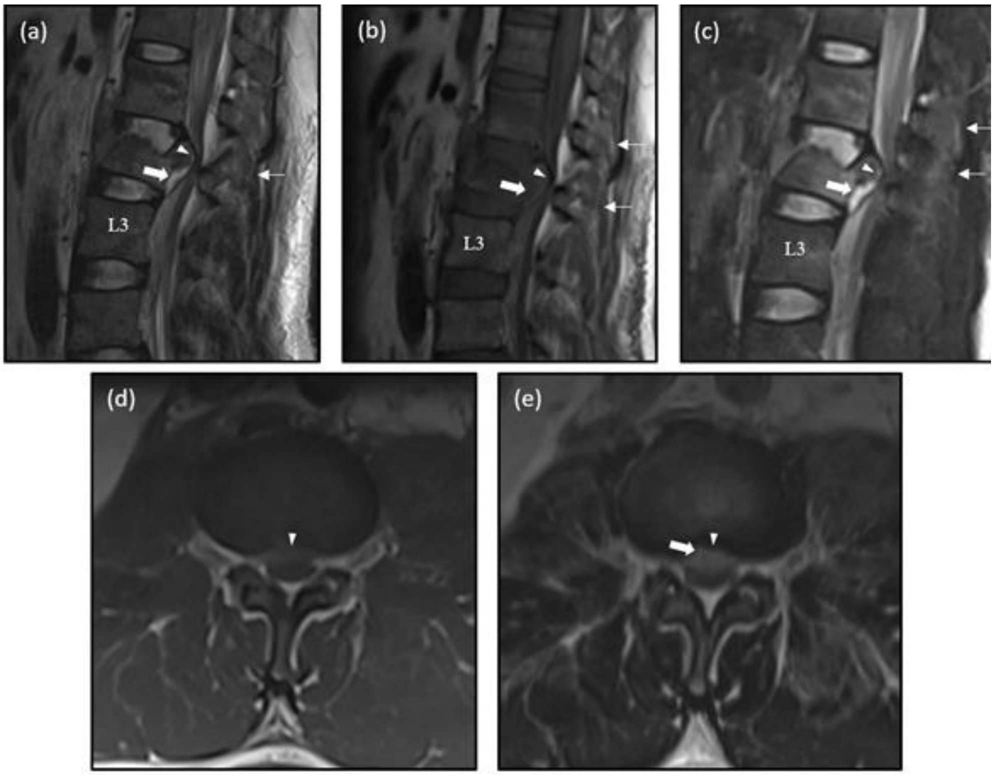

Figure 8: 32 - year - old male with motor vehicle collision (MVC) and paraplegia

Sagittal (a) T1 - weighted, (b) T2 - weighted, (c) STIR; axial T1 (d) and (e) T2 - weighted images. Burst compression fracture of L2 vertebral body with epidural hematoma (thick arrow in a, b, c) causing thecal sac compression (arrowhead). Evidence of PLC injury (thin arrow).
Classification: Burst compression type with PLC injury. TLICS score: 7.
Management: Surgical treatment.

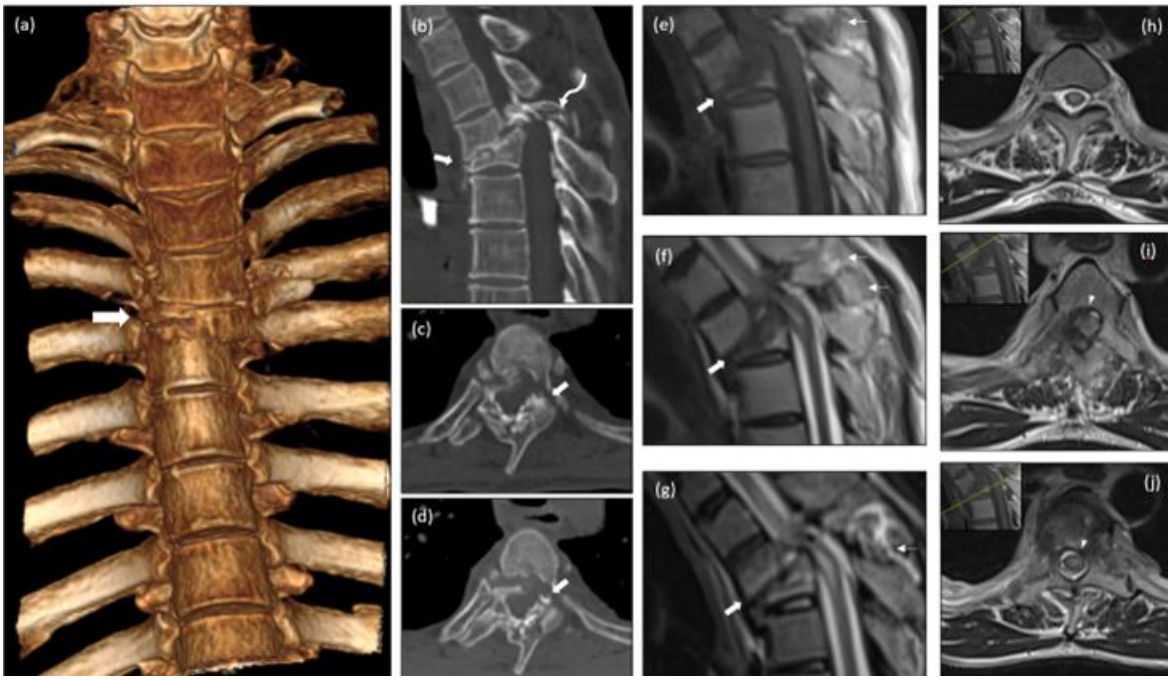

Figure 9: 45 - year - old male with MVC and paraplegia

CT images in bone window (b, c, d) with 3D VRT (a) and Sagittal (e) T1 - weighted, (f) T2 - weighted, (g) STIR; axial (h, i, j) T2 - weighted images.

Distraction injury of D4 vertebra (thick arrow) causing spinal canal narrowing (arrowhead) with evidence of PLC injury (thin arrow). Associated translational injury like facet joint disruption (curved arrow) is noted.

Classification: Distraction type. TLICS score: 10.

Management: Surgical treatment.

3. Conclusion

Thoracolumbar injuries contribute to significant morbidity, therefore the imaging evaluation with CT and MRI adds to the prompt diagnosis. TLICS system includes three major components namely injury morphology, PLC integrity and neurological status. The system classifies and provides a score which is of clinicoradiological importance; deciding the candidates for surgery, prognostication and approach to the surgery. TLICS thus bridges the gap between radiologist and surgeon avoiding confusions regarding the management.

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