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Review Article

Comprehensive Radiological Assessment of Sub-axial Spinal Injury

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ABSTRACT

Radiologists frequently interpret cross-sectional imaging of the spine in the setting of trauma. Mechanical stability of the traumatised spine is the single most important factor which guides further management.

Several classification systems have been developed over the past to assist radiologists to judge the potentially unstable injuries. The radiologists are arguably most familiar with Denis system of classification which is based on injury morphology and mechanism. This system has been criticised for being too simple, not prognostically valuable and lack of consideration of patients' neurological status. Arbeitsgemeinschaft für Osteosynthesefragen and Thoracolumbar Injury Classification and Severity Score classification systems are the next major evolutions which highlight the importance of the posterior ligamentous complex and neurological status of the patients in predicting the potentially unstable fracture.

The aim of this pictorial review is to familiarise radiologists with newer classification systems to improve their image interpretation skills and promote efficient communication with spinal surgeons. The pictorial examples are intended to illustrate the various injury types and how to classify them according to the aforementioned classification systems.

Keywords: Computed tomography; Magnetic Resonance Imaging; Radiology; Spine; Trauma

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INTRODUCTION

Spinal trauma occurs in approximately 10% of adult major trauma patients.1 Spinal fractures and dislocations without neurological injury account for the majority of spinal trauma (9.6% of trauma patients) and occur mainly in the thoracolumbar spine.[1,2] Around 50-60% of thoracolumbar fractures involve the T11-L2 levels.[2] However, spinal cord injury with or without fracture occurs in a much smaller proportion (1.8% of trauma patients) and tends to be most frequent in the cervical spine[1]. Younger patients below the age of 44 and male patients tend to be at greatest risk of spinal trauma.[1,2]

The initial investigation of spinal trauma usually comprises plain film and CT, with CT now routinely used first line in seriously injured patients. It is important for the general radiologist to be familiar with the various patterns of injury and their clinical relevance to help guide further management. This pictorial reviews the relevant clinical anatomy and classification systems used in spinal trauma, describes our imaging protocol and provides examples to illustrate the various classification systems.

ANATOMY

The spinal column consists of the vertebral body, disc (comprising annulus fibrosis and nucleus pulposus) and posterior osseous elements including the pedicles, articular pillars, facets, lamina and spinous processes.

Ligaments reinforce the osseous structures and comprise the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flavum (LV), interspinous ligaments

(ISL) and supraspinous ligament (SSL). The facet joints are contained within the facet joint capsule which is prone to rupture with flexion-distraction types of spinal injury.

Newer classification systems like AO and TLICS classifications give emphasis to the posterior ligamentous complex (PLC), which comprises the SSL, ISL, LV and facet capsules. They form the tension band of the spinal column and provide resistance against excessive compressive, distraction, rotational and translational forces and hence provide a vital contribution to spinal stability.[3] Without recognition of PLC injury progressive kyphosis and vertebral collapse may result.[4]

CLASSIFICATION OF SPINAL TRAUMA

A variety of classification systems exist, which aim to differentiate between unstable and stable fractures.[2] The underlying mechanisms of injury contribute to the fracture patterns described by these classification systems.

Axial compression injuries occur due to axial loading of the spine and either lead to wedge compression fractures or burst fractures. Burst fragments can potentially lead to retropulsion into the spinal canal. Flexion-distraction injuries occur with excessive flexion of the spine leading to failure of the posterior tension band and distraction of the posterior elements with compressive forces exerted on the anterior elements. A Chance fracture is an example of a pure trans-osseous flexion-distraction injury. Hyperextension injuries exert tensile forces on the ALL and compression injury to the posterior elements. When a rotational element is applied to compressive or flexion distraction mechanisms rotation or translation of the injured level may occur. Three widely used classification systems are discussed below:

1. Denis classification

Denis classification relies on a three-column theory, with injury to the middle column or ≥2 columns as indicators of spinal instability.[5] The anterior column comprises the ALL and anterior half of the discovertebral unit, the middle column comprises the PLL and posterior half of the discovertebral unit, and the posterior column includes the posterior ligaments and osseous elements.

The Denis system is easily reproducible and very widely used, and divides major spinal injuries into compression fractures, burst fractures, seat belt (flexion-distraction) injuries and fracture dislocations. However the classification is unable to prognosticate and does not consider neurological status.[3]

2. AO Classification

The Magerl Arbeitsgemeinschaft fur Osteosynethasefragen (AO) Classification describes three main categories of injury; (A) compression, (B) distraction and (C) axial torque.[2,6] Progression from the A to C types of injury indicates a greater severity of injury and increasing likelihood of instability.[2] It is a highly complicated classification system containing multiple subgroups which lead to poor inter-observer reproducibility and not all subgroups are clinically relevant.[7,8]

Reinhold et al. proposed a revised AO classification in 2013 comprising fewer subgroups and allowed for a greater degree of reliability with good inter-observer agreement[7]. An overview of this classification is provided in Table 1.

Table 1: Revised AO Classification7. In cases of Type B or C injury if there is an associated compression fracture this is classified separately.

Type A - Axial Compression injury of anterior elements Posterior ligamentous complex is intact. No displacement or dislocation.	A1 – Wedge or impaction fracture (fig.1)	No posterior vertebral wall involvement. Single endplate involvement.
	A2 – Split or pincer fracture (fig.2)	No posterior vertebral wall involvement. Both superior and inferior endplates involved.
	A3 – Incomplete burst fracture (fig.3)	Posterior wall involvement. Single endplate involvement.
	A4 – Complete burst fracture (fig.4)	Posterior wall involvement. Both superior and inferior endplates involved.
Type B - Tension band injury (injury to the posterior ligamentous complex).	B1 – Monosegmental transosseous fractures (Chance type/seat-belt injury). Figure 5	Horizontal fracture across vertebral body and pedicles
	B2 – Osseoligamentous disruption - All other tension band injury with or without bone involvement. (fig. 6&7)	Facet joint, pars fractures. LV, ISL and SSL injuries.
Type C - Displacement injuries	C1 – Hyperextension injury (fig. 6&7)	Widening of the anterior disk space or fracture through anterior vertebral body.
	C2 – Rotation/translational injury. (fug. 8)	Due to circumferential disruption of spinal column causing translation/rotation.
	C3 - Separation injury	Complete separation of cranial and caudal parts of the spinal column

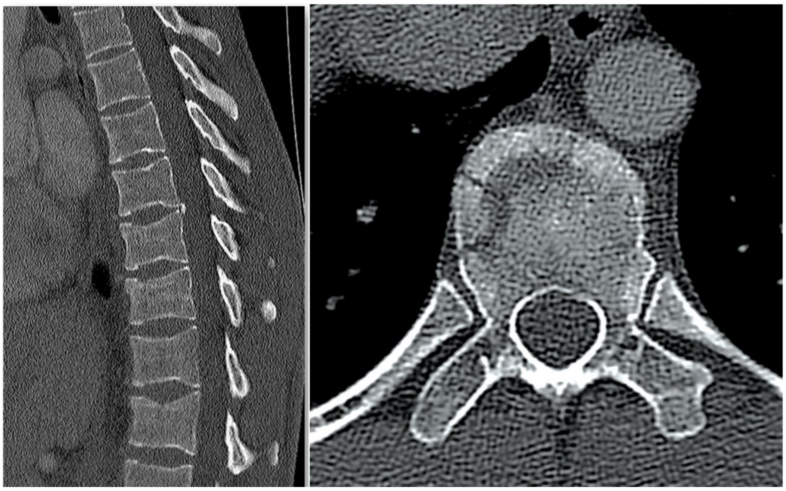

Figure 1: Wedge compression fracture (Single column injury, AO Classification: A1, TLICS Morphology Compression – score 1). Sagittal (1a), axial (1b) CT slices demonstrate a compression fracture in the lower thoracic spine involving the superior cortex. By definition there is no involvement of the posterior cortex of the vertebral body and there is only single (superior in this case) end plate involvement. MRI will not be required as this is a stable injury.

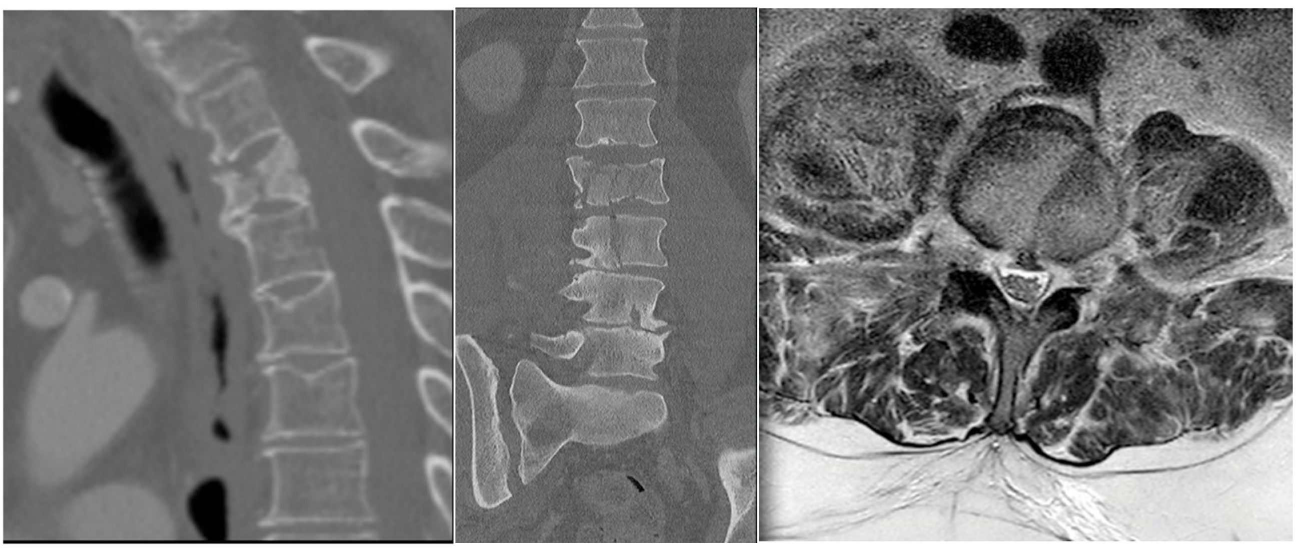

Figure 2: Split or pincer type fracture (AO Classification: A2, not featured in TLICS). Sagittal (2a) CT slice demonstrates a coronal split fracture in the upper thoracic spine. Note that the fracture involves both superior and inferior end plates, but does not involve the posterior vertebral cortex. This should be differentiated from a sagittal split fracture (shown in Coronal CT (2b) and Axial MR (2c) which breaches the superior and inferior end plates as well as the posterior vertebral cortex and therefore involves two columns and is potentially unstable. Note the additional crush fracture at the level above in 2b.

Figure 3: Incomplete burst fracture (Two column injury, AO classification: A3, TLICS morphology burst – score 2). Sagittal (3a) and Axial (3b) CT slices demonstrate an incomplete burst fracture of L1 which involves by definition a single (in this case superior) end plate and extends to the posterior vertebral cortex. There is slight retropulsion into the spinal canal in this case. Sagittal T2 (3c) and STIR (3d) demonstrates the incomplete burst fracture with intact posterior ligamentous complex and no cord or conus injury. Despite being a 2 column injury can be treated conservatively as was done in this case.

Figure 4: Complete burst fracture (two column injury, AO classification: A4, TLICS morphology – score 2). Sagittal (4a) and axial (4b) CT slices demonstrate a burst fracture of L2 which by definition involves the superior and inferior endplate, and the posterior vertebral cortex. There is significant communition and fracture fragment retropulsion into the spinal canal. Sagittal STIR (4c) and Axial T2 (4b) demonstrate significant canal stenosis associated with the fracture but no significant signal changes within the PLC.

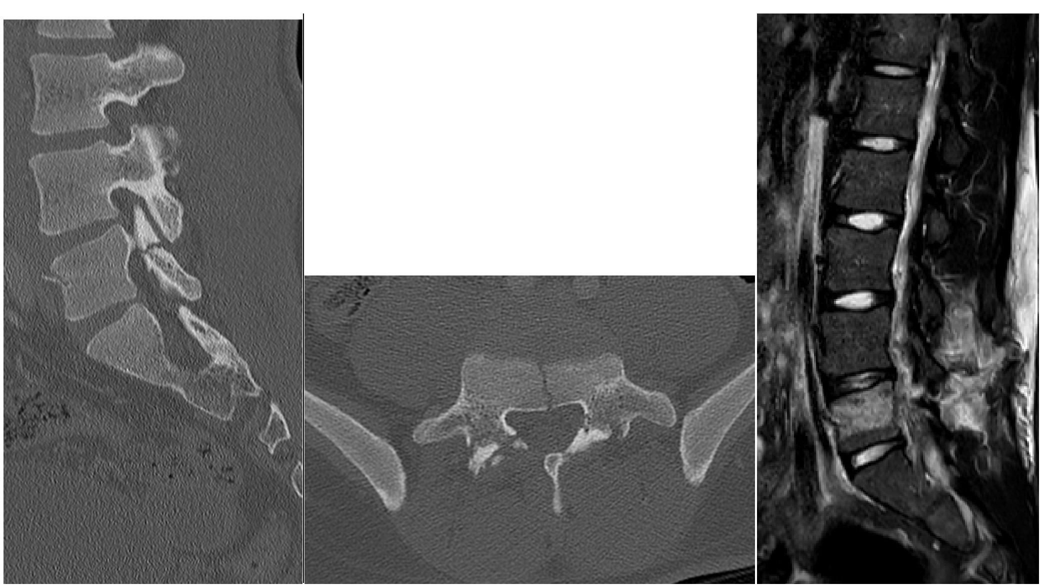

Figure 5: Monosegmental trans-osseous injury (Chance) (three column injury, AO classification: B1, TLICS morphology: distraction – score 4, and PLC status: definite injury – score 4). Sagittal (5a) and Axial (5b) CT demonstrates a fracture across the L5 vertebral body extending into the posterior elements (straight arrows) involving the pars interarticularis. Sagittal STIR (5c) demonstrates disruption of the ALL, PLL, ligamentum flavum, interspinous ligament and supraspinous ligament in keeping with PLC disruption and highly unstable injury.

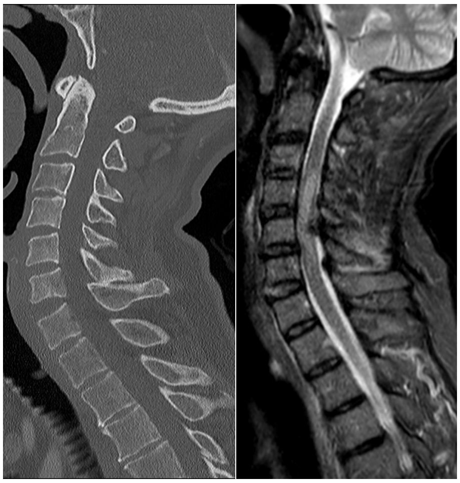

Figure 6: Osseoligamentous/Hyperextension/Distraction injury (three column injury, AO classification: B2/C1, TLICS morphology: distraction – score 4, and PLC status: definite injury – score 4). Sagittal (6a) CT demonstrates subtle widening of the C6/7 anterior disc space and narrowing of the interspinous space at the same level. Sagittal STIR (6b) demonstrates disruption to the ALL with fluid in the disc space at the C6/7 level, and oedema in the interspinous ligament in keeping with injury. Oedema within the cervical cord is in keeping with central cord syndrome due to trauma and background degenerative spinal canal narrowing.

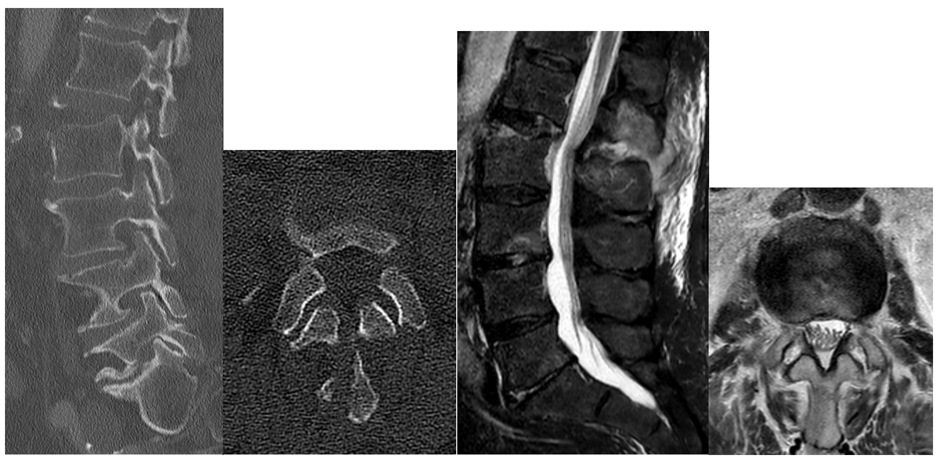

Figure 7: Osseoligamentous/Hyperextension/Distraction injury (three column injury, AO Classification: B2/C1, TLICS morphology: Distraction – score 4, PLC status: definite injury – score 4). Sagittal (7a) and axial (7b) CT demonstrate widening of the anterior disc space at the L1/2 level, with avulsion of the anterior superior corner of L2, widening of the facets joints in keeping with capsular rupture and fracture through the right L1 lamina and spinous process. Corresponding sagittal STIR (7c) demonstrates disruption of the ALL, interspinous ligament and supraspinous ligament. Axial T2 (7d) demonstrates significant widening and fluid within the facet joints in keeping with facet joint capsular rupture, a sign of instability.

Figure 8: Translation/Rotation injury (three column injury, AO Classification: C2, TLICS morphology: Translation/Rotation – score 3, PLC status: definite injury – score 4). Sagittal (8a) and axial (8b) CT demonstrate an anterior translation injury of T5 on T6 with fracture through the anterior superior corner of T6. Slight rotation of the anteriorly translated T5 vertebral body can be appreciated in the axial image (8b). Corresponding sagittal T2 (8c) demonstrates tear of the ligamentum flavum.

3. Thoracolumbar Injury Classification and Severity Score

Denis and AO systems offer descriptions of fracture morphology but provide limited prognostic information and guidance on suitability for operative treatment. Thoracolumbar Injury Classification and Severity Score (TLICS) assigns a numerical score based on the (A) fracture morphology, (B) integrity of the PLC and (C) neurological status of the patient to help guide treatment.9

The system simplifies the classification of fracture morphology and emphasises on the importance of the posterior tension band (PLC) for spinal stability. It incorporates the neurological status allowing for prognostication and treatment decisions. An overview of the classification is provided in Table 2.

Table 2: The Thoracolumbar Injury Classification and Severity Score (TLICS)[9]

Descriptor	Subgroups	Scoring
Morphology	Compression	1
	Burst	2
	Translation/Rotation	3
	Distraction	4
Posterior ligamentous complex (PLC)	Intact	0
	Suspected/indeterminate injury	2
	Definite injury	4
Neurological status	Intact	0
	Nerve root involvement	2
	Incomplete cord or conus injury	3
	Complete cord or conus injury	2
	Cauda equina syndrome	3

A TLICS score of 3 or less is deemed suitable for conservative management. A score of 5 or more requires surgery with an anterior approach for patients with neurological deficit and intact PLC and posterior approach for injured PLC. Combined approaches are suggested for patients with neurological deficit and injured PLC. A score of 4 is indeterminate and decisions to operate is made through clinical judgement.

IMAGING PROTOCOL

The initial investigation of spinal injury is usually with plain film and CT. Computed tomography is excellent at providing information on bony injury providing distinction between compression, burst, rotational/translational and distraction injury. Review of the axial as well as the sagittal and coronal reformats is essential to accurately determine fracture morphology.

Limited detail regarding the integrity of ligamentous structures in particular the PLC can be inferred from CT. There are however several indirect signs which should be reviewed to highlight potential ligamentous injury:[3]

- Widening of the disc space (ALL or PLL injury)
- Widening of the interspinous space (LV, ISL and SSL injury)
- Widening, subluxation or dislocation of the facet joints (ruptured facet joint capsule)
- Avulsion fractures from the spinous processes (ISL injury)
- Vertebral body translation or rotation (ALL or PLL injury)

Magnetic resonance imaging offers superior soft tissue contrast compared to CT allowing for more accurate evaluation of ligament, cord, disc and occult bone injury.[7,10] MRI can also visualise spinal cord, disc herniation or epidural haematoma.[2] The basic MRI protocol for spinal trauma should include sagittal T1, T2 and STIR and axial T2 imaging.[10] Normal anatomical structures such as the paraspinal ligaments can be evaluated for integrity and bone injury can be identified on T1. Ligamentous, disc, cord and bone oedema and injury are best visualised using a combination of sagittal T2 and STIR imaging. STIR is highly sensitive and specific for evaluating PLC injury.[11]

Pictorial case examples

The cases numbered Figure 1 to Figure 8 have been selected to illustrate the various types of spinal injuries and their categories within the Denis, Revised AO and TLICS classifications.

CONCLUSIONS

Complex spinal anatomy, multiple mechanisms of injury and differing practices in management have led to difficulties in designing single comprehensive universally accepted classification. Radiologists are arguably more familiar with and consequently more comfortable in using Dennis three columns concept of spinal injury classification but it has little influence on prognostic outcome and further management of the patients. The AO classification system is complex resulting into poor inter-observer variability but represents the continuum of increasingly severe spinal trauma. AO system recognises the importance of injury to posterior ligamentous structures which is critical in future spinal stability and thus influences the management choices. The TLICS classification is more comprehensive in that it combines the three key elements to propose the management strategy. Familiarity to the newer classification systems is therefore crucial for radiologists to ensure efficient image interpretation and patient-centred communication with the clinicians.

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