Traumatic spinal injuries: what the spine surgeon needs to know

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Learning objectives

To illustrate the most common traumatic spinal injuries and understand the use of their classification.

To understand the concepts of structural and neurological instability as indications for surgical intervention.

To familiarise the radiologist with the variety of spinal hardware used in spinal column stabilisation and with the early postoperative complications.
Background

Spinal trauma is a common cause of disability.

The most frequent sites of spinal injuries following trauma are:

- the cervical spine (vast flexibility and lack of the structural protection provided by strong muscles and ribs)
- the thoracolumbar junction (transitional anatomy and limited shock-absorbing properties)

When assessing a spinal trauma patient, findings of instability are fundamental in the decision-making process, because the treatment option can drastically affect the outcome. Treatment can be conservative (collar, halo vest etc) or surgical.

In order to judge spinal stability and take a treatment decision, the spine surgeon collaborates with the radiologist and the neurologist. The radiologist evaluates the injury morphology (the immediate stability) and the disco-ligamentous complex integrity (the long-term stability), while the neurologist evaluates the neurological status (the so-called "neurological stability"). These three injury characteristics are recognised as major and largely independent predictors of clinical outcome [1].

The evolution of MDCT and MRI allowed for a better visualisation and understanding of trauma. Consequently, new classification systems were developed, which rely more on morphologic findings, de-emphasizing the use of mechanism and recoil position in grading injuries.

Classification systems act as a common language for all those involved in treating spinal trauma patients, id est the multidisciplinary team which provides care for this type of patients.

The Subaxial Injury Classification System (SLIC) and Thoracolumbar Injury Classification System (TLICS) are injury severity scales that gained acceptance among spine surgeons because they are specifically tailored to aid in the decision-making process (help predict the need for surgery) and have high interobserver reliability [2].

There are several spinal devices used in spinal column stabilisation and fusion, of which the radiologist must be informed in order to properly evaluate the early postoperative status of the patient (correct positioning, integrity, possible associated complications: epidural hematoma, infection, instability, canal stenosis, CSF leakage).
Findings and procedure details

The Subaxial Injury Classification System (SLIC)

The SLIC system assigns numerical values to each injury based on three categories: injury morphology, integrity of the disco-ligamentous complex (DLC), and neurological involvement (Table 1).

Surgical treatment is recommended when the score is #5 and consists of realignment, neurological decompression (if indicated) and stabilisation. A score between 1 and 3 warrants non-operative treatment.

Table 1: SLIC scale

<table>
<thead>
<tr>
<th>Morphology</th>
<th>No Abnormality</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>immediate stability</td>
<td>Compression</td>
<td>1</td>
</tr>
<tr>
<td>Burst</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Distraction</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Rotation / Translation</td>
<td>/ 4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disco-ligamentous complex (DLC)</th>
<th>Intact</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>long-term stability</td>
<td>Disrupted</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Neurological Status</th>
<th>Intact</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>neurologic stability</td>
<td>Root Injury</td>
<td>1</td>
</tr>
<tr>
<td>Complete Injury</td>
<td>Cord</td>
<td>2</td>
</tr>
<tr>
<td>Incomplete Injury</td>
<td>Cord</td>
<td>3</td>
</tr>
<tr>
<td>Continuous Cord Compression in setting of neuro</td>
<td>+1</td>
<td></td>
</tr>
</tbody>
</table>
Injury morphology takes into consideration the pattern of spinal column disruption, rather than the mechanism of the injury itself.

The relationship of the vertebral bodies with each other gives birth to three main categories:

1. COMPRESSION
   • defined as a visible loss of height through part of or an entire vertebral body, or disruption through an end-plate
   • includes: traditional compression fractures, burst fractures, sagittal or coronal plane fractures of the vertebrae, and “tear-drop” or flexion compression fractures primarily involving the vertebral body

2. DISTRACTION
   • defined as an anatomical dissociation in the vertical axis
   • it usually involves ligamentous disruption propagating through the disk space or through the facet joints (→ facet subluxation or dislocation)
   • includes also hyperextension injuries disrupting the anterior longitudinal ligament and widening the anterior disk space
   • concomitant compression across the posterior elements (facet, lamina, spinous process) can lead to posterior element fractures or spinal cord compression through inward buckling of the ligamentum flavum
   • MRI is very useful for evaluating the degree of disruption of the DLC
   • the facet capsules and bony anatomy of the facet joints - primary posterior determinants of stability

3. TRANSLATION/ROTATION
   • defined as the horizontal displacement of one part of the sub-axial cervical spine with respect to the other (disruption of both anterior and posterior structures)
   • threshold of rotation - a relative angulation of 11 degrees or greater
   • any visible translation unrelated to degenerative causes
   • it frequently implies unilateral or bilateral facet fracture-dislocations, fracture separation of the lateral mass ("floating" lateral mass) or bilateral pedicle fractures

Complex injuries are scored based on the morphology subgroup with the highest value.
Fig. 1: 45 y.o. man on alcohol, involved in a bicycle crash. Neurological exam reveals a right arm pain and C6 radiculopathy. AP and Lateral views show unilateral right-sided facet joint dislocation at C5-C6 level (a pattern specific for translational/rotational injuries)

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**Fig. 2:** Same patient as in Fig. 1. Axial CT image confirms the unilateral facet joint lock (white arrow).

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**Fig. 3:** Same patient as in Fig. 1. Increased signal intensity in Sagittal T2 WI at C5-C6 level shows the disruption of the inter-vertebral disk and anterior longitudinal ligaments, and posterior capsulo-ligamentar disruption at the site of the facet joint.

**References:** Image courtesy of Dr. Tiberiu Maior
Fig. 4: Same patient as in Fig. 1. Postoperative Lateral view X-ray shows correct positioning of the spinal hardware used in stabilisation. The anterior approach was followed by a posterior approach due to insufficient dynamic stability.

References: Image courtesy of Dr. Tiberiu Maior
Fig. 5: Cervical spine injury following a fall from height. The patient presented mild neurological deficits. CT scan shows a pattern of translation injury.

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Fig. 6: Same patient as in Fig. 5. Screws and rods were used for spinal column stabilisation. Postoperative CT scan shows faulty alignment, but with satisfying outcome.

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The disco-ligamentous complex (DLC)

Includes:

- the intervertebral disk,
- anterior and posterior longitudinal ligaments,
- ligamentum flavum,
- interspinous and supraspinous ligaments,
- facet capsules.

The incompetence of this segment can lead to progressive instability and deformity (i.e. long-term impairment, even paralysis).
Disruption is inferred on images that show:

- widened inter-space between two adjacent spinous processes,
- dislocation or separation of facet joints,
- subluxation of the vertebral bodies,
- abnormal widening of a disk space
- high signal intensity on MRI: horizontally through a disk involving the nucleus and anulus on a T2 sagittal MRI image - suggestive of disk and anulus disruption; ligamentous regions on T2 weighted images - suggestive for edema

Distraction and translational injuries are usually associated with a variable degree of DLC compromise.
Fig. 7: 32 y.o. man involved in a road traffic accident, with neck pain and limitation during neck active range of motion. Lateral view X-rays show perched facet easily reducible in extension (marker of instability) at C4-C5 level.

References: Image courtesy of Dr. Tiberiu Maior

Fig. 8: Same patient as in Fig. 7. RM examination shows no spinal cord compression, but increased signal intensity in the posterior ligamentous complex.

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Fig. 9: Same patient as in Fig. 7. Postoperative X-ray shows correct positioning of spinal hardware.

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**Neurologic status** - the strongest predictor of treatment

Significant neurologic injury necessitates a significant force of impact, hence the potential for cervical spine instability.

When dealing with an incomplete neurologic injury, the decompressive procedure provides the best outcome, even in the presence of ongoing root or cord compression.
Surgical management is commonly preferred in the presence of congenital or spondylotic stenosis despite the absence of frank instability.

Confounders (modifiers) include ankylosing spondylitis, diffuse idiopathic hyperostosis (DISH), osteoporosis, previous surgery, degenerative disease, etc.

Multiple levels of cervical trauma necessitate separate SLIC evaluation for each level.

**The Thoracolumbar Injury Classification System** (TLICS)

The TLICS system assigns numerical values to each injury based on three categories: morphology of injury, integrity of the PLC, and neurological involvement (Table 2).

Surgical treatment is recommended when the score is 5 and consists of realignment, neurological decompression (if indicated) and stabilisation. For a score of 4 the treatment option is either surgical or non-surgical. A score 3 warrants non-operative treatment.

Table 2 TLICS

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Compression</th>
<th>1</th>
<th>X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>immediate stability</td>
<td>Burst</td>
<td>2</td>
<td>CT</td>
</tr>
<tr>
<td></td>
<td>Rotation</td>
<td>/</td>
<td>MRI</td>
</tr>
<tr>
<td></td>
<td>Translation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distraction</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Posterior ligamentous complex (PLC)</td>
<td>Intact</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>long-term stability</td>
<td>Disrupted</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intact</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neurological Status</td>
<td>Nerve root</td>
<td>2</td>
<td>Physical examination</td>
</tr>
<tr>
<td>neurologic stability</td>
<td>Cord, conus medullaris complete</td>
<td>2</td>
<td>± CT/MR</td>
</tr>
<tr>
<td></td>
<td>incomplete</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cauda equina</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
**Injury morphology**

The addition of lateral angulation in the presence of a compression fracture conveys an extra degree of instability, hence the use of a series of prefixes used for a more accurate description (e.g. axial, flexion, lateral).

**Fig. 10**: 19 y.o. boy with a L1 burst fracture. Preoperative CT scan on the left. Screw, rods and bone substitute were used for stabilisation and fusion (as seen on the right).

**References**: Image courtesy of Dr. Tiberiu Maior
**Fig. 11**: Osteoporotic L3 compression fracture. Cement was used for reinforcing the screws.

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Distraction morphology description can be improved with prefixes like extension or flexion, and compression or burst descriptors as a postfix.
Fig. 12: 24 y.o. involved in a road traffic accident. T12 distraction pattern fracture.

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Fig. 13: Same patient as in Fig. 12. During surgery, no soft tissues damage was encountered. T11-L1 trans-pedicular screw instrumentation without fusion was performed.

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Translation/rotation injury:
Fig. 14: 19 y.o. male, woodcutter involved in an occupational accident. CT scan shows severe translation-rotation injury at L4-L5 level.

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Fig. 15: Same patient as in Fig. 14. Postoperative CT aspect. Screws and rods were used for spine stabilisation.

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**Posterior ligamentous complex**

PLC includes:

- the supraspinous ligament,
- the interspinous ligament,
- ligamentum flavum,
- the facet joint capsules.
PLC disruption signs:

- widening of the interspinous space,
- widening of the facet joints,
- empty facet joints,
- facet perch or subluxation,
- dislocation of the spine,
- vertebral body translation or rotation.

PLC has a poor healing ability, thus the need for surgery.

Fig. 16: 32 y.o. male, victim of a road traffic accident. X-rays show superior L1 endplate fracture.

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Fig. 17: Same patient as in Fig. 16. Increased signal intensity on sagittal T2 WI and intraoperative picture demonstrate ligamentous disruption (a flexion-distraction injury). Ligamentous disruption was inferred through palpation during the initial examination. A painful gap between the spinous process is suggestive for interspinous ligament disruption.

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Fig. 18: Same patient as in Fig. 16. Spinal hardware seen on X-ray and intraoperative picture (downward screw trajectory used for ensuring that the L1 superior endplate is not damaged during kyphosis restoration movements).

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There are some general principles of surgical approach guided by TLICS:

- incomplete neurologic injury -> anterior procedure if neural compression from the anterior spinal elements is present following attempts at postural or open reduction;
- PLC disruption -> posterior procedure;
- combined (incomplete neurologic injury and PLC disruption) -> combined anterior and posterior procedure.

Other factors of importance in the clinical decision-making process:

- sternum fracture,
- severe closed head injury,
- limb amputation,
• multisystem trauma,
• extreme kyphosis or collapse
• lateral fracture angulation,
• open fractures,
• overlying burns,
• multiple adjacent rib fractures,
• inability to brace,
• rheumatoid arthritis,
• ankylosing spondylitis,
• osteoporosis,
• obesity,
• patient age,
• general health.

The evaluation report after surgical instrumentation should describe the type of **hardware** used and its exact location within the spine. It should also assess any possible hardware-related complications.

The most common orthopaedic spinal devices used in stabilisation after spinal trauma:

• osteosynthesis systems (screws, staples, nails, wires)
• longitudinal (plates, rods) and transverse connectors
• interbody devices (bone grafts, cages, artificial disks)

Transpedicular screws are used for attaching rods and screws to the vertebral bodies (in the thoracic and lumbar spine), while lateral mass screws and other screws are used in the cervical spine.

Cages, expandable or not (filled with bone graft or cement) are used for vertebral body replacements.
**Fig. 19:** On the left: CT scan of a lumbar burst fracture. On the right: Spinal hardware used in stabilisation and fusion: screws and rods, and Pyramesh cage.

**References:** Image courtesy of Dr. Tiberiu Maior
Fig. 20: Spinal hardware used in cervical spine fusion and stabilisation: plate and screws (anterior), cage (middle), screws and rods (posterior).

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The radiologist should consider:

- the alignment (anterolisthesis, retrolisthesis, scoliosis and rectification),
- disk space,
- correct positioning of the pedicle screws (medial or lateral deviation across the cortical and medullary canal, crossing of the anterior wall of the vertebral body)
Fig. 21: Spinal hardware complication: medial deviation of the right screw engaging the medullary canal.

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**Fig. 22:** Spinal hardware complication: both screws are crossing the anterior wall of the vertebral body, endangering the aorta.

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Fig. 23: Surgical complication: CSF leakage (blue arrow).

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Conclusion

The role of the radiologist in the multidisciplinary team is to provide an accurate diagnostic and a detailed imagistic assessment of the postoperative status.

Classifications are an important tool in communicating with the surgeon before surgery.

Basic knowledge of spinal devices improves postoperative radiological reports.


