Clinical Application of Pathology

SPINAL INJURIES

**Systems:** Bone

**Causes:** trauma, cancer

**Quiz:** IMED4121 – Spinal injuries

**Introduction:** paediatric and adult injuries will be discussed separately.

### SPINAL INJURIES CONTENTS

<table>
<thead>
<tr>
<th>Mechanisms of injury</th>
<th>Regions to be discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperflexion</td>
<td>Upper cervical</td>
</tr>
<tr>
<td>Lateral flexion</td>
<td></td>
</tr>
<tr>
<td>Flexion tear drop</td>
<td></td>
</tr>
<tr>
<td>Distractive flexion – bilateral interfacetal dislocation</td>
<td></td>
</tr>
<tr>
<td>Hyperextension</td>
<td>Lower cervical</td>
</tr>
<tr>
<td>Distractive extension – extension teardrop fracture</td>
<td></td>
</tr>
<tr>
<td>Hyperflexion and rotation - Unilateral interfacet dislocation</td>
<td>Thoracic</td>
</tr>
<tr>
<td>Hyper-extension rotation - pillar fractures</td>
<td>Thoraco-lumbar</td>
</tr>
<tr>
<td>Vertical Compression</td>
<td>Lumbar – upper and lower</td>
</tr>
<tr>
<td>Burst fracture</td>
<td></td>
</tr>
<tr>
<td>Extension Compression – pillar and laminar fractures</td>
<td></td>
</tr>
<tr>
<td>Shearing forces</td>
<td>Sacrum</td>
</tr>
<tr>
<td>Nerve avulsion, dural tears</td>
<td></td>
</tr>
</tbody>
</table>

Thursday, September 01, 2016
Factors Contributing to the susceptibility to injury in children, as compared with adults.

- Increased laxity of ligaments and soft tissues
- Open epiphyses
- Lack of development of ossification centres
- Changes in osseous strength, shape and size.

**Epiphyseal plates** are still open in the vertebral bodies of children. These start to fuse at many levels by the age of 8 years.

**Facets** are relatively horizontal in infancy but become more vertical with ossification between 7 – 10 years of age.

**Head size** is large plus a relatively poorly developed paraspinous muscles in infants which creates a relative hypermobility that leads to a predisposition for cervical spinal cord injury without plain radiographs showing an abnormality.

**Adult pattern** is reached by the age of 15 years.

**Sites:** 30% of injuries involve the upper cervical spine, 15% the lower cervical spine, 30% the thoracic spine and 25% the lumbar spine.

**Imaging:** MRI is important for infants and young children because there is a propensity for spinal cord injury, even when plain radiographs are normal.

**MRI shows:**

- Swelling of the prevertebral soft tissues
- Injury to interspinous soft tissues or posterior longitudinal ligament
- Traumatic disc herniations
- Cord injury.

Taking all cervical injuries in all age groups, the mechanism of injury accounts for the following:

- Hyperflexion 45% - disruptive hyperflexion, compressive hyperflexion, shearing injuries
- Axial compression 4% - Jefferson’s fracture, burst fractures, hyper-rotation injuries, lateral flexion injuries,
- Combined or unknown - 16%

**Cervical Spine injuries in young children**

The developmental anatomy is important, especially in children under 8 years. The diagram is courtesy of DK Bailey. The normal cervical spine in infants and children. Radiology 1952, 59(5):712.
Infancy: the occipitoatlantal articulation is clearly visible. The anterior arch of C1 is not present at birth, becoming an ossified structure during the first year of life. Then it may be visible near the
superior tip of the dens. This position is due to the ossification centre of the tip of the dens being not yet visible. The posterior arch of the atlas can be seen posterior to the dens. The subdental synchondrosis which is the growth plate separates the dens from the body of C2. The anterior aspect of the bodies from C3 to C7 appear rounded and the articular facets are horizontal. The articular masses and the laminae extend posteriorly from the vertebral bodies. The image below is a baby 8 days old (courtesy of DT Schwartz and E Reisdorff. Emergency Radiology); the small arrow points to the subdental synchondrosis, the curved arrow shows the posterior arch of C1 lying posterior to the dens.

![Image](image)

**Age 3 years** the anterior arch of C1 is completely ossified and the vertebral bodies have more ossification but still have a curved anterior surface. The articular masses and laminae remain horizontal. The atlanto-occipital joint remains partly visible. The anterior arch of C1 is ossified (arrow) and the subdental synchondrosis has nearly disappeared (arrowhead). The facets are now steeply inclined (asterisk). The posterior neural arches have fused shown by the presence of the spino-laminar junction (curved arrow).

![Image](image)

**Age 8 years** the appearance is close to that of an adult. The synchondroses of C2 have fused and the anterior curve of the vertebral bodies has lessened. Separate ossification centres for the superior and inferior end plates of the vertebral bodies have appeared but do not fuse until adulthood.
Laxity of the transverse atlantal ligament accounts for the predental space (anterior atlantodental interval) being up to 3 mm in children up to age 8 – 10 years. In adults it is less than 3 mm.

Also laxity allows the vertebral body to slip anteriorly at the C2-C3 and the C3-C4 intervertebral discs in children up to the age of 8 years.

**Clinical:** 10 – 15% of paediatric spine injuries occur in children younger than 8 years. In very young children the upper cervical spine is the site of most injuries. Spinal cord injury occurs in 35% of children with cervical fractures or dislocations and about 10% have cord injuries resulting in quadriplegia.

*** Spinal cord injury without radiographic abnormality (SCTWORA) accounts for 20% of all spinal cord injuries in children. This can be delayed for 4 days after injury due to delayed compromise of the blood supply to the cord. Most patients with SCRWORA are younger than 8 years.

**Prognosis for SCTWORA** – poor for patients younger than 3 years or those with complete cord lesions. Incomplete cord lesions may improve over time.

**Unique injuries to children:** odontoid synchondral fracture-separation with atlanto-axial subluxation or dislocation is seldom seen beyond adolescence. Injuries of the lower cervical region are usually subluxations, dislocations, or compression injuries.

**Frequency:** Atlas (C1) fractures are responsible for 10% of all cervical fractures and for 25% of the fractures of the cervicocranium. 50% are associated with other cervical fractures especially C2. The axis (C2) is one of the more commonly fractured cervical vertebrae. Odontoid fractures and neural arch fractures – (hangman’s fracture) account for 35% of the fractures of the cervicocranium.

**Occipito-atlantal dislocations:** these are found in severe head trauma and it is often a fatal injury or the child has severe neurological deficit if it survives. Damage has occurred to the ligaments of the occipito-atlantal joints which causes subluxation or complete dislocation. The occiput is commonly displaced anteriorly or posteriorly relative to the atlas. As there can be severe haemorrhage in the retropharyngeal space this can comprise the airway. In the image below, courtesy of DT Schwartz and E Reisdorff, the lateral radiograph of a 3 year old child shows superior displacement of the skull base with respect to C1 and anterior dislocation of C1 with respect to C2. The occipital condyles – c – are displaced from their fossae in C1. The forward movement of C1 with respect to C2 is shown by the dens being in the central portion of the C1 ring, instead of close behind the posterior margin of the anterior arch of C1. That is there is both occipito-atlantal and atlanto-axial dislocation.
Note: an isolated atlantoaxial dislocation may be less serious because of the capacious spinal canal at C1. The synchondrosis between the dens and the body of C2 does not fuse until age 7 – 8 years, so trauma to the odontoid does not result in a fracture through the bony dens. Instead there is a separation of the ossification centre of the odontoid from that of the body of C2.

CT with coronal and sagittal reformations are best but MRI is needed to show cord or brainstem damage.

When the transverse ligament holding the odontoid against the anterior arch of C1 is ruptured, the neck is very unstable. If radiographs are taken with the patient supine, the dislocation may be missed if note is not made of retropharyngeal swelling. Together with severe neck pain and muscle spasm this is indicative of the need for further imaging.

**Atlantoaxial rotary subluxation** is associated with **incomplete ligamentous damage**. In severe cases the change in the atlantoaxial rotational axis and asymmetrical articulation of the lateral masses of C1 and C2 are evident. One needs a lateral view and also one taken through the open mouth to display asymmetry of the lateral atlantodental intervals and the lateral masses of the atlas.

The image, courtesy of D T Schwartz and E Reisdorff, is an 8 year old boy with neck pain and his head rotated to the right but tilted to the left, after a head collision at soccer game. The head is tilted and rotated at the cranio-vertebral junction. There is lack of superimposition of the lateral masses of C1. The open-mouth view at the bottom shows the articular masses of C1 and C2 are not aligned – arrowheads. This could be treated conservatively with neck support and analgesia.

**Atlantoaxial rotary dislocation** results from severe rotatory stress. Radiographs taken are the same as for subluxation. As the fixed posture prevents obtaining an open-mouth view, the diagnosis is made by CT scan. This shows total displacement of the apposed articular surfaces. See images below, courtesy of D T Schwartz and E Reisdorff. The left shows the head of the child is fixed in
rotation to the right and C1 is rotated with respect to C2 (arrow). The right image is a CT which shows the dens dislocated with respect to the anterior arch of C1.

Jefferson Burst Fracture of C1. This is due to an axial compression causing lateral displacement of the lateral masses of C1. There is a fracture in both the anterior and posterior arch of the atlas. 50% of cases have an associated fracture of C2. The left image shows a fracture through the posterior arch of C1 (arrowhead). The X shows soft tissue swelling in the retropharyngeal space. The right image shows bilateral widening of the lateral atlas-dens interval – X. If this distance exceeds 7 mm, it indicates transverse ligament disruption and the site is unstable. If this is not present, the fracture may be considered stable (assuming no other fractures) and the neck is immobilized before any additional imaging is undertaken prior to treatment. There is also lateral displacement of the lateral masses of C1 with respect to C2 (arrows).

Fractures of the body of C2 (axis). These are usually vertical and oblique so can be hard to see on plain radiographs. A clue is when the anteroposterior diameter of the C2 body is increased, relative to C3. CT is often needed to show detail. These fractures are potentially unstable.

Hangman’s fracture: is bilateral fracture of the neural arch of C2. The mechanism is hyperextension and compression such as when the head strikes the windscreen in a head-on vehicle collision. Associated spinal cord injury is still present, although less than with judicial hanging. In the image below, courtesy of Dr Maxime St-Amant, Radiopaedia.org, rID: 19431, the arrow indicates the site of the fractures in the neural arch of C2.
This fracture is classified into 3 types. **Type 1** is the most common and show minimal displacement and considered stable but admitted to hospital. The body of C2 is not displaced and both the anterior longitudinal ligament and C2-C3 disc are intact.

**Type II** – the C2-C3 disc is disrupted and the C2 vertebral body is displaced anteriorly. The interfacet articulations are intact. These patients are more likely to have neurologic deficits than Type I and are considered unstable.

**Type III** – these have greater displacement of the vertebral body than type II and there is displacement of one or both of the articular facet joints. Fractures in other adjacent bones and neurologic compromise are common. As both the anterior and posterior columns are disrupted, the spine is unstable.

**Dens fractures** – these are seen in young patients following motor vehicle accidents but also occur in the elderly after falls. Fractures of C1 are often associated. Neurologic injury occurs in 25% of cases ranging from minimal to quadriplegia. The classification is that of Anderson and D’Alonzo.

   - **Type I** – avulsion of the dens tip by the alar ligament. These are rare and mechanically stable.

   - **Type II** – occur at the base of the dens and are the most common and unstable. Non-union in 30% due to interruption of the blood supply. Accounts for 10% of all cervical fractures.

   - **Type III** - oblique fractures through the upper part of the C2 vertebral body and is unstable. However, prognosis for healing is better than in Type II.

**Imaging:** all images courtesy of Dr Derek Moore. Orthobullets 8th August 2016. The CT image below is a Type II fracture through the base of the dens.
If an anterior screw bone fusion is passed through the cortex of the dens, the basilar artery can be injured – see relevant anatomy below.

Type III – plain radiograph, axial and sagittal CT scan. Arrow on the fracture lines.

Odontoid synchondral fracture separation is an injury of C2 in children under 7 years. Although it looks like a dens fracture, the dens is separated from the C2 vertebral body at the subdental synchondrosis. On a lateral radiograph, the anterior and posterior cortex of the dens and C2 vertebral body are out of alignment and sometimes even angulated. The injury is unstable. It can be associated with atlantoaxial dislocation.
In the MRI image below of a child, courtesy of E S Lustrin, S P Karakas, O Ortiz et al. Radiographics 2003, 23 (3), the occipitoatlantal joints, the atlantodental articulation and transverse ligament are intact. The dens is separated from the body of C2 at the subdental synchondrosis – see arrow – so that C1 can displace anteriorly with subsequent narrowing of the vertebral canal.

Thoracic and Lumbar Spine injuries – tend to involve T11 – L2 levels where the more rigid thoracic spine joins the mobile lumbar segments. Soft tissue injuries such as ligaments, cartilage or growth plates are most common. Radiographs in flexion and extension are required but for greatest detail MRI is best. 30% have associated visceral injuries.

Adolescent injuries – from 9 – 16 years

Spinal injuries are 10 times more common than in younger children. However 16 – 24 years of age have the highest incidence of spinal injuries in any age group.

Injuries tend to be more evenly distributed through the cervical levels unlike the predilection for the upper cervical spine in children 8 years or less.

Site: the C5 to C6 level is most frequently injured in adolescents. Associated spinal cord injury can be present without plain radiograph abnormalities but the latter are more common than not present.

Clinical: the severity of spinal cord injury in adolescents without radiograph abnormalities tends to be less than in those with abnormalities on radiographs. Post-traumatic spinal cord infarction causes patients to have neurological signs several hours to days after the injury. Paraplegia or quadriplegia and dissociated sensory loss occurs. Plain films and myelography are normal whereas the MRI will show anterior spinal artery infarction.

Risk factors: those patients with genetic abnormalities which have ligamentous laxity, spinal stenosis, spinal kyphosis or stenosis of the foramen magnum viz.

• Down’s syndrome
• Mucopolysaccharidoses especially Morquio syndrome
• Achondroplasia
- Klippel-Feil syndrome
- Spondyloepiphyseal dysplasia.

These patients need observation for neurologic dysfunction and neck pain serially even after minor neck trauma.

**Imaging:** radiographic evaluation is mostly identical to adults except that traumatic disc herniation in adolescents is frequently associated with fracture of the adjacent vertebral endplate. One needs plain radiographs, CT and MRI.

**ADULT POPULATION**

**General overview:** The cause of 60% of those with spinal injuries is motor vehicle accidents. Neurological deficits occur in 15% spinal injuries.

**Age:** the majority are young adults but there is a second peak in the 6th and 7th decades because cervical spondylosis renders the cord more vulnerable to injury from relatively minor trauma.

**Clinical syndromes:** the most common is complete transverse myelopathy which is total loss of all motor and sensory function below the level of injury. Above C4 there is also paralysis of the muscles of respiration including the diaphragm (C3, 4 and 5) in addition to quadriplegia. The cord lesion may result from anatomic disruption, compression, ischaemia or a combination.

**Incomplete syndromes:**

- **Central cord syndrome** – this will cause more weakness in the upper limb than the lower limb because those nerve fibres for the upper limb are located centrally in the corticospinal tracts. This is seen in extension injuries, especially in patients with cervical spondylosis.
- **Anterior cord syndrome** – when there is damage to the anterior two thirds of the cord with loss of motor function and sensation to pain and temperature but with preserved proprioception. Thus corticospinal tracts (motor) and spinothalamic tracts (pain and temperature) are damaged. Posterior columns (proprioception) is preserved. This is usually due to damage to the anterior spinal artery.
- **Brown-Séquard syndrome** – this is due to cord hemisection as for example in penetrating injuries. There is ipsilateral motor and proprioceptive loss with contralateral loss of pain and temperature sensation because the spinothalamic tracts cross immediately upon entering the cord.
- **Injuries to the roots of nerves** – when lower motor neuron deficits are seen in a radicular pattern.

**Imaging:** plain radiographs should be done for all patients with significant head trauma.

**CT scan:**

- in the axial plane this gives an optimal view of the spinal canal. It assesses the size, shape and integrity of the canal. It will show fracture fragments and foreign bodies within the canal and also show the posterior elements.
- Shows unsuspected fractures of the lateral masses, pedicles, lamina and posterior element fractures.
- Shows widening of the apophyseal joints which equate with instability of the spine.
- The CT data can be reformatted to provide views in any plane.
- May also include examination of the head, thorax and abdomen where there may be additional injuries.
**MRI:**

- Detects cord and nerve roots damage and is performed on patients presenting with a neurological deficit.
- Shows cord compression by disc material, bone fragments, haematoma
- Shows intrinsic cord pathology such as cord haemorrhage or contusion. Intramedullary haemorrhage seems to be visualized only in the most severe injuries and implies a complete lesion.
- Can assess prognosis of a cord contusion by examining 24 – 72 hours after the injury.
- Shows ligamentous integrity and can detect disc rupture.
- Late follow up evaluates possible post-traumatic syrinx or cord atrophy
- It is not as good as CT to show bony abnormalities.

**Myelography with postmyelography CT** – the best tool to show dural tears and nerve root avulsion.

**Risk Factors in adults:**

- Congenital basilar impression
- Small foramen magnum
- Arnold-Chiari malformation
- Os odontoideum
- C1-C2 subluxation
- Block vertebrae
- Congenital and acquired spinal stenosis
- Cervical spondylosis
- Rheumatoid arthritis
- Ankylosing spondylitis

**Mechanical instability of the spine analysis,** with the first on the list being the most unstable and the last on the list, the least unstable.


- Rupture of the transverse ligament of the atlas
- Fracture of the dens (odontoid fracture)
- Burst fracture with posterior ligamentous disruption (flexion teardrop fracture)
- Bilateral facet dislocation
- Burst fracture without posterior ligamentous disruption
- Hyperextension fracture dislocation
- Hangman fracture
- Extension teardrop (stable in flexion)
- Jefferson fracture (burst fracture of the ring of C1)
- Unilateral facet dislocation
- Anterior subluxation
- Simple wedge compression fracture without posterior disruption
- Pillar fracture
- Fracture of the posterior arch of C1
- Spinous process fracture (clay shoveler fracture)
Cranio-cervical and upper cervical spine injuries

Damage to the cervical cord occurs more frequently with injuries to the lower cervical spine below C2. However, upper cervical spine injuries can have major medullary lesions or vertebral artery injuries leading to death.

As in children, already described, there is atlanto-occipital dislocation, Jefferson fracture, atlantoaxial dislocation, odontoid fracture and hangman’s fracture.

Middle and Lower Cervical spine injuries

Overview: In adults injuries to the middle and lower cervical spine are more common than in the upper cervical spine and more frequently result in damage to the cord with neurological deficits. Flexion injuries are most common and often are accompanied by compression forces. The spine may be split into three "columns" for the purpose of assessment of stability. This is after the Denis classification of Thoraco-lumbar fractures:

1. Anterior column - Involves the anterior two thirds of the vertebral body/intervertebral disc, and the anterior longitudinal ligament.
2. Middle column - Involves the posterior aspect of the vertebral body/intervertebral disc, and the posterior longitudinal ligament.
3. Posterior column - Involves the posterior elements - the lamina, facet joints, spinous processes, and the associated ligaments.

- An injury to the spine is considered unstable if two of the three columns are disrupted. Generally, if the middle column is disrupted, either the anterior or posterior columns are also involved, and the injury is unstable.
- The middle column is the fulcrum from which the spine pivots into flexion and extension. It is generally thought that the middle column remains intact, and is therefore stable, in simple flexion and extension injuries. Axial compression, distraction and rotational injuries, or a combination of these with flexion or extension, usually disrupt the middle column.

Mechanism: A flexion force tears ligaments between the spinous processes which disrupts capsular ligaments around facet joints and fractures posterior elements. This leads to disruption of the posterior longitudinal ligament and rupture of the disc space. The upper vertebral body can slide forward on the body below resulting in anterior subluxation. The superior end plate becomes impacted and the anterior cortex buckles. In adults these are often secondary to an underlying osteoporosis, metastasis or trauma.

Compression fractures of vertebral bodies occur with flexion or with axial loading but often these are due to both forces. If the anterior height is less than 3mm the height at the posterior aspect of the vertebral body, there is a wedge compression fracture.

This fracture involves loss of vertebral body height anteriorly;
- posterior wall remains intact, and upper vertebra rotates downward about two facet joints;
- posterior ligaments become taut when anterior height loss is about 25%;
- compression of > 50% without compression of the posterior wall may indicate posterior ligamentous injury, which may convert this to a complex fracture;
- disruption of the posterior ligamentous complex in face of anterior fracture or dislocation is strong indication of instability and of potential need for surgical stabilization;
- exceptions may include the upper thoracic spine, which is inherently more stable

- compression fracture of 3 contiguous vertebrae leads to increase in risk of posttraumatic kyphosis; The image below showing this fracture in C7 is courtesy of DT Schwartz and E Reisdorff.

![Image](image_url)

**Treatment:**
- fractures with up to 25% compression and intact posterior wall are treated with braces/collar;
- if dynamic lateral views reveal instability, posterior interspinous wiring with a bone graft stabilize disrupted posterior ligament complex.

The most severe type is **the flexion teardrop fracture** which can cause quadriplegia and death. Occurs in diving accidents and motor vehicle accidents. The posterior aspect of the vertebral body extends into the vertebral canal causing severe cord damage. The anterior aspect of the body is also fragmented from the remainder of the body giving it the name of “teardrop”. The left image is an MRI, courtesy of Dr Ahmed Abd Rabou, Radiopaedia.org, rID: 22719 showing a tear-drop fracture of C5 with cord compression due to the posterior displacement of the posterior portion of the vertebra. The image on the right is a CT showing injury at C4 and C5 with posterior displacement and tilt of the vertebral bodies, courtesy of Dr Andrew Dixon, Radiopaedia.org, rID: 32497.
Axial compression – burst fractures. These can occur by a fall from a great height or travelling at high speed. The burst fracture is categorized by the "severity of the deformity, the severity of (spinal) canal compromise, the degree of loss of vertebral body height, and the degree of neurologic deficit." Burst fractures are considered more severe than wedge compression fractures because long-term neurological damage can follow. The neurologic deficits can reach their full extent immediately, or can appear on a delayed basis.

When downward compressive force is transmitted to lower levels in the cervical spine, the body of the cervical vertebra can shatter outward, causing a burst fracture. This fracture involves disruption of the anterior and middle columns, with a variable degree of posterior protrusion of the latter.

Radiographically, this fracture is seen as a vertical fracture line in the frontal projection and by comminution and protrusion of the vertebral body anteriorly and posteriorly with respect to the contiguous vertebrae in the lateral view. Posterior protrusion of the middle column may extend into the spinal canal and can be associated with anterior cord syndrome. Burst fractures always require an axial CT scan or MRI to document the amount of middle column posterior shift.

Imaging: the CT image at the level of the vertebral body shows the retropulsion of a fragment into the vertebral canal (courtesy of E Toh, T Nomura, M Watanabe, J Mochida. Int Orthop 2006 Feb; 30(1):54-58.

Treatment: Initial management of burst fractures with a loss in height of more than 25%, retropulsion, or neurologic deficit is accomplished by applying traction with cervical tongs. When none of those problems exist, the fracture is considered stable.
**Compression and extension injury – Pillar fracture. (unilateral articular mass)**

When extension and compression forces are concentrated on one side it produces unilateral articular mass (pillar) fractures. These are actually extension-rotation injuries.

**Site:** tend to involve the inferior facet surface more often than the superior facet surface when an isolated feature. However, the fracture is often comminuted and can involve other structures of the posterior arch. Usually occur in the lower cervical spine and in 30% of cases are associated with radiculopathy.

**Clinical:** if radiculopathy is absent, the site is considered stable.

Sometimes the extension force causes the vertebral body to move anteriorly, especially on the side of the pillar fracture with a subsequent disc injury. This injury is unstable.

**Frequency:** articular facet and pillar fractures have an incidence of 10%.

**Imaging:** The right oblique radiograph below, courtesy of D T Schwartz and E Reisdorff, shows forward slip of C5 on C6 (arrowhead). The C6 articular pillar is shortened. There is loss of the shingled configuration of the laminae at C5-C6 suggesting fracture of the C6 articular pillar with displacement – see arrow. The CT image shows the left articular pillar and lamina are fractured – see arrow. Ignore the lucency in the right lamina – arrowhead – as this is an artefact.

**Laminar fracture** – these are the result of compression between adjacent laminae.

**Site:** occur at any level, are often bilateral and frequently associated with other injuries.

**Clinical:** if the injury is isolated to one segment and there are no neurological deficit, the injury is considered stable. If there are neurological abnormalities, it is suspicious of associated injuries or comminution of the laminae with impingement on nerves by fracture fragments.
**Imaging:** a fracture may be seen as a lucency in the posterior arch on a lateral view – see image arrowheads, courtesy of D T Schwartz and E. Reisdorff. If a fracture is undisplaced it will only be seen on a CT, as in this example in the right lamina of C3 – arrow on lower image.

**Extension Tear-drop fracture:** distraction and extension causes the anterior longitudinal ligament to avulse a triangular bone fragment from the anterior and inferior corner of the vertebral body. This occurs most commonly at C2 in older adults with degenerative disease but younger patients do sustain this fracture which occurs in that group at lower cervical levels.

**Clinical:** if it is an isolated extension teardrop fracture it is mechanically stable and is usually without neurological deficit.

**Hyperflexion with rotation** – will cause unilateral interfacet dislocation.

**Unilateral interfacet dislocation:** the rotational component causes dislocation of the articular facet on one side of the vertebra. The fractured facet is displaced up and over the articular facet below it, so that it lies anterior to the articular mass below it. The vertebral column is rotated at that level.

**Clinical:** patients have severe pain, and often have nerve root compression. The site is stable and sometimes called ‘locked facets’. If the articular mass is fractured or the contralateral facet joint is injured the injury is unstable.

**Imaging:** CT is essential to confirm the injury and detect associated lateral mass or posterior element fractures. The fractured facet encroaches on the intervertebral foramen which causes nerve root compression and this type is unstable.
The image, courtesy of L L Yao, S B Gay, QDM Vu et al. Imaging evaluation of cervical spine, Radiology Dept, University of Virginia, shows the anterior dislocation of the affected C4 vertebral body by less than half of the vertebral body AP diameter – red arrow. There is discordant rotation above and below the involved level. The displaced facet will be seen in the intervertebral foramen on an oblique view. There is widening of the interspinous distance – blue arrows.

**Bilateral interfacetal dislocation is the result of a distractive-Flexion force.** It is caused by flexion without axial compression. There is complete anterior dislocation of the affected vertebral body by half or more of the vertebral body AP diameter – red arrow. There is also disruption of the posterior ligament complex and the anterior longitudinal ligament. It is unstable. Image courtesy of L L Yao et al.

**Extension injuries:** these often occur with trauma to the face or in motor vehicle accidents when the victim’s vehicle is struck from behind.
**Mechanism:** the anterior longitudinal ligament tears which causes the vertebral bodies to separate either by rupture of the disc or by avulsion of the upper body from the disc. The posterior longitudinal ligament strips from the posterior aspect of the lower vertebral body allowing the upper body to slide posteriorly which damages the cord. A **central cord syndrome is frequent.** If the posterior elements are not injured, the spine recoils into normal alignment after the injury, accounting for the normal plain radiographs after hyperextension dislocation.

With more severe injuries there may be rupture of the facet capsule and posterior ligamentous complex which is a very unstable situation. The head and upper cervical spine can slide forward simulating a flexion injury. Neurological deficits are common.

**Examples** that have been discussed in the paediatric section and occur also in adults are:-

Avulsion fracture of the anterior arch of C1, fracture of the posterior arch of C1 fracture, hangman’s fracture (traumatic spondylolisthesis). Additionally there is the laminar fracture and the Extension teardrop fracture.

**Treatment of cervical injuries:** The eventual outcome for the spine trauma patient often depends upon action taken by the emergency team in the first 6 to 12 hours after injury. The main objective in cervical trauma management is to prevent cord injury and to minimize any secondary injuries to spinal cord tissue as a result of inadequate immobilization, persistent spinal cord compression, poor blood flow or oxygenation. The goal is to optimize the environment for the spinal cord to recover as much as possible.

**Surgical intervention:** indications - Neurologic deficit, Spinal instability, Intractable pain.

If a cervical fracture or dislocation is found, orthopaedic or neurosurgical consultation should be obtained immediately.

**Immobilisation devices:** halo vest or Philadelphia collar. Courtesy of L L Yao et al.

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**Treatment of Specific levels in cervical spine:**

**Fracture of atlas:**

**Jefferson fracture** is treated with halo immobilization for 12 weeks, which usually results in primary union of the ring of C1 and stability of C1 with respect to C2. Surgical fusion may be needed if there is atlantoaxial instability after removal of the halo.
**Fractures of axis:**

**Odontoid fracture:**

Type I is rare. It usually does not have any neurologic symptoms. It is treated with a Philadelphia collar.

Type II is the most difficult type to treat in the halo vest. Even with proper management, the nonunion rate is still as high as 30-60%. If nonunion persists, surgical posterior fusion is indicated.

Type III is treated with halo immobilization. It usually has a high rate of union.

Hangman's fracture: is unstable. It usually heals with halo immobilization for 12 weeks. Surgical fusion is rarely indicated.

**Fractures and dislocations of lower cervical spine:**

Vertical compression fractures are normally treated initially with traction to reduce fragmentation and subsequently with a halo vest. They tend to heal well with halo immobilization.

Unilateral facet dislocations do fairly well with halo immobilization.

Bilateral facet dislocations are treated conservatively. The facet joints are reduced and immobilized. The posterior ligament usually heals poorly.

Clay Shoveler's fractures are treated with a soft collar for comfort. Prognosis is excellent.

**THORACO-LUMBAR SPINE TRAUMA**

**Upper thoracic injuries**

Preamble: the thoracic kyphosis predisposes to a flexion injury in most cases of severe upper thoracic spine fractures and fracture-dislocations. Usually result in complete loss of neurological function below the level of the injury. The thoracic canal is circular and smaller than the cervical and lumbar. As one passes inferiorly, the vertebral bodies increase in size and discs increase in height resulting in an increased resistance to vertical compression forces. The lumbar segment has greater potential for motion than the thoracic segment. However, there are large para-spinal muscles in the lumbar region which provide more stability than the cervical musculature. Upper thoracic discs are narrower so a fracture is more typically a true anterior wedge. In addition the anterior height of the upper thoracic discs is normally 1.5 mm less than the height posteriorly which favours a wedge fracture developing.

Haemomediastinum or haemothorax is frequently produced by the spinal lesion. There are also associated injuries of the lungs, heart and great vessels.

The example that follows shows a chest radiograph with a widened mediastinum – see arrows on the edge of what is later shown to be haematoma by the CT scan. An aortogram has been performed and the aortic arch wall is shown to be bulging at the side of a dissection and is close to rupture. Satisfactory repair of the injury occurred in this 21 year old male.
Severe injuries result in burst fracture and anterior subluxations.

Also posterior element fractures are common with severe thoracic injuries and one needs to use CT scan to assess the canal diameter. MRI is best to show thoracic cord compression and intrinsic cord lesions.

**Assessment of spinal injuries** relies on the Denis Classification. This is based on radiological findings and divides the spinal motion segment into three columns.


The posterior column consists of the posterior ligamentous complex. The middle column includes the posterior longitudinal ligament, posterior annulus fibrosus and posterior wall of the vertebral body. The anterior column consists of the anterior vertebral body, anterior annulus fibrosus and anterior longitudinal ligament.

Denis further divided injuries into Major and Minor.

Major injuries: compression, burst, seat-belt-type and fracture-dislocation.

Minor injuries: fractures of the transverse processes, articular process, pars interarticularis and spinous processes.

**Thoraco-lumbar junction and upper lumbar spine injuries (T10 – L3):** 66% of thoraco-lumbar fractures occur between T12 and L2. Lower thoracic discs and lumbar region discs are larger and more effective as shock-absorbers. Thus herniation into the cartilaginous end plates is more likely to occur in the lower thoracic and lumbar regions. If the flexion force continues the
anterior aspect of the vertebral body is compressed. Multiple contiguous wedge fractures may lead to delayed instability and in the thoracic region to cord deficits.

Hyperflexion injuries are the most common. The predisposition to injury is due to;

- Relatively no protection of the rib cage at this level
- Sagittally oriented facet joints allow for greater mobility in flexion and extension
- Vulnerable to axial compression and flexion forces

**Types of injury:**

- Simple compression fractures – due to axial loading and flexion
- Burst fractures
- Distraction injuries which are frequently associated with the use of lap seat belts.

**Simple compression fractures:**

- Loss of height of the anterior aspect of the vertebral body
- No retropulsion of bone into the spinal canal
- Posterior elements and ligaments are not injured
- Neurologic deficits are uncommon.

**Imaging:** shows wedging of two vertebral bodies, T11 and T12, courtesy of Grainger and Ellison. Diagnostic Radiology – see arrows.

**Burst fractures:** these are caused by axial loading with slight flexion.

- Compression of the vertebral body
- Posterior displacement of the superior end plate into the spinal canal
- 65% of cases have neurological damage
- Posterior element fractures, especially the lamina and lateral masses are seen in most burst fractures and these are unstable.
- Widening of the facet joints means ligamentous instability.

The images, courtesy of Paul and Juhl. Essentials of Diagnostic Imaging show a burst fracture of the second lumbar vertebra with anterior wedged compression. There is retropulsion of the posterosuperior margin of the vertebral body – arrow- which compromises the vertebral canal. The open arrow indicates a horizontal fracture through the lamina of L1.

The CT scan shows retropulsion of a split fragment, with marked compromise of the spinal canal. There is also a fracture of the left lamina. The superior surface of the vertebral body is comminuted. There are also fractures of the transverse processes.
**Distraction Injuries:** these are caused by hyperflexion and are frequently associated with falls.

- There is disruption and separation of the posterior elements
- There can be a fracture through spinous processes extending through the pedicle to the body.
- There can be posterior ligamentous rupture that extends anteriorly through the disc.
- The severity of neurological deficit depends on the degree of displacement and canal narrowing. If the AP diameter of the spinal canal is less than 10 mm there is usually complete and permanent neurological deficit.

**Lower Lumbar Injuries**

- Less common than thoraco-lumbar junction
- Compression and flexion are the dominant forces
- May be associated with abdominal organ lesions; retroperitoneal haematoma, renal lesions
- Associated can be traumatic spondylolysis with spondylolisthesis – need CT

**Sacral injuries**

- Occur most frequently in combination with pelvic fractures
- Occur after falls or MVA where there is sudden deceleration of the lower extremities causing vertical shearing force with disruption of the anterior and posterior pelvic rings
- Associated with severe haemorrhage due to tearing of the lumbosacral venous plexus or superior gluteal arteries
- Neurological deficits are less common but can occur due to nerve root compression from fractures through the lower spinal canal or neuroforamina.

**Types:**

- Sacro-iliac joint diastasis
- Sacral lip fractures
- Vertical shear fractures
- Comminuted fractures

**Imaging:** needs CT for best demonstration of sacral fractures.
Miscellaneous injuries of the spine:

**Penetrating injuries:** gunshot and knife attacks especially in the thoracic region.

**Features:**

- Damage to the cord by transection
- Contusion from shock waves produced by a bullet
- Compression by bone fragments
- Compression by haematoma
- Cord lesions are frequently partial.

**Imaging:** plain radiographs show the path of the bullet.

CT shows if there are bullet fragments within the spinal canal.

CT Myelography identifies the epidural haematomas compressing the cord and also shows dural tears.

MRI – shows integrity of the cord but if there are bullet fragments in the canal it will distort the image.

**Dural tears**

**Dural tears:** these may occur either by laceration of the dura or by avulsion of the nerve roots.

Laceration of the dura is usually caused by bone fragments that are displaced into the spinal canal with severe fractures. Also the result of penetrating injuries.

When the dura is lacerated, nerve roots can herniate into the dural tear and be compressed or damaged.

**Imaging:** CT myelography can show contrast leaking through a hole in the dura.

**Cord avulsion:** this can be seen in obstetrics if there is a breech presentation and the head is stuck.

There can be cord damage without bone damage. It usually occurs at the lower cervical level or upper thoracic level.

It may also be found after MVA, especially in the upper thoracic region where the cord is thinnest and is the level most frequently involved. MRI is needed.

In the thoracic region, nerve root avulsion can result in pleuro-meningeal fistulae. The avulsed root retracts laterally, leaving a cavity or pseudomeningocele in the nerve root sheath which then fills with CSF.

The images below, courtesy of R Tse, J N Nixon, R S Iyer, KA Kuhlman-Wood and G E Ishak 2014 Neuroradiol 35: 1425-32, show three consecutive left-sided pseudomeningoceles with absent rootlets at C7-T1.

A, C and E are images from a CT myelogram. Images B, D and F are from a MR myelogram on the same patient.
The pseudomeningoceles are indicated by arrows in A and B, arrowheads in C and D and arrows in E and F.

**Axial view**  

**Coronal view**  

**Parasagittal view**

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**Acute arachnoid cyst:** isolated fluid collection without macroscopic nerve root or cord injury. Occurs during the acute phase of spinal trauma, with the thoracolumbar region being involved; less frequent in the cervical region. There is an acute mass effect, with a delayed onset after the trauma. It is a surgical emergency.

**Underlying lesions such as Metastases** can result in minor trauma producing severe cord damage.

In the image below, courtesy of Dr Roberto Schubert, Radiopaedia.org, rID 13684, the white arrows indicate the perimeter of the metastasis which has weakened the lumbar vertebra with subsequent collapse. The compression of the lumbar theca and cauda equina is shown due to the crumbling vertebra displacing posteriorly.
Long Term Sequelae of Spinal Cord Injury

- Cord atrophy – usually neurologically stable
- Myelomalacia
- Intramedullary cysts
- Subarachnoid cysts
  The 2nd, 3rd and 4th dot points may have progressive loss of neurological function months to years after the injury. The cysts can be treated with shunting but nothing can be done for myelomalacia.
- Arachnoiditis

END