SPINAL CORD TRAUMA

FUNCTIONAL ANATOMY:

- AXIAL VERTEBRAE (C1, C2)
  - Anatomically and functionally unique --> allows for rotary motion

- SUBAXIAL VERTBRAE (i.e. anything below C2):
  - Fundamentally the same
  - According to weightbearing function, they get bigger toward the lower end of the vertebral column

- SPINAL CORD:
  - Continuous with the medulla oblongata
  - Gives rise to 31 pairs of spinal nerves
  - The vertebral column lengthens more than the cord with growth (ends at L1-2 in adults)

- SPINAL STABILITY:
  - Mostly due to the strong ligaments that connect vertebral bodies and arches to each other
  - Three methods to define stability:
    - Separation of adjacent vertebral bodies has enough ligamentous disruption to be unstable
    - Radiographically
    - THREE COLUMN PRINCIPLE (Denis system):
      - Anterior (anterior half of body, anterior longitudinal ligament)
      - Middle = posterior half of body and posterior longitudinal ligament
      - Posterior = posterior vertebral arch and the posterior ligamentous complex
      - If greater than 2 columns involved --> UNSTABLE
    - Compression can indicate instability.
      - >25% compression of C3-7
      - >50% compression of T or L-spine.
  - If any neurological symptoms or radiographic evidence of injury = assume instability...
  - Recall that ligamentous structures can be damaged w/out associated radiographic abnormalities.
    - ?Flex-Ex films vs MRI debate.

CERVICAL SPINE FRACTURES:

OCCIPITAL CONDYLE FRACTURES:

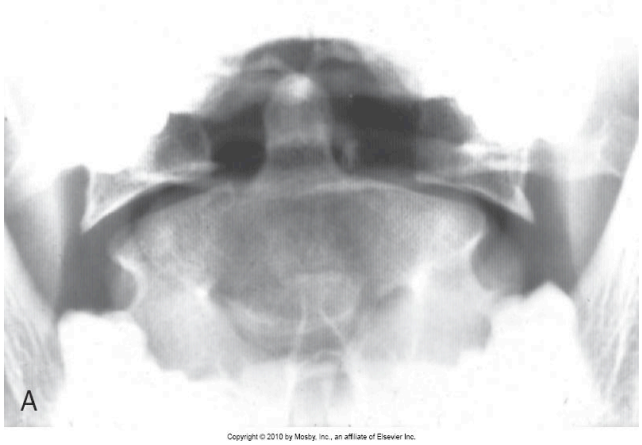
- High velocity cervicocranial injuries
- *Lower cranial nerve deficits and/or limb weakness*

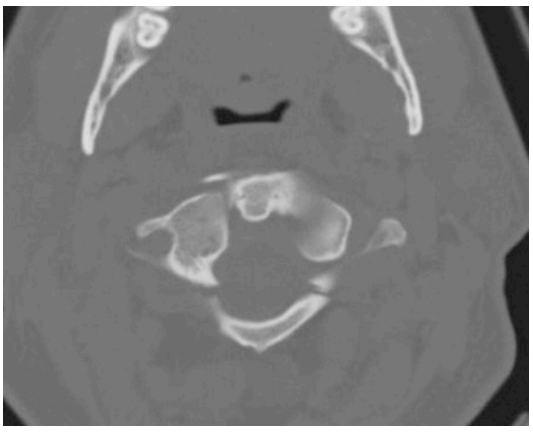
OCCIPITOATLANTIAL DISSOCIATION:

- Skull may be displaced anteriorly or posteriorly.
- FREQUENTLY RESULTS IN DEATH
- EXTREMELY UNSTABLE !!
- Basion dental interval should be ≤8.5mm on CT

JEFFERSON FRACTURE:

- Axial load forces occipital condyles downward & drives lateral masses of C1 apart = *burst fracture.*
- If displacement of both lateral masses is >7mm (added together) then rupture of transverse ligament is likely [ie. unstable].





TRANSVERSE LIGAMENT DISRUPTION:

- RUNS ON INSIDE OF THE RING OF C1 AND ALONG THE POSTERIOR SURFACE OF THE DENS.
    - *CRUCIAL TO MAINTAINING STABILITY OF C1 ON C2*
- Pure ligamentous rupture without fracture occurs in older patients from a direct blow to the occiput
- PREDENTAL SPACE:
    - Normally < 3mm
    - >3mm (2mm on CT) implies damage
    - > 5mm implies rupture of transverse ligament

ROTARY SUBLUXATION OF C1 ON C2:

A

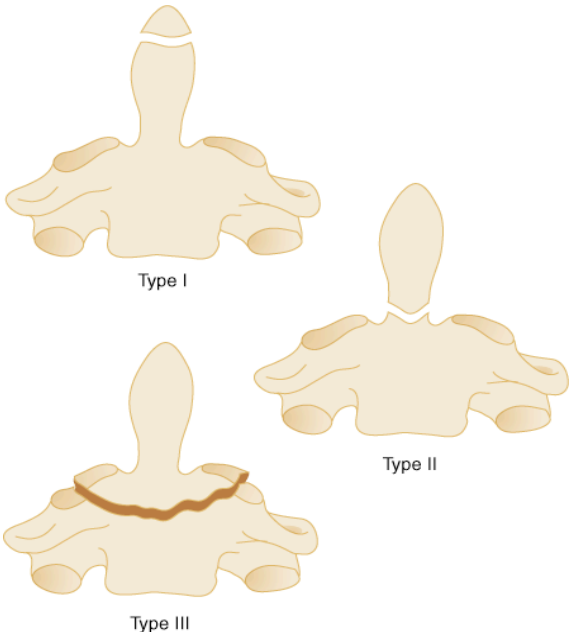
- CAUSED BY ROTATIONAL INJURY
- Asymmetry in relationship of lateral masses of C1 to odontoid
- Unstable injury

POSTERIOR ARCH OF ATLAS FRACTURES:

- Hyperextension
- If isolated injury → considered stable

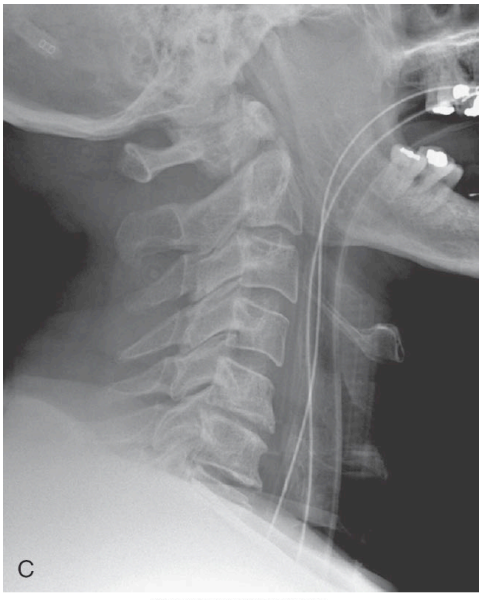
ODONTOID FRACTURES:

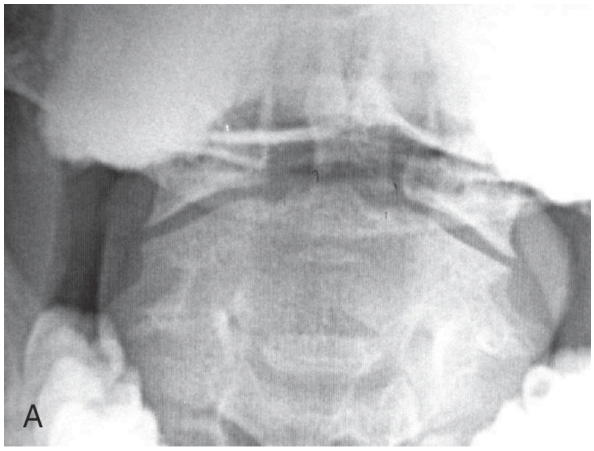
- Often significant external force required (multi-trauma common).
- Conscious patients have immediate, severe pain + muscular spasm.
- 18-25% have neurological injury.



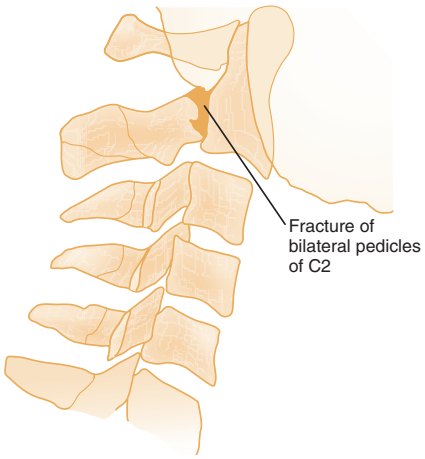
- TYPE 1: stable, avulsion of tip, transverse ligament remains attached
- TYPE 2: junction of dens with body of C2, most common. Poor prognosis, unstable
- TYPE 3: through superior portion of C2 at base of dens. Unstable

TYPE 2 ODONTOID FRACTURES



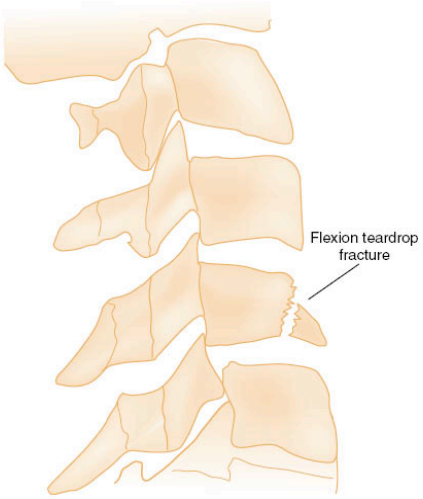


HANGMAN'S FRACTURE: - aka. traumatic spondylolisthesis of the Axis.



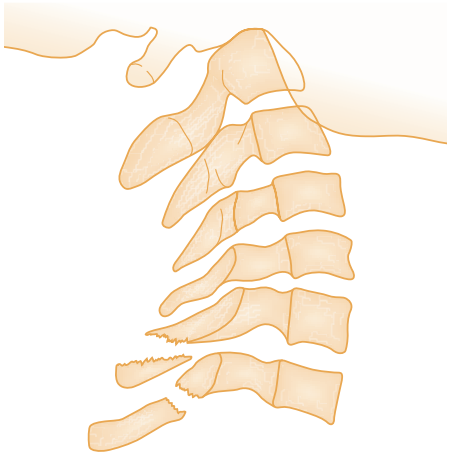
- Fracture of both pedicles of C2, allows body of C2 to displace anteriorly on C3
- Extension mechanism as a result of abrupt deceleration (judicial not suicidal hangings, MVC, diving accidents)
- Large diameter of canal may allow patients to be neurologically intact

FLEXION TEARDROP FRACTURES:



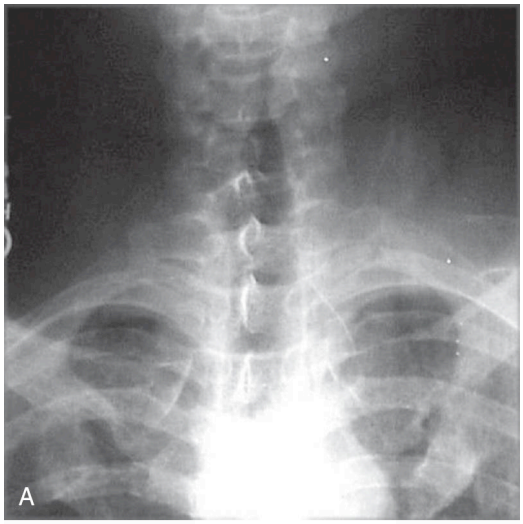
- Extreme flexion
- "Teardrop" = anteroinferior portion of vertebral body
- Associated with ventral cord syndrome due to impingement of cord on fracture-induced hyperkyphosis
- HIGHLY UNSTABLE

SPINOUS PROCESS AVULSION FRACTURE ("CLAY-SHOVELLERS":



- Avulsion off lower cervical spinous processes
- Intense flexion against a contracted posterior erector spinal muscle
- Stable

UNILATERAL INTERFACETAL DISLOCATION:



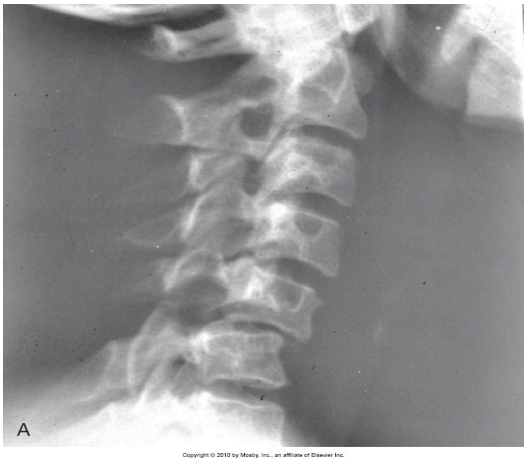
A: shows spinous processes of cervical vertebrae offset in relation to thoracic vertebrae.

C: a lateral view showing C5 articular facet lying anterior to the corresponding facet of C6 = BOW-TIE DEFORMITY, with subluxed C5 anteriorly to C6.
Usually stable unless associated fracture.

BILATERAL INTERFACETAL DISLOCATION:

- Disruption of *all ligamentous structures* due to HYPERFLEXION
- If vertebral body dislocated anteriorly more than 50% --> UNSTABLE
- In partial bilateral interfacetal dislocation --> PERCHING can occur (locked facets) --> implies a degree of stability, but this is misleading.

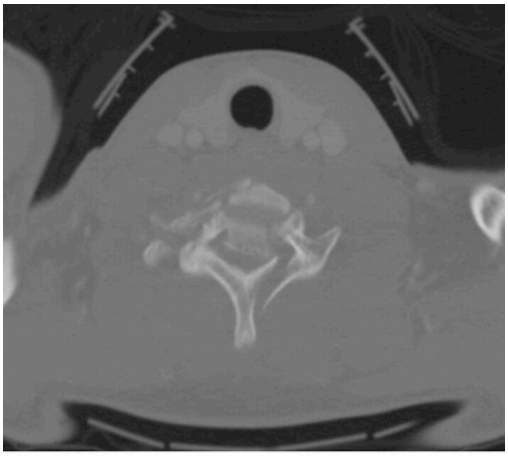
Facets of C6 lie anterioly to those of C7 with severe subluxation



Subluxation of C5 on C6 with associated severe subluxation

BURST FRACTURES:

- Direct axial load to the lower cervical spine may cause fracture fragments to be displaced in all directions --> unstable !



THORACIC SPINE FRACTURES:

T1-T10

- Rigid, reinforced by articulation with rib cage
    - A large force is required to overcome this stability
    - Hence an injury at this level indicates that severe forces were present
- Most injuries are neurologically complete if spinal cord injury occurs
- Patients with blunt chest trauma and mediastinal widening should be evaluated for both aortic and thoracic spine injuries

THORACOLUMBAR JUNCTION (T11 - L2):

- Considered a TRANSITIONAL ZONE, more mobile and thus more vulnerable to injury.
- Width of spinal canal is relatively large, hence most do not have neurologic deficits.

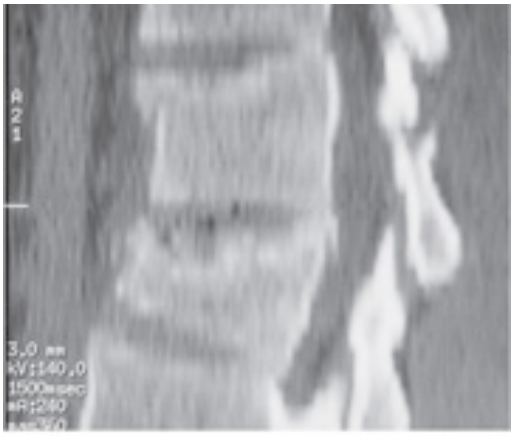
LUMBAR SPINE:

- L3-L5, more mobile
- Spinal cord ends at level of L1, thus fracture rarely injure the spinal cord
- Cauda equina, isolated nerve root deficits

SPECIFIC THORACIC AND LUMBAR FRACTURES.

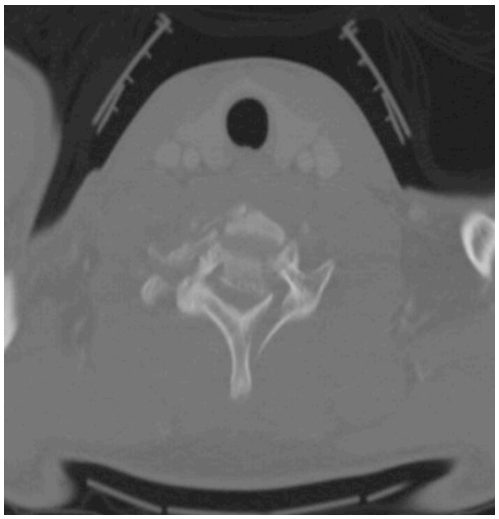
COMPRESSION:

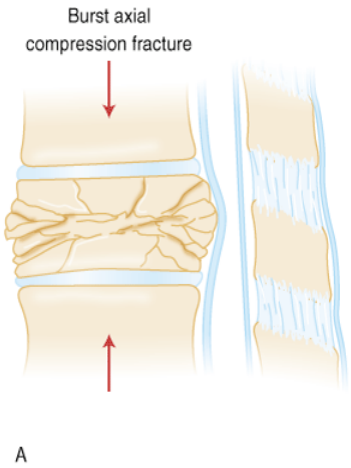
- Axial loading and flexion
- Failure of *anterior column*
- Usually stable unless ≥50% loss of height



BURST:

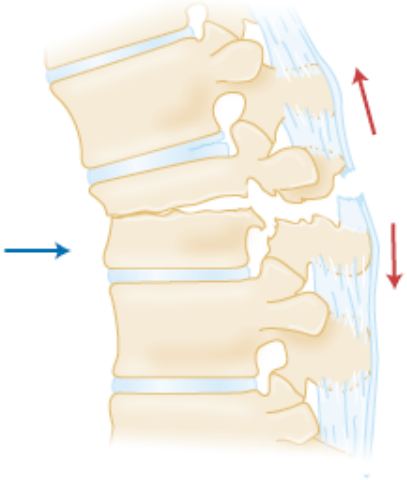
- Axial load
- *Anterior AND middle columns fail =* ***UNSTABLE***

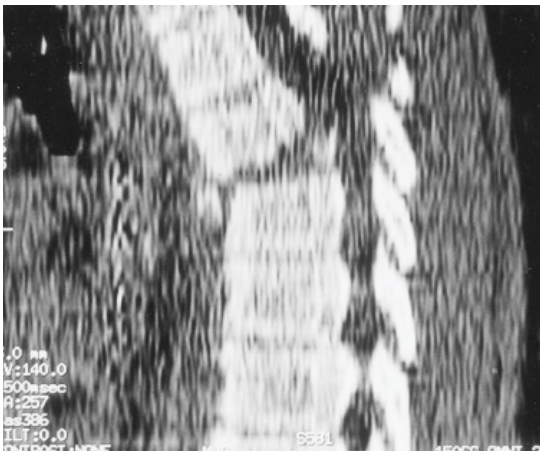




FLEXION-DISTRACTION INJURIES:

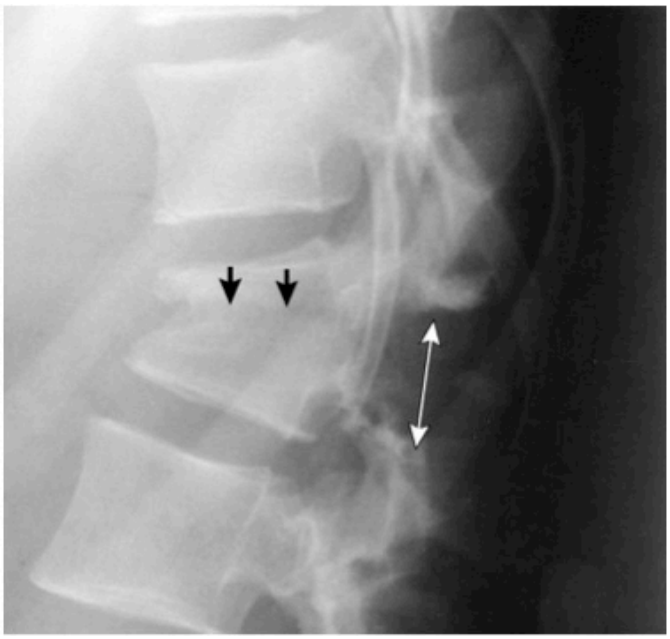
- Commonly seen following seat-belt-type injuries - seat-belt serves as the axis of rotation during distraction
- FAILURE OF BOTH POSTERIOR AND MIDDLE COLUMNS
- Typical radiographic findings are of posterior opening of the disk space, increased height of posterior vertebral body





CHANCE:

- Minor anterior vertebral compression and significant distraction of middle and posterior ligamentous structures
- Often misdiagnosed as an anterior compression fracture
- UNSTABLE
- SENTINEL INJURY - HIGH ENERGY, LOOK FOR INJURIES ELSEWHERE



FRACTURE-DISLOCATION:

- The most damaging of injuries
- Grossly unstable spine

NEUROLOGICAL EXAMINATION:

- Detailed assessment crucial after initial stabilisation
- Note presence of incontinence or priapism = patient is at high risk for SCI
- Physical examination should delineate the level of the lesion, which is important in event of deterioration for re-asseessment later

ANOGENITAL REFLEXES:

- Important as any *sacral sparing delineates incomplete injury* and thus is important for prognosis
- BULBOCAVERNOSUS REFLEX - squeeze penis, anal sphincter should contract
- Cremasteric reflex.

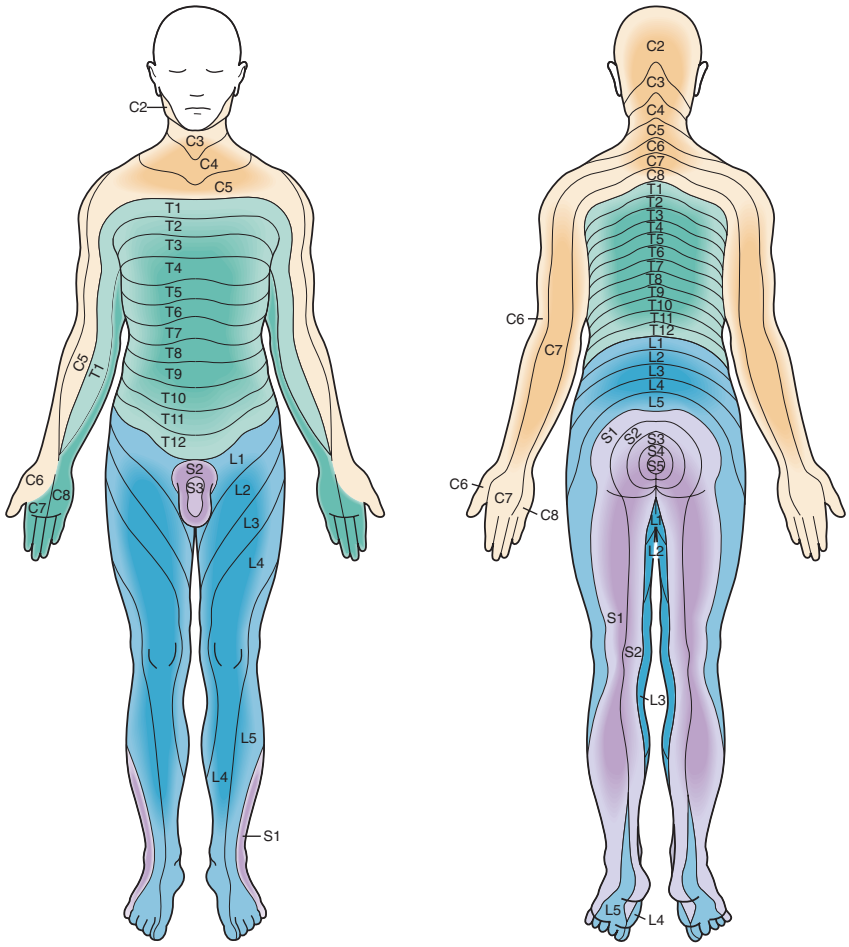
- Proprioception and vibration sense to assess dorsal column function.
- Sensory level (from dermatomes) - *see image below*
- Motor assessment & reflexes

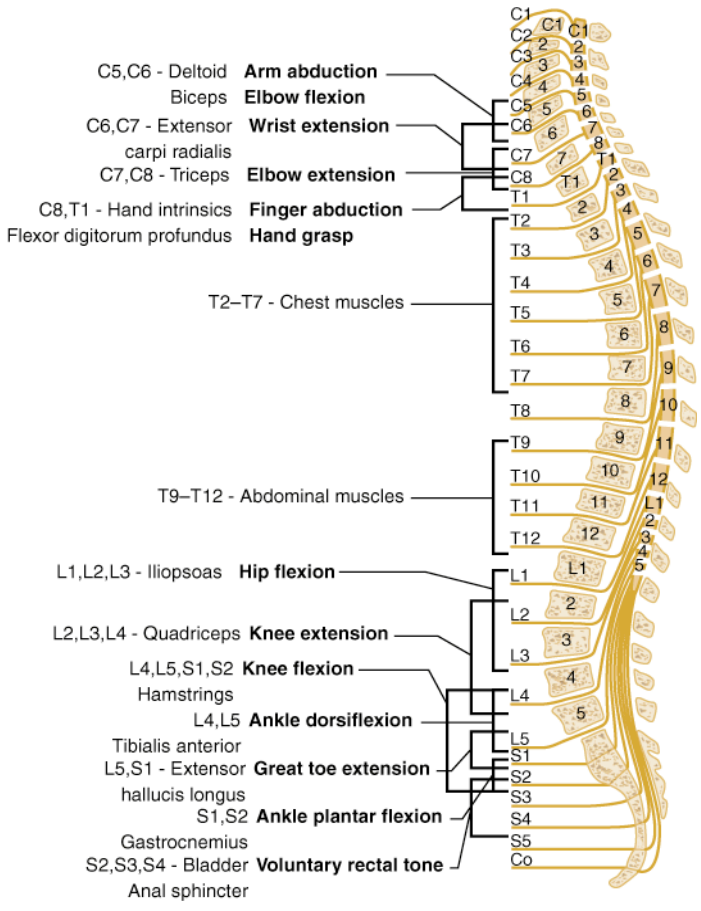
Table 255-4 Motor Grading System

Grade	Movement
0	No active contraction
1	Trace visible or palpable contraction
2	Movement with gravity eliminated
3	Movement against gravity
4	Movement against gravity plus resistance
5	Normal power

Table 40-3 Spinal Reflex Examination

LEVEL OF LESION (AT OR ABOVE)	RESULTING LOSS OF REFLEX
C6	Biceps
C7	Triceps
L4	Patellar
S1	Achilles


C2
C3
C4
C5
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
C6
C7
C8


C5,C6 - Deltoid Arm abduction
Biceps Elbow flexion
C6,C7 - Extensor Wrist extension
carpi radialis
C7,C8 - Triceps Elbow extension
C8,T1 - Hand intrinsics Finger abduction
Flexor digitorum profundus Hand grasp
T2–T7 - Chest muscles
T9–T12 - Abdominal muscles
L1,L2,L3 - Iliopsoas Hip flexion
L2,L3,L4 - Quadriceps Knee extension
L4,L5,S1,S2 Knee flexion
Hamstrings
L4,L5 Ankle dorsiflexion
Tibialis anterior
L5,S1 - Extensor Great toe extension
hallucis longus
S1,S2 Ankle plantar flexion
Gastrocnemius
S2,S3,S4 - Bladder Voluntary rectal tone
Anal sphincter

CLASSIFICATION OF SPINAL CORD INJURIES:

PRIMARY:

- Direct mechanical injury from traumatic impact
- Characterised by haemorrhage into the cord and formation of oedema
- Transection of neural elements

SECONDARY:

- Maximum neurological deficit following blunt spinal cord trauma is often not immediately apparent and may progress over many events
- Relates to a *complex cascade of events*
- Other mediating factors include hypoxia, hypotension, hyperthermia, hypoglycaemia and mishandling by medical personnel
    - Preventing above is paramount in management of SCI

CLASSIFICATION OF SPINAL CORD LESIONS:

COMPLETE SCI.

- Total loss of motor power and sensation distal to the site of an SCI.
- Recovery rare.
- MIMICKED BY SPINAL SHOCK
    - Those in spinal shock lose all reflex activities below the area of injury and lesions cannot be deemed complete until spinal shock has resolved. This can take up to 2 weeks.
    - Return of bulbocavernosus reflex = resolution of spinal shock !

INCOMPLETE SCI

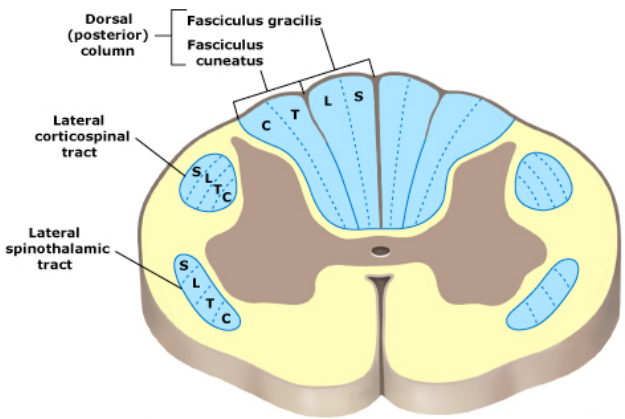
- If motor, sensory or both functions are partially present below the neurological level.

The following image displays of descending and ascending tracts,
the THREE MOST IMPORTANT ARE:

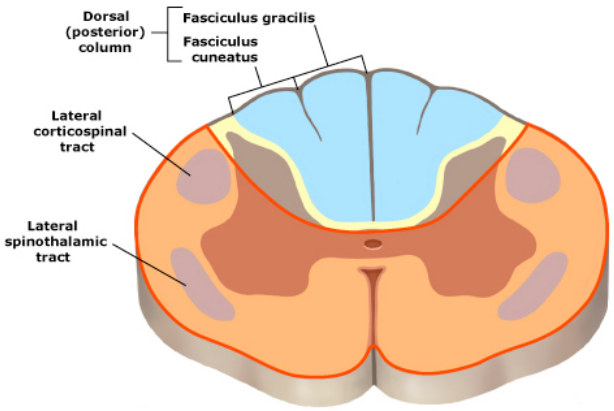
1. CORTICOSPINAL: descending motor pathway (esp lateral (carries 90% of motor fibres. Damage leads to ipsilateral muscle weakness, spasticity, ↑'d DTR, upgoing plantars

2. SPINOTHALAMIC: transmits contralateral pain and temperature

3. DORSAL COLUMN TRACT: ipsilateral light touch, vibration sense and proprioception

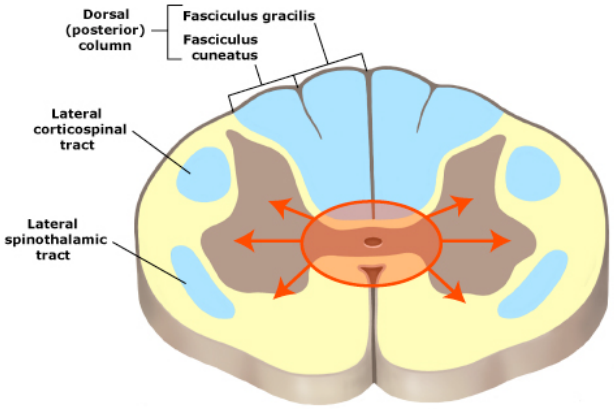


VENTRAL CORD SYNDROME:



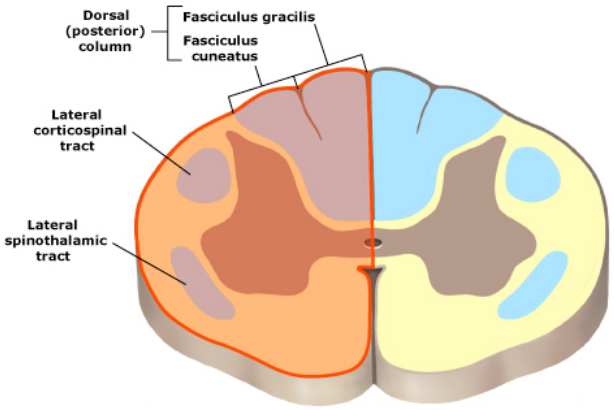
- Damages corticospinal and spinothalamic tracts. Posterior columns preserved
- Loss of motor function and pain and temperature sensation distal to the lesion
- Direct injury from *forward flexion injury* with bony fragments of contusion
- Thrombosis of anterior spinal artery can also cause this
- Poor prognosis

CENTRAL CORD SYNDROME:



- Usually in older patients who sustain hyperextension injury
- Centrally located fibres of corticospinal and spinothalamic tracts are affected
- *Neural fibres to upper extremities are located most medial* hence ↓'d power (& pain/temperature to lesser degree) in *upper more than lower extremities*
- Good prognosis, but most do NOT regain fine motor function

BROWN-SEQUARD SYNDROME:



- Hemisection of the cord, usually penetrating mechanism
- *Ipsilateral* loss of motor function, proprioectpion and vibration sense
- *Contralateral* loss of pain and temperature
- Best prognosis for recovery

OTHER INCOMPLETE SCI:

CAUDA EQUINA:

- Injury to this area results in peripheral nerve injury
- Symptoms include variable motor and sensory loss in the lower extremities, sciatica, bowel and bladder dysfunction, saddle anaesthesia

NEUROGENIC SHOCK:

- Occurs with peripheral sympathetic denervation (i.e. with high thoracic and cervical injuries) (↓'d SVR & hypotension)
- If sympathetic innervation to heart is lost (T1-T4), vagal tone to heart is unopposed --> bradycardia
- Patients with neurogencic shock are warm, vasodilated and bradycardic
    - Usually well tolerated as oxygen delivery is maintained
- DIAGNOSIS OF EXCLUSION --> exclude haemorrhagic, cardiogenic (contusion) and obstructive (tamponade) as causes first in trauma.
- Treat with fluid resuscitation and aim for MAP 75-80
    - Caution as excess fluid can result in pulmonary oedema / CCF.
    - If organ perfusion remains compromised --> positive inotropic agents are beneficial (typically noradrenaline)

SPINAL SHOCK:

- NOT THE SAME AS NEUROGENIC!
- Refers to the temporary loss or depression of spinal reflex activity that occurs below a SCI
- FLACCID AREFLEXIA IS CHARACTERISTIC.

GENERAL APPROACH TO PATIENTS WITH SPINAL INJURY

PREHOSPITAL:

- Recognition of the 'at risk patient'
- IMMOBILISATION
- Transfer to appropriate centre ASAP

ED STABILISATION:

- Treatment should not differ to others with multi-system trauma (ABCDE)
- THE HIGHER THE LEVEL OF INJURY, THE MORE COMPELLING THE CASE FOR EARLY AIRWAY INTERVENTION
    - ≥C5 --> potential to tire and develop respiratory failure.
    - RSI with in-line immobilisation

- BLOOD LOSS is the cause of hypotension until proven otherwise !
- Detailed neurological assessment after initial stabilisation
- THE DETERMINATION OF A SPINAL COLUMN INJURY AT ONE LEVEL SHOULD PROMPT IMAGING OF THE REMAINDER OF THE SPINE
    - ~10% of patients with a spine fracture in one segment will have a second fracture at another

DIAGNOSTIC IMAGING:

- INDICATIONS FOR IMAGING
- CONSIDER USE OF NEXUS AND CANADIAN C-SPINE RULES TO DECREASE UNNECESSARY IMAGING

Table 255-5 National Emergency X-Radiography Utilization Study Criteria: Cervical Spine Imaging Unnecessary in Patients Meeting These Five Criteria
Absence of midline cervical tenderness
Normal level of alertness and consciousness
No evidence of intoxication
Absence of focal neurologic deficit
Absence of painful distracting injury

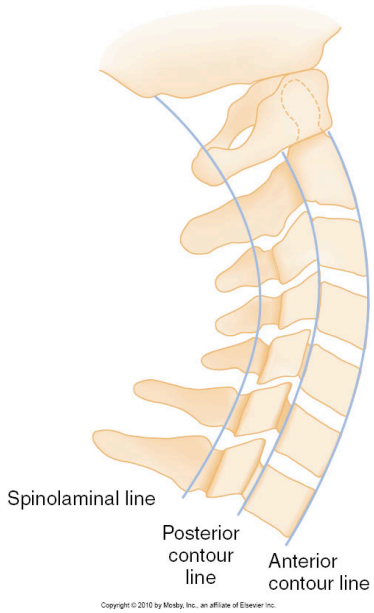
If all five of above negative, NPV ~99.7%, sensitivity 99.6%, only 12.9% specificity

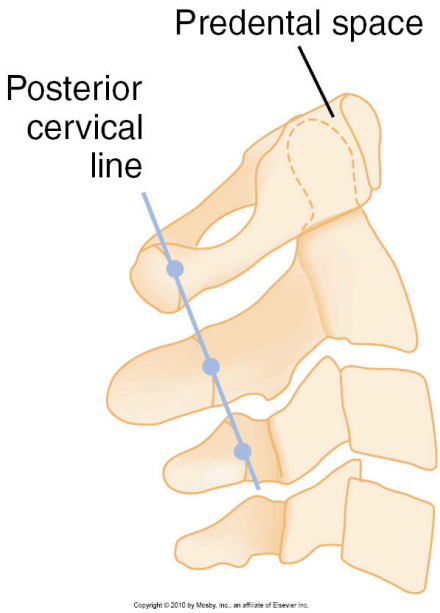
Table 255-6 Canadian Cervical Spine Rule for Radiography: Cervical Spine Imaging Unnecessary in Patients Meeting These Three Criteria	
Question or Assessment	**Definitions**
There are no high-risk factors that mandate radiography.	High-risk factors include:
	Age 65 years or older
	A dangerous mechanism of injury (fall from a height of >3 ft; an axial loading injury; high-speed motor vehicle crash, rollover, or ejection; motorized recreational vehicle or bicycle collision)
	The presence of paresthesias in the extremities
There are low-risk factors that allow a safe assessment of range of motion.	Low-risk factors include:
	Simple rear-end motor vehicle crashes
	Patient able to sit up in the ED
	Patient ambulatory at any time
	Delayed onset of neck pain
	Absence of midline cervical tenderness
The patient is able to actively rotate his/her neck.	Can rotate 45 degrees to the left and to the right

IF THE ANSWER IS NOT TO ALL THREE ABOVE --> NO IMAGING!
100% SENSITIVITY, 42.5% SPECIFICITY

PLAIN FILM RADIOGRAPHY:

- AP, LATERAL AND ODONTOID VIEWS
- A study comparing CT to plain radiographs showed sensitivity of CT to be nearly 100% vs ~70% for plain films
- Interpretation is predicated on *adequate films* (on lateral able to see from C1 to junction of C7/T1)





- The three lines above should form smooth, continuous lordotic curve
    - Exception is pseudosubluxation of C2 on C3.
        - Use posterior cervical line, if base of C2 lies more than 2mm anterior or posterior to posterior cervical line, then an injury at that level should be suspected
- Consider flexion/extension views when there is concern for a ligamentous injury despite negative radiographs
    - HIGH FALSE POSITIVES --> *MRI superior*

CT scanning:

- **More sensitive and specific, more expeditious.**
- FIRST LINE:
    - Altered mental status OR severe non-spinal injury
    - High risk patient:
        - High speed MVA (>55kmh), fall from >3m
        - Death at scene
        - Significant CHI with ICH on CT
    - Neurological symptoms/signs referred to C –spine
    - Pelvic or multiple extremity fractures

MORE RADIATION:

- 14 FOLD TO THYROID
- 10 FOLD TO SKIN

MRI:

- Diagnostic test of choice for describing the anatomy of nerve injury, spinal cord contusions, herniated discs
- CT/X-ray better at osseous injury.

Table 255-8 Indications for Thoracic and Lumbar Imaging after Trauma	
Mechanism	Gunshot
	High energy
	Motor vehicle crash with rollover or ejection
	Fall >10 ft or 3 m
	Pedestrian hit by car
Physical examination	Midline back pain
	Midline focal tenderness
	Evidence of spinal cord or nerve root deficit
Associated injuries	Cervical fracture
	Rib fractures
	Aortic injuries
	Hollow viscus injuries

PHARMACOLOGY FOR INCOMPLETE CORD INJURY:

- HIGH DOSE STEROIDS CONTROVERSIAL
- NASCIS GROUP:
    - Reported 30mg/kg methyprednisolone as bolus followed by 5.4mg/kg/hour in blunt SCI with neurological deficit within 8 hours of injury resulted in improvement in both motor and sensory function
    - Recent meta-analysis have questioned this
        - Most recent guidelines state there is insufficient evidence
    - No mention of steroid side effects

PENETRATING INJURIES:

- No role for steroids
- If GSW with transabdominal tract --> broad spectrum antibiotics
- Surgical debridement and laminectomy not effective in reducing infective complications
- Bullet removal in thoracic and cervical injuries does not improve neurological status
    - THORACOLUMBAR GSW may significantly improve post bullet removal

OPERATIVE VS NON-OPERATIVE STABILISATION:

- Rationale for surgery is benefit of early mobilisation in preventing PE, DVT, skin breakdown, atelectasis
    - All agree progressive neurologic deterioration is an important indication for urgent surgery
- Non-operative external immobilisation complicated by pain, pressure, muscle weakness and disuse atrophy as well as venous compromise and psychological dependence