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Cauda Equina Syndrome and Acute Spinal Injuries

Objectives:

The ability to demonstrate knowledge of the following:

- ★ Basic anatomy of the spine
- ★ Initial assessment and treatment of spinal injuries at the field
- ★ Management of Cauda equina syndrome
- ★ Principle of spinal stability
- ★ Basic understanding of neurologic syndromes caused by spinal trauma

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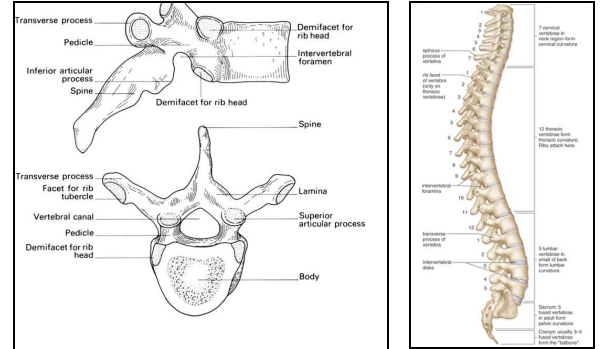
References: 435 Lectures And Notes, Apley

Anatomy of the spine

In the spine there are bones, joints, ligaments and muscles.

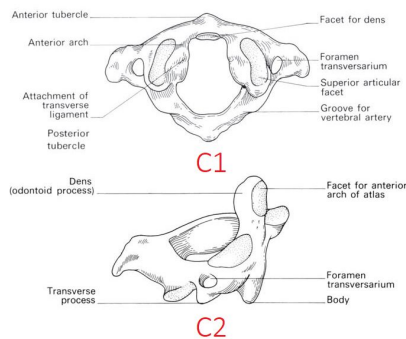
Anatomy of the vertebral column

The spinal column is made up of 33 vertebrae, of which 24 are discrete vertebrae (these 24 vertebrae are: 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae) and 9 are fused in the sacrum and coccyx. The basic vertebra is composed of a **body** and of a **neural arch** surrounding the vertebral canal. The neural arch is made up of a pedicle and lamina on either side, spinous process posteriorly, 2 transverse processes laterally, and upper and lower articular facets. The pedicle bears a notch above and below which, with its neighbour, forms the intervertebral foramen. Vertebral column has 2 Functions: (1) weight bearing. (2) Movement.



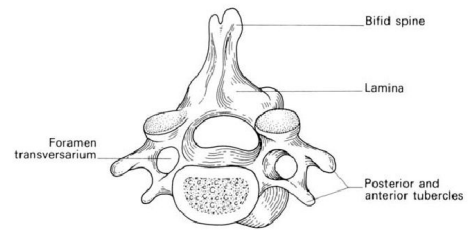
The cervical vertebrae

C1 (Atlas) & C2 (Axis)



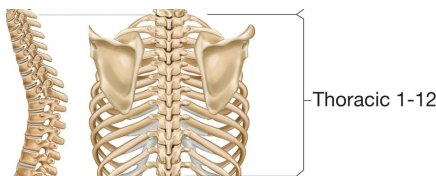
The atlas (C1) has no body. The axis (C2) bears the dens (odontoid process), that projects upward into the Atlas. This unique anatomy provide a great degree of mobility for the skull. Approximately 50% of flexion extension of the neck happens between the occiput and C1; 50% of the rotation of the neck happens between C1 and C2.

C3 -C7



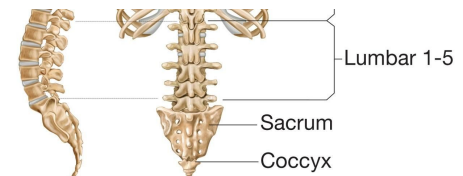
C3-C7 are more classic vertebrae, having a body, pedicles, laminae, spinous processes, and facet joints. **Note that:** All cervical vertebrae (C1 to C7) have a **foramen transversarium**. Vertebral artery travels through foramen transversarium. As we all know vertebral artery is a component of Circle of Willis, so if there was a fracture and a piece of bone cut or obstructed the vertebral artery the blood supply of the brain will be affected.

The thoracic vertebrae



(1) Rib attachments provide a strength and stability to the thoracic spine. (2) The rib cage and ligaments limit range of motion and protect many vital organs. So thoracic vertebrae are somehow stiff and they are relatively stronger than cervical vertebrae and the lumbar vertebrae. They are less likely to degenerate, and to develop any trauma.

The lumbar vertebrae

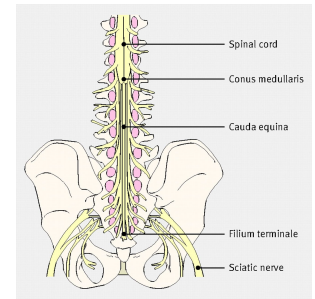


As we go down the vertebra becomes bigger in size. L5 is the biggest vertebra and C1 is the smallest vertebra. This correlates with their function in weight bearing - so initially (in cervical spine) there is only the weight of the head. And then the weight of the chest will be added on the thoracic vertebrae. And then in the lumbar vertebrae there will bear the whole weight of the trunk and pelvis - and then the weight transmitted to the hip joint

Anatomy of the spinal cord

Gross Anatomy

The spinal cord is continuous above with the medulla oblongata at the level of the foramen magnum and ends below at the lower level of the 1st, or the upper level of the 2nd lumbar vertebra (in children, it extends up to L3). Inferiorly, it tapers into the conus medullaris from which a prolongation of pia mater, the filum terminale, descends to be attached to the back of the coccyx. The lumbar and sacral roots below the termination of the cord at vertebral level L2 continue as a leash of nerve roots termed the cauda equina.

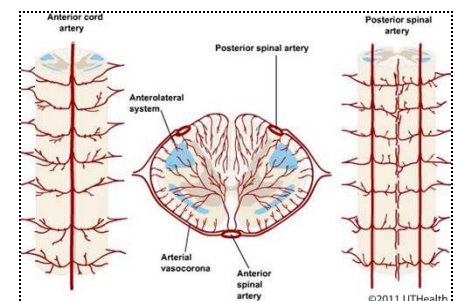


Intrinsic pathways

Descending tracts	Ascending tracts
<p>1/ The <u>pyramidal (lateral cerebrospinal or crossed motor) tract</u> (90% of the pyramidal fibers). The motor pathway commences at the pyramidal cells of the motor cortex, decussates in the medulla, then descends in the pyramidal tract on the contralateral side of the cord. So: Any lesion of the lateral corticospinal tract causes an ipsilateral (because fibers have already crossed) upper motor neuron syndrome: weakness, disuse atrophy, spastic tone, increased reflexes, clonus, and a Babinski response</p> <p>2/ The <u>direct pyramidal (anterior cerebrospinal or uncrossed motor) tract</u> (10% only). It is a small tract descending without medullary decussation.</p>	<p>1/ The <u>lateral and anterior spinothalamic tracts</u>. Lateral spinothalamic tracts carry pain and temperature fibers. Anterior spinothalamic tracts carry pressure and crude touch fibers. These fibres cross to the opposite side in the spinal cord to ascend in these tracts to the thalamus, where they are relayed to the sensory cortex. So: Any lesions of the lateral spinothalamic tract cause loss of pain and temperature sense on the opposite side of the body below the site of the lesion. Just notice how the fibers are arranged inside the tract (in the 2nd pic - anterior and lateral spinothalamic tracts). The cervical fibers (upper limb) are the most medial fibers followed by trunk fibers, lumbar fibers (lower limb) and then sacral fibers (perianal sensation)</p> <p>2/ The <u>posterior columns</u> comprise a medial and lateral tract, termed respectively the fasciculus gracilis and fasciculus cuneatus. They convey 1st order sensory fibres subserving fine touch, vibration and proprioception, mostly uncrossed, to the gracile and cuneate nuclei in the medulla the 2nd order fibres decussate, pass to the thalamus and 3rd order fibres are relayed to the sensory cortex. So: Any lesions of the posterior column cause loss of fine touch, vibration and proprioception sense on the ipsilateral side of the body below the site of the lesion</p>

Blood supply

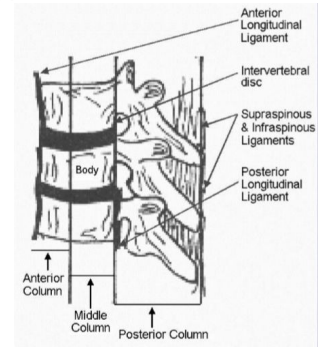
The arterial blood supply to the spinal cord is derived from two branches of vertebral artery, the anterior and two posterior spinal arteries. So, if anterior spinal artery is injured that's it, the anterior 2/3 of the spinal cord is gone (infarcted). However posterior spinal infarctions are less common, due to the **dual posterior spinal artery** and the pial collateral network.



The three columns

Denis three column model proposes that the **thoracolumbar** spine can be divided into three columns. Vertebral body has 70% of weight bearing function that's why they are occupying 2 columns and the posterior elements of the vertebra occupy 1 column.

- The first column includes the anterior longitudinal ligament (ALL) up to the first half of the vertebral body.
- The second column includes the second half (posterior half) of the vertebral body, up to, and including the posterior longitudinal ligament (PLL).
- The third column includes the pedicles, spinal cord/theclal sac, lamina, transverse processes, facet joints, spinous process, and the posterior ligaments (supraspinous, interspinous, and ligamentum flavum).



It is used to describe which injuries to the thoracolumbar spine is considered "unstable". If the injury involved **one third or less of the spine** (= one column or less) - it is considered a "stable injury" and it is **managed conservatively**. If the injury involved **two third or more of the spine** - it is considered an "unstable injury" and it is **managed by surgery**.

Acute spinal injury

Incidence and Significance

- 50,000 cases per year. It is common.
- **40-50%** involving the **cervical** spine
- 25% have neurologic deficit
- Age: mostly between **15-24 years**
- Gender: mostly **males** (3:1)

Mechanism of Injury

- MVA: 40-55%
- Falls: 20-30%
- Sports: 6-12%
- Others: 12-21%

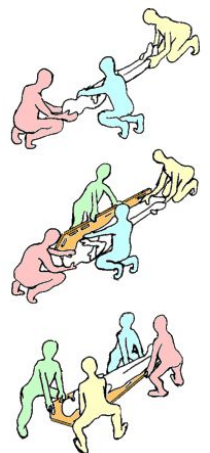
Assessment of the spine injured patient



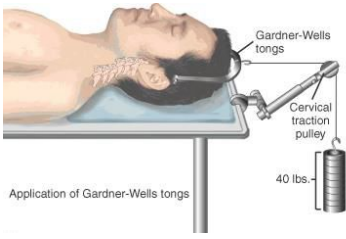
1/ Immobilization

Trauma patients are usually assessed at the scene by paramedics and then they are transported to the hospital. The assessment at the scene is very important. So every trauma patient that presents in the emergency needs to be immobilized with **cervical collar and spinal board** and spinal injury is assumed in every patient to prevent further neurological deficit that can happen if the patient was not immobilized.

At the scene, one member of rescuer team stabilizes head and neck in neutral position without applying traction. Another rescuer should apply a cervical collar. Then rescuer 1 stabilizes the head and neck and the others perform log-rolling to place the patient in the spine board. Even with the collar in place, Rescuer 1 must maintain the head and neck in a neutral position until the log-rolling maneuver is complete.

Once the patient is transported safely to the hospital we can use **cervical traction**.



	 <p>It has holes in the sides for the straps and it also have handles for carrying the patient. The head of a child is bigger than that of an adult; placing a paediatric patient on a standard spine board could cause dangerous flexion of the head. Different type of spine board has to be used only in paediatric patients in order to ensure the correct and safe neutral position for the spinal column with the ideal alignment of the airways</p>	
cervical collar	spine board	cervical traction

2/ History

- **Mechanism of injury:** compression, flexion, extension, distraction. (Each one of them can cause one kind of injury that's why it is extremely important)
- Head injuries and facial injury (it can lead to cervical spine trauma)
- Seat belt injury (People who are wearing a lap belt only → can lead to chance injury which is also known as seat-belt fracture)

3/ Physical examination

- Inspection (ecchymosis, swellings, open wound...), palpation (tenderness, gaps, steps,)
- Neurologic examination. ISNCSCI by ASIA (american spinal injury association). [click here](#). **PLEASE READ IT**

It is important to perform the neurovascular examination. So you need to examine the patient (dermatome and myotome neurological evaluation) in order to know the level of injury and to know if an immediate intervention is needed to save the patient's life. The higher the level of injury (NLI), the greater will be the impact on the body.

RIGHT			LEFT		
MOTOR KEY MUSCLES	SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)		SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)	MOTOR KEY MUSCLES	
	C2			C2	
	C3			C3	
	C4			C4	
UER (Upper Extremity Right)	Elbow flexors C5			C5 Elbow flexors	UEL (Upper Extremity Left)
	Wrist extensors C6			C6 Wrist extensors	
	Elbow extensors C7			C7 Elbow extensors	
	Finger flexors C8			C8 Finger flexors	
	Finger abductors (5th finger) T1			T1 Finger abductors (5th finger)	
Comments (Non-key Muscle? Reason for NT? Pain?)					
	T2			T2	
	T3			T3	
	T4			T4	
	T5			T5	
	T6			T6	
	T7			T7	
	T8			T8	
	T9			T9	
	T10			T10	
	T11			T11	
	T12			T12	
	L1			L1	
LER (Lower Extremity Right)	Hip flexors L2			L2 Hip flexors	LEL (Lower Extremity Left)
	Knee extensors L3			L3 Knee extensors	
	Ankle dorsiflexors L4			L4 Ankle dorsiflexors	
	Long toe extensors L5			L5 Long toe extensors	
	Ankle plantar flexors S1			S1 Ankle plantar flexors	
(VAC) Voluntary Anal Contraction (Yes/No)	S2			S2	
	S3			S3	
	S4-5			S4-5	
RIGHT TOTALS (MAXIMUM)	(50)	(56)	(56)	LEFT TOTALS (MAXIMUM)	(50)

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.

B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments (S4-S5) by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body. (This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3 .

D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3 .

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.

Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

1) Determine sensory levels for right and left sides. Examine all dermatomes from C2 to S5 (right & left). and then put a score according to your findings

0 = absent, 1 = altered, 2 = normal or NT = not testable (if patient's GCS is 3 for example)

Don't forget the deep anal pressure¹ (DAP) as a part of sensory examination. DAP may be the only evidence of an incomplete injury (in the absence of S3 or S4-5 sensation and VAC)

¹ A gentle pressure is applied to the anorectal wall by the examiner's finger. Perceived pressure is graded as absent or present.

2) Determine motor levels for right and left sides. Examine all myotomes → upper & lower extremities (right & left) + voluntary anal contraction (VAC)². and then put a score according to your findings

NT = not testable, 0 = paralysis, 1 = visible contractions, 2 = active movement with gravity elimination, 3 = active movement against gravity, 4 = active movement against some resistance, 5 = active movement against full resistance (functional movement means power is 3 or more)

3) Determine the neurological level of injury (NLI)

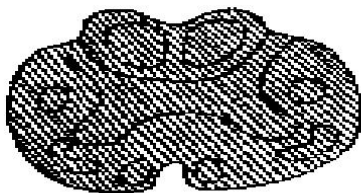
4) Determine whether the injury is Complete or Incomplete. If there is absent voluntary anal contraction + absent Deep anal pressure + absent perianal sensation → it is considered as complete injury or grade "A". Otherwise, injury is Incomplete. Intact VAC and S4-5 is associated with a good prognosis

5) Determine ASIA Impairment Scale (AIS) Grade. E = normal, D & C & B = incomplete, A = complete
B, C, D can be helped usually with surgery. A have a really poor prognosis. D can have a full recovery if there is an early diagnosis and intervention. **READ the pic on the right**

Before proceeding to investigation and management, you have to be familiar with different clinical presentations you might see in SCI

Spinal cord syndromes

Complete spinal cord injury



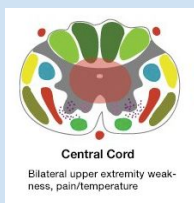
Complete cord transection

Complete spinal cord injury affects everything from the injury down.

- Flaccid paralysis below level of injury (complete cord transection causes spastic paralysis (UMN injury), but in acute settings they present with LMN injury (due to spinal shock) which will manifests as flaccid paralysis)
- May involve diaphragm if injury above C5. Injury in the upper part of the cervical spine is very dangerous (because C3,4,5 → phrenic nerve → supply the diaphragm) → our priority here is to keep patient alive. They need mechanical ventilation.
- Sympathetic tone lost if fracture above T6. Parasympathetic nerve fibers arise from craniosacral region while sympathetic fibers arise from thoracolumbar region and in case of spinal injury sympathetic nerve fibres are going to be affected → Unopposed vagal tone → vasodilation of all the vessels below the NLI → the blood will keep pooling and the pressure will drop and the patient will present with a “neurogenic shock”.

Incomplete spinal cord injury = Good prognosis for recovery

There are many incomplete SCI syndromes but these are the most common and they have good prognosis



Central cord syndrome

Upper limb > lower limb deficit. (with sacral sparing)

It is believed to be caused by spinal cord compression and central cord edema. Anatomy of spinal cord explains why upper extremities and hand preferentially affected as the hands and upper extremities (cervical, thoracic fibers), are located "centrally" in the tracts

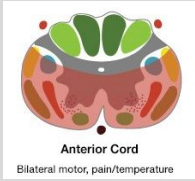
² The patient is asked to voluntarily contract the external anal sphincter around the examiner's finger. The contraction is scored as absent or present.



Brown-Sequard syndrome

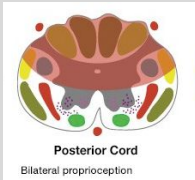
Caused by complete cord hemitransection
Usually seen with penetrating trauma
ipsilateral deficit → Posterior column (proprioception & vibratory sense) and Corticospinal (Motor deficit)
contralateral deficit → Spinothalamic (pain & temperature)
You need to rule out stroke. (check cranial nerve)

The others are rare and they are not related to trauma .. (wasn't mentioned in the slides)



Anterior cord syndrome

Anterior cord syndrome often occurs as a result of flexion injury, or due to injury to the anterior spinal artery. This may occur as a result of vascular or atherosclerotic disease in the elderly, or iatrogenic secondary to cross clamping of the aorta
Bilateral Loss → corticospinal (motor) & spinothalamic (pain, temperature)
preserved → DC (proprioception, vibratory sense)



Posterior cord syndrome

Extremely rare, vascular compromise appears to be the most common etiology. With occlusion to the posterior spinal artery, a Posterior Cord Syndrome will ensue.
(Remember we have 2 posterior spinal arteries. That's why it is very rare)

Other neurologic syndrome

Conus medullaris syndrome	<p>Conus medullaris: It is the terminal part of the spinal cord around L1/L2. It is the area between spinal cord and the cauda equina.</p> <p>Mixture of UMN deficits (Because spinal cord is injured → myelopathy) and LMN deficits (Due to damage of cauda equina → radiculopathy)</p> <p>So it is confusing clinically. In the x-ray you will see fracture around L1</p>
Cauda-Equina syndrome	<p>Cauda equina: They're peripheral nerves (LMN deficit) that haven't form plexuses yet, The lesion is usually around L4- L5 or L5 - S1.</p> <p>In general, PNS heals better than CNS and recovery is possible.</p> <ul style="list-style-type: none"> ● Urinary retention, bowel incontinence and saddle anesthesia ● Signs of CES include lower back pain, sciatica (L4,L5 is involved); foot weakness; saddle-type hypesthesia or anesthesia in the areas innervated by nerve roots S2 to S5; and retention or incontinence of urine, stool, or both. ● Causes: <ul style="list-style-type: none"> ○ Central disc herniation. ○ Burst fractures³ of lumbar spine. ○ Tumors compressing the lower spinal nerve roots. ○ Penetrating injuries such as stab wounds or bullets. ● Usually due to large central disc herniation rather than fracture ● It is a surgical emergency ● Requires full neurologic examination including rectal examination for anal tone ● Investigations: X-rays initially, but MRI is mandatory as X-rays are usually unremarkable. I need to see the nerve (It is a soft tissue) ● Treatment: Emergency decompression-usually discectomy- within 24 hours.
Nerve root deficit	<p>LMN deficits</p> <p>Patient with L3 fracture will present with ipsilateral weakness in knee extension and absent knee jerk loss of sensation in L3 dermatome with no other deficits.</p> <p>This is the simplest kind of neurological deficit and usually have the best outcome in term of prognosis. If fracture was fixed (decompression of L3) the patient will recover.</p>

³ Burst fractures are a type of compression fracture related to high-energy axial loading spinal trauma that results in disruption of the posterior vertebral body

The difference between “spinal shock” and “neurogenic shock”

Spinal shock This is neurological and transient

- Transient loss of spinal reflexes below the NLI (= LMN injury)
- Lasts 24-72 hours

It is a state of loss of motor and sensory as well as total loss of reflexes after an injury or trauma happens. It starts after a few minutes from injury though it may take several hours for the effects to fully manifest. It is manifested by a flaccid areflexia post spinal cord injury. As edema around the cord resolves, symptoms will improve over a period of time (24 -72 hours usually). This is associated with poor prognosis because it means a disconnection between brain and spinal cord.

Neurogenic shock This is a true “shock”

- Reduced tissue perfusion due to loss of sympathetic outflow and unopposed vagal tone → Peripheral vasodilatation. Usually noted with lesions above T6.
- Rx: fluid resuscitation. No vasoconstrictor is given (why?) we are concerned with tissue perfusion here!!! So only give IV fluids to increase intravascular volume → redistribution of fluid from vessels to the tissue.

4/ Investigation (Imaging)

Paramedics brought the patient safely, You took the spine board off, You have done your ABCD evaluation and the patient is managed initially, you examined the patient and now you know the NLI. Order X-ray according to where is the lesion.

1) X-rays:

- Cervical → 3 views: AP, lateral and open mouth⁴.
- Thoraco-lumbar → 2 views: AP & lateral
- Flexion-Extension views.⁵

2) CT: best for bony anatomy

3) MRI: best to evaluate soft tissue

5/ Management of Spinal Injuries

Depends on: (1) Level of injury. (C3 Vs. L5? totally different consequences). (2) Degree and morphology of injury: STABILITY. (3) Presence of neurologic deficit. (4) Other factors (Pathological fracture Vs. High energy trauma)

- Some general rules:
 - Stable injuries are usually treated conservatively
 - Unstable injuries usually require surgery
 - Neurologic compression requires decompression

Specific Injuries

Cervical spine fractures

- Descriptive: depends on mechanism of injury
 - Flexion/extension
 - Compression/distraction
 - Shear
- Presence of subluxation/dislocation
- SCI:
 - High fracture results in quadriplegia
 - Low fracture results in paraplegia

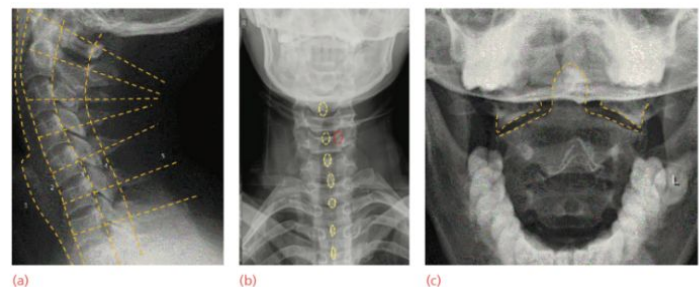
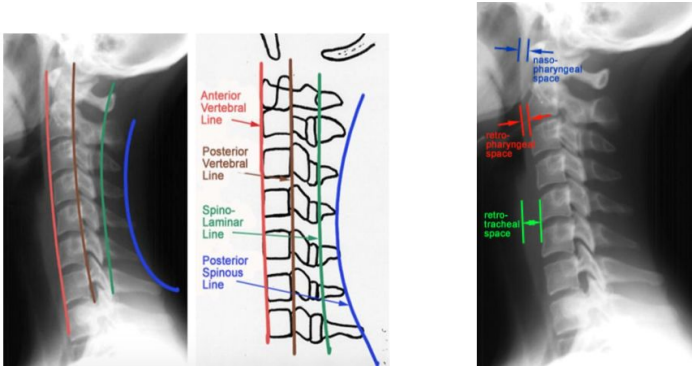



Figure 28.11 Cervical spine – normal X-ray findings (a) In the lateral projection, the radiological lines are: 1 soft-tissue line; 2 anterior vertebral body line; 3 posterior vertebral body line; 4 spinolaminar line. 5 The lines of convergence are drawn down the spinous processes and should converge posteriorly; these help identify posterior element disruption. (b) AP view confirms alignment of the spinous processes. (c) Open-mouth view should show a centrally placed dens with congruous and symmetrical C1/C2 lateral mass joints.

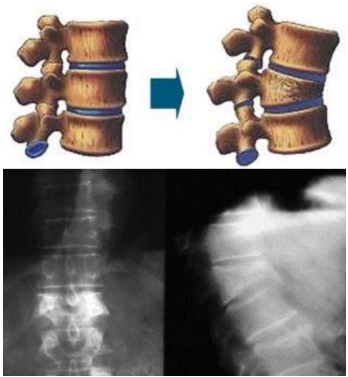
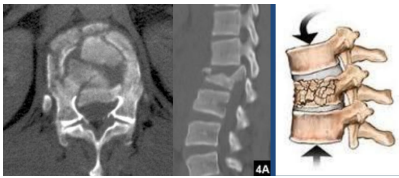
⁴ An open mouth view is a special view → AP view of C1 and C2 vertebrae.

⁵ Do not do it in trauma patient as it may cause iatrogenic spinal cord injury. You might do it later.

Normal lateral X-ray	Here what do you see?
	
<ul style="list-style-type: none"> The lateral view must include the occiput and T1, otherwise an injury at the cervicothoracic junction could be missed. If the cervicothoracic junction cannot be seen, the lateral view should be repeated while the patient's shoulders are pulled down. If this fails, then a CT scan is required. The alignment should be normal (checked by drawing lines) The soft-tissue shadows. Increased soft tissue space anterior to upper cervical vertebrae indicates hemorrhage from fractures. (In front of C2 = 6mm / In front of C6 = 22mm) 	<p>Over 50% anterior subluxation of C5 over C6 Spine is Unstable.</p>

Thoracolumbar fractures

- Spinal cord terminates at L1/2 disc in adult (L2/3 in a child)
- 50% of injuries occur at **Thoracolumbar junction** (why?) Most injuries of the thoracolumbar spine occur in the transitional area – T11 to L2 – between the somewhat rigid upper and middle thoracic column and the flexible lumbar spine.

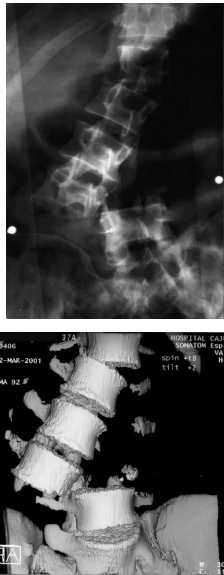
Common Thoracolumbar fractures		
<p>Wedge fracture (flexion/compression)</p>		<p>This is by far the most common vertebral fracture and is due to severe spinal flexion. The posterior part of the vertebral body, pedicles, laminae and spinous processes are intact. Pain may be quite severe but the fracture is usually stable (one third or less of the spine - anterior vertebral body only = anterior column only). Neurological injury is extremely rare.</p>
<p>Burst Fracture (compression)</p>		<p>Severe axial compression may 'explode' the vertebral body. The posterior part of the vertebral body is shattered and fragments of bone and disc may be displaced into the spinal canal. The whole vertebral body is affected = anterior column and middle column (sometime posterior column is affected as well) Most of the time is unstable.</p>

Chance Fracture
(flexion/distraction)
= jack-knife injury
= seat-belt fracture



Combined flexion and posterior distraction may cause the mid-lumbar spine to jack-knife around an axis that is placed anterior to the vertebral column.
This is seen most typically in **lap seat-belt injuries**, where the body is thrown forward against the restraining strap. **In clinical Exam you will feel a gap.**
The tear passes transversely through the **bones** (spinous process, the transverse processes, pedicles and the vertebral body) or the **discoligamentous structures, or both.**
This is a three columns injury = **unstable** injury.
X-rays may show horizontal fractures in the pedicles or transverse processes, and in the AP view the apparent height of the vertebral body may be increased. If it was in the ligaments the x-ray will be normal, but in clinical examination you will feel the gap, and there will be severe tenderness upon palpation.

Fracture dislocation



All three columns are disrupted and the spine is grossly unstable. These are the most dangerous injuries and are often associated with neurological damage to the lowermost part of the cord or the cauda equina. There will be coronal and sagittal loss of alignment on X-rays.

Pathological fractures

- Usually due to infection or tumor
- Low-energy fractures. Fractures may occur even with normal stresses if the bone has been weakened by a change in its structure.
- Osteoporotic is common. What is the most common cause of pathological fracture? Osteoporosis
- X-rays: “winking owl” sign. The (absent) pedicle sign. The pedicles have an extensive blood supply that's why they are affected first.
- You need to treat the fracture and the underlying cause.

