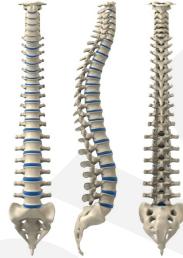


Spinal Cord Injury, Cord Syndromes, Initial Management and Imaging



Mr M J H McCarthy
Consultant Spinal Surgeon



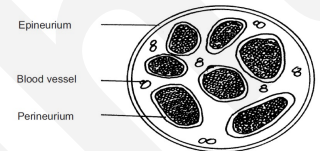
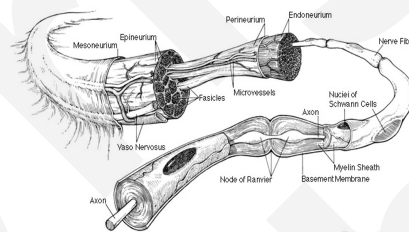
Aims / Objectives

- Cord Anatomy
- SCI
- Cord Syndromes
- UMN / LMN
- Initial Management SCI / Spinal Trauma
- Radiology

Nerve Structure

- Nerve fiber is a single axon, within an endoneurium (loose connective tissue)
- Fascicle is a bundle of fibers within a perineurium (coarse connective tissue)
- Nerve is a bundle of fascicles within an epineurium (tough fibrous sheath)

Nerve Structure



Schematic representation of a cross-section of a typical individual nerve fibre.

Spinal Cord Anatomy

- Protected by vertebral column, meninges, cerebrospinal fluid and vertebral ligaments
- Meninges
 - dura mater, arachnoid, pia mater
 - Inflammation = meningitis



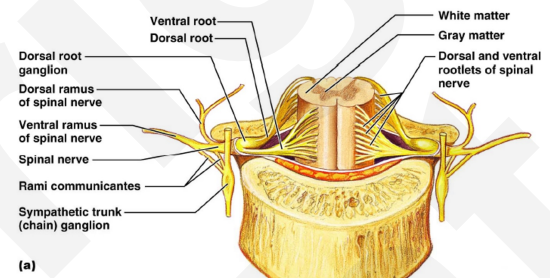
Spinal Cord Anatomy

- Continuation of medulla oblongata
- Terminates approx second lumbar vertebra
- Tapered portion = conus medullaris, from which arise the filum terminale and cauda equina

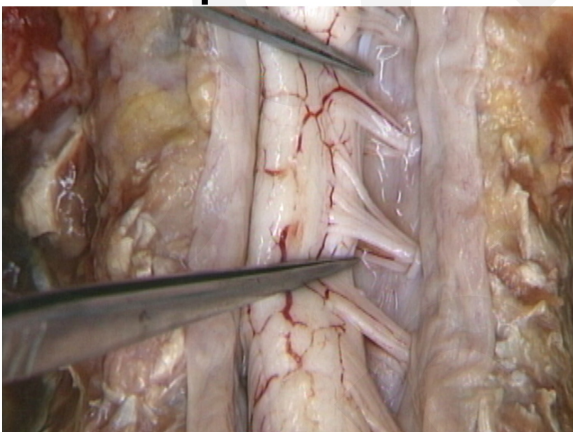
Anatomy - Neural

Roots

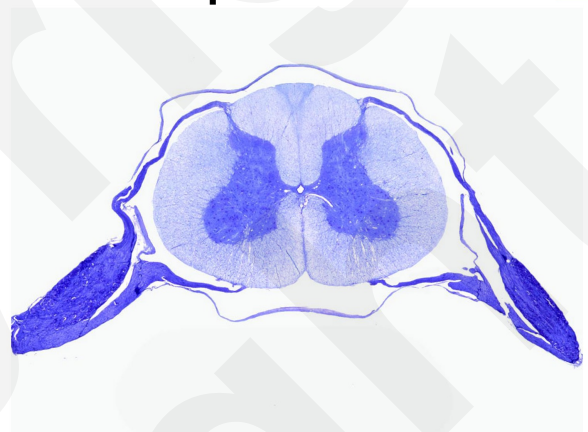
- Dorsal root + DRG = sensory
- Ventral root = motor (cell bodies in grey matter)
- Unite = spinal nerve
- Dorsal ramus = to the back
- Ventral ramus = to the front
- Sinuvertebral nerve = to the spinal column



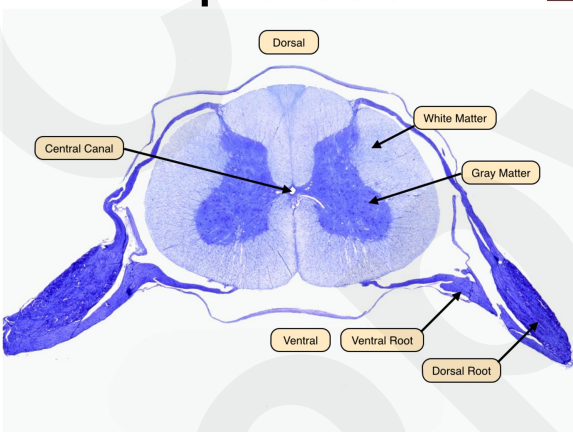
Spinal Cord



Spinal Cord



Spinal Cord

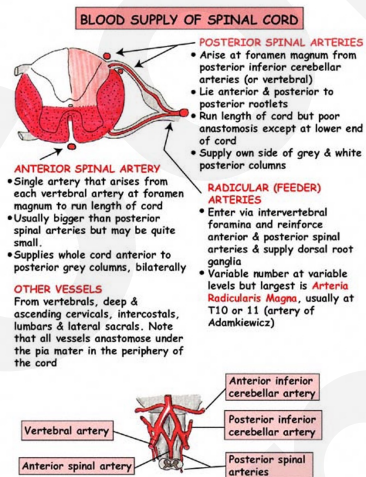


Spinal Cord

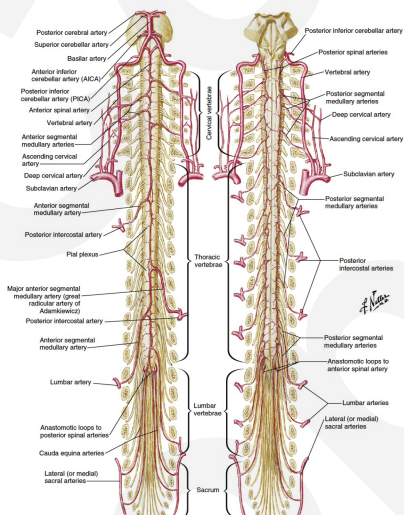
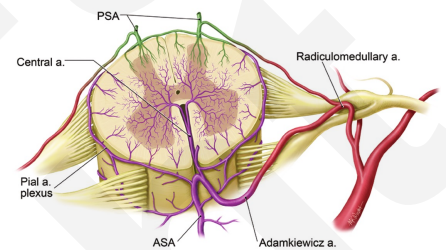
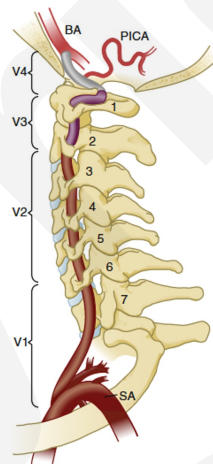
- Grey Matter
 - Neuron cell bodies
 - Deep in spinal cord
- White matter
 - Mainly myelinated axons
 - Bundles – Tracts
 - Superficial in spinal cord

Spinal Cord

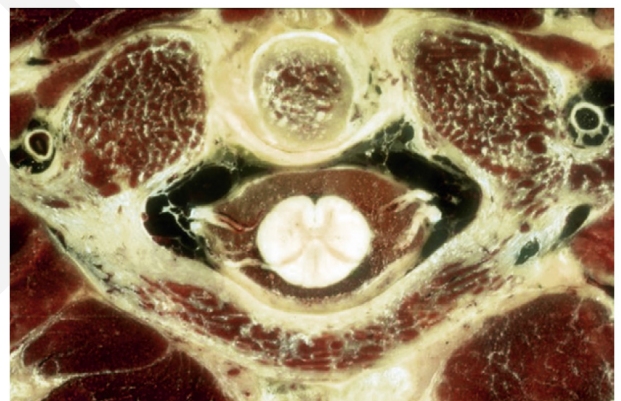
- Grey Columns - central
 - Anterior Horn - motor
 - Alpha, Gamma and small neurons
 - Cell bodies motor fibres going to trunk / limbs
 - Lateral Horn - sympathetic
 - Posterior Horn - sensory
 - Partially laminated (I and II well defined)
 - I and II nociception, temperature, itching
 - III and IV mechanical pressure
 - V and VI proprioception, nociception
 - Cell bodies sensory relay going to brain (2nd order)
 - Cell bodies of sensory fibres in DRG (1st order)

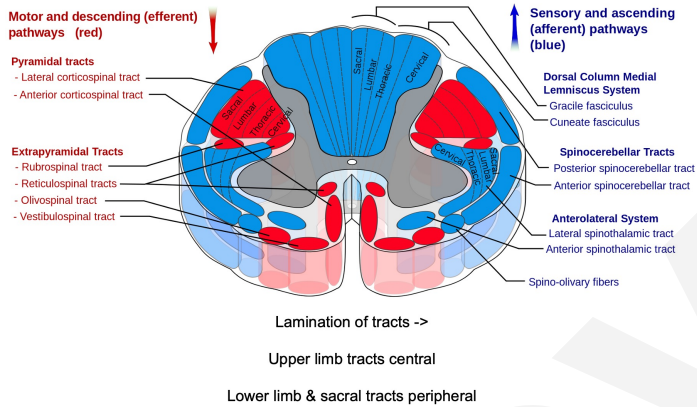


- White Columns - peripheral
 - Dorsal
 - Vibration, Proprioception and Discriminative Touch
 - Anterolateral
 - Pain, Temperature, Light Touch and Pressure

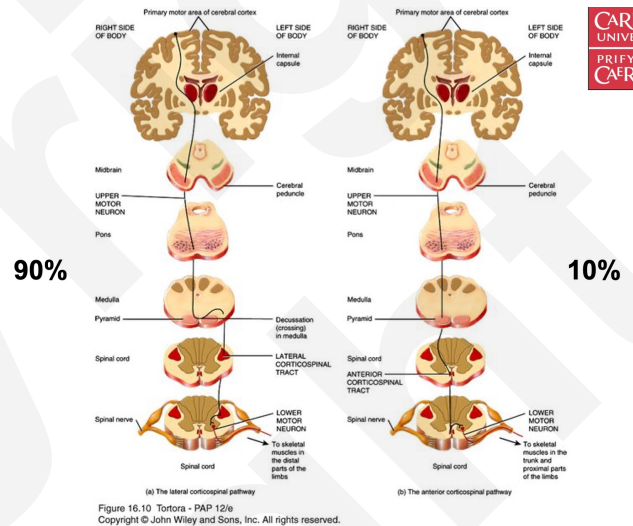
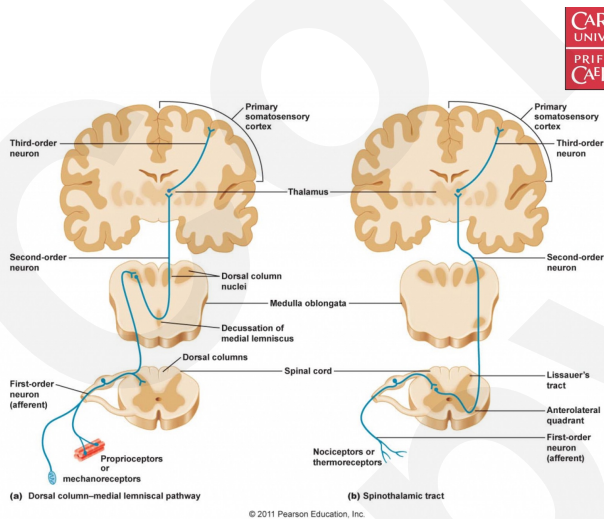


Spinal Cord





Pathway	Direction	Origin	Cross-over	Destination	Function
Corticospinal *	Descending	Motor cortex	90% as lateral CST; 10% as anterior CST	Alpha motor neurons	Skilled motor to extremities
Reticulospinal	Descending	Reticular formation	Variable levels	Alpha and gamma motor neurons	Cortical control of voluntary motor function
Rubrospinal	Descending	Red nucleus	Immediate	Alpha and gamma motor neurons	Facilitate flexors, inhibit extensors (for balance control)
Vestibulospinal	Descending	Vestibular nucleus	None	Alpha and gamma motor neurons	Facilitate extensors and inhibit flexors (for balance control)
Lateral spinothalamic *	Ascending	Free nerve endings	Immediate	Posterior central gyrus	Pain, temperature
Anterior spinothalamic *	Ascending	Free nerve endings	Variable levels	Posterior central gyrus	Light touch and pressure
Posterior column: fasciculus gracilis and cuneatus *	Ascending	Meissner's corpuscles, Pacinian corpuscles, muscle spindle, tendon organs	None	Posterior central gyrus	Discriminative touch, vibration sense, proprioception



UMN vs LMN

Spinal Cord Injury (SCI)

Sign	UMN Above AHC	LMN In / Below AHC
Weakness	More diffuse	More focal
Atrophy	Mild general	Severe focal
Atrophy vs Weakness	Severe weakness Mild atrophy	Severe atrophy Mild weakness
Fasciculations	Never seen	+/-
Muscle Tone	Increased	Decreased
Muscle Stretch Reflexes	Increased	Decreased / Absent
Clonus	+/-	Never present
Plantar Response	+/-	Absent

- Primary / Secondary
- Complete / Incomplete
- Cord Syndromes

In another lecture!

Spinal Cord Injury

- Primary (at the time of injury)
- Secondary (occurring after the injury)
- **Complete spinal cord injury**
 - no sensation or voluntary motor function below the level of the injury
- It can only be confirmed **after the resolution of spinal shock** when reflex activity has returned
- The level of the injury is defined as the first with useful partial neurological function >3/5
- The overall prognosis for recovery of neurological function in complete lesions is poor

Spinal Cord Injury

- **Incomplete spinal cord injury means that there is some function caudal to the injury**
- In general, the greater the function the faster the recovery and better the prognosis
- Sacral sparing after spinal cord injury
 - the presence of sacral sensation, voluntary rectal tone and great toe movement
 - indicates intact long tract neurones and the potential for recovery
- Prognostic for predicting recovery except in lesions involving the conus medullaris or cauda equina

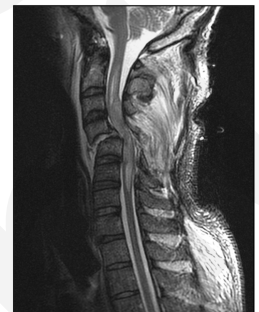
Pathophysiology SCI

- Primary injury:
 - Initial insult to cord
 - Local deformation
 - Energy transformation
 - Mainly COMPRESSION



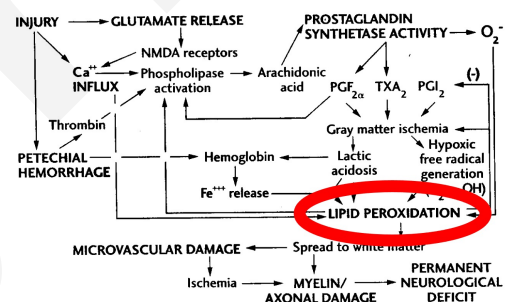
Pathophysiology SCI

- Transient Neurapraxia
- Oedema
- Haemorrhage
- Transection

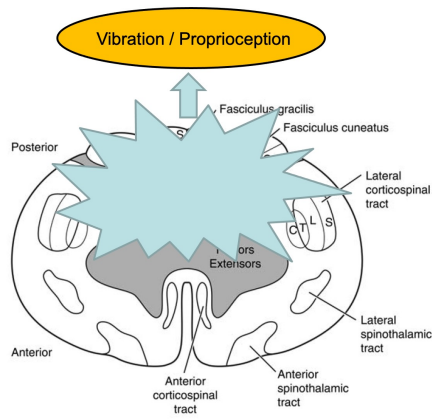


Pathophysiology SCI

- Secondary injury
 - Biochemical cascade
 - Cellular processes
 - Therapy aims to reduce the secondary injury

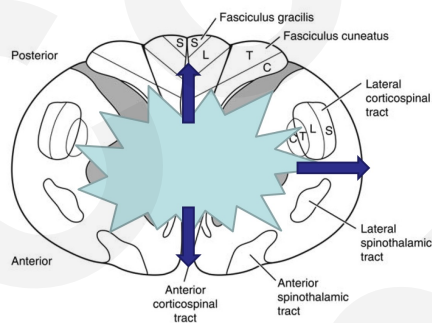


**Hypoxia
Hypoperfusion**



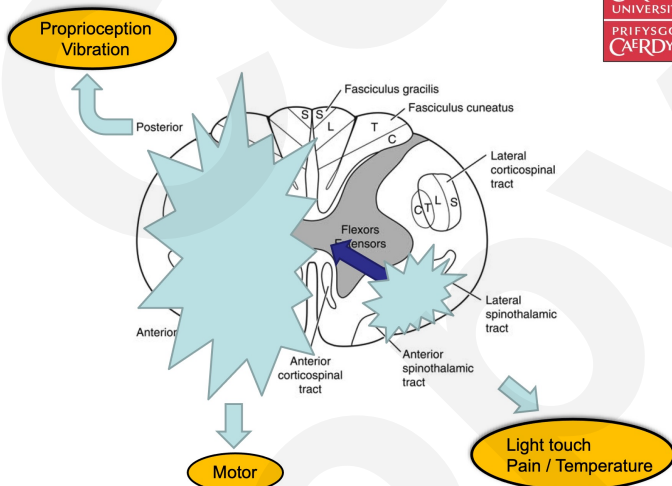
Posterior Cord Syndrome

- Rare
- Loss of proprioception, vibration and 2 point discrimination
- Motor preservation



Central Cord Syndrome

- Cervical spondylosis
- Bilateral spastic paralysis
- Sacral sparing
- Upper limbs > Lower limbs – Cape distribution
- Recovery pattern LL > bladder > UL > sensory



Brown Sequard

- Usually penetrating injury
- Ipsilateral paralysis
- Dissociate anaesthesia - loss of ipsilateral proprioception / vibration & contralateral pain / temp / light touch / pressure
- Best prognosis for ambulation

Summary of Tracts

The diagram illustrates a cross-section of the human brainstem with the following labeled structures and findings:

- Gracile fasciculus**: A small blue-shaded area in the dorsal midline.
- Cuneate fasciculus**: A larger blue-shaded area in the dorsal lateral region.
- Ipsilateral loss of tactile discrimination and position and vibration sensation from leg**: Points to the blue-shaded dorsal midline area.
- Ipsilateral loss of tactile discrimination and position and vibration sensation from arm**: Points to the blue-shaded dorsal lateral area.
- Ipsilateral spastic paresis**: Points to the right lateral region.
- UMN – above AHC**: A red label indicating upper motor neuron involvement above the anterior horn cell.
- Ipsilateral loss of position & motion sense**: Points to the right lateral region.
- Contralateral loss of pain and temperature sensation one segment below lesion**: Points to the left lateral region.
- Ipsilateral flaccid paralysis in affected myotomes**: Points to the right lateral region.
- LMN – at below AHC**: A red label indicating lower motor neuron involvement at or below the anterior horn cell.
- Bilateral loss of pain and temperature sensation within dermatomes of involved segments**: Points to the bilateral ventral lateral regions.
- Other labeled structures**: corticospinal tract, spinocerebellar tract, Dorsal horn, Ventral horn, spinothalamic tract, and Ventral white commissure.

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LMN



Suspecting Spinal Injury

- Mechanism of Injury
- Unconscious
- Neurological Deficit
- Spinal Pain / Tenderness

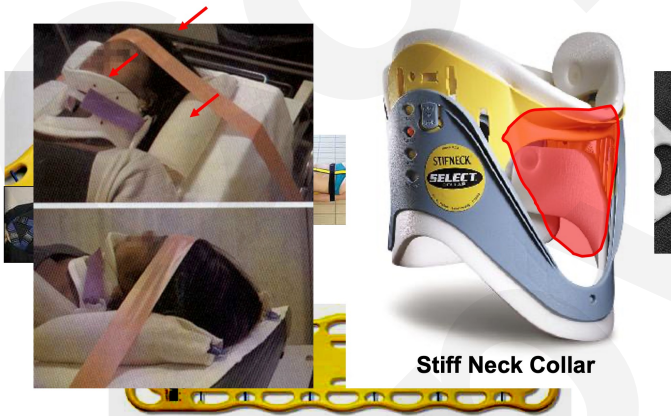
Goals of Spine Trauma

- Protection
 - Detection
 - Optimize conditions for neuro recovery
 - Maintain / restore spinal alignment
 - Minimize loss of spinal mobility
 - Obtain healed and stable spinal column
 - Rehabilitation
- #s = Manage the ass soft tissue injury

Management Spinal Injury

- ABCDE / ATLS Approach (not typical H&Ex)
- Protection - **THINK SPINAL CORD INJURY**
 - Maintain airway with spine control
 - Always aim to have a team of 6 for transfers (min 4 for log rolls)
- Detection
 - Level of injury
 - Complete or Incomplete cord injury
 - Spinal or Neurogenic shock
- Management
 - Conservative or Surgical treatment

Immobilise Entire Spine



The Spinal Board

- Transport device
 - Remove ASAP
 - Regular log rolls
-
- Pressure sores
 - Same goes for some collars...

Assessment

- **History**
 - Pain
 - Mechanism
 - Immediate post injury neurology
 - Associated injury
- **Examination**
 - Spine
 - Tenderness
 - Gap
 - Step
 - Marked spasm
 - Spinal cord
- **Imaging**

Examination

- Spinal Cord
- Partial / Complete SCI
 - Sensory level
 - Sensory modality
 - Motor level
 - Sphincter tone
 - Bulbocavernosus reflex

ASIA Chart

Examination

SCI in the Unconscious Patient

- Flaccid areflexia
- Diaphragmatic breathing
- Pain response above clavicle
- Bradycardia / Hypotension
- Priapism



“Shock”

- Refers to a state of inadequate organ perfusion and tissue oxygenation
- Hypovolaemic – Haemorrhagic or fluid loss
- Tension Pneumothorax
- Cardiac Tamponade
- Cardiogenic
- Neurogenic
- Septic
- Anaphylactic

Pump Failure (incl Obstructive)
Circulatory Failure

Spinal “Shock”

- Refers to the flacid paralysis, areflexia and lack of sensation secondary to physiologic spinal cord “shut down” in response to injury
- Usually resolves within 24 hours when reflex arcs caudal to injury return
- Lowest that can be tested clinically
 - bulbocavernosus reflex
- **Importance of spinal shock**
 - **determining whether a patient has a complete or incomplete spinal cord injury**

Neurogenic Shock

- State of inadequate tissue perfusion and oxygenation due to:
- Reduced sympathetic outflow (T1-L2) with resultant unopposed vagal tone
- Hypotension due to loss of blood vessel tone with resultant venous pooling
- Bradycardia due to reduced cardiac stimulation
 - distinguishes neurogenic shock from other types of shock (e.g. hypovolaemic, cardiac, anaphylactic)

Spinal Injury Screening

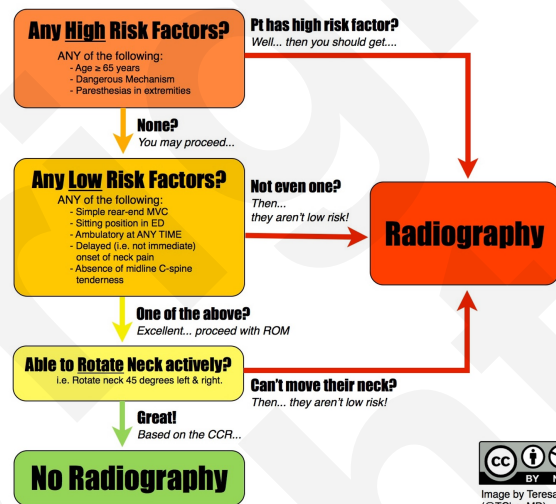
- Clinically
 - Cooperative patient
 - Alert and orientated
 - Able to concentrate on spine
 - Normal neurological exam
 - No spinal pain or tenderness
 - No pain or tenderness with voluntary movement

Table 1. NEXUS criteria for low-risk cervical spine fracture

- No midline cervical tenderness
- No focal neurological deficit
- Normal alertness
- No intoxication
- No painful, distracting inquiry

Spinal Injury Screening

- Altered consciousness or symptoms
 - Radiological imaging required
 - Presume the spine is unstable
 - Protect
- Canadian C Spine Rule to follow:



Clinical Instability

The loss of the ability of the spine under physiological loads to maintain its pattern of displacement so that there is no initial or additional neurological deficit, no major deformity and no incapacitating pain



Stable ↔ Unstable

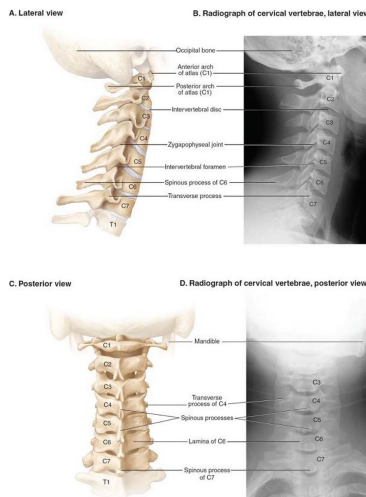
Spinal Injury Screening

- Lateral Cervical X-Ray
 - Detects 85% cervical fractures
- Image the entire spine
 - 10% with one fracture have another non contiguous injury

Orthopaedic Principles



Get
Orthogonal
Views



Development XR

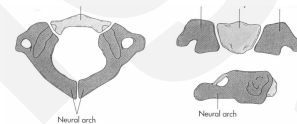
- < 6 months
 - C1 invisible, synchondroses open, VBs wedged anteriorly, no lordosis
- 1 yr
 - Body C1 visible
- 3 yrs
 - Spinous process synchondroses fuse, dens ossifies
- 3-6 yrs
 - Neurocentral body and C2-odontoid synchondroses fuse, anterior wedging of VBs resolves

Development XR

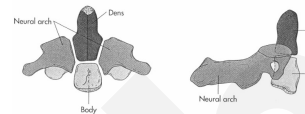
- 8 yrs
 - Pseudosubluxation and predental widening resolve, lordosis normal
- 12-14 yrs
 - 2° ossification centres spinous process tips, summit ossification odontoid fuses, sup / inf epiphyseal rings on VBs
- 25 yrs
 - Secondary ossification centres on tips spinous processes fuse, sup / inf epiphyseal rings on VBs fuse

Ossification Centres

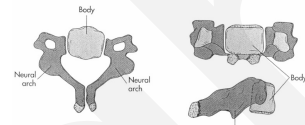
C1



C2

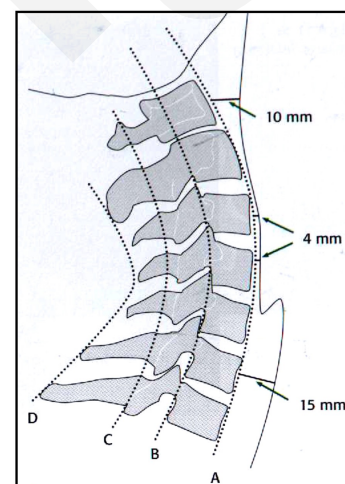
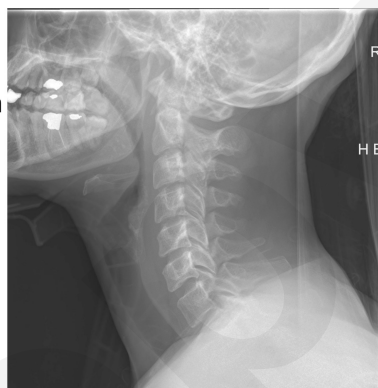


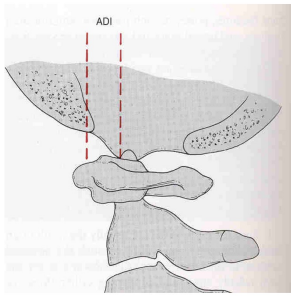
C3-L5



Lateral C Spine XR

- Name / Age
- Date
- Type of Radiograph
- A : ADEQUACY / ALIGNMENT
- B : BONE
- C : CARTILAGE
- D : DENS
- E : EXTRAAXIAL SOFT TISSUE





Atlas Dens Interval (ADI)

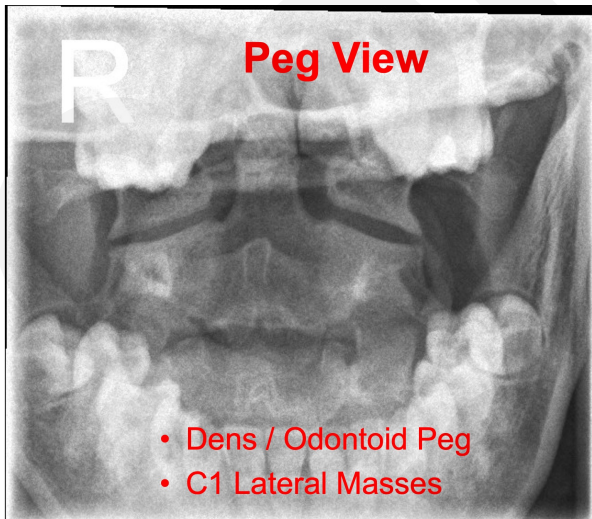
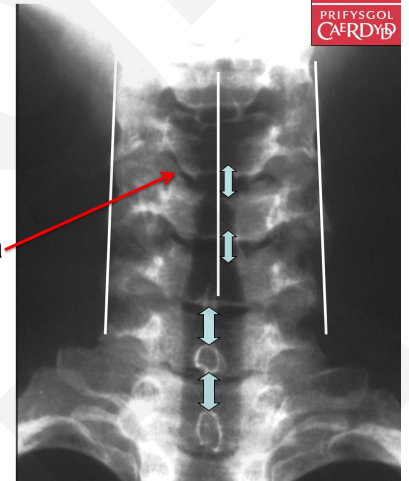
ADI = 3mm (<5mm)

Steels Rule of Thirds at C1

- 1/3 Peg
- 1/3 Cord
- 1/3 CSF

AP View

- Alignment
- Vertebral Bodies
- Lat Masses
- Joints of Luschka
- Sp Processes
- Discs



CT Indications

- Poly trauma – CT Head to Hips
- Plain Radiographs have failed to visualise all the cervical spine
 - Cervico-thoracic junction
 - Intubated patient (no odontoid peg view) – continue brain CT down to C3
- Plain Radiographs show injury
 - Confirm and further categorise extent of injury

MRI in Spinal Trauma

- Overview for exclusion of injury in difficult cases (ankylosing spondylitis)
- Ligamentous injury
- Unexplained neurology
- Prognosis in neurological injury
 - Compression vs oedema vs haemorrhage vs transection
- Is surgical fixation safe?
 - Extruded disc may be made worse by surgical manipulation / Other discs ligaments may be injured



Erect XRs

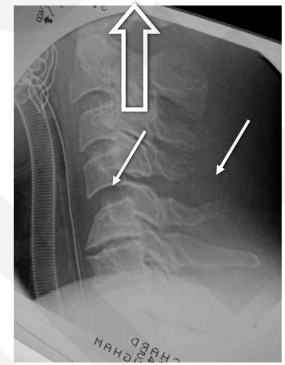
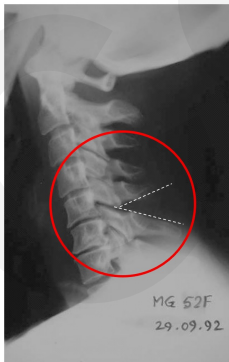
- Normally after discussion with specialist
- Load bearing - physiological
- Normally done in collar
- Useful adjunct after a CT showing a “stable injury” – checks for development of load bearing deformity and ligament injury (cf def of instability above)

Dynamic XRs



- Normally after discussion with specialist
- Physiological
- Normally done at 2 weeks post injury to check for stability or after treatment in a collar to ensure no latent instability
- Flexion and Extension X-Rays

Traction Films



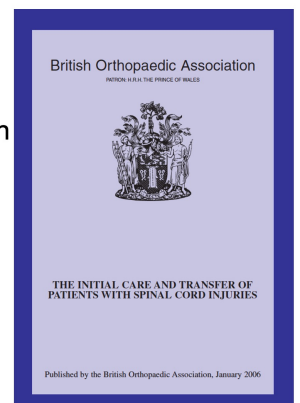
Spinal Cord Injury Without Radiological Abnormality (SCIWORA): Is It Still a Notable Definition?

Orhan Buyukbeceri^{1*}, Onur Bilge², Burcin Karali³, Burak Kutluhan Kacira⁴, Harun Kutahya⁵ and Mustafa Igik¹

- Rare
 - 0.5% of paediatric spinal trauma
- SCIWORA
 - No fracture, no ligament injury, no extraneural compression
 - Oedema / haemorrhage / infarct / transection / concussion
- SCIWONA (N=Neuroradiological)
 - Nil at all on imaging – prognosis good

Spinal Cord Injury (SCI)

- Of 569 patients admitted to Spinal Cord Injuries Centre in UK:
 - 9% missed at presentation
 - 5% experienced further avoidable deterioration
 - 1/3 of those missed had significant head injury
- Multiple Fractures in 5%
- Use of Steroids
 - NOT recommended



Consequences of SCI



- (Paralysed...)
- Inadequate ventilation
- Abdominal evaluation compromised
- Occult compartment syndrome

Management Spinal Injury



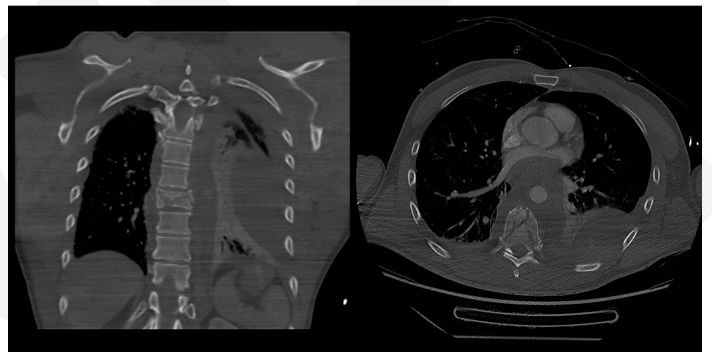
- Treat life threatening injuries first
- Ventilation and Oxygenation
- Maintain blood pressure
- Maintain spinal cord perfusion

Management Hypotension



- In Major Trauma:
- Haemorrhagic shock until proven otherwise
- Consider neurogenic shock
- Monitor urine output

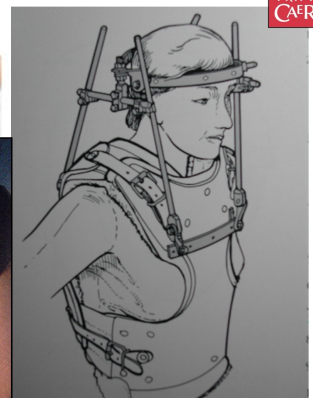
Hypotensive Bradycardic...



Indications for Conservative Treatment



- Stable Fracture
- Some Polytrauma patients
- Unfit for surgery
- Osteoporotic bones



Spinal Surgery



Principles

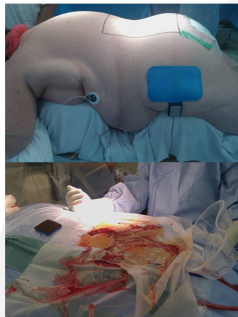
- Anatomic Reduction
- Stable Internal Fixation
- Atraumatic Technique
- Early Active Mobilisation / Rehabilitate

Decompress – Direct / Indirect
Realign
Stabilize
Prevent Late Pain / Deformity

- Cord Transection / Haemorrhage / Oedema / Compression

The Personalities

- Personality of the patient
 - Age
 - Comorbidity
 - Bone stock
 - Energy of injury / other injuries
 - Time since injury



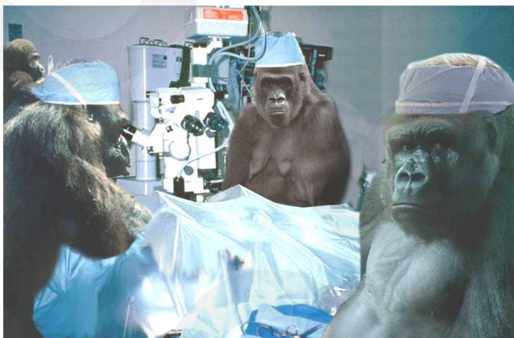
The Personalities

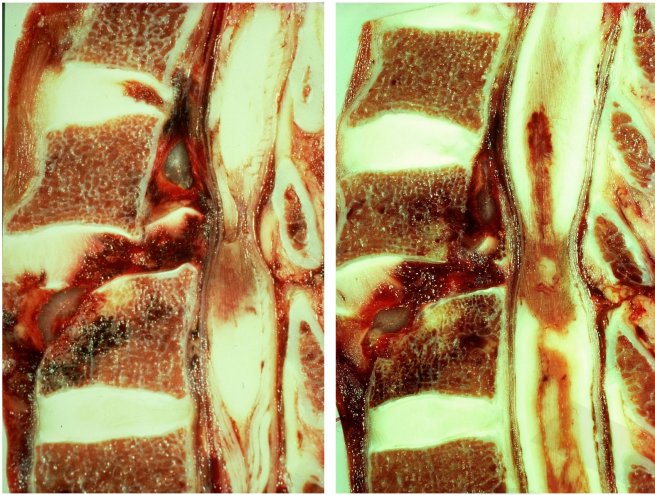
- Personality of the fracture
 - Canal compromise
 - Neurologic compromise
 - Kyphosis / Scoliosis
 - Anterior collapse
 - Progression



The Personalities

- Personality of the surgeon





Complications SCI

- Pneumonia
- Postural Hypotension
- DVT / PE
- Autonomic Dysreflexia
- Renal Failure
- Pseudo-obstruction
- Sexual Dysfunction
- Pressure Sores
- Psychological Problems

Outcomes Paralysis 1

- 25yr tetraplegic >60% normal life expectancy (level below C5)
- 25yr paraplegic >80% normal life expectancy
- 25yr partial paraplegic with mobility >85% normal life expectancy
- 90% of patients with complete tetraplegia will recover some level of function in the muscles below the neurologic level of injury

Outcomes Paralysis

- MRC 1-2/5 at 30 days have 97% chance progressing to 3/5 at 1 year
- MRC 0/5 at 30 days only 57% recover to 1/5 and 27% to 3/5 at 1 year
- 80% of patients with incomplete paraplegia recover to grade 3/5 in their hip flexors and knee extensors at 1 year (enough to stand with aids)



Remember the 7p's



**Pay attention to the detail
Never let your guard down**



Summary

- Remember ABCDE / ATLS
 - Treat life threatening injuries first
- Protect then Detect
- Think second injury

