



## **Cervical Spine Injuries: Who, What, Where, When, and Why**

Cervical spine trauma is one of the most devastating injuries of patients presenting to the emergency department. The lecturer will discuss the clinical presentations of spinal injuries in adults and children and examine the use of plain radiography, CT scanning, and MRI. A comprehensive review of normal and abnormal plain radiographs will be presented. Interventions for the unstable cervical spine injury will also be discussed, as will the clinical approach in the emergency department to possible cervical spine injury.

- Discuss the indications and limitations of plain radiographic views of the cervical spine.
- Describe the limitations of flexion-extension views, CT scanning, and MRI in the evaluation of patients with spinal injuries.
- Discuss the interventions in cervical spinal trauma.
- Describe the impact of the NEXUS study on the practice of emergency medicine.

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## **FACULTY**

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# Traumatic Diseases of the Spinal Cord

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## Examination of the spinal cord

### Spinal cord - general

- extends from base of skull to L2
- diameter of spinal canal must be > 11 mm in neck
- bony level not = neuro level
  - C6-7 bony = C8 neuro
  - T10 bony = T12 neuro

### Two column support structure

#### Posterior column

- spinal canal
- pedicles - cylindrical
- transverse processes - from junction of lamina and pedicle
- articulating facets
- laminae - flattened
- spinous processes
- nuchal ligament complex
  - supraspinous, interspinous, and infraspinous
- capsular ligaments
- ligamenta flava - connects laminae; elastic to allow for flexion

#### Anterior

- bodies and discs
- anterior and posterior longitudinal ligament

## Essential spinal cord anatomy

### Dorsal columns

- position, vibration, and fine touch
- ipsilateral ascent in posterior columns cross at base of medulla to thalamus to cortex
- sacral fibers medial, cervical lateral

### Lateral corticospinal tract

- motor cortex crosses in medulla contralateral lateral CS tract anterior motor horn cells ventral root
- about 10% descend the ipsilateral ventral CT tract, then cross at dermatome level
- crossed and uncrossed fibers
  - bilateral innervation
  - able to perform crude trunkal movements in spite of unilateral lesion
- medial fibers to arms, lateral to legs

### lateral spinothalamic tract

- pain and temp
- enters cord, synapses in dorsal horn gray matter crosses within 2 cord segments after entering SC and going up
  - contralateral thalamus cortex

- also synapses with anterior motor horn, and above and below dermatome (the hot stove)

### **ventral spinothalamic tract**

- simple touch and pressure
- ipsi and contra: enters SC, axon synapses in dorsal gray AND sends axon up about 10 spinal segments, synapsing in dorsal gray. Both of these secondary neurons then cross over to ventral ST tract thalamus
- thus, need bilateral damage to abolish touch in thoracolumbar lesions

### **Autonomic system**

- originates in hypothalamus
- sympathetic vs. parasympathetic
- why not all Horner's?

### **Horner's and pupillary responses**

- both constrict with light no III nerve
- dim dilate
- larger pupil dilates in dim smaller pupil is Horner's (C7-T2)
- test visual fields separate and together (parietal lobe)

### **Neurologic Findings in spinal cord syndromes**

#### **Central cord**

- intubation
- syringomyelia
- most common in older men
  - cervical spondylosis and stenosis
  - hyperextension
  - can occur with flexion injuries
  - the man with a bruise on his head and quadriplegia, arms > legs

#### **Central cord**

- central gray (anterior motor horn cells)(LMN) and central portions of pyramidal(UMN) and spinothalamic tracts affected
  - also picks up crossing pain fibers
- upper extremities >> lower extremities, with hands and fingers affected the most
- with large lesions, quad + sacral sparing
- sensory deficit variable - most severe in hands and fingers
- painful hyperaesthetic state

#### **Central cord**

- at thoracolumbar junction - mixed conus medullaris and cauda equina lesion
- below conus medullaris - cauda equina injury
  - lower motor neuron, flaccid, bowel and bladder
- in pediatrics, can be delayed, occur after seemingly trivial trauma
  - whiplash injury in child abuse
- prognosis ~ speed of recovery
  - about 50% able to walk subsequently

Rivello et. al. Ped Emerg Care 1990; 6:113  
Morse, AEM 11:436, 1982

### **Cruciate paralysis of Bell**

- damage to pyramidal decussations in lower medulla/high cervical
- difficult to distinguish from central cord
- upper extremities >> lower
- injuries near foramen magnum  
e.g. odontoid
- if lateral: ipsi (crossed) arm, contra (uncrossed) leg

### **Brown Sequard**

- penetrating injuries mostly
- also lat mass Fx of C-spine, rotational injuries
- ipsi motor and position/vibration, contra pain/temp (several levels below injury), normal bowel and bladder
- ipsi hypersensitive to pin
- crude touch OK
- loss of parietal peritoneal pain fibers(unilateral) occult abdomen without muscle rigidity (remember this in stab/GSW)
- good to excellent prognosis
- majority recover to walk OK

### **Anterior cord**

- affects corticospinal and spinothalamic tracts, anterior motor horn cells
- paralysis + hypalgesia, normal posterior column (crude touch, position, vibratory)  
note: crude touch may be spared through either posterior or spinothalamic tract
- flexion injury, bony fragment, disk, anterior spinal artery
- always rule out a compressive lesion
- poor prognosis

### **Posterior cord**

- rare
- fractures of the lamina
- proprioceptive loss in lower extremities with spasticity  
difficulty walking in spite of good motor function

### **Vertebral artery syndrome**

- chiropractic manipulation of neck
- cervical injury
- other causes of vascular occlusion
- medulla/pons/cerebellum/spinal cord/occipital lobe

## **Examination**

### **Terminology**

- "complete" - no sparing
- level + last intact functioning spinal cord level  
C5 nl, C6 gone = C5 level  
C5 nl, C6 partial, C7 none = C5  
incomplete/C6complete

### **Gradation of strength**

- 0 nothing
- 1 twitch
- 2 move on bed
- 3 gravity
- 4 resistance
- 5 normal

### **Sensory testing**

- isolated roots may have normal sensation  
other roots may overlap enough
- watch out for "shawl" area of C4  
C5-T1 go to arm  
C4 adjacent to T2 over chest
- light touch - posterior column
- pin - lateral spinothalamic
- crude touch - anterior spinothalamic

### **Sensory testing**

- sensory - move from area of sensation to sensation
- deterioration correlates with cephalad movement of level of hypesthesia
- any sparing at or below lesion 50% of functional motor recovery
- if complete for 24 hours 99% stay that way  
during the first 24 hours, the lesion may seem complete but recovery is possible

### **Sacral sparing**

- perianal sensation
- normal sphincter tone
- flexor toe movement

### **Spinal shock**

- days to several weeks, whether complete or incomplete
- symptoms
  - sweating absent
  - flaccid paralysis and anesthesia
- when resolved hyperreflexia
- functional transection lasts < 24 hr
- returns with bulbocavernosus (signifies end of spinal shock)
  - finger in rectum tug on penis rectal contraction
  - if positive at 24-48 hours, but no motor/sensory grim prognosis

### **Spinal cord injury - vascular**

- extradural hematoma (e.g. anticoagulant patients)
- epidural
- if deficit x-ray findings think of vascular injury
  - e.g. lower C7 injury compress vertebral artery during its course through foramen transversarium
  - blood flow through ant. spinal artery (originates at C1) C1 level from C7 injury
  - radicular artery of Adamkiewicz enters at L1 with branches to T4. Therefore, L1 injury T4 level

### **Clearing the neck**

**Who needs x-rays**

- altered mental status
- central pain in neck
- significant head or facial trauma
- hypotension of ? etiology
- other painful injuries + suspicious mechanism of injury
- minor injury but major symptoms
- underlying bony/ligamentous disease  
osteoporosis, rheumatoid arthritis, Ca
- the "no risk" patient doesn't  
99% CI - need about 30,000 patients

**Distribution of injuries**

- C1 3%
- C2 5%
- C3 6%
- C4 21%
- C5 37%
- C6 20%
- C7 8%

**Can we pick out the one with the injury?**

- Jacobs et. al. AEM 15:44, 1986: sens 46%, spec 94%
- Cadoux et. al. AEM 16, 738, 1987: no
- McKee et. al. J Trauma 30:623, 1990: THE famous case

**Which and how many views?**

- Three vs. five view
- Flexion-extension views
- CT  
3D reconstructions
- tomos
- MRI
- the man from Elmhurst

**How long does it take to get them?**

- Yale, prospective  
12% positive  
43% missed on the lateral  
definitive clearance: 1.8 to 181 hours  
median 15 hours

**"Safe" Techniques**

- slowly pull on arms
- walk fingers down sides
- touch shoulders
- dilemma - paralysis involving muscles which pull shoulder down unopposed forces in opposite direction.  
This patient needs C7-T1 interface the most  
swimmer's, CT, oblique  
the taxi driver from Iran
- upper thoracic - swimmer's, off lateral, CT, tomo

**CTLV**

- Alignment  
with foramen magnum



anterior margins of cervical vertebrae  
 posterior margins of cervical vertebrae  
 spinolaminar line  
 tips of spinous processes  
 predental joint space
 

- ◆ 3 mm adult
- ◆ 5 mm child

 pseudosublux C2 and C3 children
 

- ◆ about 20% of < 8 y.o.
- ◆ while subluxed, C1-3 spinolaminar lines should line up

 normal variants vs. trauma

### Foramen magnum

- clivus posterior 1/2 of odontoid
- spinolaminar line (connecting bases of spinous processes) should hit the posterior foramen magnum
- odontoid process should be within 4 mm of anterior margin of foramen
- air cells of mastoid project over region of spinal canal

### AP view

- vertical alignment of the center of the spinous processes
- lateral margins
- vertebral bodies
- uncinat processes

### Open mouth odontoid

- atlanto-occipital joint
- atlanto-axial joint
- odontoid
  - ?midline position
- lateral edges

### Obliques

- pedicles - cylindrical
- intervertebral foramina
- facet alignments
- lamina - flattened

### Flexion-extension

- ?how dangerous
- alert and cooperative patient
- muscle spasm may false negative
- can definitely pick up things missed by normal XR
- look for:
  - anterior sublux
  - widening of spinous processes
  - change in the predens space

### Accuracy of standard X-ray views

- CTLV - misses 15%
- 3 views - misses < 5%
- 5 views - misses < 3 views
- how do we get to 100%?

### Standard measurements



- body of C2 - 7 mm
- C3/4: < 1/2 body width
- C6 to trachea: 22mm adult, 14 mm children  
Clark et. al. Skeletal Radiology 3:201, 1979
- incidence of swelling with bony injury
  - 49%
  - 63% of anterior
  - 29% of posterior
 Miles et. al. Injury 19: 177, 1988

### **Retropharyngeal soft tissue measurements**

- large overlap between normal and abnormal
- criteria many false positives (>50%)  
Templeton, et. al. Skel Radiol 1987, 16:98

### **We should x-ray elsewhere (?automatically??)**

- 212 with spinal injuries. 64% had double level injuries.  
Delay in Dx 28%. Conclusion: high energy + CNS  
change check the whole thing. If identify one area ->  
check all areas. (?referral bias ortho for simple L-spine?)  
Powell et. al. Toronto. J Trauma 29: 1146, 1989
- 400 patients 2/3 had other Fx (average 2.4)  
Charlton et.al. JAMA 242:1073; 1979  
Miller et. al. Am J Roent 130: 659, 1978
- 63 spine injuries. 8% had injuries at multiple levels.  
Pal et. al. Montreal. J Trauma 28:1282, 1988
- 817 with spinal Fx. 6.4% had discontinuous injuries.  
Possible that more were diagnosed later.
  - ♦ Keenen et. al. J Trauma 30:489, 1990



## CAT Scans

### CT clarifies the plain film

- Mt. Sinai Med Center, Cleveland
  - 20 patients
  - XR vs. CT
  - conflicting results in 60%
  - 20% nl XR, abnormal CT
  - 40% abnormal XR, normal CT (?false + XR)
- Mace, Ann Emerg Med 14:973, 1985

### CT clarifies what's on the plain films

- 179 CT
  - 54 with + or ? XR CT (+) in 39 of 54
  - Sx, (-)XR 2 (+) CT
  - 123 CT for inadequate XR one fx
- Borock et al J Trauma 1991; 31:1001-1006

### CT

- may miss horizontal Fx
- may miss subluxation
- advantages of tomo
  - small compression Fx
  - odontoid fx
- ?role of 3D CT

### Scary paper

- WOW. Because of 3 patients with nl CSXR + CT, they took 50 patients with significant head trauma
    - 12 + CT for ICH
    - 4 of these + CT for C1-3 injuries not seen on CSXR.
- Kirshenbaum et. al. JEM 8:183, 1990

### CT indications

- CS inadequate
- normal XR, markedly positive symptoms
- XR suspicious
- + XR will pick up additional fractures and rule out false positive findings
- look at spinal canal (bony fragments, disc, hematoma)
  - MRI number one for this
- ? altered mental status

### MRI

- best for looking at spinal canal
- lacks high resolution for bones and fractures (esp. posterior element Fx)
- any neuro Sx or progression of Sx MRI

### MRI (cord) vs. CT (bone)

- 33 patients
  - bony abnormalities: CT 22 vs. 10 MRI
  - disc: MRI 19 vs. CT 7
  - transection, edema, hemorrhage, compression: MRI 13 vs. CT 0
- Levitt et. al. Am J EM 9:131, 1991

**Tomography**

- known injury, looking for others
- equivocal x-ray
- normal x-ray, suspicious patient

**Utility of tomography**

- 25% showed findings not seen on plain films
- 25% disproved suspicious plain films
- 40% of bony abnormalities identified by tomo not seen on plain films
- management changed in 12%  
Binet et.al. Spine 2:163, 1977

**Etiology and clinical course of missed spine fractures**

- 253 patients with spinal injuries  
1/3 assessed at tertiary care center
- delayed Dx in 15%, from 1-36 days
- secondary neurologic deficits  
in 1.4% if no delay  
in 10.5% if delay
- why missed?  
misread  
inadequate films  
not obtained  
Reid et.al. JTrauma 1987; 27:980

**Clearing the C-spine in the unconscious patient: how can we?**

- Study on neck injuries  
384 neck injuries  
141 neuro deficit without abnormal XR (37%)  
Hardy, Paraplegia 14:296; 1977

**Classification of injuries**

- flexion
- flexion-rotation
- extension
- vertical compression
- lateral hyperflexion
- vascular injury

**Flexion**

- pulls nuchal ligament complex (usually OK)
- wedge Fx of body  
posterior column intact
- teardrop Fx (ant inferior) - unstable  
fulcrum - tear posterior ligaments
- Clay shoveler's Fx - stable
- subluxation - unstable (usually anterior ligament is stable)

**Flexion**

- bilateral facet dislocation - quite unstable  
ant lig and annulus fibrosis torn  
bilateral locked facets: usually at least a 50%  
vertebral subluxation

- atlantooccipital dislocation - quite unstable
- odontoid Fx - generally unstable
  - Type I - fx through the tip
  - Type II - transverse fx at the base
    - ♦ many do not heal with halo surgery
    - ♦ most unstable
  - Type III - extends into body of C2
- Fx transverse process - stable per se

### Lateral hyperflexion

- (MVA broadside)
- transverse process fracture
- uncinat process fracture
- dens fracture with lateral displacement
- lateral wedge fracture
- obliques required to see injury well
  - Schaaf et. al. Skeletal Radiol 3:73, 1978

### Rotation

- unilateral locked facet (fixed - stable)
  - locked in place; stable; posterior ligament is ruptured
  - abrupt widening of laminar space
  - bow-tie
  - 25% sublux
  - deviated spinous process toward facet
- articular processes nearly vertical in lumbar region. Therefore, no locked facets. Rather, articulation is fractured unstable.

### Extension injuries

- C1 - posterior fracture
- Hangman's
  - bilateral fx thru pedicles (if rope is under chin)
  - increase the AP diameter of the spinal canal SC
  - often not injured
    - ♦ airway obstruction from swelling
    - has been reported from MVA with no direct impact to head (pure whiplash)

### Extension injuries

- extension teardrop
  - avulsed anterior-inferior ligament. Stable in flexion, not extension
- extension injury in the elderly
  - osteo + spondylosis extension injury from narrowed canal (ant. vertebral ridge pushing into cord + buckling of ligamentum flavum)
- the old man and the banister

### Vertical compression

- burst fracture. ligaments OK, but fragments impinge on spinal canal
- Jefferson - C1
  - fracture + disruption of transverse ligament
  - extremely unstable

note: with posterior fractures, no prevertebral swelling

- Jefferson vs. malformation of atlas  
Gehweiler et. al. Am J. Roent. 104:1083, 1983

### **Special Considerations in Children**

#### **Neck injury in children**

- < 8, most at C1-C2
- >12, normal distribution
- ~50% normal XR

#### **SCIWORA**

- distraction/stretching type of mechanism  
more horizontal facets
- usually complete + little recovery in younger children
- usually incomplete + recovery in adolescents  
Apple et. al. Pediatr Radio 17:45, 1987  
Jaffe et. al. AEM 16:270, 1987  
Hadley et. al. J Neurosurg 68:18, 1988  
Ruge et. al. J Neurosurg 68:25, 1988

#### **SCIWORA**

- Children's Hospital of Pittsburgh.  
55 children with SCIWORA
  - ♦ (67% of all children with spinal cord injury).  
Severe lesions C1-4 (90%) vs. C5-8 (15%)  
T1-6 worse than T7-12
  - ♦ pedestrian run over face down  
95% of severe below age 8.  
Delayed deterioration (hours to days) in 27%
  - ♦ most had transient initial symptoms: paresthesias,  
subjective paralysis, lightening sensation
  - ♦ 30 min to 4 days  
Recurrent cord injury in 15% after minor trauma  
Pang et. al. J Trauma 29:654, 1989

#### **Burning hands syndrome**

- football
- neurapraxia of the spinal cord
- extension injury at C6/7
- hyperextension or hyperflexion
- sensory - burning pain, numbness, tingling, loss of sensation
- motor - mild weakness paralysis
- transient (minutes to hours)
- recovery complete
- usually free of neck pain

#### **Burning hands syndrome**

- check for disc, spinal stenosis, congenital cervical fusion, instability  
if normal, ??subsequent risk
- may be the only complaint  
Maroon, JAMA 238:2049, 1977

#### **Immobilization**

- soft collar (hickeys)
- hard collar - ?C1/2 and C6/7
- how much does the neck move during application of collar?
- paralysis
- the X-ray tech
- leave 'em on for 3-4 hours
- occipital osteo
- discomfort from immobilization

### **Log rolling**

- cadaver with unstable lesion: 2 cm AP, 5 mm lat, 30 degrees rotation
- also in nl volunteer, patient with unstable fx  
McGuire, J Trauma 27: 525, 1987

### **Studies on immobilization and airway management**

- cadaver vs. human
- studies don't report % unstable fractures
- cric unproven
- recent study using bag valve mask
- would you report such a thing?
- technique for immobilization varies from study to study

### **Airway management options**

- BVM  
    ?the worst
- no traction
- orotracheal
- RSI  
    ?safely of cricoid pressure
- cricothyroidotomy

### **Realignment**

- by neurosurgeon
- surgery vs. traction  
    for identified lesions needing traction, roughly 5 lb per interspace to start
- thoracic and lumbar injuries  
    no traction  
    surgery

### **Neurogenic (systemic) shock**

- BP (fluids)
- HR changes
- ileus
- hypersecretion of acid
- dysfunction of the pancreatic sphincter
- no DTR's, no sensation, no bowel or bladder function, no sweating
- hypothermia
- aspiration

### **Treatment**

- steroids
- NG tube

- Foley
- avoid pressure necrosis

### Acute spinal injury

- methylprednisolone
- 30 mg/kg TBW over 15 min      wait 45 min      23 hours of 5.4 mg/kg/hr
- must be given within 8 hours
- did not include patients less than 13
- improvement ~ one level
- at one year follow-up:
  - Rx < 8 hr.      persistent improvement (p = 0.03)
  - Rx > 8 hr.      worse than placebo (p = 0.08)

### Acute spinal injury

- Naloxone
    - alone, no good in doses and regimen used
  - complications
    - wound infection 7.1% vs. 3.6 % placebo
    - GI bleed 4.5% vs. 3.0% - both NS
- Bracken et. al. 1990. NEJM 322:1405-1411.

### GM-1 ganglioside

- neuronal glycolipid component of cell membrane
- lab: stimulates growth of nerve cells and regeneration of damaged neurons
  - central gray matter highest metabolic rate, most sensitive to ischemic injury
  - white matter lower metabolic activity, cell bodies distant from site of injury
  - motor function can return to normal if 4-6% of cortical neurons regain connection
- randomized, small study (34)
- groups differed in severity (treated group worse)
- delayed (within 72 hours), prolonged compared to steroid treatment
- ?combination with steroids
  - Geisler, et. al. NEJM 1991; 324:1829

### Later complications

- DVT and pulmonary embolus
  - decubitus ulcers
  - contractures
  - spastic bladder (facilitates emptying)
  - post-traumatic cystic myelopathy (syringomyelia) in 1-2%
    - reported 3 months to 23 years, mean 4.7 years
    - can extend in either direction from the level of injury, usually dorsal
    - motor loss, intractable pain, hyperhidrosis, increased spasticity, autonomic dysreflexia, Horner's, respiratory compromise
- Eismont et. al. J Bone Joint Surg 1984a; 66A: 614  
Barnett et. al. 1966; Brain 89:159-174

### Autonomic dysreflexia

- any stimulus      stimulate segmental reflexes
- no inhibitory modulation from above

- occurs in 80% of quadriplegics
- bladder number one

**Autonomic dysreflexia**

- sweating
- facial flushing
- nasal congestion
- feeling cold
- pilomotor erection
- shivering
- throbbing headache
- nausea
- hypertension
- tachy or bradycardia
- mydriasis, conjunctival congestion

**Treatment of autonomic dysreflexia**

- treat symptoms
  - reverse Trendelenburg
  - ganglionic blockade
  - alpha blockade
  - nitroprusside
  - chlorpromazine
- search for stimulus
- take care: a thorough exam may precipitate more symptoms

**Enough, already.**

These notes, along with extensive references, will be posted at  
[www.viccellio.com/lectures/cspine.html](http://www.viccellio.com/lectures/cspine.html)

Any questions or comments – send to:

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