

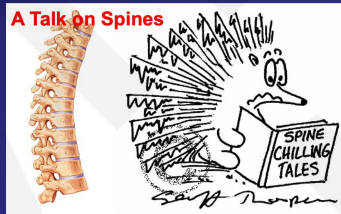
Military Spinal Injuries



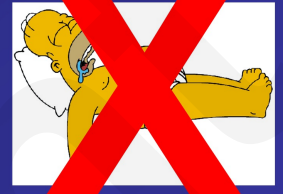
Mr M J H McCarthy
Consultant Spinal Surgeon



A Talk on Spines



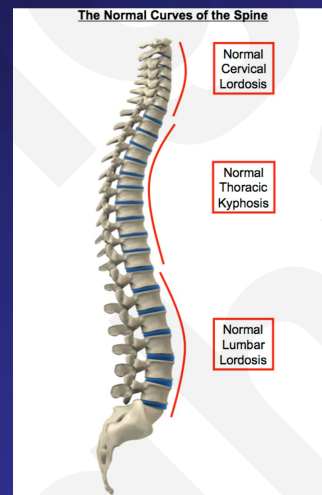
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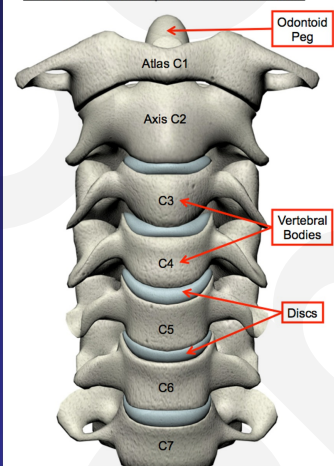
Introduction

- Anatomy and Biomechanics of the Spine
- Spinal Injury Epidemiology
- Spinal Injury Management
- Military Spinal Injuries

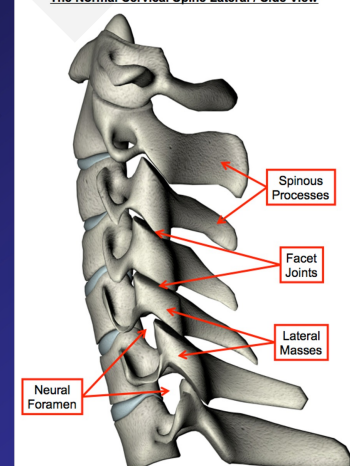
The Normal Curves of the Spine



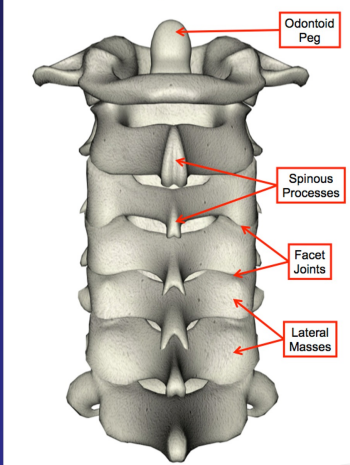
The Normal Cervical Spine Anterior / Front View



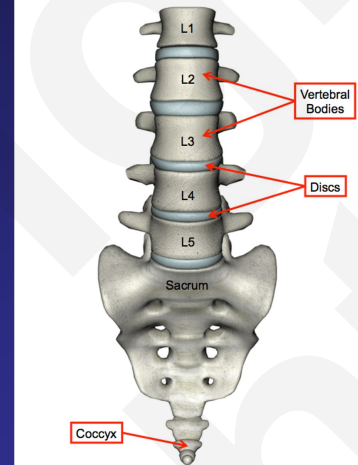
The Normal Cervical Spine Lateral / Side View



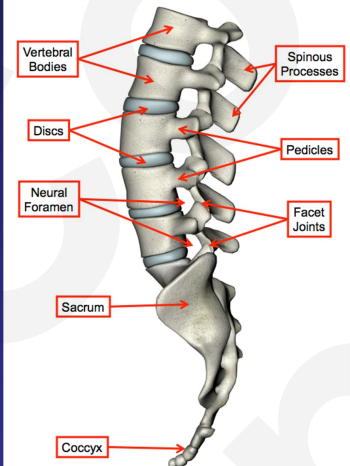
The Normal Cervical Spine Posterior / Back View



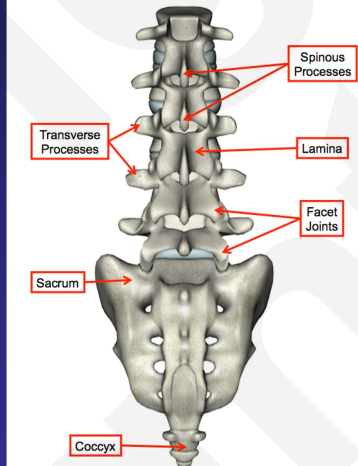
The Normal Lumbar Spine Anterior / Front View



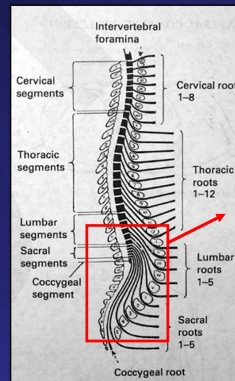
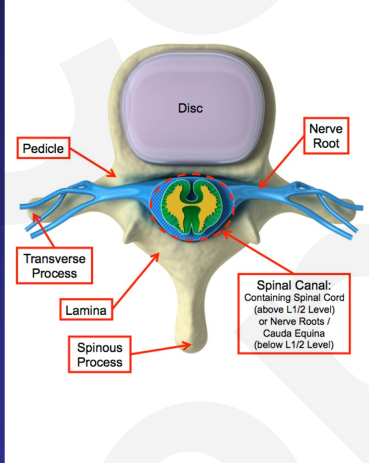
The Normal Lumbar Spine Lateral / Side View



The Normal Lumbar Spine Posterior / Back View



The Normal Spine in Cross Section



Illustrated Neurosurgery.
Lindsay et al. 1994; 2nd ed.: p.

Conus medullaris
(of spinal cord)

Cauda equina
"Horses tail"

L5 nerve root

L5 / S1 disc



Atlas of Human Anatomy.
McMinn et al. 1993; 3rd ed.: p91.

Patient Name _____
 Examiner Name _____ Date/Time of Exam _____

ASIA **STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY** **ISCS**

MOTOR
 KEY MUSCLES (Nerve roots in parentheses)

	R	L
C5	☐	☐
C6	☐	☐
C7	☐	☐
C8	☐	☐
T1	☐	☐
T2	☐	☐
T3	☐	☐
T4	☐	☐
T5	☐	☐
T6	☐	☐
T7	☐	☐
T8	☐	☐
T9	☐	☐
T10	☐	☐
T11	☐	☐
T12	☐	☐
L1	☐	☐
L2	☐	☐
L3	☐	☐
L4	☐	☐
L5	☐	☐
S1	☐	☐
S2	☐	☐
S3	☐	☐
S4	☐	☐

UPPER LIMB TOTAL (max 100) _____
 LOWER LIMB TOTAL (max 100) _____
 TOTALS (max 200) _____

SENSORY
 KEY SENSORY POINTS

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

PIN PRICK SCORE (max 100) _____
 LIGHT TOUCH SCORE (max 100) _____

Reflexes

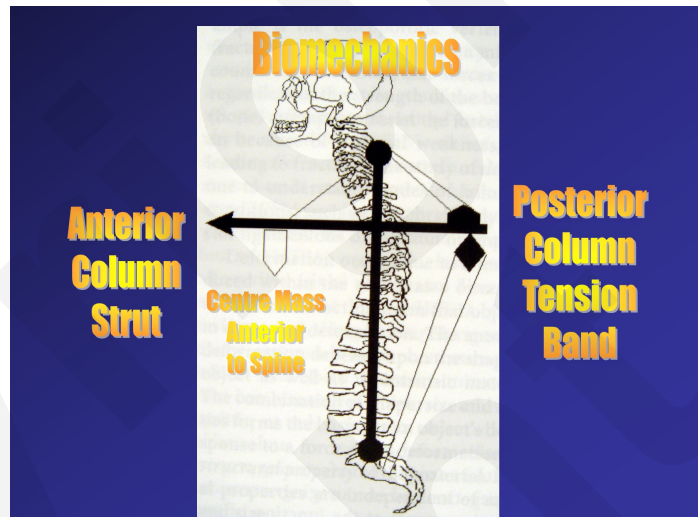
L2 ☐ Hip flexors
 L3 ☐ Knee extensors
 L4 ☐ Ankle dorsiflexors
 L5 ☐ Long toe extensors
 S1 ☐ Ankle plantar flexors

Voluntary anal contraction (VAC) ☐ S4-5

Any anal sensation (Yes/No) _____

NEUROLOGICAL LEVEL: _____
 SENSORY MOTOR: _____
 COMPLETE OR INCOMPLETE: _____
 ASSA IMPAIRMENT SCALE: _____

Key Sensory Points



Spinal Cord Injury

- 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

British Orthopaedic Association
HERIOT WATSON THE PRINCE OF WALES

THE INITIAL CARE AND TRANSFER OF PATIENTS WITH SPINAL CORD INJURIES

Published by the British Orthopaedic Association, January 2006



Suspecting a Spinal Injury

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

Goals of Spine Trauma Care

- Protection
- Detection
- Optimize conditions for neuro recovery
- Maintain / restore spinal alignment
- Minimize loss of spinal mobility
- Obtain healed and stable spinal column
- Rehabilitation

Management of Spinal Injury

- ABCDE / ATLS Approach
- 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 The Entire Spine



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

Examination

- **SCI in the Unconscious Patient**
 - Flaccid areflexia
 - Diaphragmatic breathing
 - Pain response above clavicle
 - Bradycardia / Hypotension
 - Priapism

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 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

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
 - Probably not possible in the field

Spinal Injury Screening

- Altered consciousness or symptoms
 - Radiological imaging required
 - Presume the spine is unstable
 - Protect

Spinal Injury Screening

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

CT Indications

- 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

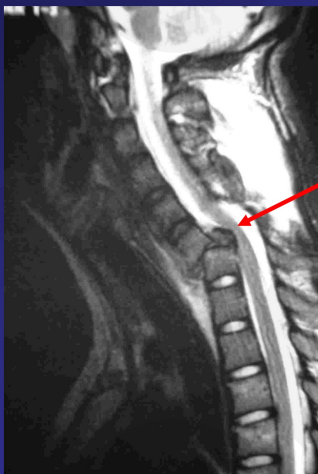
- Overview for exclusion of injury in difficult cases (ankylosing spondylitis)
- Ligamentous injury
- Unexplained neurology
- Prognosis in neurological injury
- Is surgical fixation safe?
 - Extruded disc may be made worse by surgical manipulation

Radiology of Cervical Spine

dislocation with
normal neurology

MRI

reduction



DISC

The Spinal Board

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

Consequences of SCI

- Inadequate ventilation
- Abdominal evaluation compromised
- Occult compartment syndrome

Management of Spinal Injury

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

Management of Hypotension

- Haemorrhagic shock until proven otherwise
- Consider neurogenic shock
- Monitor urine output



- Echelon 1
 - In the field – combat medics
 - Echelon 2
 - Forward surgical team: gen surgeon / orthoped
 - Echelon 3
 - Combat support hospital within field of operation
 - CT scanner
 - Echelon 4
 - Regional Medical Centre (Germany)
 - Echelon 5
 - Military treatment facility
- Transfer usually 24-48hrs

The military medical management of missile injury to the spine: A review of the literature and proposal of guidelines N Buxton

- Resuscitation
 - Assessment
 - Stabilisation
 - Evacuation
-
- Civilian GSW 2nd-3rd most common cause of SCI in USA

- 2000 to 2009
- 4048 cervical spine fractures in 13,813,333 service members Rate 0.29 per 1000
- Ass SCI 70 per million

- Operation Iraqi Freedom
- The Surge - 4122 soldiers
- 7.4% (29 / 390) spinal injuries
- Blunt / explosive injuries 65%
- Open injuries 7%

Spinal Column Injuries Among Americans in the Global War on Terrorism

James A. Blair, MD, Jeanne C. Patzkowski, MD, Andrew J. Schoenfeld, MD, Jessica D. Cross Rivera, MD, Eric S. Grenier, MD, Ronald A. Lehman Jr., MD, Joseph R. Hsu, MD, and the Skeletal Trauma Research Consortium (STRC)

- 2001 – 2009 OIF OEF
- 10,979 evacuated casualties
- 598 Spine +/- SCI (5.5%)
- 17% SCI
- 72% Blunt : 33% Penetrating (5% Both)
- 56% Explosion : 29% MVC : 15% GSW

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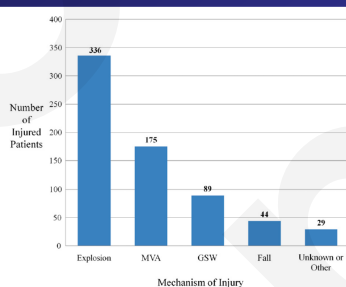


Fig. 5
Mechanisms of injury causing spinal injuries in Operation Iraqi Freedom and Operation Enduring Freedom. The value associated with each bar represents the number of individual service members injured by that mechanism. Note that many service members sustained spine injuries from multiple mechanisms of injury. MVA = motor vehicle accident, and GSW = gunshot wound.

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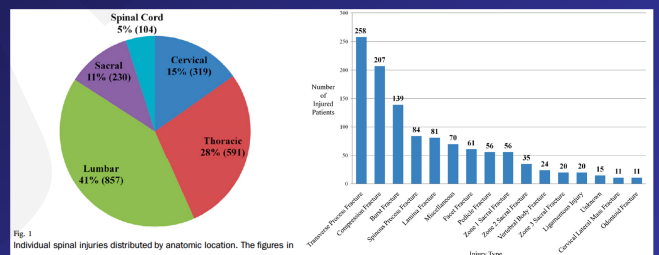


Fig. 1
Individual spinal injuries distributed by anatomic location. The figures in parentheses represent the number of individual spinal column lesions in the entire cohort of patients.

Fig. 2
Spinal injuries represented by patient. The value associated with each bar represents the number of injured service members with that specific injury. Note that many service members sustained multiple spine injuries.

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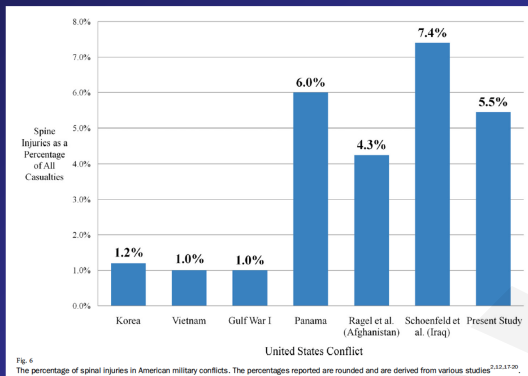


Fig. 4 The percentage of spinal injuries in American military conflicts. The percentages reported are rounded and are derived from various studies.^{2,3,5,17,20}

Combat Spinal Injuries

THE SPINE JOURNAL
2012

- 1950-1991
 - Combat Spinal Injuries = 1%
- Recently
 - up to 7%
 - Asymmetric warfare – sniper attacks, ambush, roadside bombs, improvised explosive devices

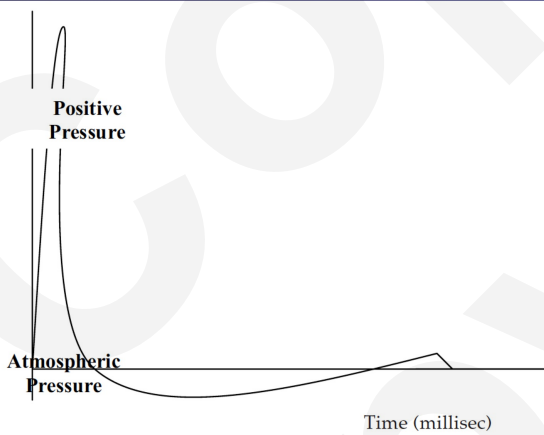
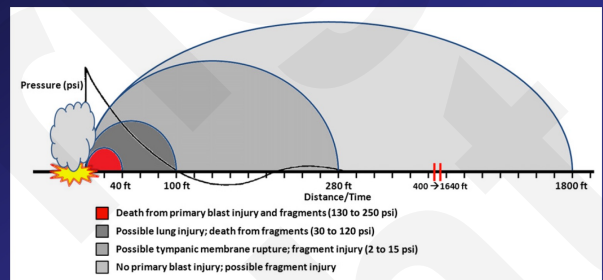


Fig. 2. Blast Wave form.



Mass casualty and blast trauma types of explosives.

High energy explosives	Low energy explosives
TNT	Pipe bombs
C-4	Gun powder
Semtex	Pure petroleum based bombs
Nitroglycerine	"Molotov cocktail"
Dynamite	
Ammonium Nitrate Fuel Oil (ANFO)	

Mechanisms of blast injury.

Category	Characteristics	Body part affected	Types of injuries
Primary	Unique to HE, results from the impact of the over-pressurization wave with body surfaces.	Gas filled structures are most susceptible – lungs, GI tract, and middle ear.	Blast lung (pulmonary barotrauma) TM rupture and middle ear damage Abdominal hemorrhage and perforation – globe (eye) rupture – concussion (TBI without physical signs of head injury) Traumatic amputations
Secondary	Results from flying debris and bomb fragments.	Any body part may be affected.	Penetrating ballistic (fragmentation) or blunt injuries Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind.	Any body part may be affected.	Fractures Closed and open brain injury
Quaternary	All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms. Includes exacerbation or complications of existing conditions.	Any body part may be affected.	Burns (flash, partial, and full thickness) Crush injuries Closed and open brain injury, asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes Angina Hyperglycemia, hypertension

LE (low-order explosives) are classified differently because they lack the self-defining HE over-pressurization wave. LE's mechanisms of injuries are characterized as due from ballistics (fragmentation), blast wind (not blast wave), and thermal. There is some overlap between LE descriptive mechanisms and HE's Secondary, Tertiary, and Quaternary mechanisms.
(From DHHS-CDC <http://www.btc.cdc.gov/masstrauma/explosions.asp> Accessed 8/18/2005)

Overview of explosive-related injuries.

System	Injury or condition
Auditory	TM rupture, ossicular disruption, cochlear damage, foreign body
Eye, orbit, face	Perforated globe, foreign body, air embolism, fractures
Respiratory	Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, A-V fistulas (source of air embolism), airway epithelial damage, aspiration pneumonia, sepsis
Digestive	Bowel perforation, hemorrhage, ruptured liver or spleen, sepsis, mesenteric ischemia from air embolism
Circulatory	Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury
CNS injury	Concussion, closed and open brain injury, stroke, spinal cord injury, air embolism-induced injury
Renal injury	Renal contusion, laceration, acute renal failure due to rhabdomyolysis, hypotension, and hypovolemia
Extremity injury	Traumatic amputation, fractures, crush injuries, compartment syndrome, burns, cuts, lacerations, acute arterial occlusion, air embolism-induced injury

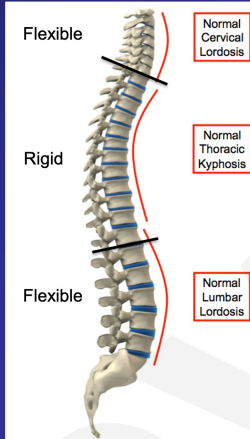
(From DHHS-CDC <http://www.btc.cdc.gov/masstrauma/explosions.asp> Accessed 8/18/2005)

Victim groups according to blast loading.

Group	Overpressure (kPa)	Blast loading
1	< 150	Minor: Maximum overpressure sustained sufficient to cause ruptured tympanic membrane
2	150-350	Moderate: Higher overpressure than Group 2, but probably insufficient to cause primary lung damage in a significant number of casualties
3	350-550	Severe: Sufficient overpressure to cause primary lung damage in a significant proportion of casualties
4	> 550	Very severe: Sufficient overpressure to cause severe primary lung damage with a significant incidence of death

From Mellor SC, Cooper GJ. Analysis of 828 servicemen killed or injured by explosion in Northern Ireland 1970-1984: the Hostile Action Casualty System. Br J Surg 1989;76:1006-1010.

- Thoracolumbar junction fractures commonest in civilians
 - low lumbar fractures are rare
- Military - higher incidence of low lumbar fractures and lumbosacral dissociation
 - Body armour protects thoracolumbar junction
 - more challenging to treat



- 2001 – 2009
- Operation Iraqi Freedom and Operation Enduring Freedom
- 78% of spinal injuries had at least 1 other associated injury – mean 3.4
- 62% explosive injuries
- Musculoskeletal > chest > abdo > brain
- 76% had multiple spinal fractures



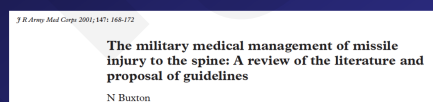
- 2001 – 2009 OIF OEF
- 598 Spine +/- SCI
- Complications 3% Non Op vs 25% Op
- Major complications = 9%
- Increased risk
 - Dismounted, penetrating injuries, surgery
- 10% Surgical infections



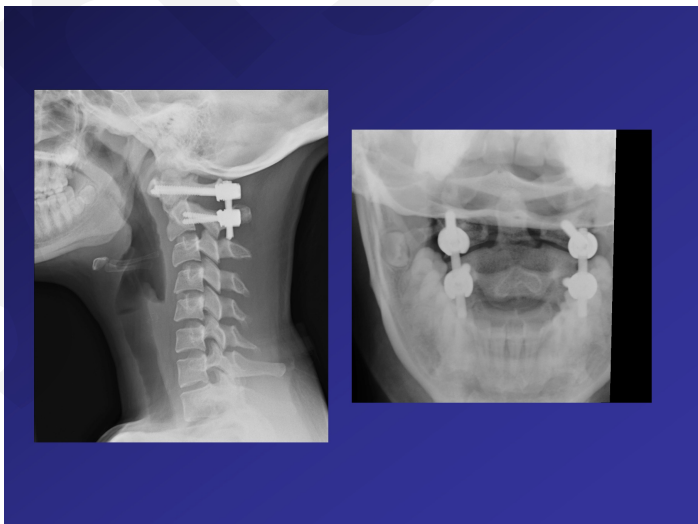
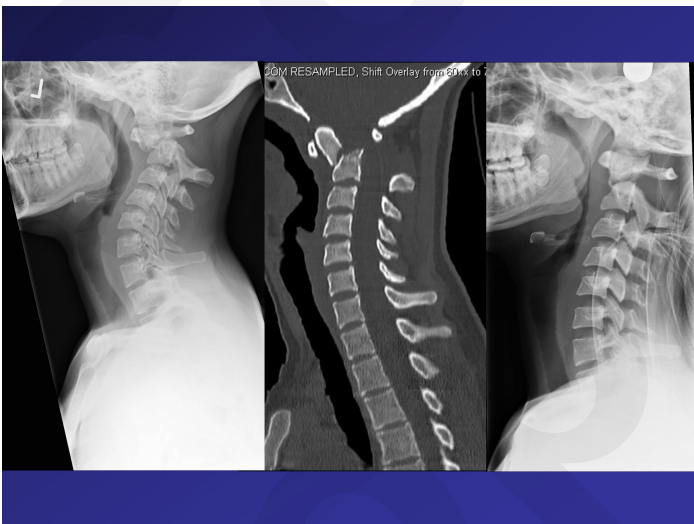
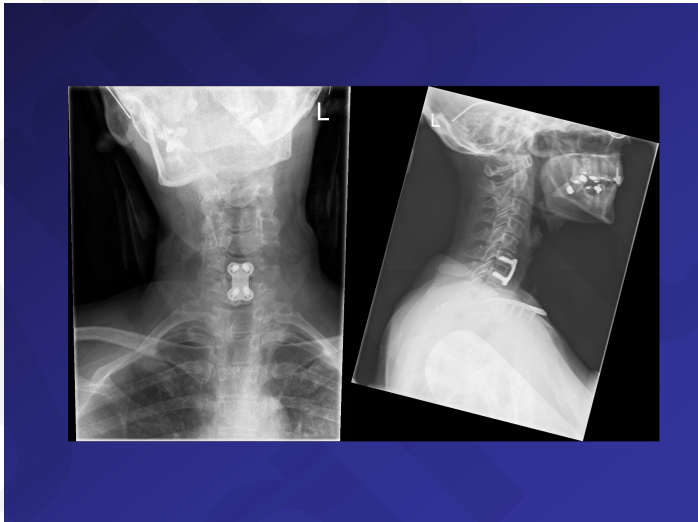
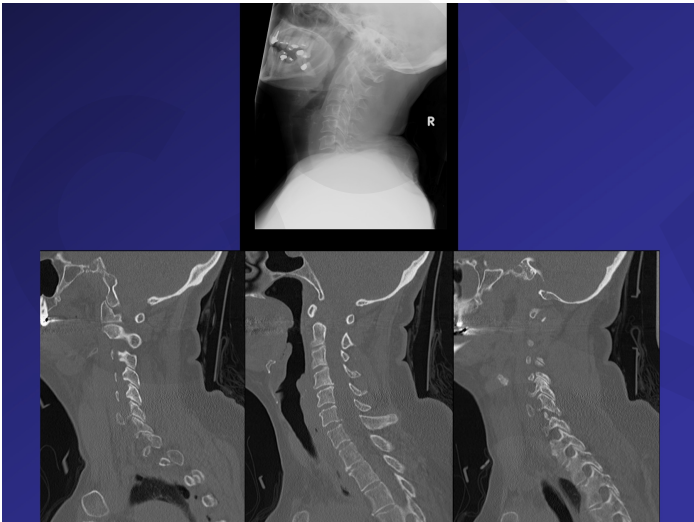
- 2001 – 2009 OIF OEF
- 598 Spine +/- SCI
- Penetrating Injuries
 - Higher rates SCI
 - Increased trend towards operation
 - Decreased neurological improvement

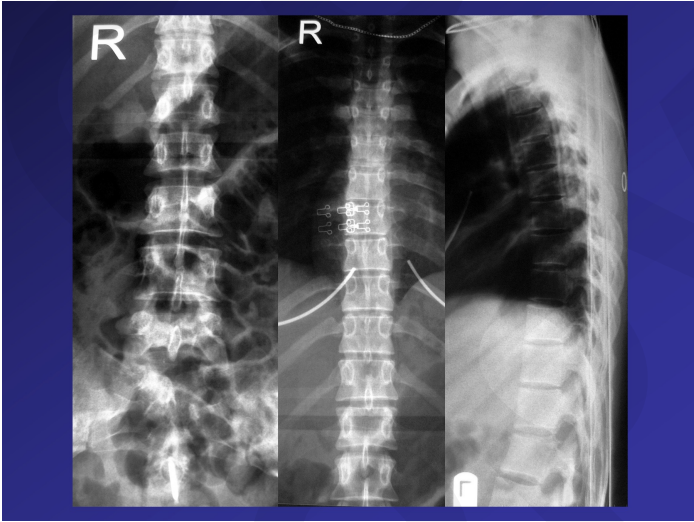
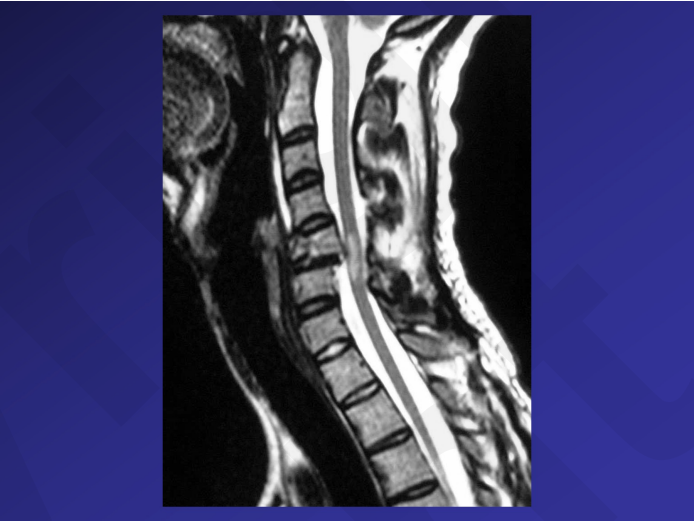
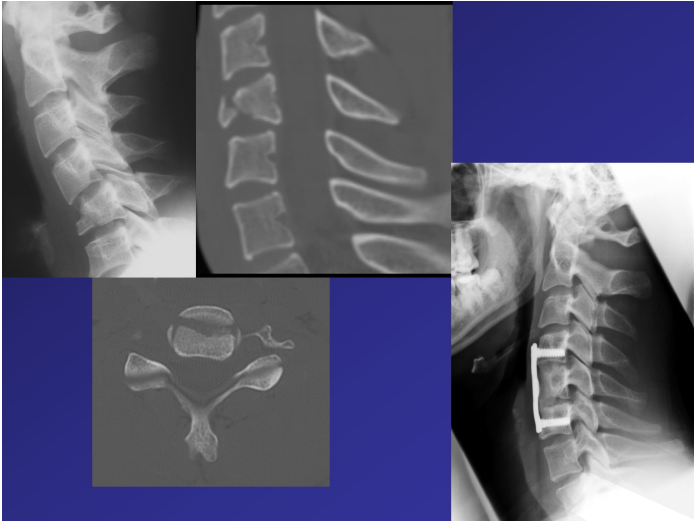


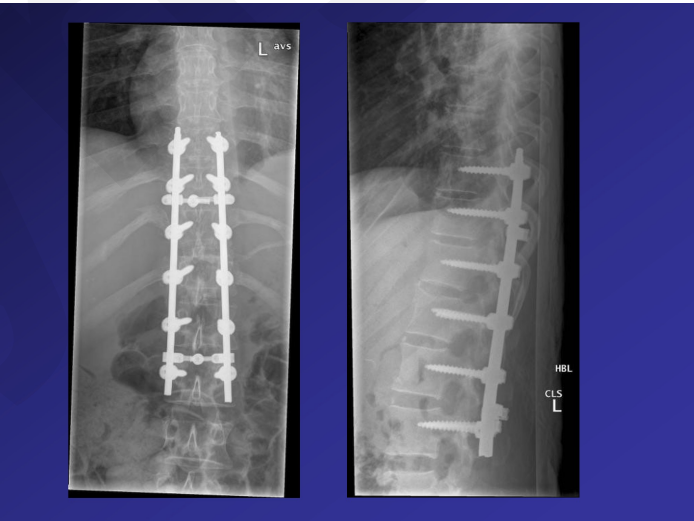
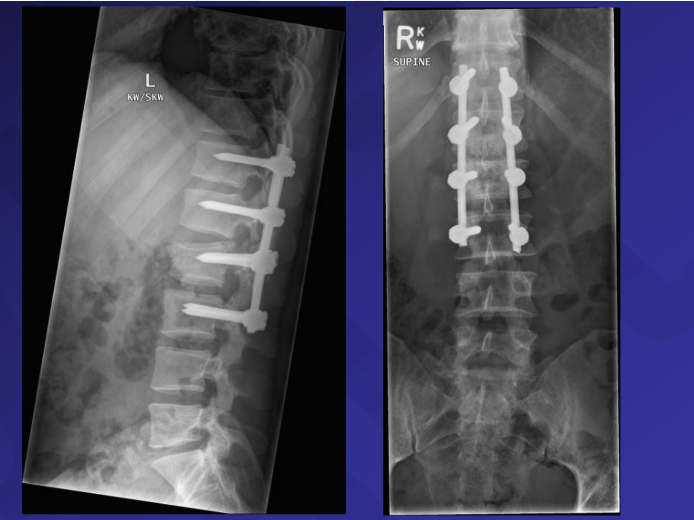
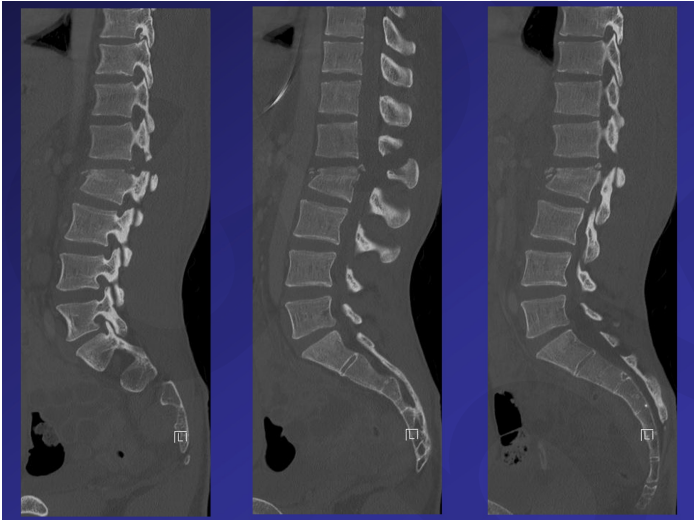
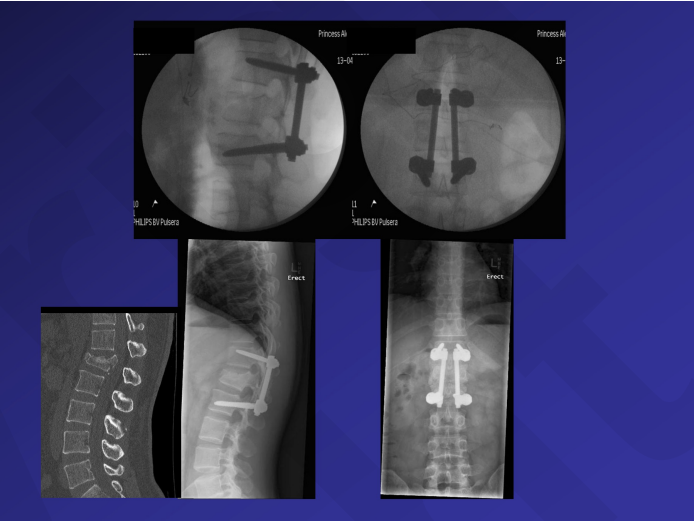
Conclusions: Penetrating ballistic trauma to the neck is associated with a high mortality rate. Our data suggests that it is very unlikely that penetrating ballistic trauma to the neck will result in an unstable cervical spine in survivors. In a hazardous environment (e.g. shooting incidents or terrorist bombings), the risk/benefit ratio of mandatory spinal immobilisation is unfavourable and may place medical teams at prolonged risk. In addition cervical collars may hide potential life-threatening conditions.

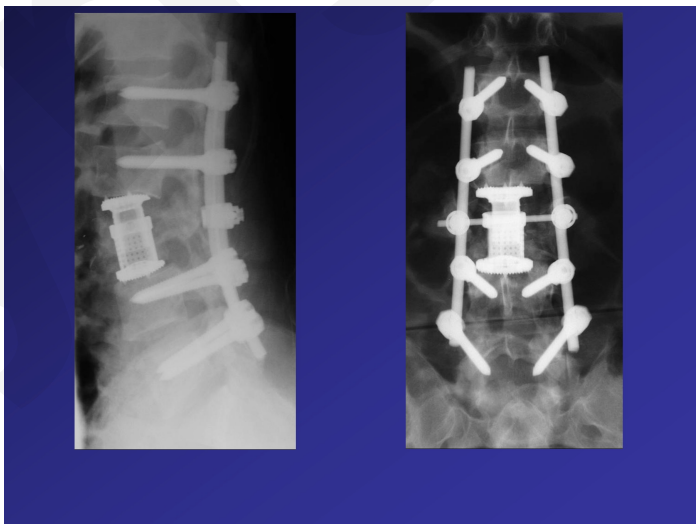
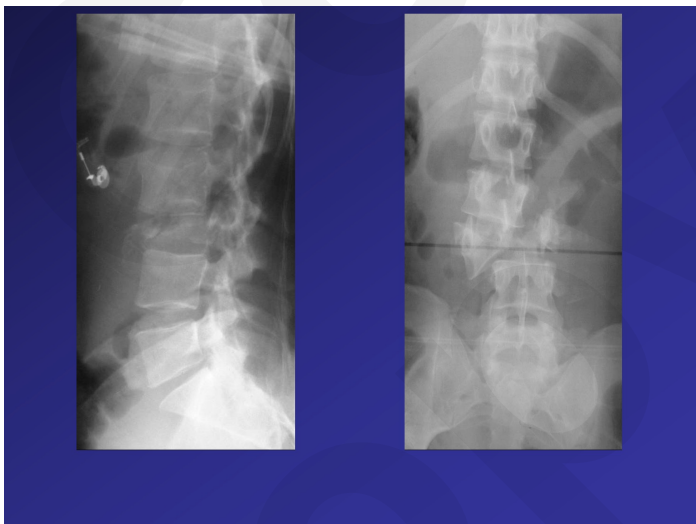
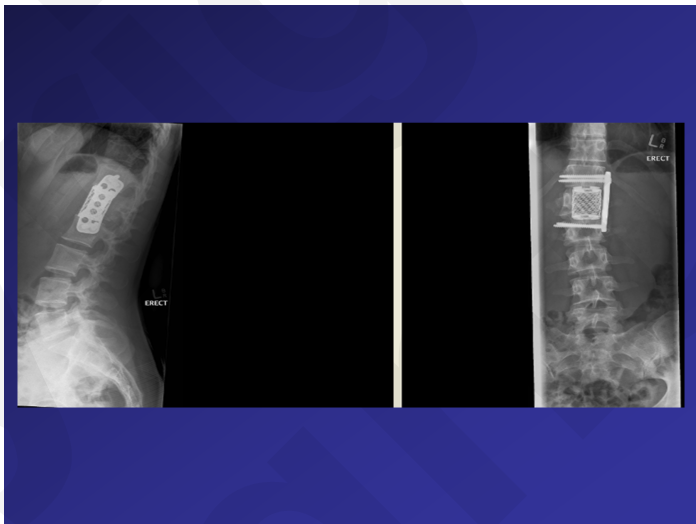
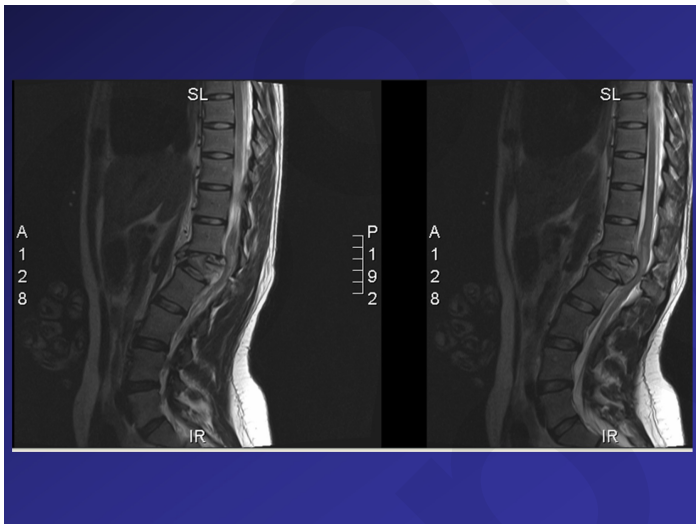
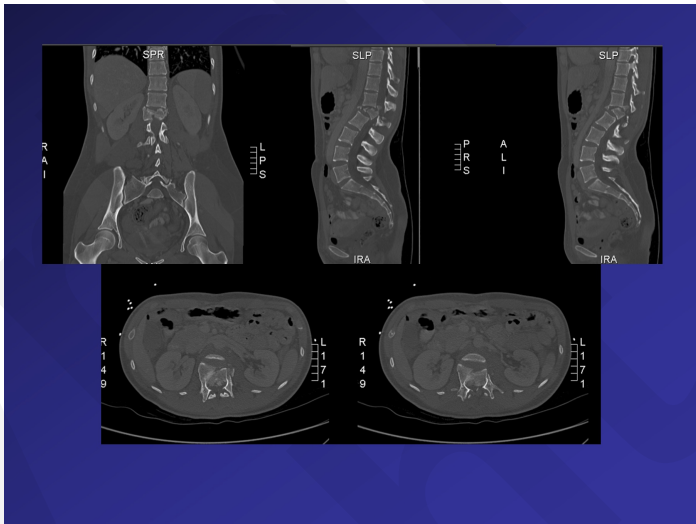


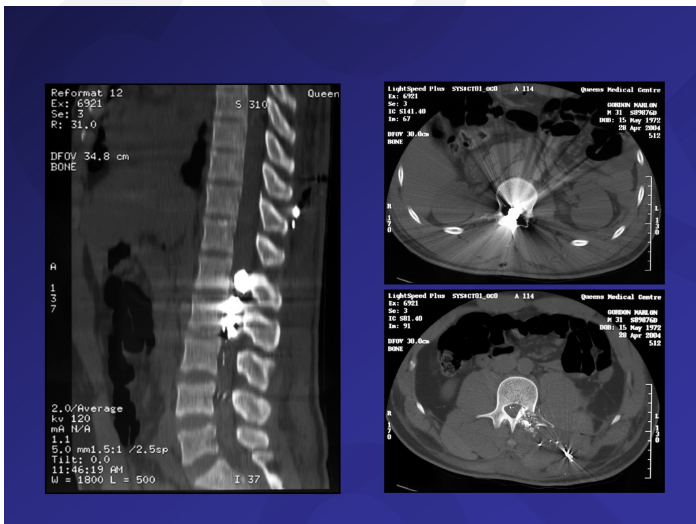
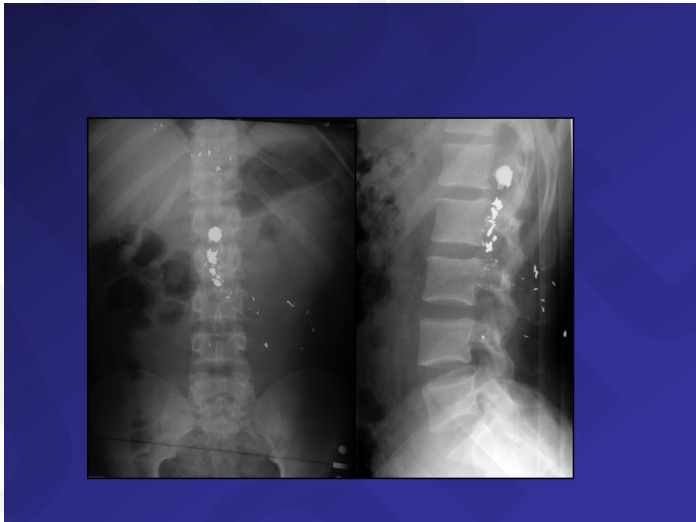
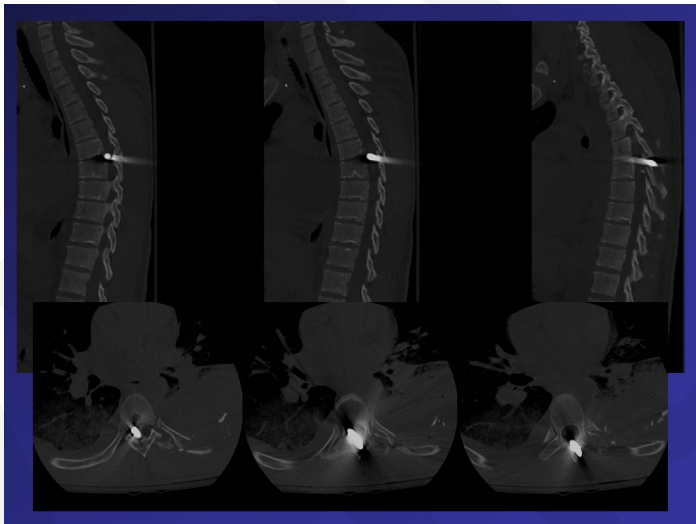
- Take care not to mask neck injuries by collar
 - Check wounds regularly
- Complete SCI unlikely to require surgery
- Surgery for progressive neurological deficit, CSF leaks, delayed infection, FB reaction, copper or lead FB in joint, radicular pain due to FB
- Steroids – no role
- High dose broad spectrum antibiotics > 7 days
- Prognosis $\propto$ presenting neurology
 - 90% permanent

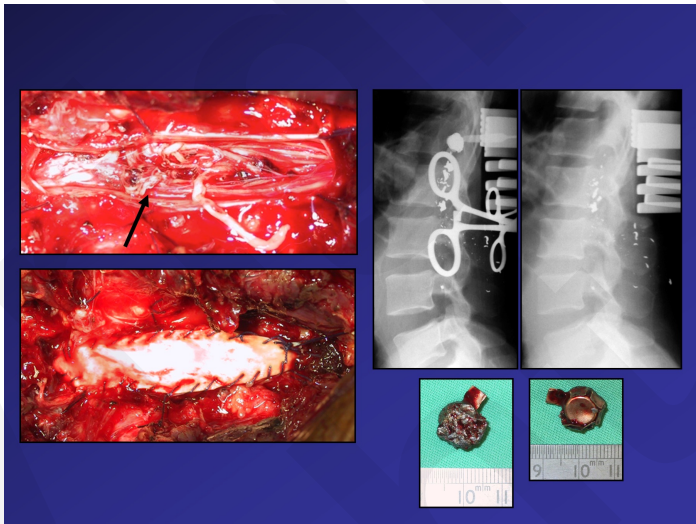
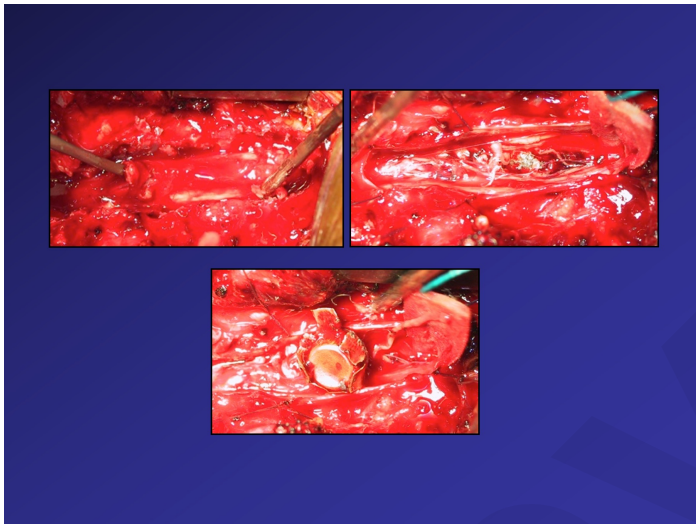












Summary

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



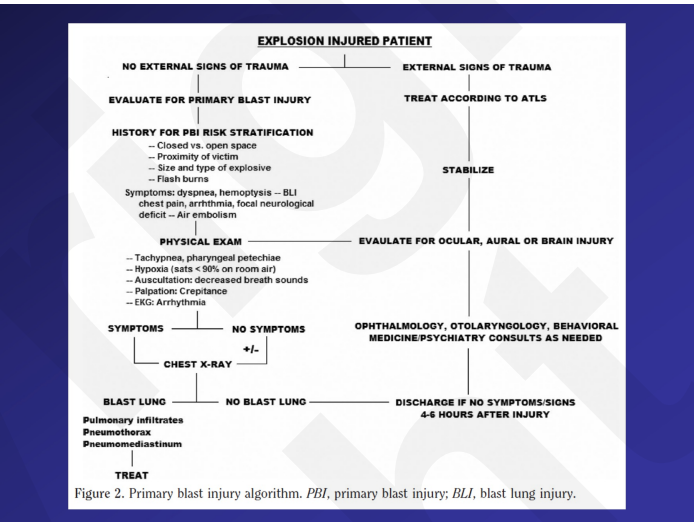
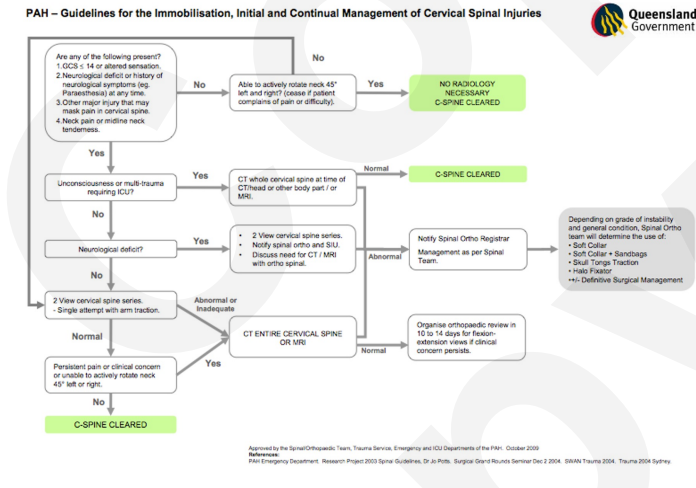


Figure 2. Primary blast injury algorithm. PBI, primary blast injury; BLI, blast lung injury.



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THE ETIOLOGY OF MISSED CERVICAL SPINE INJURIES

James W. Davis, MD, FACS,* David L. Phreaner, MS-4,[†] David B. Hoyt, MD, FACS,* and Robert C. Mackerzie, MD, FACS[‡]

Missed or delayed diagnosis of cervical spine (C-spine) injuries may lead to extension of those injuries and subsequent preventable mortality or morbidity. Previous reports examining the incidence of missed C-spine injuries have not determined the nature of the causal clinical errors made or the extent to which these errors are avoidable. This study was undertaken to (1) determine the incidence of delayed or missed diagnosis of C-spine injuries and the consequences of those missed injuries; (2) define the clinical errors leading to the delays; and (3) to determine if these errors are the result of fundamental problems or a lack of advanced diagnostic skills or equipment. Between August 1985 and February 1991, 32,117 trauma patients were admitted to one of the six trauma centers in San Diego county. Cervical spine injuries were identified in 740 patients and the diagnosis was delayed or missed in 34 patients (4.6%). Ten of the 34 patients (29%) developed permanent sequelae as a result of these delays. The single most common error was the failure to obtain an adequate series of C-spine roentgenograms. Delayed diagnosis could have been avoided in at least 31 of 34 injuries by the appropriate use of a standard three-view C-spine series and careful interpretation of those roentgenograms. Patients at risk for C-spine injuries require a technically adequate three-view C-spine series and skilled radiographic interpretation. Cervical spine precautions should be maintained, particularly in high risk patients, until appropriate and expert review of the cervical spine roentgenograms can be obtained.

Missed Cervical Spine Injury

- 32117 trauma pts, San Diego
- Cervical spine injuries in 740, diagnosis missed/delayed 4.6%
- 29% of these developed permanent sequelae
- Inadequate views, misread XRs

Error Type	Number of Errors
Inadequate standard C-spine series	15
Lateral view only	12
Nonvisualization of T-1	2
No cervical roentgenograms in unconscious patient	1
Misread roentgenograms	16
With adequate standard series	8
Lateral view only	7
Nonvisualization of C-7-T-1	1
Technically adequate/negative roentgenographic findings	1
Indeterminable	2
Total	34

Error	Attributed Complication				Total
	Death	Quad/Hemiplegia	Deficit	None	
Inadequate C-spine series	1	1	1	13	17
Misread roentgenograms	1	2	2	10	14
Error in judgment	0	1	0	0	1
Indeterminable	0	0	1	1	2
Totals	2	4	4	24	34

Patient groups

Group	Classification	Important Characteristics
1	Asymptomatic	Awake, alert No neck pain/tenderness Normal neurologic function No intoxication No distracting injuries
2	Temporarily nonassessable	Asymptomatic Intoxicated or has distracting injuries Expect resolution in 24-48 h
3	Symptomatic	Cervical pain or tenderness Neurologic deficits
4	Obtunded	Abnormal cognitive function that interferes with clinical examination

Asymptomatic

- National Emergency X-Radiography Utilization Study (NEXUS) validated a clinical protocol that cleared cervical spine in asymptomatic pt
- Specific criteria to identify low-risk pt who can be cleared clinically without imaging
- Criteria:
 - awake, alert patient
 - no intoxication or distracting injury
 - E.g. major injury above shoulder, pelvic fracture, long bone or periarticular fracture, thoracolumbar spine injury, severe soft-tissue injury, major visceral cavity injury
 - no cervical spine pain or midline tenderness
 - no neurologic signs or symptoms

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Nexus

- 21 centres, prospectively screened 34,069 pts using NEXUS criteria
 - At 2 wks reassessed to confirm presence/absence of cervical spine injury
 - Overall, 2.8% had cervical injuries
- Overall sensitivity of screening method excellent
 - 99.0% all cervical injuries, 99.6% for significant cervical injuries
 - negative predictive value excellent at 99.8%
- indicating pt who does not meet criteria for XRs is extremely unlikely to have a significant cervical injury
- However, because very low specificity (12.9%), many potentially unnecessary XRs were taken when NEXUS criteria were used

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Canadian c-spine rule

- Awake, non intoxicated pts with GCS 15
- identifies those who require XR by answering 3 questions

1. Is pt high-risk enough that XRs are required?
 - age >65 yrs, reports of paresthesia, and dangerous mechanism
 - ie, fall from height >1 m or 5 stairs
 - axial load to head
 - high-speed [>100 km/h] automobile, motorcycle, recreational vehicle, or bicycle accident)
2. Low risk factor, allow safe assessment of ROM?
 - E.g. simple rear-end motor vehicle crash, pt has sat upright in ED or ambulatory, delay of onset pain, and no tenderness
3. Can pt actively rotate head 45° to right and left without pain
 - not at high risk and can safely perform rotation test can be cleared clinically without XR

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Canadian c-spine rule

- 8,924 pts from 8 centres (Stiell)
- Sensitivity 100% and specificity was 42.5%
- 25% to 50% reduction XRs, c.f. NEXUS

The flowchart, titled "Canadian C-Spine Rule", outlines the decision process for cervical spine imaging. It starts with three screening questions. If any are positive, a radiograph is required. If all are negative, no radiograph is needed.

- Any High-Risk Factor Which Mandates Radiography?**
 - Age > 65 years
 - Dangerous mechanism* (e.g., Paravertebral in activities)
 - Neurological deficit
 - Distraction injury
 - Open head injury
 - Recent alcohol or drug ingestion
 - Coagulopathy or anticoagulant use
 - High energy trauma
 - High speed motor vehicle crash
 - Fall from height
 - Violence
 - Wrist or hand pain
 - Midline neck tenderness
 - Any other high-risk factor
- Any Low-Risk Factor Which Allows Safe Assessment of Range of Motion?**
 - Simple mechanism MVC**
 - Sitting position in ED
 - Anteriorly at any time
 - Divided tenderness of neck pain***
 - Absence of midline c-spine tenderness
- Able to Actively Rotate Neck?**
 - 45° left and right
 - Neurological deficits
 - Midline tenderness
 - Distraction injury
 - Open head injury
 - Recent alcohol or drug ingestion
 - Coagulopathy or anticoagulant use
 - High energy trauma
 - High speed motor vehicle crash
 - Fall from height
 - Violence
 - Wrist or hand pain
 - Midline neck tenderness
 - Any other high-risk factor

* Dangerous mechanism includes:

- High speed motor vehicle crash
- High speed motorcycle crash
- Fall from height
- Violence
- Wrist or hand pain
- Midline neck tenderness
- Any other high-risk factor

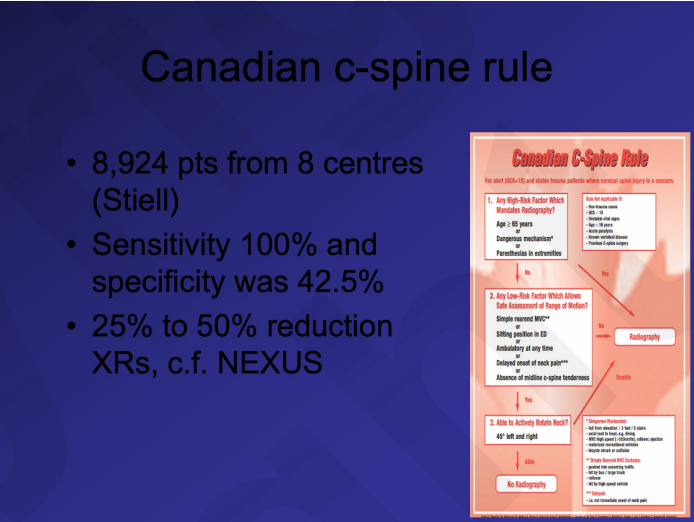
** Simple mechanism includes:

- Low speed motor vehicle crash
- Low speed motorcycle crash
- Fall from height
- Violence
- Wrist or hand pain
- Midline neck tenderness
- Any other high-risk factor

*** Divided tenderness of neck pain includes:

- High speed motor vehicle crash
- High speed motorcycle crash
- Fall from height
- Violence
- Wrist or hand pain
- Midline neck tenderness
- Any other high-risk factor

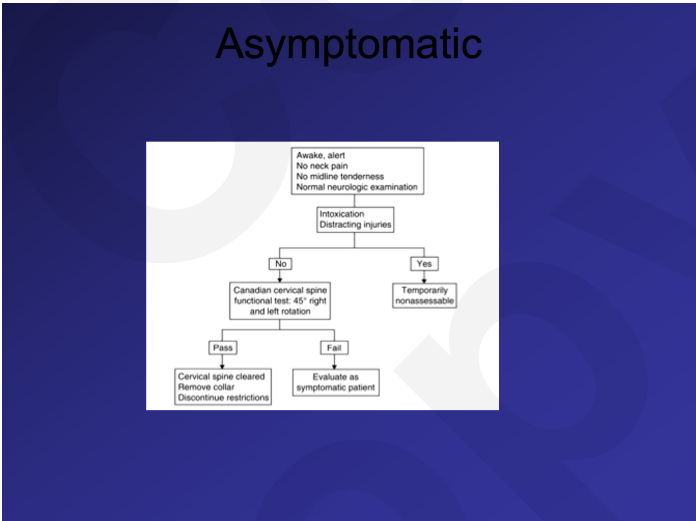
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-
- Canadian C-Spine Rule**
For adult (≥15 y/o) and stable trauma patients with potential cervical spine injury in a conscious patient.
- 1. Any High-Risk Factor Which Mandates Radiography?**
- Age > 65 years
Dangerous mechanism*
or
Paradoxical movement in extremities
- Yes** → Radiography
No → 2.
- 2. Any Low-Risk Factor Which Allows Safe Assessment of Range of Motion?**
- Simple isolated MVC**
Sitting position in ED
Ambulatory at any time
or
Divided tenderness of neck pain***
Absence of midline c-spine tenderness
- No** → Radiography
Yes → 3.
- 3. Able to Actively Rotate Neck?**
- 45° left and right
- No** → Radiography
Yes → 4.
- 4. Discharge Instructions:**
No further restriction if 1 day, 2 days, and 3 days from ED, 4 days, 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days, 22 days, 23 days, 24 days, 25 days, 26 days, 27 days, 28 days, 29 days, 30 days, 31 days, 32 days, 33 days, 34 days, 35 days, 36 days, 37 days, 38 days, 39 days, 40 days, 41 days, 42 days, 43 days, 44 days, 45 days, 46 days, 47 days, 48 days, 49 days, 50 days, 51 days, 52 days, 53 days, 54 days, 55 days, 56 days, 57 days, 58 days, 59 days, 60 days, 61 days, 62 days, 63 days, 64 days, 65 days, 66 days, 67 days, 68 days, 69 days, 70 days, 71 days, 72 days, 73 days, 74 days, 75 days, 76 days, 77 days, 78 days, 79 days, 80 days, 81 days, 82 days, 83 days, 84 days, 85 days, 86 days, 87 days, 88 days, 89 days, 90 days, 91 days, 92 days, 93 days, 94 days, 95 days, 96 days, 97 days, 98 days, 99 days, 100 days, 101 days, 102 days, 103 days, 104 days, 105 days, 106 days, 107 days, 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608 days, 609 days, 610 days, 611 days, 612 days, 613 days, 614 days, 615 days, 616 days, 617 days, 618 days, 619 days, 620 days, 621 days, 622 days, 623 days, 624 days, 625 days, 626 days, 627 days, 628 days, 629 days, 630 days, 631 days, 632 days, 633 days,



Asymptomatic

```
graph TD; A["Awake, alert  
No neck pain  
No midline tenderness  
Normal neurologic examination"] --> B["Intoxication  
Distracting injuries"]; B --> C{No}; B --> D{Yes}; C --> E["Canadian cervical spine  
functional test: 45° right  
and left rotation"]; E --> F{Pass}; E --> G{Fail}; F --> H["Cervical spine cleared  
Remove collar  
Discontinue restrictions"]; G --> I["Evaluate as  
symptomatic patient"]; D --> J["Temporarily  
nonassessable"];
```

The flowchart outlines the process for clearing an asymptomatic cervical spine. It begins with a patient who is awake, alert, has no neck pain, no midline tenderness, and a normal neurologic examination. The next step is to check for intoxication or distracting injuries. If present, the patient is temporarily nonassessable. If not, a Canadian cervical spine functional test (45° right and left rotation) is performed. A 'Pass' leads to clearing the cervical spine, removing the collar, and discontinuing restrictions. A 'Fail' leads to evaluating the patient as symptomatic.



Asymtomatic

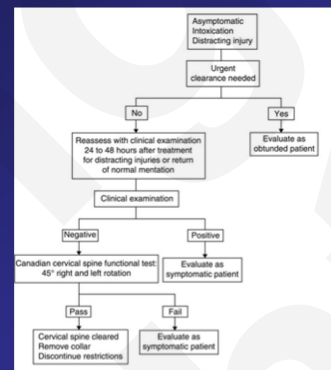
- level I evidence that asymptomatic patients do not require radiographic evaluation

- # Asymtomatic
- level I evidence that asymptomatic patients do not require radiographic evaluation

Temporarily unassessable

- Collar immobilization
- Clinical examination repeated 24-48 hrs, following management distracting injuries and return of normal cognitive function

Non assessable



Symptomatic

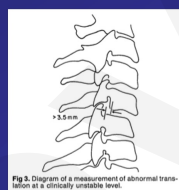
- neck pain, tenderness, or neurologic symptoms requires radiographic imaging as adjunct to physical examination
 - plain XR
 - flexion-extension XR
 - CT
 - MRI

Plain XR

- Readily available, inexpensive, quick, and specific for cervical spine injury
- No validated guidelines for use in blunt trauma pts
- Sensitivity low, 52-85%, although many missed injuries have little significance
- Major limitation inability to delineate injuries at occipitocervical and cervicothoracic junctions

Plain XR

- lateral, odontoid, and AP views
 - Oblique/swimmer's views only slightly improve sensitivity and cost-efficient
- Efficacy of cervical XR=dependent on quality of views
 - Davis, 94% of errors leading to missed or delayed diagnosis resulted from inability to obtain adequate XR



Flexion-Extension XR

- Cervical spine XR may fail to detect unstable cervical spine injury in 15%
- Appropriate only for alert pt with negative cervical XR and persistent symptoms who can voluntarily undergo study and whose entire c-spine can be visualized on standard views
- Efficacy in acute setting controversial ?timing
- Recognised complications in literature
- Not cost-effective and reserved for sub-acute setting



CT

- CT with reformations has gradually replaced plain XR for c-spine clearance
 - Some advocate CT as preferred initial imaging modality for pts with moderate-high risk for cervical spine injury
- Volume imaging
- Quick and efficient imaging in all planes
- MDCT has equal sensitivity in all planes
 - So less risk of missing non-displaced transverse #
 - e.g. type II dens #



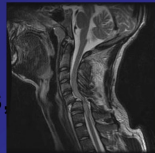
CT

- CT alone identifies 99.3% of all cervical spine #
 - missed fractures required minimal or no treatment
- Cost-effectiveness of helical CT to complement superior sensitivity
 - even greater when applied as extension of primary CT of other organs (eg, head, thorax, abdomen)
- Disadvantages:
 - greater expense
 - increased radiation exposure
 - limited availability (c.f. plain radiography)
 - static imaging



MRI

- Noninvasive imaging for detection of neural, ligamentous, or disk injury
- Primarily indicated for pt who presents with neurologic deficit
 - epidural hematoma, spinal cord edema, and spinal cord compression.
- Additional MRI indicated when ligamentous injury suspected clinically



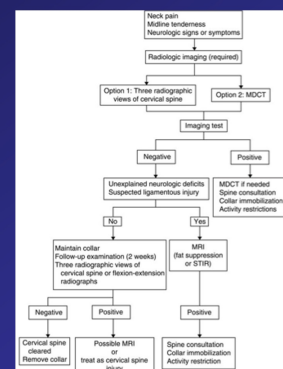
MRI

- Useful when other imaging modalities are not consistent with neurologic presentation
 - 25% of pts with cervicothoracic injuries and neurologic deficit on presentation preliminary treatment plan altered after MRI
- Not indicated for primary cervical spine clearance
 - Extensive time to perform, interferes with monitoring equipment, and expensive
 - Difficult series to obtain in unwell pt
- Although MRI has negative predictive value approaching 100%, positive predictive value less impressive

MRI

- Unlike flexion-extension XR, MRI provides valuable information regarding cervical ligaments, disks, and joint capsules without placing spinal cord or neural elements at risk
- No consensus exists on imaging criteria for establishing ligamentous injury
- Delays that allow resolution of edema and hemorrhage can decrease MRI sensitivity in cervical spine clearance
 - 48-72 hrs suggested as optimal time interval, but no data exist to substantiate this

Symptomatic



Symptomatic Pts

- Require imaging.
- 3-view plain XRs with adjunctive CT if needed for inadequate XR, or MDCT
 - If undergoing CT scanning of other locations, addition of cervical MDCT recommended
- Flexion-extension XR for cervical clearance is not recommended but appropriate in subacute setting (ie, 2 weeks) if symptoms persist
- MRI not indicated for screening
 - may be warranted for evaluation of pt with spinal cord injury, suspected ligamentous injury, or neurologic deterioration

Obtunded



- Controversial and unresolved
- Risks of occult cervical spine injury must be weighed against potential morbidities of continued cervical immobilization
- Concern cervical injuries resulting from high-energy trauma might include soft-tissue damage not readily identifiable on XR/CT
- 0.6% incidence isolated ligamentous cervical spine injuries in all blunt trauma patients
 - difficult to detect and may result in neural injury
 - neurologic sequelae ass with spinal injury 10X more likely to occur in event of missed injury

Obtunded

- Several recent investigations have advocated CT as a single modality capable of detecting all clinically sig cervical spine injuries
 - Harris, 367 obtunded trauma pts using CT, all clinically sig cervical spine injuries identified. Failed to detect minor injury in only one pt
 - Tomyecz, 180 obtunded trauma pts, no neurologic deficits and GCS $\leq$ 13 by CT, and if normal, by MRI
 - MRI id acute abnormalities in 21% pts with negative CT; however, no injuries deemed clinically significant
 - Authors concluded that use of MRI is obviated by negative MDCT.
 - Similar results were reported by Como et al and Schuster et al

Obtunded

- Stelfox et al compared clinical examination and helical CT reconstruction with MRI
 - CT alone had sensitivity equal to MRI but faster and resulted in 67% fewer adverse events
 - » e.g. decubitus ulcers, delirium, and hospital-acquired pneumonia (while awaiting imaging)

Obtunded

- Delineating risk in functional survivor pts with blunt trauma and obtunded
 - When CT negative and no apparent spinal deficit, instability is unlikely (2.5%), c.f.
 - Prolonged collar use, 26.2% increased ICU complications,
 - 9.3-14.6% for secondary brain injury with MRI transport
 - 20.6% aspiration during MRI scanning

Obtunded

- Although CT sensitive in identification of osseous abnormalities, not been shown to have same level of accuracy as MRI in detecting isolated ligamentous injury
 - Menake, 203 obtunded trauma pts with normal CT and found 8.9% abnormality identified by MRI
 - 2 pts with normal cervical spine by CT required surgical intervention for ligamentous injury, and 14 others required immobilization in orthosis
 - CT cannot reliably detect all clinically sig cervical injuries and MRI remains necessary adjunct
 - Diaz, 32% sensitivity for helical CT for cervical spine ligamentous injuries, negative predictive value only 78%
 - CT not effective in evaluating ligamentous injuries and recommends obtunded patients undergo MRI

Obtunded

- Munchow, (meta-analysis) five level I studies, 464 trauma pts evaluated using MRI and plain radiographs or CT
 - 20.9% incidence abnormalities on MRI that were not detected by plain radiographs or CT
 - MRI demonstrated sensitivity of 97.2%, specificity of 98.5%, and negative predictive value of 100%
 - Negative MRI study definitive standard for cervical spine clearance in obtunded pt
 - However, high rate of false negatives makes usefulness of MRI as screening tool questionable

OBTUNDED

- Stassen, algorithm in which obtunded trauma pt undergoes both helical CT and MRI procedure to facilitate cervical spine clearance
 - 30% pts with normal CT findings demonstrated abnormal findings on MRI ($P < 0.01$)
 - Furthermore, MRI identified all abnormalities indicated by CT
- American College of Radiology (ACR)
 - CT and MRI the most appropriate modalities for cervical spine evaluation in obtunded trauma patient
 - Evaluate cervical spine in pts whose neurologic status cannot be fully evaluated within 48 hrs of injury, including those in whom CT results are normal

Obtunded

- Dynamic XR
 - Obtained under supervision and with bedside fluoroscopy, traction, and general anesthesia
 - Require:
 1. Review of cervical spine XRs before fluoroscopy
 2. Visualization of entire cervical spine, is mandatory
 - 1% pts may demonstrate an undiagnosed ligamentous injury and most such applications are inadequate because do not visualize cervicothoracic junction
 - Further cases of neurologic deterioration from flexion-extension radiographs have been noted

Obtunded trauma patient



Literature

- Historical / Major Conflicts
- U.S.A.
- Cause of S.C.I.
 - 1. M.V.A. (38%)
 - 2. Falls (16%)
 - 3. Gunshot wounds (13%)
- National Spinal Cord Injury Data Research Centre
 - 1973-1981
 - 6,014 cases with 782 gunshot wounds

Literature

- Major Conflict
 - high velocity
 - increased contamination
 - increased tissue damage
- Civilian
 - low-velocity

Historical

- Sir Astley Paston Cooper (1768-1841)
 - “If you could save one life in ten...an operation, it is your duty to attempt it, notwithstanding any objections, which some foolish persons may have urged against it”
- Sir Charles Bell (1774-1842)
 - “..recommendations daily given to students who are taught to despise the study of books, and to neglect all authority but that of the person addressing them..but that of the hospital to which chance has led them?”

History of the Treatment of Spinal Injuries
Silver JR. 2003. Published by Kluwer

Donald Munro

- 1936, Boston City Hospital
- Munro's doctrine
 - “...no matter how extensive the paralysis may be in such a patient and provided that he has full use of his hands, arms and shoulders, ambulation, with infallible 24 hour control of bladder and bowel...ability to lead a normal social and work life within the limits imposed by the necessary use of braces and crutches...” (Munro, 1952)
- Pressure area care
- Urinary tract care

History of the Treatment of Spinal Injuries
Silver JR. 2003. Published by Kluwer

The Effects of Removal of Bullet Fragments Retained in the Spinal Canal”

A Collaborative Study by the National Spinal Cord Injury Model Systems

Prospective, 12

Demographic

- centre, from 1984
- Civilian gunshot injury
 - bullet or major bullet fragment lodged inside the spinal canal
- Calibre

– unknown	52
– .22	12
– .38	13
– other	13
- Neurology
 - 70 paraplegic
 - 41 complete
 - 20 quadriplegic
 - 13 complete

Waters RL and Adkins RH
Spine 1991; 16(8): p934-9.

The Effects of Removal of Bullet Fragments Retained in the Spinal Canal”

A Collaborative Study by the National Spinal Cord Injury Model Systems

Infection

Other literature

- 19 patients (20%)
- alimentary canal penetration
- 10 left in situ
- 9 removed
- 0% infection
 - meningitis
 - spinal infection
- broad-spectrum antibiotics
- course 7 to 14 days

Waters RL and Adkins RH
Spine 1991; 16(8): p934-9.

The Effects of Removal of Bullet Fragments Retained in the Spinal Canal”

A Collaborative Study by the National Spinal Cord Injury Model Systems

CSF leak

Not influenced

- 2 patients
- resolved
- Pain
- Lead toxicity

Waters RL and Adkins RH
Spine 1991; 16(8): p934-9.

The Effects of Removal of Bullet Fragments Retained in the Spinal Canal”

A Collaborative Study by the National Spinal Cord Injury Model Systems

• Bullet removal

- 32 patients bullet removal
- Multivariate analysis of variance
- Level dependent
- T12 to L4 = Significantly greater motor recovery ($p < 0.001$)
- Above T12 = no significant effect on motor recovery

Waters RL and Adkins RH
Spine 1991; 16(8): p934-9.

“Thoracolumbar Infections in Penetrating Injuries to the Spine”

- Single hospital
 - Thomas Jefferson Univ, Penn, U.S.A.
- 239 patients
- 1979 to 1994
- Penetrating wound from T1-L5
 - 219 gunshot, 215 handgun
- Demographic
 - 222♂ (93%), 17♀
 - 26 yrs (12 to 74)
- Neurology
 - paraplegic
 - complete
 - quadriplegic
 - complete

Heary RF, Vaccaro AR, et al.
Ortho Clin N Am 1996; 27(1): p69-81.

“Thoracolumbar Infections in Penetrating Injuries to the Spine”

- Infection
 - 5 patients (2%)

Heary RF, Vaccaro AR, et al.
Ortho Clin N Am 1996; 27(1): p69-81.

“Thoracolumbar Infections in Penetrating Injuries to the Spine”

- Different missiles
 - bullet velocity
 - bullet mass

DeMuth, 1966

Heary RF, Vaccaro AR, et al.
Ortho Clin N Am 1996; 27(1): p69-81.

“Thoracolumbar Infections in Penetrating Injuries to the Spine”

- Surgical objectives war time penetrating S.C.I.s
 - Debride track and clear canal
 - Dural closure +/- grafting
 - Visualise cord for prognosis
 - Decompression

Heiden et al., 1975

- Add conus and below
 - progressiv neurology

Heary RF, Vaccaro AR, et al.
Ortho Clin N Am 1996; 27(1): p69-81.

“Thoracolumbar Infections in Penetrating Injuries to the Spine”

- Majority
- Conservative (nonoperative) treatment with IV broad spectrum antibiotics
- Tetanus prophylaxis
- Neurologic deficit
 - progressive
 - compression

Heary RF, Vaccaro AR, et al.
Ortho Clin N Am 1996; 27(1): p69-81.