Subaxial Cervical Spine Trauma

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Updated by Robert Morgan, MD November 2010
Learning Objectives

• Articulate cervical spine instability patterns
• Articulate procedure for spine “clearance”
• Identify management considerations
• Identify operative indications
• Articulate nonoperative management methods
Subaxial Cervical Spine

- From C3-C7
- ROM
  - Majority of cervical flexion
  - Lateral bending
  - Approximately 50% rotation
Osseous Anatomy

- Uncovertebral Joint
  - Lateral projections of body
  - Medial to vertebral artery
- Facet joints
  - Sagittal orientation 30-45 degrees
- Spinous processes
  - Bifid C3-5, ? C6, prominent C7

FIGURE 22-20. Anterior (left) and lateral (right) views of the midcervical vertebrae (C4 and C5). (1) Vertebral body, (2) disk, (3) uncovertebral joint, (4) uncinate process, (5) facet joint, (6) nerve root canal, and (7) spinous process.
Lateral Mass Anatomy

- Medial border - Lateral edge of the lamina
- Lateral border - watch for bleeders
- Superior/Inferior borders - facets
- C7 frequently has abnormal anatomy
- Vertebral artery is just anterior to the medial border of the lateral mass, enters at C6
- Nerve runs dorsal to the artery and anterior to the inferior half of the lateral mass
- 4 quadrants of the lateral mass with the superolateral quadrant being “safe”
Ligamentous Anatomy

- Anterior
  - ALL, PLL, intervertebral disc
- Posterior
  - Nuchal Ligaments - ligamentum nuchae, supraspinous ligament, interspinous ligament
  - Ligamentum flavum and the facet joint capsules
Vascular Anatomy

- Vertebral Artery
  - Originates from subclavian
  - Enters spine at C6 foramen
  - At C2 it turns posterior and lateral
  - Forms Basilar Artery
  - Foramen Transversarium
    - Gradually moves anteriorly and medially from C6 to C2
Neuroanatomy

- Spinal cord diameter subaxial: 8-9mm
- Occupies ~ 50% of canal
- Neural Foramen
  - Pedicles above and below
  - Facets posteriorly
  - Disc, body and uncinate process anteriorly
Columns

- Holdsworth 2 column theory
  - Anterior Column
    - Body, disc, ALL, PLL
    - Posterior Column
      - Spinal canal, neural arch and posterior ligaments
Instability

“Clinical instability is defined as the loss of the spine’s ability under physiologic loads to maintain its patterns of displacement, so as to avoid initial or additional neurologic deficits, incapacitating deformity and intractable pain.”

White and Panjabi 1987
Stability

- Evaluation of stability should include
  - anatomic components (bony and ligamentous)
  - static radiographic evaluation of displacement
  - dynamic evaluation of displacement (controversial)
  - neurologic status (unstable if neurologic injury)
  - future anticipated loads
# Radiographic Exam

## Spine Stability

<table>
<thead>
<tr>
<th>Element</th>
<th>Point value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior elements destroyed or unable to function</td>
<td>2</td>
</tr>
<tr>
<td>Posterior elements destroyed or unable to function</td>
<td>2</td>
</tr>
<tr>
<td>Relative sagittal plane translation &gt; 3.5 mm</td>
<td>2</td>
</tr>
<tr>
<td>Relative sagittal plane rotation &gt; 11°</td>
<td>2</td>
</tr>
<tr>
<td>Positive stretch test</td>
<td>2</td>
</tr>
<tr>
<td>Spinal cord damage</td>
<td>2</td>
</tr>
<tr>
<td>Nerve root damage</td>
<td>1</td>
</tr>
<tr>
<td>Abnormal disc narrowing</td>
<td>1</td>
</tr>
<tr>
<td>Dangerous loading anticipated</td>
<td>1</td>
</tr>
<tr>
<td>Total of $\geq 5 = unstable$</td>
<td></td>
</tr>
</tbody>
</table>
# Spine Stability

## Table 1. SLIC Scale

<table>
<thead>
<tr>
<th>Points</th>
<th>Morphology</th>
<th>Neurological status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No abnormality</td>
<td>Intact</td>
</tr>
<tr>
<td>1</td>
<td>Compression</td>
<td>Root injury</td>
</tr>
<tr>
<td>+1 = 2</td>
<td>Burst</td>
<td>Complete cord injury</td>
</tr>
<tr>
<td>3</td>
<td>Distraction (e.g., facet perch, hyperextension)</td>
<td>Incomplete cord injury</td>
</tr>
<tr>
<td>4</td>
<td>Rotation/translation (e.g., facet dislocation, unstable teardrop or advanced staged flexion compression injury)</td>
<td>Continuous cord compression in setting of neuro deficit (Neuro Modifier)</td>
</tr>
<tr>
<td>0</td>
<td>Disco-ligamentous complex (DLC)</td>
<td>Intact</td>
</tr>
<tr>
<td>1</td>
<td>Indeterminate (e.g., isolated interspinous widening, MRI signal change only)</td>
<td>Root injury</td>
</tr>
<tr>
<td>2</td>
<td>Disrupted (e.g., widening of disc space, facet perch or dislocation)</td>
<td>Complete cord injury</td>
</tr>
<tr>
<td>3</td>
<td>Neurological status</td>
<td>Incomplete cord injury</td>
</tr>
</tbody>
</table>

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</tbody>
</table>
Physical exam

• Palpation
  • Neck pain
    • 84% patients with a clinical exam and fracture have midline neck pain
    • 20% of patients with a clinically significant cervical spine fracture with negative plain films have a fracture on CT scan
      Mace,S.E. Ann.Emerg.Med; 1985, 14, 10, 973-975
  • Step off between spinous processes
  • Crepitus
  • Range of motion
  • Detailed neurologic exam (RECTAL!)
Radiographic Evaluation

- Lateral C-spine to include C7-T1
- BEWARE with changing standards (many just get CT now)
- Bony anatomy
- Soft tissue detail
- Don’t forget T-L spine
Which films?

- Cross table lateral
  - Must include C7-T1 (5% of C-spine injuries)
- Three view trauma series
- Flexion/Extension
  - Controversial as to timing
  - Only in cooperative alert patient with pain and negative 3 view
  - Negative study does not rule out injury
  - If painful, keep immobilized, reevaluate
Missed Injuries

The presence of a single spine fracture does not preclude the inspection of the rest of the spine!
Mechanism of Injury

- Hyperflexion
- Axial Compression
- Hyperextension
Hyperflexion

- Distraction creates tensile forces in posterior column
- Can result in compression of body (anterior column)
- Most commonly results from MVC and falls
Compression

- Result from axial loading
- Commonly from diving, football, MVA
- Injury pattern depends on initial head position
- May create burst, wedge or compression fx’s
Hyperextension

- Impaction of posterior arches and facet compression causing many types of fx’s
  - lamina
  - spinous processes
  - pedicles
- With distraction get disruption of ALL
- Evaluate carefully for stability
- LOOK FOR CENTRAL CORD SYNDROME
Classification

- Allen and Ferguson Spine 1982
- Harris et al OCNA 1986
- Anderson Skeletal Trauma 1998
- Stauffer and MacMillan Fractures 1996
- AO/OTA Classification
- Most are based on mechanism of injury
- SLIC is not mechanism based
AO/OTA Classification

- Not specific for cervical spine
- Provides some treatment guidelines

- Type A
  - Axial loading; compression; stable

- Type B
  - Bending type injuries

- Type C
  - Circumferential injuries; multi-axial
Allen and Ferguson

• 165 patients
• Stability of each pattern is based on the two column theory
• Each category is broken down into stages
• Uses both mechanism and stability to determine treatment and outcome

• 6 categories
• Compressive flexion
• Vertical compression
• Distractive flexion
• Compression extension
• Distractive extension
• Lateral flexion

Allen and Ferguson Spine 1982
Distraction-Flexion


Wiring?

• Shapiro 1993
  • Retrospective case series of 24 patients with unilateral locked facets
  • 5 patients underwent successful closed reduction with 2/5 having resubluxation in halo.
  • 1 of 24 patients posteriorly reduced and wired resubluxed and subsequently underwent an anterior fusion with plating.
  • Conclusion: Posterior reduction and wiring was more effective than halo management for unilateral locked facet injuries.

• Hadley 1992
  • Retrospective case series of 68 patients with facet fracture dislocations
  • 125/30 patients with unilateral facet injuries were followed for a mean of 18 months. 34/37 patients with bilateral facet injuries were followed for a mean of 24 months.
  • 28 patients failed closed reduction. 7/31 closed reduced patients treated in halo developed late instability. 1/24 patients treated with open reduction went on to late instability
  • Conclusion: Posterior reduction and wiring was more effective than halo management for unilateral and bilateral facet fracture dislocations. Late instability was common in injuries able to be reduced and subsequently treated closed.
Wiring?

• Lukhele 1994
  • Retrospective case series of 43 patients with facet fractures treated with posterior wiring
  • 12 patients had associated laminar fractures, 5 of which went on to develop deformity and increased neurologic deficit. These were subsequently treated with anterior diskectomy and plating.
  • Conclusion: Intact posterior elements are necessary for successful posterior wiring.
Wiring?

- Koivikko 2004
  - Retrospective study of 106 distraction flexion injuries with operative arm and nonoperative control group
  - Operative management consisted of posterior Rogers wiring in 51 patients. 6 of these patients subsequently required revision for loss of reduction.
  - 16 nonoperatively treated patients subsequently underwent operative management for late instability or neurologic decline.
  - Operatively treated patients had improved radiographic parameters and less neck pain. There was no difference in neurologic outcomes.
  - Conclusion: Operative management with posterior wiring was safe and effective and operatively managed patients had improved radiographic parameters and less neck pain.

Bohlman Triple Wiring
Unilateral Facet Dislocation (Distraction Flexion stage 2)

- Flexion/rotation injury
- Painful neck
- 70% radiculopathy, 10% SCI
- Easy to miss-supine position can reduce injury!
- “Bow tie” sign: both facets visualized, not overlapping
Unilateral Facet Dislocation

- Reduce to minimize late pain, instability
- Flex, rotate to unlock; extend
- 50% successful reduction
- OR vs. halo
Unilateral Facet Dislocation

Note C7 fracture also!
Unilateral Facet Dislocation
Treatment

• **Nonoperative**
  • Cervicothoracic brace or halo x 12 weeks
  • Need anatomic reduction

• **OR approach and treatment depends on pathology**
  • Anterior diskectomy and fusion w/plate
  • Posterior foraminotomy and fusion with segmental stabilization
Halo treatment

- Pasciak 1993
  - Retrospective case series of 32 patients with unilateral facet dislocations
  - 9 patients presented with spinal cord injury and were operated upon without further comment.
  - 15/23 dislocations were able to be reduced and held in traction up to 3 weeks.
  - Instability was demonstrated in 7 patients with subsequent unspecified fusion. 8 patients failed closed reduction and underwent posterior reduction and fusion.
  - Conclusion: Failure of closed reduction and late instability is common in unilateral facet injuries.
Bilateral Facet Dislocation (Distraction Flexion-Stage 3)

- Injury to cord is common
- 10-40% herniated disk into canal
- Treatment somewhat controversial
- Vertebral body displaced at least 50%
Bilateral Facet Dislocation

- Timing for reduction
  - Spinal cord injury may be reversible at 1-3 hours
- Need for MRI
  - If significant cord deficits, reduce prior to MRI
  - If during awake reduction, paresthesias or declining status
- Difficult closed reduction
  - If neurologically stable, perform MRI prior to operative treatment (loss of reduction?)
Surgical Decompression and Stabilization

Figure 2. Spinal cord test apparatus used to create a 12.5-g/cm spinal cord injury.

Figure 14. Histology: neurologic recovery versus duration of canal. Narrowing axial gross sections of time until decompression injury groups (0, 2, 6, 24, and 72 hours) demonstrating progressively more severe dorsal cord cavitation. Note the almost total myelomalacia of the cord at 72 hours.
Timing of Reduction vs. MRI

- 82 pts uni/bilateral facet fx/dx
- CR successful 98%
- Emergent OR in 2
- Post-reduction MRI
  - 22% herniation
  - 24% disruption
- Prereduction MRI
- 2/11 HNP
- 5/11 HNP post reduction
- One patient with secondary neuro deterioration
  - Root impingement
  - Onset several hours after reduction

Grant et al, J Neurosurg, 1999
Bilateral Facet Dislocation Treatment

- Closed reduction/imaging as discussed
- Definitive treatment requires surgical stabilization
  - Review MRI for pathology
  - Anterior decompression and fusion
  - If poor bone quality, consider posterior segmental stabilization
  - Occasional anterior & posterior stabilization
SLIC Algorithm

**Unilateral or Bilateral Facet Subluxation or Perched Facets**

- Morphology = 3
- DLC = 2
- Neurology (Cord Injury + Compression) = 0 - 4
- SLIC Total = 5 + Neuro

**MRI shows disc herniation into spinal canal**

**Anterior** Cervical Discectomy, extend to restore alignment, Fusion and Anterior Plating
Risk is incomplete reduction intra-operatively & possible posterior ligament infolding

**MRI shows disc and posterior ligament disruption without herniation**

**Posterior** Open Reduction, resection of ligamentum flavum and lateral mass fixation and fusion
Risk is progressive disc collapse and development of segmental kyphosis
What about isolated facet fractures?

- Stability depends on ligamentous complex
  - SLIC 0
  - Can be rotationally unstable
- Most commonly involves superior articular process (80%)
- Can have late pain and disability
- Late arthrodesis is an option
- Be aware of “fracture separation” of lateral mass
Anterior Only

• Brodke 2003
  • Randomized prospective study of 52 patients with spinal cord injuries and subaxial instability
  • 24 distraction flexion injuries total were treated with 6 anterior diskectomy and plating procedures and 18 posterior instrumented fusions.
  • There was no statistically significant difference in complications, neurologic or radiographic outcomes between the two groups
  • Conclusion: Both anterior diskectomy and plating as well as posterior instrumented fusion are safe and effective in treating distraction-flexion injuries.
More on Anterior Only

- **Elgafy 2007**
  - Retrospective case-control study of 65 patients with cervical fracture dislocations treated with posterior instrumentation
    - Instrumentation was 47.6% lateral mass plating, 46.2% interspinous process wiring, combined 6.2%.
    - Iliac crest autograft was used in 57/65 patients. Solid fusion was achieved in 96.7%.
    - Bilateral facet injuries with initial segmental kyphosis was strongly associated with late kyphosis.
    - Conclusion: Consider anterior/posterior procedure in bilateral facet subluxations/dislocations to prevent late kyphosis.

- **Ordonez 2000**
  - Retrospective case series of ten patients with distraction-flexion injuries treated with anterior reduction and plating.
    - Satisfactory reduction was obtained in 9 patients with one patient requiring an additional posterior procedure to achieve reduction.
    - Two patients had asymptomatic partial resubluxations that did not result in further operations.
    - Risk factors for failed reduction include significant posterior element disruption and facet fracture comminution.
    - Conclusion: Anterior diskectomy and plating is safe and effective in distraction-flexion injuries that are not highly unstable or involve facet fractures.
Compression Fractures

- Flexion force
- The question is one of ligamentous damage/posterior instability
- Stability determines treatment
Compression

**FIGURE 33-5.** Vertical compression injuries. Axial loading in relative isolation results in what are otherwise known as burst fractures. **A:** Stage I injury, showing cupping of the superior or inferior end plate.
Compression-Flexion

FIGURE 33-4. Compression flexion injuries. Axial loading with flexion of increasing intensity results in progressively severe injuries. A: Stage I injury, showing blunting of the superior vertebral body (low-grade compression fracture involving only the anterior column with no ligamentous disorder). B: Stage II injury, with progression to beaking. C: Stage III injury, beak fracture (teardrop fracture that may involve the vertebral body caudal to the fracture, as well as the interspinous ligament and facet joint capsules). D: Stage IV injury, retroolisthesis of the vertebral body indicating ligamentous injury. E: Stage V injury, with retroolisthesis greater than 3 mm indicating severe ligamentous injury. (Adapted from Rizzolo SJ, Cotler JM. Unstable cervical spine injuries: specific treatment approaches. J Am Acad Orthop Surg 1993; 1:57-66, with permission.)
Burst Fractures

- Comminuted body fracture with retropulsion
- Traction reduction
- Treatment based on neuro status and instability
Teardrop Fracture

- Extension (upper cervical spine)
  - Usually benign
  - Avulsion type
- Flexion (lower cervical spine)
  - Anterior wedge or quadrangular fragment
  - Unstable
Teardrop Fracture

- High energy flexion, compressive force
- Often posterior element disruption
  - Unstable injury
- Routinely requires surgery
Burst Fractures Treatment

- Surgical treatment routine for high grade burst fractures
- Most commonly treated with corpectomy, anterior grafting of some type and rigid plate fixation
- Supplemental posterior fixation if patient osteopenic or injury to posterior structures warrants stabilization
Compression-Extension


Lateral Mass Fractures

- Lateral mass fracture involves ipsilateral lamina and pedicle
- Extension type injury?
- Understand the anatomy
- 2 level surgical stabilization
CAUTION!

Beware:

- Ankylosing spondylitis
  - If neck pain, treat as fracture
- Obese patients
- Poorly imaged patients
- Distracting injuries
- Rotational injuries
SLIC Algorithm

Hyper-extension Injury +/- Avulsion Fractures
Morphology = 3
DLC (likely disrupted) = 2
Neurology (Cord Injury + Compression) = 0 - 4
SLIC Total = 5 + Neuro

Anterior Discectomy Fusion and Plate
In a very stiff spine (DISH) may choose to add posterior fixation

Be cautious of anterior only constructs in osteoporosis!
Distraction Extension

## Distraction-Extension

<table>
<thead>
<tr>
<th>Series (reference number)</th>
<th>Description of Study</th>
<th>Quality of evidence</th>
<th>Topic and conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccaro 2001</td>
<td>Retrospective consecutive case series of 24 patients with distraction-extension injuries</td>
<td>Very low</td>
<td>16 injuries were treated operatively, 8 nonoperatively. 9 patients were treated anteriorly only, 6 patients were treated with combined anterior and posterior procedures, one patient was treated posteriorly only. 2 patients treated operatively deteriorated due to over distraction at time of graft placement. Almost 50% of patients had ankyosing spondylitis or diffuse idiopathis skeletal hyperostosis. Conclusion: Anterior fusion with plating was safe and effective if overdistraction was avoided. Combined procedures were often necessary. Closed reduction and treatment with halo was successful. Overall mortality in this patient population is high.</td>
</tr>
<tr>
<td>Lieberman 1994</td>
<td>Retrospective case series of 41 patients age greater than 65 with cervical spine fractures</td>
<td>Very low</td>
<td>3 patients with distraction-extension injuries. 1 died, one was treated with a collar, one quadriparetic patient was treated with operative reduction, anterior fusion Conclusion: This was an uncommon injury pattern in this series</td>
</tr>
<tr>
<td>Anderson 1991</td>
<td>Retrospective case series of 30 patients treated with posterior cervical plating</td>
<td>Very low</td>
<td>One patient with an extension type injury at C56 was quadriparetic and treated with posterior plating to solid fusion despite a screw loosening in a C4-C7 construct. Conclusion: posterior plating is safe and effective in this uncommon injury.</td>
</tr>
<tr>
<td>Rockswold 1990</td>
<td>Retrospective case series of 140 patients with cervical spine injuries</td>
<td>Very low</td>
<td>7 patients sustained unstable extension injuries, 3 were successfully treated in a halo vest, 3 were successfully treated operatively. One patient not included in the data analysis died due to flexion position in the halo resulting in airway compromise. Conclusion: Nonoperative management may be successful if flexion positioning can be avoided.</td>
</tr>
<tr>
<td>Bucholz 1989</td>
<td>Retrospective case series of 124 cervical spine injuries</td>
<td>Very low</td>
<td>12 extension injuries, all treated initially in halo. 1/12 failed halo treatment and subsequently underwent posterior wiring with successful result. Conclusion: halo treatment of these injuries may be safe and effective in the treatment of distraction extension injuries.</td>
</tr>
</tbody>
</table>
Lateral Flexion

Non-operative Care

- Rigid collars
  - Conventional collars offer little stability to subaxial spine and transition zones
  - May provide additional stability with attachments (JTO!)
  - Good for post-op immobilization
- Halo
  - Many complications
  - Better for upper cervical spine injuries
  - Subaxial “snaking”

Treatment Guidelines

- Anterior Approach
  - Burst fx w/SCI
  - Disc involvement
  - Significant compression of anterior column

- Posterior Approach
  - Ligamentous injuries
  - Lateral mass Fx
  - Dislocations

Occasionally you need circumferential approach!
Anterior Surgery

- Advantages
  - Anterior decompression
    - Trend towards improved neuro outcome
  - Atraumatic approach
  - Supine position
    - Acute polytrauma

- Disadvantages
  - Limited as to number of motion segments included
  - Potential for increased morbidity
  - Poor access to CT transition zone
Posterior Surgery

• Advantages
  • Rigid fixation
  • Foraminal decompression
  • Deformity correction
  • May extend to occiput and CT transition zones
  • Implant choices

• Disadvantages
  • Minimal anterior cord decompression
  • Prone positioning
  • Trend towards increased blood loss
Lateral Mass Screws
(workhorse of posterior instrumentation)

- **Magerl**
  - Start slightly medial to center of lateral mass
  - Upward and outward trajectory
  - Improved biomechanical stability (longer screw)
  - Decreased risk of morbidity to root or artery

- **Roy-Camille**
  - Straight, slightly lateral trajectory from center of lateral mass

- **An**
  - Split the difference
Controversies

- Myth of Myelopathy
- Blunt Vertebral Artery Injury
- Clearing the Cervical Spine
Myth of Myelopathy

- No clear case of spinal cord injury after direct laryngoscopy in English literature
  - McLeod and Calder Criteria
- All airway maneuvers cause some motion at fracture site
  - Lessened with manual in line immobilization
  - Increased with increasing instability
- Fiberoptic intubation minimizes displacements
  - May still require direct laryngoscopy
  - May require surgical airway

Crosby, E. Airway Management in Adults After Cervical Spine Trauma. Anaesthesiology. 2006
**Blunt Vertebral Artery Injury**

**Table 1. SCREENING TRIGGERS FOR SUSPECTED BLUNT CEREBROVASCULAR INJURY**

- Cervical spine fracture
- Neurologic exam not explained by brain imaging
- Homer's syndrome
- LeFort II or III facial fractures
- Skull base fractures involving the foramen lacerum
- Neck soft tissue injury (e.g., seatbelt injury or hanging)

**Table 4. ARTERIAL INJURY RATES ASSOCIATED WITH EACH SCREENING CRITERION**

<table>
<thead>
<tr>
<th>Condition</th>
<th>CAI Rate</th>
<th>VAI Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical spine fracture (n = 109)</td>
<td>6 (5%)</td>
<td>36 (33%)</td>
</tr>
<tr>
<td>Neck hematoma (n = 28)</td>
<td>5 (18%)</td>
<td>2 (7%)</td>
</tr>
<tr>
<td>Facial fracture (n = 28)</td>
<td>3 (11%)</td>
<td>2 (7%)</td>
</tr>
<tr>
<td>Homer's syndrome (n = 20)</td>
<td>2 (10%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Neuro. exam incompatible with brain imaging (n = 19)</td>
<td>6 (31%)</td>
<td>3 (16%)</td>
</tr>
<tr>
<td>Basilar skull fracture (n = 10)</td>
<td>3 (30%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

CAI, carotid artery injury; VAI, vertebral artery injury.
### Treatment?

<table>
<thead>
<tr>
<th></th>
<th>Current Study (2 year period)</th>
<th>Prior Study (5 year period)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of injuries</td>
<td>27</td>
<td>75</td>
<td>—</td>
</tr>
<tr>
<td>Incidence</td>
<td>0.39%</td>
<td>0.50%</td>
<td>.25</td>
</tr>
<tr>
<td>Stroke rate</td>
<td>33%</td>
<td>31%</td>
<td>.78</td>
</tr>
<tr>
<td>VAI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of injuries</td>
<td>49</td>
<td>64</td>
<td>—</td>
</tr>
<tr>
<td>Incidence</td>
<td>0.71%</td>
<td>0.40%</td>
<td>.04</td>
</tr>
<tr>
<td>Stroke rate</td>
<td>0%</td>
<td>14%</td>
<td>.0007</td>
</tr>
</tbody>
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CAI, carotid artery injury; VAI, vertebral artery injury.

Diagnosis?

<table>
<thead>
<tr>
<th></th>
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<th>VAI</th>
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<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>47%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td><strong>MRA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
<td>50%</td>
<td>47%</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>100%</td>
<td>97%</td>
</tr>
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CAI, carotid artery injury; VAI, vertebral artery injury.

Clearing the Cervical Spine

Table 1. The NEXUS Low-Risk Criteria.

<table>
<thead>
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<th>Criteria</th>
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<tbody>
<tr>
<td>No posterior midline cervical-spine tenderness,†</td>
<td></td>
</tr>
<tr>
<td>No evidence of intoxication,‡</td>
<td></td>
</tr>
<tr>
<td>A normal level of alertness,§</td>
<td></td>
</tr>
<tr>
<td>No focal neurologic deficit,¶ and</td>
<td></td>
</tr>
<tr>
<td>No painful distracting injuries.‖</td>
<td></td>
</tr>
</tbody>
</table>

* Criteria are from Hoffman and colleagues.†
† Midline posterior bony cervical-spine tenderness is present if the patient reports pain on palpation of the posterior midline neck from the nuchal ridge to the prominence of the first thoracic vertebra, or if the patient evinces pain with direct palpation of any cervical spinous process.
‡ Patients should be considered intoxicated if they have either of the following: a recent history provided by the patient or an observer of intoxication or intoxicating ingestion, or evidence of intoxication on physical examination such as an odor of alcohol, slurred speech, ataxia, dysmetria, or other cerebellar findings, or any behavior consistent with intoxication. Patients may also be considered to be intoxicated if tests of bodily secretions are positive for alcohol or drugs that affect the level of alertness.
§ An altered level of alertness can include any of the following: a Glasgow Coma Scale score of 14 or less; disorientation to person, place, time, or events; an inability to remember three objects at five minutes; a delayed or inappropriate response to external stimuli; or other findings.
¶ A focal neurologic deficit is any focal neurologic finding on motor or sensory examination.
‖ The precise definition of a painful distracting injury is possible. This category includes any condition thought by the clinician to be producing sufficient pain to distract the patient from a second (neck) injury. Such injuries may include, but are not limited to, any long-bone fracture; a visceral injury requiring surgical consultation; a large laceration, degloving injury, or crush injury; large burns; or any other injury causing acute functional impairment. Physicians may also classify any injury as distracting if it is thought to have the potential to impair the patient’s ability to appreciate other injuries.

Any high-risk factor that mandates radiography?
Age ≥65 yr or dangerous mechanism or paresthesias in extremities

Any low-risk factor that allows safe assessment of range of motion?
Simple rear-end motor vehicle collision or sitting position in the emergency department or ambulatory at any time or delayed (not immediate) onset of neck pain or absence of midline cervical-spine tenderness

Able to rotate neck actively?
45° left and right

No radiography
### Characteristics of the 8283 Study Patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y) mean ± SD</td>
<td>37.6 ±16</td>
<td>Characteristics of motor vehicle collision — no. (%)</td>
<td>1812 (21.9)</td>
</tr>
<tr>
<td>Range</td>
<td>16–100</td>
<td>Simple rear-end collision</td>
<td>68 (0.8)</td>
</tr>
<tr>
<td>Male sex — no. (%)</td>
<td>4328 (52.3)</td>
<td>Rollover</td>
<td>444 (5.4)</td>
</tr>
<tr>
<td>Mechanism of injury — no. (%)</td>
<td></td>
<td>Death of other(s) in same collision</td>
<td>42 (0.5)</td>
</tr>
<tr>
<td>Motor vehicle collision</td>
<td>5364 (67.2)</td>
<td>Head-on collision</td>
<td>263 (3.2)</td>
</tr>
<tr>
<td>Motorcycle collision</td>
<td>78 (0.9)</td>
<td>Time from injury to assessment (hr)</td>
<td>4.1 ±16.2</td>
</tr>
<tr>
<td>Collision involving other motorized vehicles</td>
<td>53 (0.6)</td>
<td>Arrived at hospital by ambulance — no. (%)</td>
<td>5210 (62.9)</td>
</tr>
<tr>
<td>Pedestrian struck and thrown</td>
<td>107 (1.3)</td>
<td>Transferred from another institution — no. (%)</td>
<td>476 (5.7)</td>
</tr>
<tr>
<td>Cervical-spine radiography performed — no. (%)</td>
<td>158 (1.9)</td>
<td>Cervical-spine radiography performed — no. (%)</td>
<td>5936 (71.7)</td>
</tr>
<tr>
<td>Bicycle struck</td>
<td>96 (1.2)</td>
<td>Telephone follow-up required — no. (%)</td>
<td>2338 (28.2)</td>
</tr>
<tr>
<td>Bicycle collision</td>
<td>61 (0.7)</td>
<td>Acute cervical-spine injury — no. (%)</td>
<td>217 (2.6)</td>
</tr>
<tr>
<td>Other bicycle accident</td>
<td>105 (1.3)</td>
<td>Fracture</td>
<td>209 (2.5)</td>
</tr>
<tr>
<td>Fall from elevation &gt;10 ft (3 m) or down &gt;15 stairs</td>
<td>183 (2.2)</td>
<td>Dislocation</td>
<td>71 (0.9)</td>
</tr>
<tr>
<td>Fall from elevation of 3 to 10 ft (1 to 3 m) or down</td>
<td>350 (4.2)</td>
<td>Ligamentous instability</td>
<td>8 (0.1)</td>
</tr>
<tr>
<td>5 to 15 stairs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall from elevation &lt;3 ft (1 m) or down &lt;5 stairs</td>
<td>641 (7.7)</td>
<td>“Clinically important” cervical-spine injury — no. (%)</td>
<td>169 (2.0)</td>
</tr>
<tr>
<td>Assault with a blunt object</td>
<td>73 (0.9)</td>
<td>Development of neurologic deficit — no. (%)</td>
<td>45 (0.5)</td>
</tr>
<tr>
<td>Assault with fist or feet</td>
<td>199 (2.4)</td>
<td>Stabilizing treatments — no. (%)</td>
<td>180 (2.2)</td>
</tr>
<tr>
<td>Diving</td>
<td>23 (0.3)</td>
<td>Internal fixation</td>
<td>44 (0.5)</td>
</tr>
<tr>
<td>Fall onto head (axial load)</td>
<td>32 (0.4)</td>
<td>Halo</td>
<td>45 (0.5)</td>
</tr>
<tr>
<td>Contact sports (axial load)</td>
<td>88 (1.1)</td>
<td>Brace</td>
<td>13 (0.2)</td>
</tr>
<tr>
<td>Heavy object onto head (axial load)</td>
<td>74 (0.9)</td>
<td>Rigid collar</td>
<td>81 (1.0)</td>
</tr>
<tr>
<td>Other sports</td>
<td>166 (2.0)</td>
<td>Admitted to hospital — no. (%)</td>
<td>430 (5.2)</td>
</tr>
<tr>
<td>Head struck by other object</td>
<td>106 (1.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit head on an object</td>
<td>101 (1.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>23 (0.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Plus–minus values are means ±SD.
†“Clinically important” cervical-spine injury was defined as any injury except an isolated avulsion fracture of an osteophyte; an isolated fracture of a transverse process not involving a facet joint; an isolated fracture of a spinous process not involving lamina; and a simple compression fracture with less than 25 percent loss of vertebral body height. All clinically important injuries were detected at the initial visit to the emergency department.
Table 4. Sensitivity, Specificity, and Negative Predictive Value of the Two Rules for 162 Cases of “Clinically Important” Injury among 7438 Patients. *

<table>
<thead>
<tr>
<th>Result of Assessment</th>
<th>Canadian C-Spine Rule</th>
<th>NEXUS Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injury</td>
<td>No Injury</td>
</tr>
<tr>
<td>Positive (no.)</td>
<td>161</td>
<td>3995</td>
</tr>
<tr>
<td>Negative (no.)</td>
<td>1</td>
<td>3281</td>
</tr>
<tr>
<td>Sensitivity (%)</td>
<td>99.4 (95% CI, 96–100)‡</td>
<td>90.7 (95% CI, 85–94)‡</td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>45.1 (95% CI, 44–46)‡</td>
<td>36.8 (95% CI, 36–38)‡</td>
</tr>
<tr>
<td>Negative predictive value (%)</td>
<td>100</td>
<td>99.4</td>
</tr>
</tbody>
</table>

* A total of 845 cases were classified as indeterminate and are therefore omitted from this analysis.
‡ P<0.001. CI denotes confidence interval.
Clearing the Cervical Spine

- Neck pain, negative CT
  - MRI negative, no late decompensation
  - (93 patients Shuster et al Arch Surg 2005)
- Obtunded or unreliable
  - MRI negative 354/366, picked up cord contusion
  - MRI negative for ligamentous injury 362/366
    - 4 incidental sprains
  - CT negative predictive value 98.9% ligamentous injury
  - CT negative predictive value 100% for instability
  - (Hogan et al Radiology 2005)

OK to clear the spine based on good quality CT images with reconstructions except in the spondylotic spine!
Summary

- Successful treatment based on knowledge of anatomy, mechanism of injury and compromise of bone and/or soft tissue
- Stabilization of the spine
- Decompression of neurological deficit
- Restore alignment
- Restore function
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