Spinal Cord Injury Acute Management - Preserving The Partial Cord Injury

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Photomicrograph showing the traumatized spinal cord at the C-4 level 5 days after an incomplete cord injury due to a C4--5 fracture dislocation. Multiple hemorrhages are confined to the gray matter. The white matter adjacent to the hemorrhagic gray matter shows decreased staining, whereas the subpial peripheral white matter of the lateral and posterior columns is preserved. H & E and luxol fast blue, original magnification X 7.

Spared Spinal Tissue

- In animal models, motor function can recover to normal levels after spinal cord injury if as few as 4-6% of cortical motor neurons regain physiologic connection through injured cord segment.
- An increase in axonal survival at injury site of from <3% to >6% allows function to return through the site and converts paralyzed muscles to those with normal function.
- Sparing 5-10% of fibers at lesion center can drive segmental circuits in production of locomotion.
Sparing Continued

• Studies performed in the 1950s indicate that limited preservation of white matter can sustain substantial spinal cord function. Preservation of less than 10% of the normal axon complement in the cat spinal cord can support walking, although this should not be viewed as the optimal requirement. Moreover, detailed anatomical postmortem studies of chronic SCI in humans reveal that small residual connections across the lesion can preserve some function. For example, one individual with ASIA Grade CSCI had retained only 1.17 mm² of white matter at the level of the lesion. Another patient with some preserved motor function below the level of a cervical injury had only 3175 corticospinal axons less than 8% of the number (41,472) found in normal controls.

ASIA

A Complete; no sensory or motor function preserved in S4-S5
B Incomplete; sensory but not motor function preserved below neurological level and extending through S4-S5
C Incomplete; motor function preserved below neurological level.
Most key muscles have < grade 3 power
D Incomplete: motor function preserved below neurological level. Most key muscles have > grade 3 power
E Normal motor and sensory function

Improvement after injury

Complete cord lesion at 72 h: 10-15% improve. Only 3% improve to attain class D
* Class B at 72 h: 54% will improve to a lesser degree of weakness
* Class C and D at 72 h: 86% will achieve useful motor function below the level of the lesion

Photomicrographs displaying the traumatized spinal cord 3 months after complete cord injury due to C5-C6 fracture dislocation. Upper: The injured segment shows marked anterior column degeneration with virtually no identifiable gray matter. The anterior spinal artery at the lowermost aspect of the specimen was patent. Lower: A rostral segment of the cord at approximately C3. Well-demarcated necrotic areas (arrows), which have the appearance of circumscripted infarcts, are seen at the base of the posterior white columns. The more external portion of the posterior white columns shows Wallerian degeneration. H & E and luxol fast blue, original.
Age Distribution

- In Last 30 years Spinal Injury Rates Increased By 5 Times in over 70 Age Group.
Primary Injury

- Neurons that pass through injury site are physically disrupted and exhibit diminished myelin thickness.
- Nerve transmission may be further disrupted by microhemorrhages or edema near the injury site.
- Gray matter is irreversibly damaged within the first hour after injury whereas white matter within 72 hours after injury.

Spinal Cord Contusion

Blood Vessel Time Course

Naive 1d 3d 7d
Neutrophil Infiltration

**Figure 5:** Posterior cord syndrome. A laminar fracture is depicted with anterior displacement of the fractured bone and compression of the posterior aspect of the spinal cord. The damaged area of the cord (roughly stippled in the upper diagram) includes the posterior columns and the posterior...
Figure 2: Features of classic Brown-Séquard syndrome.

Figure 3. Major spinal cord tracts and relation to hemisection of cord. Hemisection shown in green.
Is Spinal Cord Injury an Emergency?

- The Golden Hour of Trauma
- The golden first ?? hours after spinal cord trauma. Does “Time = Neurons” “Cord Attack”
- Steroid Data
- Decompression Data
Role of EMS

Prehospital Immobilization

- Standards: None
- Guidelines: None
- Options: It is suggested that all trauma patients with a cervical spinal column injury or with a mechanism of injury having the potential to cause cervical spinal injury should be immobilized at the scene and during transport using one of several available methods. A combination of a rigid cervical collar and supportive blocks on a backboard with straps is very effective in limiting motion of the cervical spine and is recommended. The longstanding practice of attempted cervical spinal immobilization using sandbags and tape alone is not recommended.

Has EMS Helped

- Estimated 3% to 25% of spinal cord injuries occur after initial traumatic insult
- Multiple cases of poor outcome from mishandling
- 20% of injuries involve multiple non-continuous levels
Has EMS Helped?

- Over last 30 years there has been dramatic improvement in neurologic status of spinal cord injured patient arriving to ED.
- In 1970’s 55% of patients referred to Regional Spinal Cord Injury Centers arrived with complete lesions
- In 1980’s 61% arrived with partial injuries
- EMS initiated in 1971

Transportation

- Standards: There is insufficient evidence
- Guidelines: There is insufficient evidence
- Options: Expeditious and careful transport of patients with acute cervical spine or spinal cord injuries is recommended from the site of injury using the most appropriate mode of transportation available to the nearest capable definitive care medical facility.
Airway Management - ABC
1. The most immediate threat to patients with injury of the cervical spinal cord is hypoxemia from hypoventilation or aspiration of gastric contents.

2. Patients with spinal cord injuries in the upper cervical region may require early intubation and assisted ventilation.

Cardiovascular Resuscitation
1. The loss of systemic sympathetic vasomotor tone after cervical injury may result in vasodilatation, increased venous capacity, and hypotension.
2. The associated bradycardia should distinguish this reaction from shock due to hemorrhage. Intravenous crystalloid solution will generally correct the relative hypovolemia.
3. Fluid should be replaced until systemic arterial pressure responds, but the pulmonary-artery wedge pressure should not be allowed to rise above 18 mm Hg, since patients with spinal cord injuries may sustain pulmonary vascular damage from an injury-associated catecholamine surge, and are thus predisposed to pulmonary edema.

Radiographic Assessment in Asymptomatic Patients
• Standards: Radiographic assessment of the cervical spine is not recommended in trauma patients who are awake, alert, and not intoxicated, who are without neck pain or tenderness, and who do not have significant associated injuries that detract from their general evaluation.
• Guidelines: None
• Options: None

The C-Spine Rule War and Other Controversies in SCI Management
NEXUS TRIAL

- Prospective study at 21 centers across U.S.
- No midline cervical tenderness, no focal neurologic deficit, normal alertness, no intoxication and no painful distracting injury.
- 34,069 patients. 818 with C-Spine injury.
- Negative predictive value 99.8 percent.

Table 3. Performance of the Clinical Criteria in Ruling Out Cervical-Spine Injuries in Patients with Blunt Trauma

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>99.0 (98.0–99.6)</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>99.8 (99.6–100)</td>
</tr>
<tr>
<td>Specificity</td>
<td>12.9 (12.8–13.0)</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>2.7 (2.6–2.8)</td>
</tr>
<tr>
<td>Patients with clinically significant injuries</td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>99.6 (98.6–100)</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>99.9 (99.8–100)</td>
</tr>
<tr>
<td>Specificity</td>
<td>12.9 (12.8–13.0)</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>1.9 (1.8–2.0)</td>
</tr>
</tbody>
</table>

*CI denotes confidence interval.
Table 4. Sensitivity, Specificity, and Negative Predictive Value of the Two Rules for 162 Cases of “Clinically Important” Injury among 7438 Patients.\cite{1}

<table>
<thead>
<tr>
<th>Result of Assessment</th>
<th>Canadian C-Spine Rule</th>
<th>NEXUS Criteria</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Injury</td>
<td>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.

Table 5. Characteristics of Patients with Cervical Spine Injury Not Identified by Decision Rules.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Mechanism of Injury</th>
<th>CCR Positive</th>
<th>CCR Negative</th>
<th>Injury</th>
<th>Hospitalized</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C2 arch fracture</td>
<td>No</td>
<td>Hard collar</td>
<td></td>
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<tr>
<td>2</td>
<td>67</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C2 odontoid fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>42</td>
<td>M</td>
<td>Fall &gt;10 ft (3 m)</td>
<td>Dangerous</td>
<td>C7 body fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>28</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C2 odontoid fracture</td>
<td>No</td>
<td>Hard collar</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>71</td>
<td>F</td>
<td>Pedestrian struck</td>
<td>Dangerous</td>
<td>C4 pedicle fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C7 body or pedicle fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>59</td>
<td>M</td>
<td>Fall &gt;35 ft (11 m)</td>
<td>Dangerous</td>
<td>C5–C6 parched facet</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>26</td>
<td>M</td>
<td>Contact sports, axial</td>
<td>Dangerous</td>
<td>C7 pedicle fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>M</td>
<td>Fall &gt;35 ft (11 m)</td>
<td>Dangerous</td>
<td>C7 compression fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C2 hangman’s fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>71</td>
<td>M</td>
<td>Fall &gt;10 ft (3 m)</td>
<td>Dangerous</td>
<td>C6–C7 facet fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>M</td>
<td>Contact sports, axial</td>
<td>Dangerous</td>
<td>C5–C6 parched facet</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>31</td>
<td>M</td>
<td>All terrain vehicle, head</td>
<td>Dangerous</td>
<td>C1 arch fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>56</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>Dangerous</td>
<td>C7 bifoveal laminar fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>42</td>
<td>F</td>
<td>Fall &gt;35 ft (11 m)</td>
<td>Dangerous</td>
<td>C1 arch facet fracture</td>
<td>Yes</td>
<td>Halo</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>35</td>
<td>M</td>
<td>Motor vehicle, head</td>
<td>None – CCR</td>
<td>C1–C2 ligamentous instability</td>
<td>No</td>
<td>Hard collar</td>
<td></td>
</tr>
</tbody>
</table>
Radiographic Assessment in Symptomatic Patients

- Standards: A three view cervical spine series (AP, lateral, and odontoid views) is recommended for radiographic evaluation of the cervical spine in patients who are symptomatic following traumatic injury. This should be supplemented with computed tomography to further define areas that are suspicious or not well visualized on the plain cervical x-rays.

- Guidelines: There is insufficient evidence to support treatment guidelines.

Continued

- Options: It is recommended that cervical spine immobilization in awake patients with neck pain or tenderness and normal cervical spine x-rays (including supplemental CT as necessary) be discontinued following either: a) Normal and adequate dynamic flexion/extension radiographs; or b) Normal MRI study obtained within 48 hours of injury. Cervical spine immobilization of obtunded patients with normal cervical spine x-rays (including supplemental CT as necessary) may be discontinued: a) Following dynamic flexion/extension studies performed under fluoroscopic guidance; or b) Following a normal MRI study obtained within 48 hours of injury; or c) At the discretion of the treating physician.

Bony Injury

- 4 Alignment Lines
  - Anterior
  - Posterior
  - Spinolaminar
  - Spinous Process

- Predental Space Adults < 3mm, Peds < 5
- Prevertebral Space 6mm C2, 22 mm C6.
Stable Fractures

- Anterior Subluxation
- Clay Shoveler’s
- Posterior arch C1
- Unilateral facet dislocation
- Wedge Fracture

Unstable Fractures

- Jefferson (C1 Burst)
- Bifacet dislocation
- Odontoid types II and III
- Any Fracture/Dislocation
- Hangman’s Fracture (posterior C2)
- Teardrop Fracture

Least to Most Stable

- Ruptured transverse ligament atlas
- Type II odontoid
- Burst fracture with posterior ligamentous disruption (flexion teardrop)
- Bilateral facet dislocation
- Burst fracture without posterior ligamentous disruption
- Hyperextension fracture dislocation
Least to most stable

- Compression fracture of C2 with anterior/posterior displacement (Hangman)
- Extension teardrop
- Compression C1 (Jefferson)
- Unilateral facet
- Anterior subluxation
- Simple wedge fracture
- Isolated spinous process (Clay Shoveler’s)

CT versus Plain Films

- 3 View Missed injuries in up to 57% high risk and 7-35% overall.
- Inadequate visualization in 50-80% of initial series and 25% of repeat radiographs.
- High false positive rate (between 18 and 63%) especially when used in elderly patients.

CT versus Plain Films

- 31.7% of plain films in one study missed “unstable” fractures.
- CT sensitivity 97.4-100% versus 39-44% plain films.
- EAST Guidelines: CT used in only 2 scenarios: 1) Area is not well visualized or is suspicious after 3 view. 2) Patient is obtunded and expected to remain so >24hr.

CT versus Plain Films

- Cost Effectiveness (Blackwell) High, Moderate, Low risk Groups
- High Risk group primary CT eval would prevent 23 cases paralysis and save 3.4 million
- Moderate and Low risk groups primary CT would prevent 8 and 4 cases but cost 2.3 and 5.8 million dollars
CT versus Plain Films

- High Risk (>5%) Harborview Criteria: MVA > 35 mph, death at scene, fall> 10ft, Significant head injury, Neurological signs or Sxs, Pelvic or multiple Extremity Fractures.
- Validation Study 14% patients high risk with 8.7% cspine injury.
- Remaining 86% patients low risk with injury in only 0.2%

CT Radiation

- Total Radiation is 1/35th that of Abdominal CT
- BUT Thyroid receives 14 times greater radiation from ct than 3 view plain films
- Peds CT exposes thyroid 90-200 times radiation
- Peds more sensitive to radiation
- 1 year old 59.28 mGy, 5 year old 52.3 mGy in thyroid region
- Relative risk of thyroid cancer doubled in age <4

C-Spine Evidence

- Assess need for Xrays Nexus or CCR
- If Xrays needed assess risk for C-spine injury: MVC>35, Fall >10ft, Death at Scene, Neuro deficit, GCS <8/Sig. Head Trauma, Multiple Extremity Fx, Pelvis Fx
- Also Primary CT for Age >65, History Degenerative joint disease, Intubated patients
- Secondary CT for patients with C-spine injuries seen on plain films and inadequate visualization.
Flexion Extension

- Efficacy recently challenged
- Risk of neurological deterioration low <.3%
- But Inadequate visualization in 17-33%
- False Negative rate as high as 57%
- MRI is safer but should take place within 72 hours to avoid false negative results from resolution of tissue edema

Clinical Assessment Following Injury - Neurological

- Neurological Examination:
  - Standards: There is insufficient evidence
  - Guidelines: There is insufficient evidence
  - Options: The ASIA international standards for neurological and functional classification of spinal cord injury is recommended as the preferred neurological examination tool for clinicians involved in the assessment and care of acute spinal cord injury patients.

Functional

- Standards: There is insufficient evidence
- Guidelines: The Functional Independence Measure (FIM) is recommended as the functional outcome assessment tool for clinicians involved in the assessment and care of acute spinal cord injury patients.
- Options: The modified Barthel Index (MBI) is recommended as a functional outcome assessment tool for clinicians involved in the assessment and care of acute spinal cord injury patients.
Initial Closed Reduction

- Standard: There is insufficient evidence
- Guideline: There is insufficient evidence
- Option: Early closed reduction of cervical spinal fracture-dislocation injuries with cranio-cervical traction is recommended for the restoration of anatomic alignment of the cervical spine in awake patients. 
  C. Closed reduction in patients with an additional rostral injury is not recommended.

Closed Reduction Continued

- Patients with cervical spinal fracture dislocation injuries who are not able to be examined during attempted closed reduction, or prior to open posterior reduction, should undergo MRI prior to attempted reduction. The presence of a significant disc herniation in this setting is a relative indication for a ventral decompression prior to reduction. 
  D. MRI study of patients who fail attempts at closed reduction is recommended.

Continued

- Pre-reduction MRI performed in patients with cervical fracture dislocation injury will demonstrate disrupted or herniated intervertebral discs in one third to one half of patients with facet subluxation. These findings do not appear to significantly influence outcome following closed reduction in awake patients and therefore the utility of pre-reduction MRI in this circumstance is uncertain.

Management in ICU

- Standards: There is insufficient evidence
- Guidelines: There is insufficient evidence
- Options: Management of patients with acute SCI, particularly patients with severe cervical level injuries, in an intensive care unit or similar monitored setting is recommended. 
  Use of cardiac, hemodynamic, and respiratory monitoring devices to detect cardiovascular dysfunction and respiratory insufficiency in patients following acute cervical spinal cord injury is recommended.
Blood Pressure Management

• Standards: There is insufficient evidence
• Guidelines: There is insufficient evidence
• Options: Hypotension (systolic blood pressure < 90 mm Hg) should be avoided if possible or corrected as soon as possible following acute SCI. Maintenance of mean arterial blood pressure at 85 - 90 mm Hg for the first seven days following acute SCI to improve spinal cord perfusion is recommended.

Treatments

Steroid Mechanism

• Anti-inflammatory effect – inhibit cell chemotaxis, phagocytosis, synthesis of mediators, release of lysosomal enzymes.
• Reduces lipid peroxidation, protects membrane – bound enzymes like ATPase and intracellular molecular assemblies like neurofilaments and reverses increase of lactic acid.
• Dose is 1000 times amount necessary to activate glucocorticosteroid receptors.

Methylprednisolone

• Doses similar to those that inhibit lipid peroxidation and breakdown of neurofilament in animal models. The breakdown of membrane peaks within 8 hrs of injury.
• Methylprednisolone does not produce a significant decrease in neutrophil accumulation but does reduce vascular permeability and tissue edema.
• Does INCREASE leukotriene B4 synthesized by neutrophils.
• Protective effects are not neutrophil mediated.

Therapy after Acute SCI

• Corticosteroids: Standards: There is insufficient evidence
• Guidelines: There is insufficient evidence
• Options: Treatment with Methylprednisolone for either 24 or 48 hours is recommended as an option in the treatment of patients with acute spinal cord injuries that should be undertaken only with the knowledge that the evidence suggesting harmful side effects is more consistent than any suggestion of clinical benefit.
Therapy After Acute SCI

- **GM-1 Ganglioside:** Standards: There is insufficient evidence to support treatment standards.
- Guidelines: There is insufficient evidence to support treatment guidelines.
- Options: Treatment of patients with acute spinal cord injuries with GM-1 ganglioside is recommended as an option without demonstrated clinical benefit.

GM-1

- Gangliosides are complex glycolipids that can accelerate neurite outgrowth and reduce edema in CNS
- Given with steroids 797 patients 5 year
- Trend of improvement

DVT

- Standards: Prophylactic treatment of thromboembolism in patients with severe motor deficits due to spinal cord injury is recommended.
- The use of low molecular weight heparins, rotating beds, adjusted dose heparin, or a combination of modalities is recommended as a prophylactic treatment strategy.
- Low dose heparin in combination with pneumatic compression stockings or electrical stimulation is recommended as a prophylactic treatment strategy.

Pediatric C-spine

- Guidelines: In children who have experienced trauma and are alert, have no neurological deficit, no midline cervical tenderness, no painful distracting injury, and are not intoxicated, cervical spine radiographs are unnecessary to exclude cervical spine injury and are not recommended. In children who have experienced trauma and who are either not alert or have neurological deficit, midline cervical tenderness, painful distracting injury, or are intoxicated, it is recommended that cervical spine radiographs be obtained.
SCIWORA

Occurs most often in pediatric population; -accounts for up to 2/3 of severe cervical injuries in children < 8 years of age;

-Inherent elasticity in pediatric cervical spine can allow severe spinal cord injury to occur in absence of x-ray findings;

Causes - - unrecognized interspinous ligamentous injury;
MRi may give a more anatomic diagnosis by showing hemorrhage or edema of the spinal cord;
-pseudosubluxation: anterior displacement may be up to 4 mm; - Treatment: spine is immobilized for one to three weeks;

SCIWORA

Standards: There is insufficient evidence to support diagnostic standards.
Guidelines: There is insufficient evidence to support diagnostic guidelines.
Options: • Plain spinal radiographs of the region of injury and CT scan with attention to suspected level of neurological injury to exclude occult fractures are recommended.
• MR of the region of suspected neurological injury may provide useful diagnostic information. • Plain radiographs of the entire spinal column may be considered.

Early Surgical Decompression

• Retrospective review of 50 patients - Improvement if surgical decompression before 24 hours.
• Shorter ICU times
• Definitive study needs to be performed but NIH will not fund it. However……
STASCIS

- 170 patients from 10 Canada and US Centers
- Cervical SCI and imaging evidence of spinal cord compression
- 24 hour cutoff point based on pilot data
- Patients had to undergo surgery within 7 days
- Complications (cardiopulmonary and urinary tract) also decreased 37.1% vs. 48.6% in early decompression.

STASCIS

- 1 year results of large NIH funded multicenter study
- 24% of patients who received decompressive surgery within 24 hours experienced a 2 grade or greater improvement on ASIA compared with 4% of those in delayed treatment group.

Hypothermia

- AANS Position Statement
- Recent high profile case of football player led to committee to review evidence.
- Not enough evidence to recommend for or against either local or systemic hypothermia.
- Clinicians should be aware that systemic hypothermia has been associated with medical complications in the head injured population

Is Spinal Cord Injury an Emergency? YES

- The Golden Hour of Trauma
- Steroid Data
- Decompression Data