Spinal Cord Injury

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Disclosures

• None
Epidemiology

- 14,000 traumatic spinal cord injuries (SCI) annually
- Predominantly young males (20 times higher than age-matched females)
- MVCs – most common cause
- Cervical spine most commonly affected region and has the highest rate of associated morbidity and mortality
- Falls – most common cause in the elderly
  - Cervical degenerative changes and stenosis may cause a significant SCI event without bony or ligamentous disruption

Epidemiology

• There has been a substantial improvement in the surgical and nonsurgical care of SCI patients
  • Prehospital, Emergency Room, Intensive Care Unit (ICU)
• Improved care and outcomes in SCI
  • Due to propagation of evidence based guidelines
  • Formation of organized trauma networks
  • Timeliness of transport to treatment institutions
  • Improved critical care medicine

Clinical Presentation & Prehospital Management

- Early management begins at the scene of the accident.
- Chief concern is that neurologic function might be impaired due to pathologic motion.
- 3-25% injuries occur after initial insult (transit/early in course of management).
- First responders primary concern is safe extraction from the site of the accident, initial resuscitation and rapid determination of possible SCI.

Clinical Presentation & Prehospital Management

• American College of Surgeons Advanced Trauma Life Support recommend a rigid backboard in conjunction with a hard cervical collar and tape or straps to immobilize the entire patient

• Studies evaluating the method of transport indicate that the exact method is less important but rapid and safe transport to the nearest facility capable of definitive SCI care
Hospital Course and Management

• Initial evaluation: primary and secondary surveys with adjunctive radiographic evaluation as deemed necessary while maintaining spinal precautions

• Initial neurological exam for patients with potential acute traumatic spinal cord injury
  • Initial neurologic exam
  • Level and content of consciousness
  • Brainstem reflexes
  • Gross extremity movement
  • Gross sensation and potential sensory level
Hospital Course and Management

American Spinal Injury Association (ASIA) scoring system and the ASIA Impairment Scale (AIS)

• Trained trauma, emergency department, critical care, rehabilitation medicine, neurology, or neurosurgery practitioners typically carry out determination of the ASIA score

• A detailed motor exam, including strength testing for each major muscle group in isolation; a light-touch modality sensory exam; and assessment for sacral root involvement by assessing rectal tone
American Spinal Injury Association (ASIA) scoring system and the ASIA Impairment Scale (AIS)

**ASIA Impairment Scale (AIS)**

- **A = Complete.** No sensory or motor function is preserved in the spinal cord segments S4-S5.
- **B = Sensory Incomplete.** Sensory but not motor function is preserved above the neurological level and includes the spinal segments S4-S5 (light touch or pin prick at S4-S5 in one or more dermatomes and preserved pain and temperature above the neurological level). Motor function is preserved in more than three levels below the motor level on one side of the body.
- **C = Motor Incomplete.** Motor function is preserved at the most caudal spinal segments for sensory and motor function (S4-S5 in the case of the ability for sensory incomplete status). Sensory function preserved at the most caudal spinal segments (S4-S5) by pin prick or cold, and has some sparing of motor function in more than three levels below the neurological motor level on either side of the body (This includes key key muscle groups to determine key muscle status). For ASIA C- less than half of key muscle functions below the single NLI have a muscle grade ≤ 3.
- **D = Motor Incomplete.** Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.
- **E = Normal.** Sensation and motor function as tested with the ENMG are normal in all segments, and the patient has no deficits of the FDI grade ≥ 2. Someone without an ENMG does not receive an AIS grade.

**Using NDI:** To document the sensory, motor and NDI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

**Figure:**

A diagram showing the ASIA Impairment Scale (AIS) with sections for Motor, Sensory, and Urologic function, along with specific levels and descriptions.
Hospital Course and Management

Initial radiographic analysis

- Hoffman et al. (2000) evaluated more than 34,000 blunt cervical trauma patients, 4,300 of whom were asymptomatic.
- A decision-making tool, known as the National Emergency X-Radiography Utilization (NEXUS) criteria, had 99% sensitivity for the identification of a cervical spine injury.

- Steell et al. (2001) evaluated almost 9,000 awake and asymptomatic trauma patients across Canada.
- The resulting Canadian C-spine Rule (CCR) had 100% sensitivity for the presence of a significant cervical spine injury.
Initial radiographic analysis

- Anderson et al. (2010) assessed existing medical evidence for radiographic evaluation in asymptomatic trauma patients. From 1966 to 2004 there were 14 class I studies, which used criteria similar to the CCR and NEXUS studies - combined sensitivity 98%

- Level 1 recommendation: trauma patients who are awake and without neck pain, neurologic deficit, signs of intoxication, or other distracting injury need not undergo radiographic evaluation and should have cervical collars and spinal immobilization discontinued (Ryken et al., 2013a)

<table>
<thead>
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<td>No midline cervical tenderness</td>
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Management options for cervical immobilization in awake but symptomatic patients with potential acute traumatic spinal cord injury

Criteria for collar clearance in the awake but symptomatic patient

- Continue cervical immobilization until asymptomatic
- Discontinue cervical immobilization following normal and adequate dynamic flexion/extension radiographs
- Discontinue cervical immobilization following a normal magnetic resonance imaging obtained within 48 hours of injury
- Discontinue cervical immobilization at the discretion of the treating physician
Hospital Course and Management

Management options for cervical immobilization in obtunded or otherwise unevaluable patients with potential acute traumatic spinal cord injury

Criteria for collar clearance in the obtunded or unevaluable patient

• Continue cervical immobilization until asymptomatic
• Discontinue cervical immobilization following normal magnetic resonance imaging obtained within 48 hours of injury
• Discontinue cervical immobilization at the discretion of the treating physician
Pathophysiology of SCI

- Occurs in two phases
  - 1\textsuperscript{st} – primary injury that occurs at the time of trauma and is related to the mechanical force applied to the spinal cord (impact and persistent compression)
  - 2\textsuperscript{nd} – microvascular, biochemical and cellular processes

- Immediate tissue disruption caused by mechanical forces
  - Flexion/extension distraction
  - Axial compression rotation

- Acute pathophysiologic processes
  - Normal cord
  - Mechanical impact

- PRIMARY INJURY
  - NEUROPROTECTIVE INTERVENTIONS
    - In-field stabilization
    - Advanced trauma life support resuscitation
    - Pharmacologic agents
    - Prompt medical/surgical care

- SECONDARY INJURY
Pathophysiology of SCI

Primary Injury

Systemic factors
- Neurogenic shock
- Respiratory failure

Local factors
- Vascular effects
- Glutamate release
- Membrane damage
- Esete
- Cell apoptosis
- Inflammation

Ischemia

Cellular swelling
- Oxygen, glucose
- Energy failure
- Membrane depolarization

↑ Intracellular [Ca^{2+}]

Caspase and calpain activation

Proteolysis and cytoskeletal damage

Mitochondrial damage
- Permeability transition
- Cytochrome c release
- ATP production

Apoptosis

Cell Death

Vasospasm

Lipolysis
- Oxidative damage to proteins, lipids, DNA
- Membrane degradation

Reactive oxygen species
Indications for Intubation of the Patient With Traumatic Cervical Spine Injury

- Complete spinal cord injury above the C5 level
- Patients with complete injuries above the C3 level will invariably experience a respiratory arrest in the prehospital environment due to absence of diaphragmatic function

▶ Absolute Indications
  Complete spinal cord injury above C5 level
  Respiratory distress
  Hypoxemia despite attempts at oxygenation
  Severe respiratory acidosis

▶ Relative Indications
  Report of shortness of breath
  Development of quad breathing\(^b\)
  Vital capacity of <10 mL/kg or decreasing vital capacity

▶ Consideration Should Be Given
  Need to travel remote from emergency department (eg, MRI, transfer to another facility)

\(^a\) Reprinted with permission from Stein DM, et al, Neurocrit Care.\(^b\) © 2012 Neurocritical Care Society. link.springer.com/article/10.1007%2Fs12028-012-9759-0.

\(^b\) Quad breathing refers to the stereotypical breathing pattern in patients with cervical and upper thoracic spinal cord injury in which the chest wall retracts and the abdominal wall protrudes with inspiration.
Central Cord Syndrome

- Typically due to hyperextension injury and typically is NOT associated with a bony injury but rather a buckling of the ligamentum flavum which causes cord contusion
- Characteristic loss of upper extremity strength with relative sparing of lower extremity motor function because of the somatotopic organization of the corticospinal tracts
Brown-Sequard Syndrome

- Less common – hemiplegia occurs with ipsilateral loss of light touch and proprioception with contralateral loss of pain and temperature/sensation
- Typically due to traumatic hemisection from projectiles or knife wounds, or a lateral mass spine fracture
Specific Incomplete SCI Syndromes

Anterior cord Syndrome

- Relatively rare after trauma – common from ischemic injury with disruption of anterior spinal artery
- Trauma – axial compression and burst fractures with retropulsion of vertebral body and bone fragments into the anterior spinal cord
- Deficits – disruption of the motor fibers with relative sparing of the dorsal column sensory pathways
- Prognosis for recovery following anterior cord syndrome is characteristically poor.
Specific Incomplete SCI Syndromes

**Posterior cord Syndrome**

- Loss of proprioception with preservation of motor function, pain/temperature sensation
- Most commonly due to vascular compromise and rarely traumatic injury
Specific Incomplete SCI Syndromes

Cauda Equina Syndrome

• In the setting of trauma – caused by retropulsion of fracture fragments in the lumbosacral region
• Results in lower spinal nerve root compression
• Patients present with back pain, lower extremity pain, sensory loss, bowel and bladder dysfunction and saddle anesthesia
• Patients typically have reduced or absent perianal or perineal sensation, decreased rectal tone and contraction
**Anatomic Reduction and Surgical Management**

- Anatomic reduction in the setting of SCI is indicated in the situation of any neurologic deterioration, facet dislocation or bilateral locked facets.

- Goals of surgical management are to stabilize the spine, decompress the canal and prevent further neurologic injury.
Post-operative Management

- After stabilization (internal or external) the next goal is minimizing the effects of secondary complications such as:
  - venous thromboembolic disease
  - pressure ulcer prevention
  - respiratory failure
  - infections
There are few therapeutic options for the injured spinal cord itself and no neuroprotective therapy has been definitively proven to improve outcome following traumatic SCI

- **Steroids:** Enthusiasm for the use which was recommended as standard of care for decades based on results of the National Acute Spinal Cord Injury (NASCIS) trials has largely been abandoned.
- The most recent version of the AANS/CNS Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries do NOT recommend the administration of steroids for the treatment of acute SCI
- Increased complications with pneumonia and gastrointestinal bleeding
SCI Management

• Studies into a number of other agents such as an investigational Rho protein antagonist and riluzole (a benzothiazole which has demonstrated neuroprotective properties in animal models of traumatic spinal cord injury through sodium channel blockade and is US Food and Drug Administration (FDA) approved for use in ALS), are currently ongoing.

• Stem Cells: Animal models have demonstrated that treatment with allogeneic stem cells improves both motor and sensory function but no human data study to date has been conducted.

• Therapeutic hypothermia: a meta-analysis of animal studies has been described as promising. Noncontrolled human studies have suggested a potential benefit.
Intensive Care Unit Management

- The mainstay of treatment of all patients with SCI is largely supportive focusing on minimizing the secondary insults. Patients with cervical and high thoracic SCI should be monitored in the ICU given the high risk of organ dysfunction and failure.

Respiratory Management

- Respiratory dysfunction occurs in more than 85% of patients with cervical SCI.
- Reduced vital and inspiratory capacity as well as reduced expiratory muscle force can lead to hypoxemia and hypercarbia.
- Although some patients with cervical SCI can be successfully extubated, some will require a tracheostomy.
# SCI Management

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Function</th>
<th>Innervation</th>
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<tbody>
<tr>
<td>Diaphragm</td>
<td>Major muscle of respiration</td>
<td>C3 to C5</td>
</tr>
<tr>
<td></td>
<td>During inhalation, the diaphragm contracts and moves downward</td>
<td></td>
</tr>
<tr>
<td></td>
<td>During exhalation, the diaphragm relaxes, allowing for passive recoil</td>
<td></td>
</tr>
<tr>
<td>Intercostal muscles</td>
<td>During inhalation, the external intercostal muscles contract and elevate the rib cage</td>
<td>T1 to T11</td>
</tr>
<tr>
<td></td>
<td>During exhalation, the internal intercostal muscles contract and pull the ribs down</td>
<td></td>
</tr>
<tr>
<td>Abdominal muscles</td>
<td>Essential for an effective cough</td>
<td>T6 to L1</td>
</tr>
<tr>
<td></td>
<td>During exhalation, the abdominal muscles contract and compress the abdominal contents and push the diaphragm up</td>
<td></td>
</tr>
<tr>
<td>Accessory muscles</td>
<td>Elevate the rib cage and assist in deep ventilation</td>
<td>C1 to C3</td>
</tr>
<tr>
<td></td>
<td>Inadequate alone for effective ventilation</td>
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</table>
SCl Management

Cardiovascular Management

• Cardiac dysfunction following cervical spinal cord injury is very common and is associated with severity of injury as measured by ASIA and the ASIA impairment scale.

• As many as 60% of cervical SCI patients will meet criteria for cardiovascular failure and about 90% will have dysfunction

• Hypotension is associated with secondary injury due to reduced spinal cord perfusion and is associated with worse neurologic outcome

• Patients with SCI above T4 are at high risk of developing *neurogenic shock*.
  - An interruption of the sympathetic chain → unopposed vagal tone → distributive shock with hypotension and bradycardia (though they can have variable heart rates)
Cardiovascular Management

• Neurogenic Shock
  • Generally are hypotensive with warm, dry skin
  • The higher and more complete the injury, the more severe and refractory the neurogenic shock which can last from 1 to 3 weeks.
  • 1st line treatment is fluid resuscitation to ensure euvoolemia
  • 2nd line treatment is vasopressor and/or inotropes
  • No consensus has been reached on the best vasoactive agent of choice, recommendations are for use of an agent with both alpha-adrenergic and beta-adrenergic activity to treat both the hypotension and bradycardia
SCI Management

Cardiovascular Management

• Neurogenic Shock - Agents
  • **Norepinephrine** - has both alpha and some beta activity, thereby improving both peripheral vasoconstriction and inotropy, contributing to both blood pressure and bradycardia, and is most likely the preferred agent.

  • **Phenylephrine** - A pure alpha-1 agonist that is very commonly used, and easily titrated. Phenylephrine lacks beta activity and is best used in patients with high thoracic lesions in whom bradycardia is less of a concern.
Cardiovascular Management

• Neurogenic Shock - Agents
  • **Dopamine** – also frequently used, but high doses (>10 mcg/kg/min) are needed to obtain the alpha vasoconstrictor effect. It does have significant beta effects at lower doses

  • **Epinephrine** - an alpha and beta agonist that causes vasoconstriction and increased cardiac output

  • **Dobutamine** - can be useful, as it is a pure beta agonist that can affect bradycardia, and may be helpful for treatment of hypotension if the loss of sympathetic tone causes cardiac dysfunction
SCI Management

Cardiovascular Management

American Association of Neurological Surgeons and the Congress of Neurological Surgeons’ Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries

Current recommendations are to maintain mean arterial blood pressure between 85 and 90 mm Hg for the first 7 days following acute cervical spinal cord injury.

Based on several studies of aggressive protocolized blood pressure management and at least one prospective case series that demonstrated improved neurologic outcome with this aggressive hemodynamic treatment management strategy.
Other Considerations

Infection – remains the leading cause of death following SCI and aggressive screening and treatment is paramount. Early removal of indwelling central lines and aseptic technique is essential.

Aggressive management of hyperglycemia and early administration of enteral nutrition within 72 hours of admission to all patients with cervical SCI is recommended.

Stress ulcer prophylaxis is indicated in all patients with cervical SCI due to the increased risk of GI bleeding.
SCI Management

Other Considerations

**Venous thromboembolic disease** – all SCI patients are at an exceptionally high risk of developing VTE because of immobility, alterations in fibrinolysis and abnormal platelet function.

Incidence of VTE is reported to be between 12% to 64% and accounts for 10% of deaths in the first year following SCI.

Recommendations: use of a combination of modalities such as low molecular weight heparins, rotating beds, and pneumatic compression stockings.
SCI Management

Other Considerations

Venous thromboembolic disease – generally begin chemoprophylaxis treatment after 72 hours of injury.

Prophylactic inferior vena caval (IVC) filters are currently recommended only if chemical or mechanical prophylaxis is contraindicated.

Treatment for 3 months following injury is the recommended duration of prophylaxis based on both expert consensus and data from the natural history of venous thromboembolic disease following spinal cord injury.
**Other Considerations**

**Autonomic dysreflexia** – a syndrome following spinal cord injury that may affect patients in the acute or chronic phase specifically in patients with high thoracic or cervical spinal cord injuries.

A typically noxious stimulus (bladder distension or fecal impaction) occurs below the level of injury leading to a dangerous rise in systolic blood pressure due to hyperactive thoracic sympathetic reflex activity, a loss of supraspinal sympathetic control, and inadequate parasympathetic response.
SCI Management

Other Considerations

**Autonomic dysreflexia** – is defined as a greater than 20% increase in systolic blood pressure with a change in heart rate and at least one sign (sweating, piloerection, facial flushing) or symptom (headache, blurred vision, stuffy nose).

Untreated, malignant hypertension can result in intracranial hemorrhage, retinal detachment, seizures, coma, myocardial infarction, pulmonary edema, and death.

Remove the stimuli but if hypertension persist can treat with a calcium channel blocker.
Prognosis

Prognosis for neurologic recovery is invariably one of the first things about which a patient or family of a patient with spinal cord injury will inquire.

The life expectancy for a patient with spinal cord injury remains lower than for those without spinal cord injury.

Mortality rates are the highest in the first year following spinal cord injury for all ages and all severities of injury.
SCI Management

Key Points

1. Traumatic spinal cord injury accounts for 14,000 cases annually in the US
2. Injuries to the spinal cord typically occur at two peaks of age: young adults ages 15 to 29 and patients older than age 65
3. Spine immobilization if key to prevent further injury
4. Rapid and safe transport to nearest treatment center
5. Patients with injuries above the C5 level often need urgent endotracheal intubation. Respiratory arrest is common in patients with injury above C3
6. The American Association of Neurological Surgeons’ and Congress of Neurological Surgeons’ guidelines do not recommend steroids for acute cervical spinal cord injury