Pediatric Spinal Cord Injury and Spinal Shock

Christopher M. Bonfield, MD
Assistant Professor
Director, Pediatric NeuroSpine Program

Departments of Neurosurgery, Plastic Surgery, and Orthopedics
Vanderbilt University Medical Center
Nashville, TN, USA
Disclosures

• None
Outline

- Epidemiology
- Biomechanics
- SCIWORA
- Shock
- Outcomes
- Deformity
Epidemiology

- Overall incidence in USA: 1.99/100,000
- 60%-80% cervical spine
- Males > Females (2:1)
- Most common mechanism: Motor vehicle accidents (48%-61%)
  - 70%-80% not properly restrained
- Other mechanisms: Falls (18%-30% in younger age), sports injuries (20%-38% in older age), pedestrian accidents, non-accidental trauma (age <2)
- Seasonal peaks during summer and around winter holiday
- Risk for neurologic injury: Cervical > thoracic > lumbar
- Mortality rate: 16%-18%, higher in upper cervical injuries (AOD), and younger age
  - Increased rate of head injuries with higher injuries as well
Epidemiology

- Age <8: upper cervical injuries, ligamentous injuries, severe and complete injuries
- Age >8: subaxial injuries, fractures, T-L injuries
Biomechanics

• Overall: increased elasticity, hypermobility
  – Expansile ligaments, joints, discs, annulus fibrosis
  – Shallow and more horizontally oriented facet joints (30 deg at birth)
  – Wedge-shaped vertebral bodies
  – Absent uncinate process (which limits lateral and rotational movement)
  – Large head to body ratio
  – Underdeveloped neck musculature
SCIWORA (Spinal Cord Injury Without Radiographic Abnormality)

- **Causes:** High-energy injury with hypermobility of spine and lack of tolerance of the spinal cord to handle stretch.
- **Most common in children under 8**
- **Cervical spine location:** Cervical > Thoracic
- **Risk of neurologic injury:** ranges from complete to partial neurologic injury.
- **Prognosis:** predicted by neurologic status at presentation vs MRI findings (edema, hemorrhage, etc.)
- **Acute treatment:** spine precautions, determination of instability, blood pressure control, steroids (?)
- **Conservative management:** The main treatment of SCIWORA is external immobilization (12 weeks) with activity modification.
Neurogenic Shock - Pathophysiology

- Most common with injury above T6
- Sudden loss of autonomic tone due to SCI
- Disruption of the descending sympathetic pathways results in unopposed vagal tone in the vascular smooth muscle, causing decreased systemic vascular resistance and vasodilation
- Hypotension that results from neurogenic shock places patients at increased risk of secondary spinal cord ischemia
- May occur anytime after the onset of injury or illness, ranging from the time of presentation to several weeks after presentation
Neurogenic Shock - Presentation

• Respiratory insufficiency and pulmonary dysfunction
• Systemic hypotension and relative bradycardia
• Other
  – Skin is often warm and flushed initially
  – Hypothermia may develop because of profound vasodilation and heat loss.
  – Central venous pressure is low due to decreased systemic vascular resistance
Neurogenic Shock - Management

• ICU care and Cardiopulmonary support
  – Hypotension must be treated immediately in order to avoid secondary ischemic SCI (especially in patients with concurrent brain injury)
  – Management of patients with an acute SCI 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 spinal cord injury is recommended
  – The blood pressure goals in pediatric patients with SCI are unknown, however, it is recommended to maintain a MAP goal (MAP >85-90 mm Hg for 7 days) in adults according to Neurosurgery guidelines
<table>
<thead>
<tr>
<th>Day 1</th>
<th>Admission Service:</th>
<th>□ Trauma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consults:</td>
<td>□ Spine</td>
</tr>
<tr>
<td></td>
<td>Labs:</td>
<td>□ CBC qam (HCT &gt;21%) □ BMP qam</td>
</tr>
<tr>
<td></td>
<td>Radiology Studies:</td>
<td>□ Follow-up x-rays post halo placement: lateral c-spine</td>
</tr>
<tr>
<td></td>
<td>Immobilization:</td>
<td>□ Aspen collar with cervical collar maintenance □ Halo with pin care □ Halo and traction with pin care</td>
</tr>
<tr>
<td></td>
<td>Monitoring:</td>
<td>□ VS □ q1h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Neuro checks □ q1h □ Sensation checks □ q1h</td>
</tr>
<tr>
<td></td>
<td>Nursing:</td>
<td>□ MAP Goal x 5 days □ &lt;3yrs: 60 □ 3-12 yrs: 70 □ 13-16 yrs: 75 □ &gt;16 yrs: 80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Strict l/O □ Arterial line placement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Accucheks q2-4h □ Glucose control between 80-150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Ventilatory support as needed (normocapnia)</td>
</tr>
<tr>
<td></td>
<td>Vasopressors:</td>
<td>□ Dopamine ______mcg/kg/min □ Norepinephrine ___mcg/kg/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Epinephrine ______mcg/kg/min □ Neosynephrine ___mcg/kg/min</td>
</tr>
<tr>
<td></td>
<td>Medications:</td>
<td>□ Fentanyl ______mcg/kg/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Versed ______mg/kg/min □ Remifentanil ______mg/kg/min</td>
</tr>
<tr>
<td></td>
<td>Fluids:</td>
<td>□ D5 1/2 NS with 20 mEq KCl IV @ _____ ml/hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ D5 NS with 20 mEq KCl IV @ _____ ml/hr</td>
</tr>
<tr>
<td></td>
<td>Diet:</td>
<td>□ NPO</td>
</tr>
<tr>
<td></td>
<td>Activity:</td>
<td>□ Bedrest on KenAir Matress □ Strict log rolling only, HOB flat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Turn/ reposition q2h with strict spine precautions maintained</td>
</tr>
<tr>
<td></td>
<td>DVT Prophylaxis:</td>
<td>□ SCD in place (on 2hrs/ off 2hrs) □ T.E.D. hose in place</td>
</tr>
<tr>
<td></td>
<td>Bowel and Bladder:</td>
<td>□ Indwelling catheter x 24-48hrs PI □ NGT</td>
</tr>
<tr>
<td>Day 2</td>
<td>Diet: □ Enteral Feeds □ Clear Liquid □ TF @ ____ ml/hr (consider) □ Regular diet (consider) □ Physical Therapy □ Speech Therapy □ Occupational Therapy □ Rehabilitation Services Radiology Studies: □ Follow-up x-rays post halo placement: lateral c-spine (If not already obtained)</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Day 3</td>
<td>Diet: □ Enteral Feeds □ Clear Liquid □ TF @ ____ ml/hr □ Regular diet □ Physical Therapy □ Speech Therapy □ Occupational Therapy □ Rehabilitation Services Bowel and Bladder: □ Docusate ____ mg PO/per tube BID □ In &amp; Out Cath q6h □ Miralax ____ gr PO/per tube BID/TID/QID □ Docusate ____ mg PO/per tube BID □ Bisacodyl Suppository ____ mg PR daily</td>
<td></td>
</tr>
<tr>
<td>Day 6</td>
<td>Monitoring: □ Discontinue MAP goals DVT Prophylaxis: □ Convert to LMWH if not contraindicated by plan of care Consult: □ Hematology prn</td>
<td></td>
</tr>
</tbody>
</table>
Neurogenic Shock - Summary

• SCI, regardless of mechanism, may result in neurogenic shock characterized by sudden loss of autonomic tone resulting in hypotension and relative bradycardia
• Higher lesions are associated with more severe deficits
• Peripheral vasoconstrictors, chronotropes, and inotropes may be needed in cases of neurogenic shock
• The hypotension that results from loss of autonomic tone can precipitate further secondary ischemic injury to the spinal cord, and should be managed aggressively
• Treatment in the ICU leads to better outcomes
• Dysautonomia may develop and often persists several weeks after the injury
Outcomes

### Age <2, N = 27, (%)  
### Age 2-7, N = 140, (%)  
### Age 8-15, N = 373, (%)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Age &lt;2</th>
<th>Age 2-7</th>
<th>Age 8-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death during hospitalization</td>
<td>7 (26)</td>
<td>22 (16)</td>
<td>11 (3)</td>
</tr>
<tr>
<td>Normal</td>
<td>10 (37)</td>
<td>84 (60)</td>
<td>292 (78)</td>
</tr>
<tr>
<td>Persistent neurologic deficit</td>
<td>10 (37)</td>
<td>34 (24)</td>
<td>70 (19)</td>
</tr>
</tbody>
</table>

### Direct To Pediatric Trauma Center,  
\(n,\% (95\% CI); n = 180\)

| Outcome                              | Direct To Pediatric Trauma Center,  
\(n,\% (95\% CI); n = 180\) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>116, 64% (57–71)</td>
</tr>
<tr>
<td>Persistent neurologic deficit</td>
<td>51, 28% (22–36)</td>
</tr>
<tr>
<td>Death during hospitalization</td>
<td>13, 7% (4–12)</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)*</td>
<td>1.13 (0.71–1.78)</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)†</td>
<td>1.89 (1.03–3.47)</td>
</tr>
</tbody>
</table>

### Via Local Hospital,  
\(n,\% (95\% CI); n = 141\)

| Outcome                              | Via Local Hospital,  
\(n,\% (95\% CI); n = 141\) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>87, 62% (53–70)</td>
</tr>
<tr>
<td>Persistent neurologic deficit</td>
<td>43, 30% (23–39)</td>
</tr>
<tr>
<td>Death during hospitalization</td>
<td>43, 30% (23–39)</td>
</tr>
</tbody>
</table>

*Comparing the odds of normal outcome to persistent neurologic deficit or death for direct to pediatric trauma center compared to via local hospital.

†Adjusting for severity according to altered mental status, focal neurologic findings, substantial comorbid injuries (head, torso, and extremities), and for correlation among patients within a pediatric trauma center.
Deformity

• **Deformity**: Progressive deformity can occur in spinal cord injury patients, especially in those injured prior to adolescent growth spurt.
  – Ranges in studies from 46-98%
  – More severe in younger onset of paralysis, age at injury important

• Bracing may be necessary to prevent or delay surgery in growing children with history of spinal cord injury
Summary

• Pediatric spine is biomechanically unique from an adult, resulting in a different pattern of injuries
• CT and MRI can be useful modalities, especially in SCIWORA
• Management usually consists of external immobilization, but surgical treatments are frequently necessary
• More frequent neurologic deficits and spinal shock in higher injuries
• Deformity can occur after SCI, so proper follow-up is necessary
References

References


• Saul D, Dresing K: Epidemiology of vertebral fractures in pediatric and adolescent patients. Pediatr Rep 10:7232, 2018


Thank You