Management of Acute Traumatic Spinal Cord Injury

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Incidence of Traumatic Spinal Cord Injury in the United States

• 40 new SCI/ 1 million/ year
• ~ 12,500 new SCI/ year (Deaths at scene not included)
• 240,000 – 337,000 living with SCI in U.S.
• Average age 42 years
(National Spinal Cord Injury Statistical Center, 2015)

Neurologic Level of Spinal Injuries

CERVICAL VERTEBRAE 55%
THORACIC VERTEBRAE 15%
LUMBAR VERTEBRAE 15%
SACRUM 15%
COCCYX 15%

Soft Tissue Injury
Spinal Cord Injury With Out Radiographic Abnormality (SCIWORA)

- No boney abnormality seen on x-rays
- Spinal cord injury may be seen on MRI
- Has been attributed to ligamentous injury, disc prolapse, and cervical spondylosis
- Common in children < 9 years old, but also seen in middle aged and elderly
Contusion
Hemorrhage and edema of the cord

Laceration
Complete transection is rare!

Hemorrhage

Vascular damage
Complete vs. Incomplete Spinal Cord Injury

- **Complete**
  - No preservation of voluntary motor function or sensation below the lesion
- **Incomplete**
  - Varied motor and sensory loss below the level of the lesion due to sparing of some tracts

Posterior Columns (position sense)

Lateral Corticospinal Tract (motor)

Lateral Spinothalamic Tract (pain & temperature on the opposite side of body)

Central Cord Syndrome

- Fasciculus gracilis
- Fasciculus cuneatus
- Lateral corticospinal tract
- Lateral spinothalamic tract
- Anterior spinothalamic tract

Anterior Cord Syndrome

- Fasciculus gracilis
- Fasciculus cuneatus
- Lateral corticospinal tract
- Lateral spinothalamic tract
- Anterior spinothalamic tract
Brown-Sequard Syndrome

Dorsal Column Syndrome

Apoptosis
Spinal Shock

- Onset: Within 1 – 6 hours after injury
- Cessation of all spinal reflexes below the injury
- Flaccid paralysis
- Loss of autonomic control
- Loss of all sensation
- Urinary and fecal retention

Spinal Shock Resolution

- Hours to weeks after injury
- Return of reflexes below the lesion
- Flexor spasms
- Reflexive bladder emptying

Rating Scheme for Strength of the Evidence

- Class I
- Class II
- Class III

Priorities of Care

- Establish airway while maintaining head and neck alignment
- Ensure adequate ventilation/oxygenation
- Ensure sufficient circulation
- Avoid other factors causing secondary injury

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Spinal Cord Assessment

- Comprehensive
- Serial
- Well documented

Lateral Spinothalamic Tract Assessment

Posterior Columns

- Proprioception
- Position sense in each extremity

Lateral Corticospinal Tract Assessment

Voluntary motor function
Check for rectal sparing!

- Light touch / pinprick sensation S3-4
- Deep anal pressure
- Voluntary anal contraction
- More initial sacral sparing → greater recovery potential
- More gained → greater chance of motor recovery


Deep Tendon Reflexes Correlated with Level of Spinal Cord Innervations

<table>
<thead>
<tr>
<th>Deep Tendon Reflexes</th>
<th>Spinal Cord Level</th>
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</thead>
<tbody>
<tr>
<td>Biceps</td>
<td>C5 – C6</td>
</tr>
<tr>
<td>Triceps</td>
<td>C7 – C8</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>L2 – L4</td>
</tr>
<tr>
<td>Achilles</td>
<td>S1 – S2</td>
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Priapism

Sustained reflexive erection of the penis due to unopposed parasympathetic stimulation and increased arterial inflow
**Vital Sign Alterations**
- Bradycardia
- Hypotension
- Hypoventilation
- Loss of Thermoregulation

**Cervical Spinal Radiographs**
- Not necessary in awake, alert, non-intoxicated patient without neck pain or tenderness or other significant injuries
- If CT unavailable, obtain 3 views (Level 1)
  - Lateral
  - Anterior-posterior
  - Odontoid
- Must view C1 through T1

**Magnetic Resonance Imaging**
Myelogram

• Contrast medium is injected into the subarachnoid space
• Recognizes obstruction of contrast medium flow

Somatosensory Evoked Potentials

Vertebral Artery Injury (VAI) Diagnosis After Blunt Cervical Trauma

• CTA to screen selected pts who meet the Denver Screening Criteria for cerebral artery injury (Level I)

Vertebral Artery Injury (VAI) Diagnosis After Blunt Cervical Trauma

• Conventional angio for selected patients to diagnose VAI
  – Concurrent endovascular therapy
  – CTA unavailable (Level III)
• MRI to diagnose VAI
  – Complete SCI
  – Vertebral subluxation (Level II)
• Rule out VAI with comminuted fracture of axis body (Level III)
Specialized referral center
(Parent et al. J Neurotrauma, August 2011)

• Early transfer to a specialized center should be done promptly to decrease overall length of stay

• Early transfer to an integrated multidisciplinary specialized center decreases overall mortality and the number and severity of complications

What’s wrong with this picture?

Maintain spine alignment until definitive treatment or rule out spinal injury
Recommended Collar Removal

• Awake with neck pain or tenderness with normal films
  - Normal dynamic flexion/extension films
  - Normal MRI within 48 hrs
  - Physician Discretion

• Obtunded with normal films
  - Normal MRI within 48 hrs
  - At physician discretion
  - Normal flexion/extension under fluoroscopy NOT recommended (Level III)
Initial Closed Reduction of the Cervical Spine (Level III)

- Early closed reduction of cervical fracture/dislocation with traction recommended in awake patients
- NOT recommended in pts with other rostral injury
- MRI recommended for patients with cervical fracture/dislocation if they can not be examined during closed reduction or before anterior or posterior procedures when closed reduction failed
- If more contemporary treatment options unavailable, treatment of subaxial cervical fracture or dislocation with prolonged bedrest in traction recommended

Braces to Immobilize the Spine

- Halo Vest
- Yale Brace
Surgical Intervention

- Decompression
- Realignment
- Stabilization

Recommendations for Treatment of Subaxial Cervical Spine Injuries

Goal: Decompression of the spinal cord and restoration of the spinal canal

- Closed or open reduction of fractures or dislocations
- Stable immobilization by external device or internal fixation to allow for early patient mobilization and rehab
- Anterior or posterior surgical fixation and fusion is acceptable unless specific approach required

C1-C7 Posterior surgical fusion and laminectomy

Recommendations for Treatment of Acute Central Cord Syndrome

- Early reduction of fracture-dislocation injuries recommended
- Surgical decompression of the compressed cord, especially with focal and anterior compression, is recommended (Level III)

Surgical Timing in Acute SCI Study


- 6 center prospective cohort study
- 313 acute cervical SCI, 16-80yo
- 182 had surgery < 24 hours
- 131 had surgery > 24 hours
- At 6 mos. (222 pts) 19.8% early surgery pts vs. 8.8% late surgery had > 2 grade improvement in ASIA Impairment Scale
- Decompression prior to 24 hours after SCI can be safely performed and is associated with improved neurologic outcome
- Economic analysis: early decompression more cost effective

Furlan et al, World Neurosurgery. 2016;88

C5-C6 anterior fusion; C3-T1 posterior fusion

Economic analysis: early decompression more cost effective
Surgical Timing in Acute SCI Study

- Observational study
- 53 complete SCI – 33 thoracolumbar; 20 cervical
  - 38 had surgery < 24 hours; younger
  - 15 had surgery > 24 hours
- At rehabilitation discharge
  - Overall, 34% early surgery patients vs. 13% > 24 hours had improvement in ASIA Impairment Scale score
  - Of cervical SCI, 64% of early surgery patients vs. none > 24 hours had improvement in ASIA Impairment Scale score

Recommendations for Pharmacologic Use

- Administration of methylprednisolone is NOT recommended
  - No Class I or II medical evidence to support benefit
  - Scattered Class III evidence claims inconsistent effects
  - Class I, II and III data associate methylprednisolone with harmful side effects

Incidence of and Risk Factors for Organ Dysfunction and Failure
(Stein, et al, Neurocritical Care, 2010)

- 40 pts with isolated cervical SCI; in ICU >24hr
- 75% had at least 1 organ fail per Multiple Organ Dysfunction Score; 85% per Sequential Organ Failure Assessment
- Common failure: CV and Respiratory
- Respiratory, CV, neurologic, renal, hepatic and hematologic dysfunction were common
- Organ dysfunction and failures correlated:
  - Strongly with ASIA motor index score and ASIA impairment scale
  - Poorly with level of injury

Pulmonary Complications

Most common acute systemic adverse event following SCI
Most common cause of death and morbidity following SCI
ASIA Impairment Scale grade A or B was the fundamental clinical entity predicting pulmonary complications
Innervation of Respiratory Muscles

- C4 and above – no patient-initiated respirations likely
- C5-6-7-8 – Phrenic nerve intact without the intercostals
- T1-6 – Phrenic nerve intact with some intercostal function
- T1 – T11 - Internal intercostals
- T7 – T11 - Abdominal
- Below T12 – No interference with respiration

Cough

Respiratory Function with Cervical SCI

- During spinal shock
  - Intercostals are flaccid
  - As diaphragm contracts and descends → Chest wall contracts rather than expands → Loss of ventilation function (20-50% of expected)
- After spinal shock resolves
  - Intercostals become spastic
  - Chest wall becomes rigid and no longer collapses during inspiration → Ventilation function improves (60% of expected)

Impaired Cough

- Denervated muscles
  - T1 – T11 Internal intercostals
  - T7 – T11 Abdominal
- Sympathetic denervation
  - Increased bronchial tone
  - Increased mucus production

Respiratory fatigue
**Pulmonary Complications**

- Atelectasis
- Pulmonary infection
- Pulmonary edema
- Adult respiratory distress syndrome
- Pulmonary emboli

**Monitor respiratory parameters to recognize need for treatment**

- Vital Capacity ≤ 1 liter → ? need mechanical ventilation
- Negative Inspiratory Force < -20 mmHg → ?
  Need intubation to provide adequate airway clearance
- Tidal Volume < 5ml/kg

**Pulmonary Care**

- Maintain head and neck alignment
  - Use manual in-line cervical traction
  - Indirect methods may cause less movement than direct laryngoscopy
- Avoid succinylcholine as an NMB after 48 hours
- Tracheostomy often needed with C5 or above SCI

- Positive pressure ventilation
- Bronchodilator
- Positioning
- Abdominal binder
Aggressive Pulmonary Hygiene

- Comprehensive clinical pathway (structured protocol regularly using a combo of treatments i.e., positioning; assist coughing / suctioning; lung volume restoration therapy) reduces respiratory complications and costs (Berney, et al. Spin Cord, 2011)
- Suctioning
- Chest physiotherapy
- Bronchoscopy
**Additional Interventions**

- Monitor for and treat pulmonary infection
- Use hemodynamic parameters to guide fluid therapy
- Prevent, recognize and treat pulmonary emboli

**Hemodynamic Management**

- Use hemodynamic, cardiac and respiratory monitoring to detect cardiovascular dysfunction or respiratory insufficiency
- Prevent and treat hypotension - systolic BP <90 mmHg
- Maintain MABP at 85 – 90 mmHg for first 7 days after acute SCI (Level III)

**MABP Correlates with Neurological Recovery after Human Spinal Cord Injury**


- Computer system collected and stored data every 1 minute
- Determined relationship between the proportion of time MABP was below the desired threshold and neurologic recovery
- Days 2-3 → higher MABP correlated with improved recovery
- Proportion of MABP < 85 mmHg had a stronger correlation with recovery; decreasing in strength over the 1st 5-7 days
- Does NOT provide causal relationship
Hemodynamic Management

- Rule out other causes for hypotension
- Early appropriate fluid resuscitation
  - Isotonic crystalloids
  - Blood products, if appropriate
- Use hemodynamic parameters and indicators of tissue perfusion (e.g., lactate, base deficit) to guide fluid replacement
- Inotropic or vasoactives if necessary

Vasovagal Response

Sympathetic cardiac acceleration is disrupted
Intact vagal nerve slows the heart

Prevent Vasovagal Reflex

- Prevention
  - Avoid hypoxia
  - Avoid rapid position change
  - Avoid the valsalva maneuver
- Treatment – Increase HR
  - Atropine
  - Other drugs
  - Pacemaker

Orthostatic Hypotension

- Wrap legs before raising head
- Abdominal binder
- Gradually raise the head of the bed
- Medication
  - Midodrine (alpha-adrenergic agonist increases vascular tone and BP)
Venous Thromboembolism (VTE)

- Spinal cord injury is a strong risk factor
- Risk greatest in acute phase
- Level I Recommendations for Prophylaxis
  - Patients with severe motor deficits from SCI
  - Use of low molecular weight heparins, rotating beds or a combination
  - Low dose heparin with pneumatic compression stockings or electrical stimulation recommended as a prophylactic strategy

Venous Thromboembolism (VTE)

- Level II Recommendations for Prophylaxis
  - Low dose heparin or oral anticoagulation alone NOT recommended for prophylaxis
  - Early prophylaxis (within 72 hours) recommended
  - 3-month duration of prophylactic treatment
- Level III Recommendations for Prophylaxis
  - Vena cava filters NOT recommended as routine prophylactic measure; recommended for those who fail anticoagulation or are not candidates for anticoagulation and/or mechanical devices
- Level III Recommendations for Diagnosis
  - Duplex Doppler ultrasound, impedance plethysmography, venous occlusion plethysmography, venography and clinical exam recommended for use as diagnostic tests for DVT

Autonomic Dysreflexia

- Severe headache
- Vasodilatation
- Flushing
- Sweating
- Piloerection
- Vasoconstriction

Lesion
Other Signs and Symptoms

• Hypertension
• Nasal congestion
• Chest pain
• Nausea
• Bradycardia

Treatment of Autonomic Dysreflexia

• Sit patient up
• Loosen tight clothing
• Monitor BP closely
• REMOVE NOXIOUS STIMULI!
• Antihypertensive (e.g., Nifedipine, NTG)
• Alpha – adrenergic blocking agents

Poikilothermia

• Loss of thermoregulation
• Hypothermia OR may have fever
  – Neurogenic incidence reportedly 2.6 - 28%
  – Pathogenesis not clear
• Caused by disruption of the sympathetic pathways
• Must monitor temperature closely
• Take measures to maintain normothermia

Types of Spinal Cord Injury Pain

- Nociceptive
- Neuropathic

• Analgesics
• Nonsteroidal anti-inflammatory agents
• Neuropathic
  • Gabapentin
  • Pregabalin

Be cautious not to impair respiratory status!
Ileus

- Common with increased incidence with complete lesions
- Usually seen first 2-3 days
- Lasts 3 – 7 days
- Caused by disruption of the autonomic nervous system

Risk for GI Ulceration

- Autonomic nervous system disruption
- Stress
- Systemic hypotension and hypoxia
- No gastric intake

Nutrition

- Ensure adequate nutrition to meet the patient’s determined metabolic needs
- Energy expenditure is best determined by indirect calorimetry since equation estimates tend to be inaccurate
- Maintain normoglycemia
- Evaluate swallowing

Upper Motor Neuron Bowel

- Hyper-reflexive after spinal shock resolves
- No sensation or control of defecation
- Spastic external sphincter
- Unable to consciously defecate
- Allows reflexive stool propulsion
- UMN goal: soft-formed stool readily evacuated with rectal stimulation
Lower Motor Neuron Bowel

- Sacral level injury (e.g., cauda equina, conus medullaris)
- Areflexive bowel
- Slow colonic propulsion
- Hypotonic sphincter → More frequent defecation/ incontinence
- LMN goal: firm-formed stool retained between bowel care episodes and is easy to evacuate

Bowel Program

- Initiate ASAP!
- Perform at least once every 1-2 days; 30 minutes after meal
- Ensure diet with sufficient fiber and fluid
- Stool softeners/ bulk-forming agents
- Manual stimulation
- Chemical stimulants (suppositories, small enemas)
- Assistive techniques (e.g., abdominal massage) ???

Genitourinary dysfunction

- Spinal shock → Urine retention
- Reflexive neurogenic bladder
  - Injury above the conus
  - Spontaneous voiding at low volumes
- Areflexive neurogenic bladder
  - Injury at sacral level
  - Urine retention with overflow
- Continuous catheterization → Fluid intake of ≤ 3 liters and no need to monitor I & O → Intermittent catheterization

Urinary Tract Infection

- Prevention
  - Remove catheter ASAP
  - Keep bladder empty
- Treatment
  - Only symptomatic bacteruria
  - Prophylactic treatment increases antibiotic resistant infection risk
Skin Care

- Hypotension the strongest predictor of pressure ulcers
  (Wilczweski, et al J Trauma Nursing, 2012)

Spasticity

- > 80% SCI patients have spasticity
- Exact etiology is poorly understood
- Increased tone, resistance to stretch, muscle contractions
- Treatment
  - Muscle stretching, ROM
  - Proper positioning, splints
  - Antispasmodics
  - Electrical stimulation modalities?

Potential Psychosocial Alterations

- Fear
- Powerlessness
- Altered body image
- Altered self concept
- Grief
- Ineffective coping
Advanced MRI Strategies

Functional MRI

Diffusion Tensor Imaging

Improved Management of Systemic Complications

Riluzole

- Approved for amyotrophic lateral sclerosis
- Neuroprotective after SCI?
  - Blocking sodium channels
  - Decreasing glutamate release
- Multicenter randomized, placebo controlled, Phase II/III trial in humans with acute traumatic SCI to evaluate efficacy and safety underway
Monitoring and Treating Spinal Cord Perfusion Pressure

Papadopoulos, et al. Saint George’s, University of London

Spinal cord perfusion pressure = MABP – Intraspinal pressure
Typically optimal about 90 mmHg

Saadoun, Papadopoulos. Critical Care. 2016: 20:308

Neurotropic Factors

- Support neuronal survival
- Induce sprouting of neurites
- Facilitate guidance of neurons to their proper target sites

Cell Transplantation

- Extensive preclinical literature suggests stem cell based therapies may offer promise
- Intraleision transplantation of autologous mesenchymal stem cells in chronic, complete SCI is safe, feasible and may promote neuro recovery (Mendonca et al. Stem cell res. 2014)
- Human stem cell trial underway
  - 10-15 U.S. sites to enroll 52 patient
  - C5-7, At least 12 weeks after injury

Hypothermia

- Neuroprotective
- Mixed results with local and systemic hypothermia in animals
- Local hypothermia in humans
  - Not published since 1984
  - Lacked statistical power
- Systemic hypothermia safely used in humans
- Larger randomized controlled trials needed to establish efficacy
- Prospective trial underway
- at University of Miami