Spinal Cord Injury

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Objectives

- **Overview of Spinal Cord Anatomy**
- **Pathophysiology of Spinal Cord Injury**
- **Classify SCIs based on neurologic involvement**
- **Identify different Spinal Cord Injury syndromes**
- **Medical and Surgical Management**
- **Rehabilitation**
- **Recent Advances**

Epidemiology

- Annual incidence rate of 15 to 40 persons per million
- Occurs predominantly in young, otherwise healthy individuals
- Male-to-female ratio for SCI is approximately 4 to 1
- Causes - motor vehicle accidents (50%), falls and work-related injuries (30%), violent crime (11%), and sports-related injuries (9%)
- 56% of all SCI cases occur in the cervical spine.
- Lifetime estimated cost of medical care for a 25-year-old patient with SCI is approximately $3 million
- Mortality is significantly higher during the first year, is related to level, severity of injury and is influenced by availability of timely, quality medical care.

Anatomy of the Spinal Cord

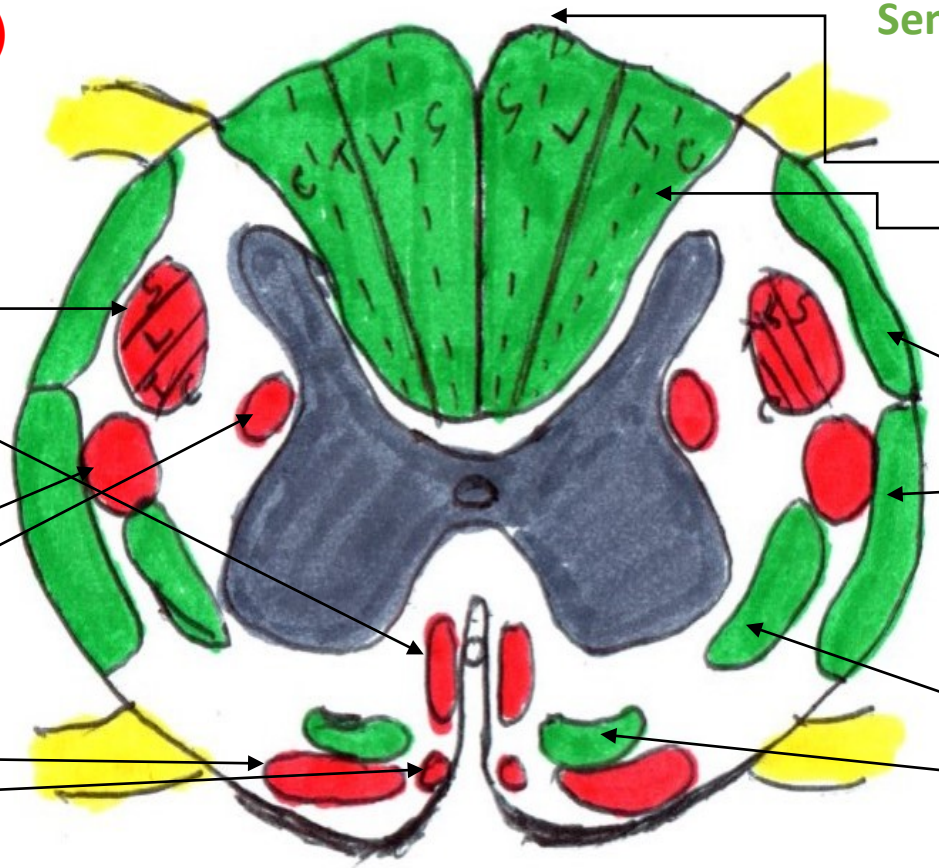
Anatomy of the Spinal Cord

Posterior

Motor and descending pathways (red)

Pyramidal tracts
- Lateral Corticospinal tract
- Anterior Corticospinal tract

Extrapyramidal tracts
- Rubrospinal tract
- Reticulospinal tract
- Olivospinal tract
- Vestibulospinal tract



Sensory and ascending pathways (green)

Dorsal Column
- Fasciculus Gracilis
- Fasciculus Cuneatus

Spinocerebellar tracts
- Posterior spinocerebellar tract
- Anterior spinocerebellar tract

Spinothalamic tracts
- Lateral spinothalamic tract
- Anterior spinothalamic tract

Anterior

*C/T/L/S = Cervical/Thoracic/Lumbar/Sacral

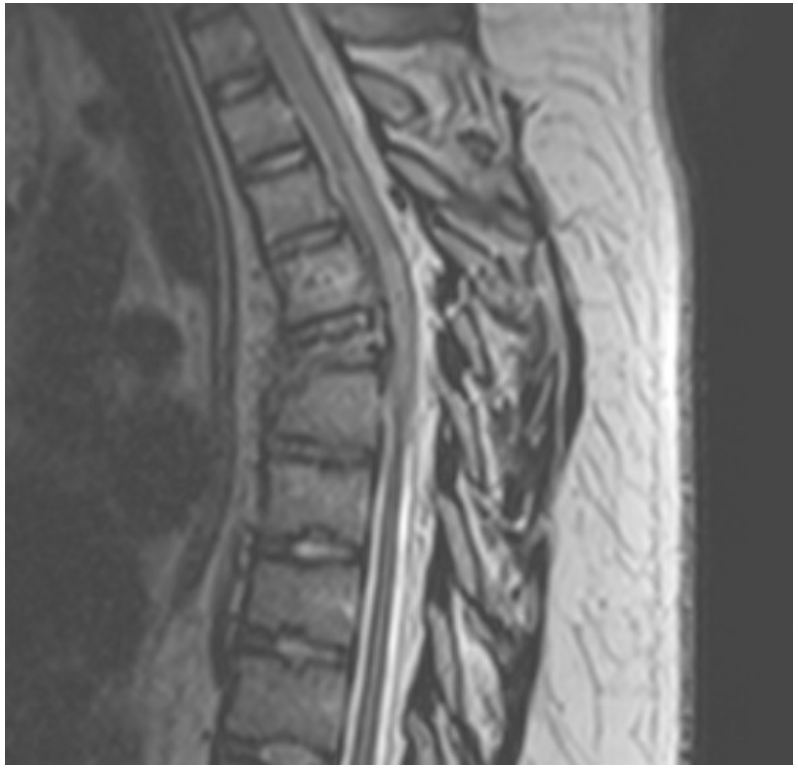
Anatomy of the Spinal Cord

Tract	Function	Side of the body
Anterior Corticospinal Tract	Skilled movement	Opposite
Lateral Corticospinal Tract	Skilled movement	Same
Vestibulospinal Tract	Facilitates extensor muscle tone	Same
Fasciculus Gracilis/Cuneatus	Position and fine touch	Same
Lateral Spinothalamic Tract	Pain and temperature	Opposite
Anterior Spinothalamic Tract	Light touch	Opposite

Pathophysiology of Spinal Cord Injury

Pathophysiology of Spinal Cord Injury

- Biphasic – primary phase and secondary phase
  - Primary Phase: initial impact as well as subsequent persisting compression
    - Typically occurs with fracture dislocation, burst fractures, missile injuries, and acutely ruptured discs
  - Secondary Phase: Primary direct cord injury then triggers a complex and delayed pathologic cascade
    - Involves vascular dysfunction, edema, ischemia, excitotoxicity, electrolyte shifts, free radical production, inflammation, and delayed apoptotic cell death
    - Result is cavitation of central gray matter along with partial or complete loss of adjacent white matter tracts.



Mechanisms of Acute Spinal Cord Injury

- Primary injury mechanisms
  - Acute compression
  - Impact
  - Missile
  - Distraction
  - Laceration
  - Shear/Stretch

Mechanisms of Acute Spinal Cord Injury

Secondary injury Mechanisms

- Systemic Effects
  - Bradycardia
  - Hypotension
  - Hypoxia
  - Hyperthermia
- Local Vascular Changes
  - Hemorrhage
  - Loss of microcirculation
- Electrolyte Changes
  - ↑sed intracellular Na^{+}, Ca^{++} and K^{+}
- Biochemical changes
  - Neurotransmitter accumulation
    - Glutamate excitotoxicity
  - Arachidonic acid release
  - Free radical production
  - Increased prostaglandins & NO
  - Lipid peroxidation
  - Endogenous opioids
  - Cytokines
  - Decrease ATP production
  - *APOPTOSIS*

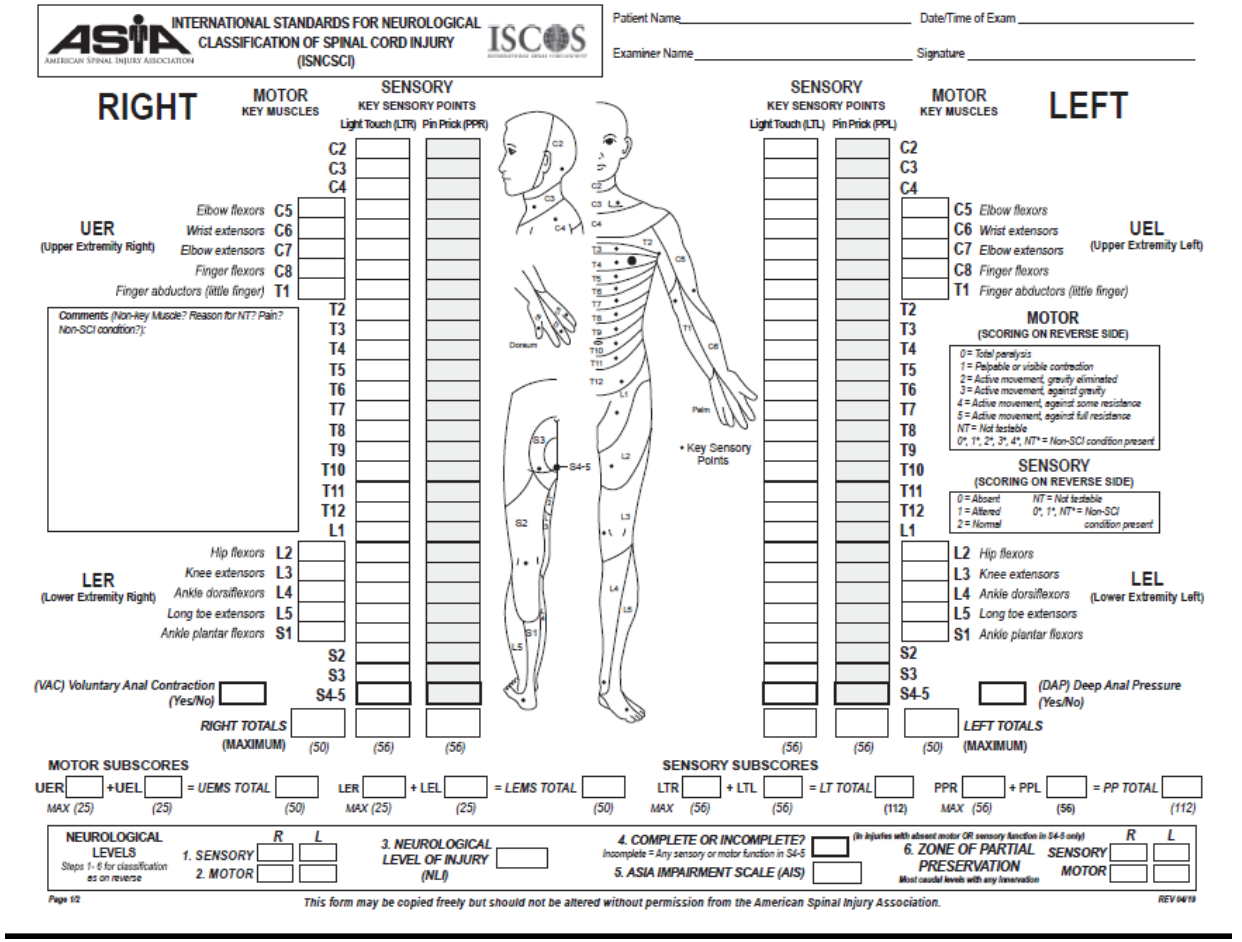
Pathophysiology of Spinal Cord Injury

- **Apoptosis**
  - process of programmed cell death
  - affects restricted populations of spinal cord cells—including oligodendrocytes and some neuronal and astrocytic subpopulations
  - Oligodendrocyte - plays a pivotal role in injury repair, disease process modulation, and the formation and maintenance of myelin
  - Oligodendrocyte cell death starts within 24 hours and continues for at least 3 weeks after injury

Classification of Spinal Cord Injury

American Spinal Injury Association (ASIA) Classification

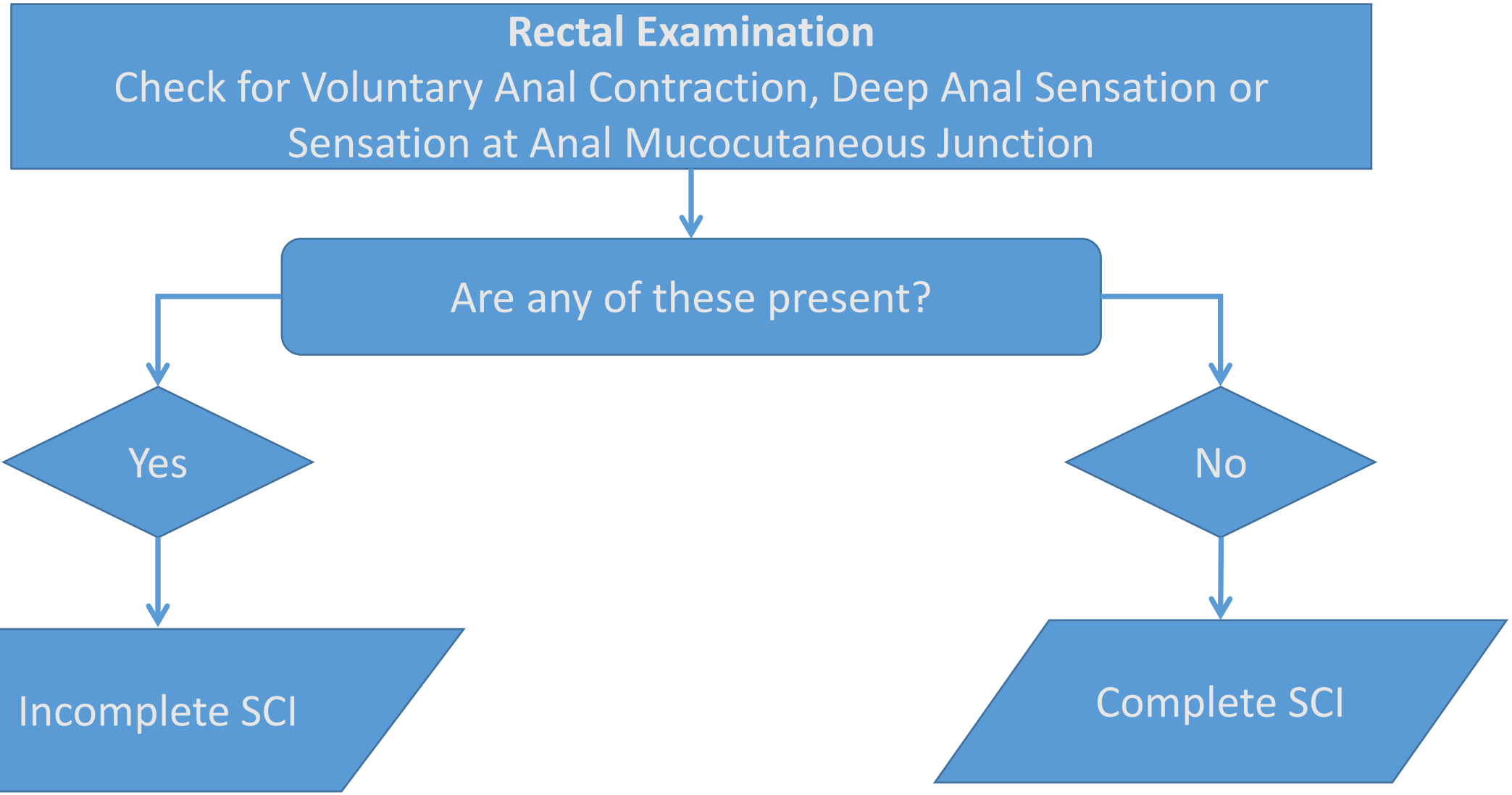
- Sensory testing – 28 dermatomes (light touch & pin prick), each side
- Motor testing – 10 myotomes, each side
- Neurologic level - most distal level with normal function
- Motor level - most distal muscle group with a power score of 3 out of 5
- Rectal examination is essential, should be accompanied by bulbocavernosus reflex testing to assess for spinal shock
- Classification of neurologic deficit as complete or incomplete cannot be determined **until spinal shock has resolved**



Spinal Shock

- It is a transient state of complete areflexia after spinal cord injury
- Typically resolves 24 hours
- During spinal shock there is no residual cord function
- End of spinal shock is heralded by return of anal wink or bulbocavernosus reflex
- If sacral reflexes do not return – injury is termed complete

Complete or Incomplete SCI?

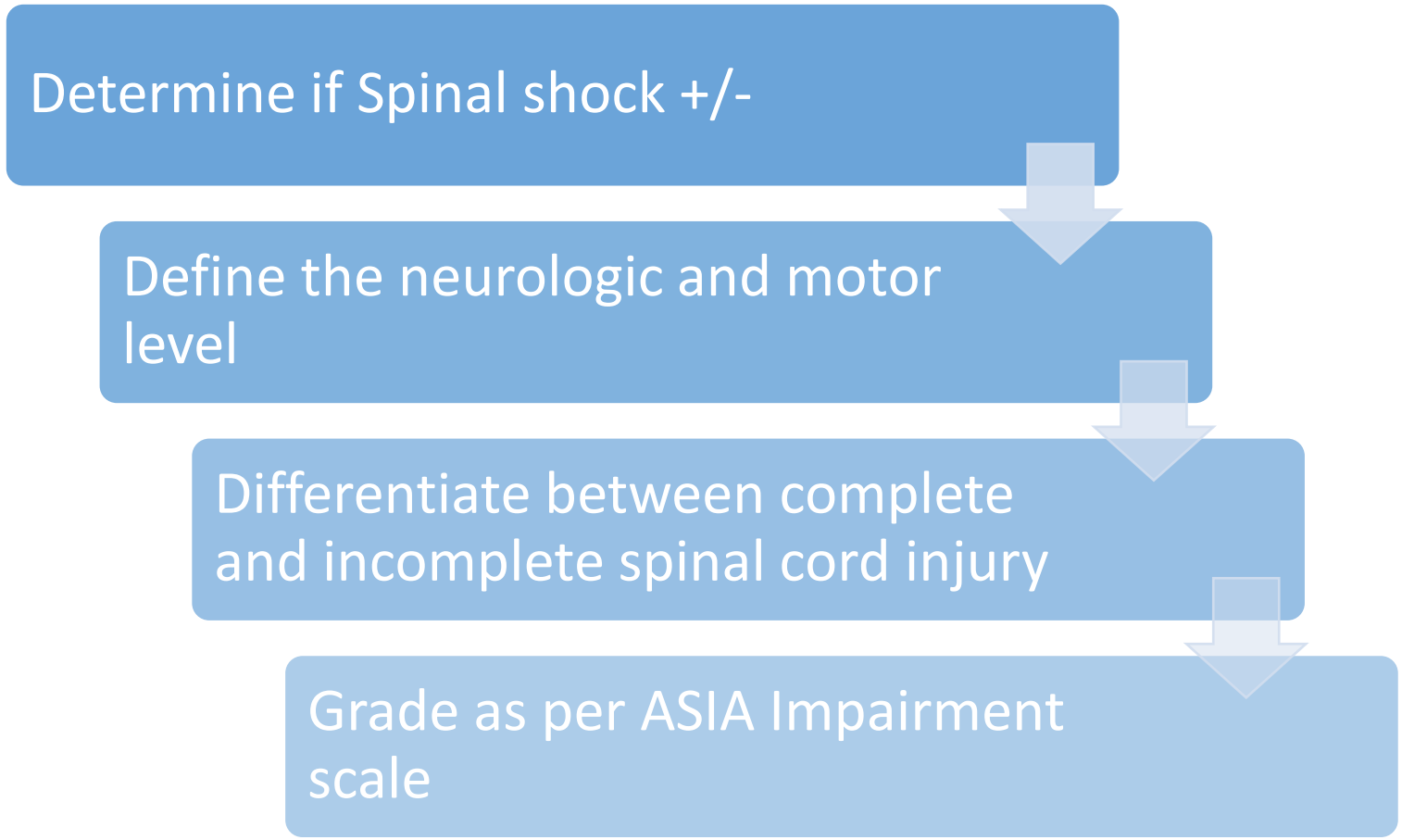


ASIA Impairment Scale

A	Complete - No sensory or motor function is preserved in the sacral segments S4-5
B	Incomplete - Sensory but not motor function is preserved below the neurologic level and extends through the sacral segments S4-5
C	Incomplete - Motor function is preserved below the neurologic level, and more than half of key muscles below the neurologic level have a muscle grade of less than 3
D	Incomplete - Motor function is preserved below the neurologic level, and at least half of the key muscles below the neurologic level have a muscle grade of greater than or equal to 3
E	Normal - Sensory and motor function is normal

Initial ASIA classification scale determines prognosis

Algorithm for ASIA Grading

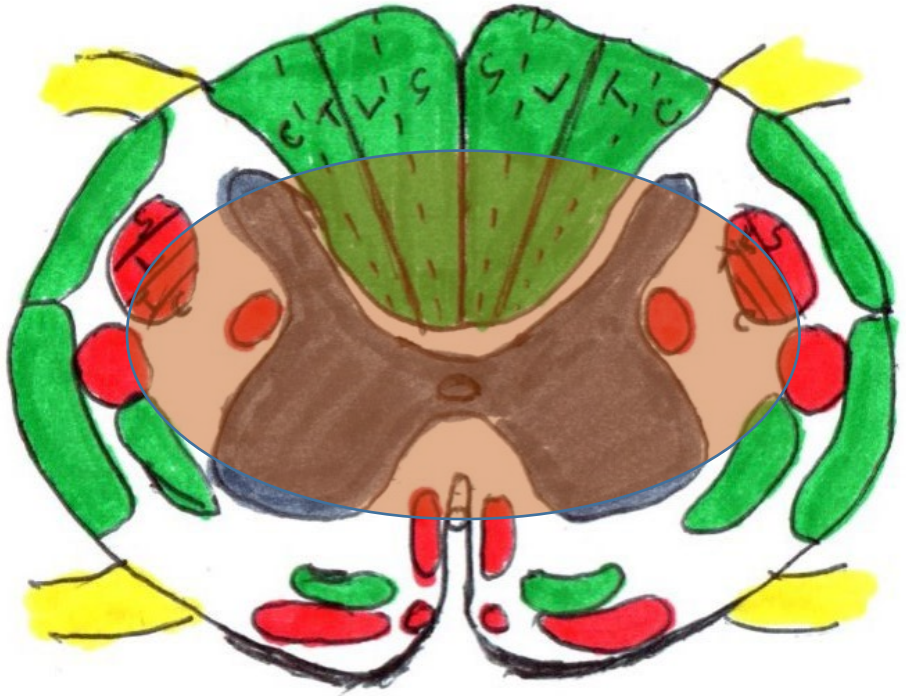


Incomplete Spinal Cord Injuries

- Have preserved motor or sensory function below the level of injury OR,
- **Sacral sparing** (preserved rectal motor function or perianal sensation)
- Involves ASIA grades B, C, and D
- Based on anatomic location within the spinal cord parenchyma, these can also be described by one of several spinal cord injury syndromes (central cord, anterior cord, posterior cord or Brown-Sequard syndromes)

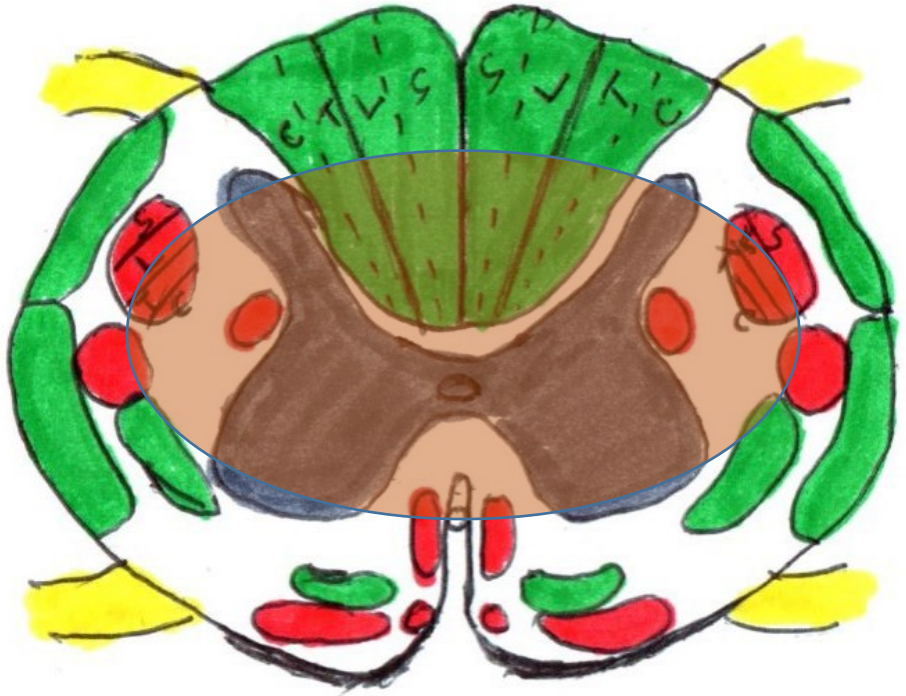
Incomplete Spinal Cord Injury Syndromes

Spinal Cord Injury Syndromes



- **Central Cord Syndrome**
  - Most common
  - Extension injury in elderly with spondylotic spine – cord gets “pinched” between anterior osteophytes and posterior infolded ligamentum flavum
  - Contusion of the central area of the cord (hematomyelia) affects the lateral corticospinal tracts
  - More centrally located motor fibers from the hand and upper extremity are disproportionately affected

Spinal Cord Injury Syndromes



- Most patients present as quadriparetic with or without bladder involvement
- Recovery is typically caudal to cranial with return of sacral motor elements followed by lumbar.
- Recovery of upper extremity function is minimal and depends on degree of grey matter destruction
- Functional recovery is moderate with 75 percent achieving independent ambulatory status

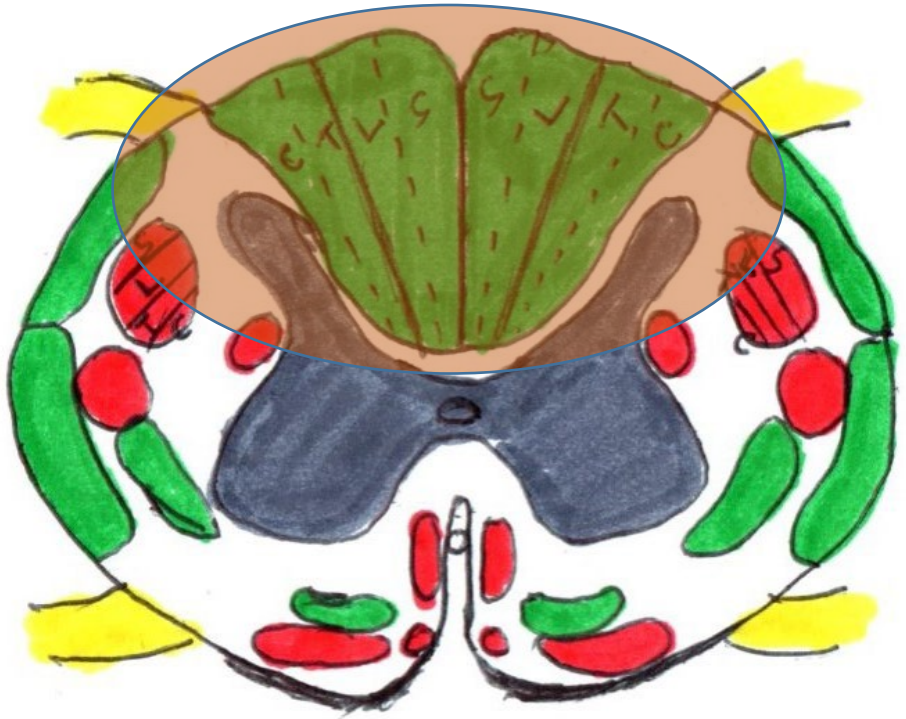
Surgical Management of Central Cord Syndrome

- In patients with ongoing cord compression, the effect of surgical timing on functional recovery has not been established conclusively leading to significant controversy about the optimal timing of surgical treatment.
- Surgical Treatment for Acute Spinal Cord Injury Study (STASCIS)
  - Only level I study
  - Patients who had surgery within 24 hours had greater improvement.
- In a meta-analysis which included 1687 patients, La Rosa et al concluded that patients with any traumatic SCI who had surgery within 24 hours had better outcomes than patients who were treated with late decompression or those who were treated conservatively.

Spinal Cord Injury Syndromes

- **Anterior Cord Syndrome**
  - Direct compression of anterior spinal cord – disc herniation or osteophyte
  - Direct trauma to anterior cord
  - Ischemia due to anterior spinal artery involvement from trauma or infection
  - Loss of motor function and pain and temperature sensation
  - Preservation of vibration and position sense
  - **Worst prognosis of all incomplete cord injuries**

Spinal Cord Injury Syndromes



- **Posterior Cord Syndrome**
  - Least common
  - Caused by injury to dorsal column from trauma, tumors or posterior osteophytes/calcified ligamentum flavum
  - Loss of vibration and joint position sense
  - Touch, pain and motor function is preserved
  - Functional recovery is fair.

Spinal Cord Injury Syndromes

- **Brown-Sequard Syndrome**
  - Hemitransection of the spinal cord
  - Usually with penetrating injury
  - Corticospinal tract involvement
    - flaccid paralysis at the level of the lesion (lower motor neuron),
    - spastic paralysis below the lesion
  - Posterior Column (uncrossed fibers) involvement
    - Ipsilateral loss of proprioception and vibration as well as fine touch
  - Spinothalamic tract involvement (fibers cross **one or two** levels after entering the cord)
    - Contralateral loss of pain, temperature and crude touch
  - Fairly good prognosis

Medical Management

Management of Spinal Cord Injury

- Goals of Management:
  - Optimize neurologic outcome
  - Allow for early mobilization by stabilizing the associated spinal injury
  - Facilitate rehabilitation – consult Rehab medicine early

Medical Management - Cardiovascular

- Transection of sympathetic pathways causes bradycardia and neurogenic shock
- Important to avoid hypotension – restore intravascular volume with fluids and administer vasopressors if needed
- Need an arterial line for blood pressure monitoring
- Early restoration of cord perfusion is associated with improved neurologic recovery*
- Disruption in autonomic nervous system can cause loss of vasomotor control with impairment in thermoregulation causing **severe** hyperpyrexia
  - Treated with external cooling devices like cooling blankets
  - In an intubated patient it may be mistaken for sepsis if autonomic dysregulation is not considered as a differential diagnosis
  - Temperatures as high as 109 degrees have been reported

*Lee YS, Kim KT, Kwon BK. Hemodynamic management of acute spinal cord injury: a literature review. Neurospine. 2020 Nov 17.

Medical Management - Pulmonary

- More common with cervical as compared to thoracic cord injuries
- Associated with loss of intercostal, diaphragmatic and abdominal muscle movements depending to level of injury
- Early tracheostomy should be considered in high cervical injuries
- Encourage aggressive pulmonary physical therapy and avoid prolonged bed rest

Medical Management – Deep Venous Thrombosis & Pulmonary Embolism

- Venous pooling secondary to decreased vascular resistance, combined with a lack of muscle contraction
- Mechanical compression decreases the likelihood of blood clotting by increasing venous outflow and reducing venous stasis
- Anticoagulation with low-molecular-weight heparin or unfractionated heparin with intermittent pneumatic compression – used for prophylaxis.
  - Potential contraindications include intracranial bleeding, perispinal hematoma, and hemothorax.
- If active bleeding is expected to continue for more than 72 hours, a vena cava filter can be considered

Medical Management – Gastrointestinal & Genitourinary

- Nasogastric Suction
- Proton Pump Inhibitors or H2 blockers
- Consider enteral nutrition once swallowing is evaluated, resuscitation is complete, and there is no evidence of ongoing shock or hypoperfusion.
- Placement of an indwelling urinary catheter is recommended no later than in the emergency department.
- Increase risk of urinary tract infection is directly associated with duration of catheterization.
- Depending on level of injury bladder maybe areflexic or flaccid
  - Areflexic bladder – abdominal pressure or clean intermittent catheterization may be used
  - Spastic bladder – if intravesical pressure is not too high and with no sphincter spasticity a condom catheter may be used.
  - Anticholinergics or smooth muscle relaxers can be used as medical treatment to aid in bladder management

Medical Management – Skin

- Immobility and lack of sensation predispose to pressure necrosis
- Sacrum, occiput, scapulae, trochanters, ankles, and heels are most affected areas
- Appropriate skin care - repositioning every 2 hours, inspecting the skin regularly, and maintaining a clean, dry area underneath the patient

Medical Management – Psychological Issues

- Stressful for both patient and family
- May become apparent after a few days once things settle down –
  - Regularly assess for depression, posttraumatic stress disorder, suicidal ideations
- Consider use of anti-depression medications

Rehabilitation

Rehabilitation

- Goal is to facilitate maximal neurologic recovery through medical and surgical treatment
- Rehabilitation is aimed towards developing compensatory strategies for neurologic loss
- Involvement of the rehab team early after injury is beneficial
- Multimodal approach typically involves physical therapy, occupational therapy, speech and language pathology teams

Recent Advances

Emerging Therapies

- Promote neuroprotection
- Stimulate intrinsic axonal regrowth
- Enhance remyelination
- Remove or block inhibitory molecules within damaged myelin and within the astroglial scar.

Emerging Therapies

- **Methylprednisolone (MPSS)**
  - Most extensively investigated
  - Antioxidant properties,
  - Decreases Tumor necrosis factor–α (TNF-α) protein synthesis
  - Anti-inflammatory
  - High-dose MPSS has been associated with an increased prevalence of wound infections, pneumonia, sepsis, and death due to respiratory complications
    - Routine use is controversial, and it should be used with caution

Emerging Therapies

- **Methylprednisolone (MPSS)**
  - **Systematic review suggests**
    - **Not offering a 24 hour infusion of high dose MPSS to adult patients who present after 8 hours with acute spinal cord injury**
    - **24 hour infusion of high dose MPSS may be offered to adult patients within 8 hours of injury can be offered as a treatment option**
    - **Not offering a 48 hour infusion of high dose MPSS to adult patients with acute spinal cord injury**

Fehlings MG, Wilson JR, Tetreault LA, et al. A Clinical Practice Guideline for the Management of Patients With Acute Spinal Cord Injury: Recommendations on the Use of Methylprednisolone Sodium Succinate. *Global Spine J*. 2017;7(3 Suppl):203S-211S. doi:10.1177/2192568217703085

Emerging Therapies

- 21- Aminosteroids - capable of inhibiting lipid peroxidation
- GM-1 Ganglioside - located in high concentrations in the outer membranes of nervous tissue - ability to enhance the function of axons traversing the site of injury but no effect on the gray matter at the level of trauma
- Opioid Antagonists – antagonize dynorphins which contribute to neurodegeneration and toxicity
- Thyrotropin releasing hormone - antagonize effects of endogenous opiods and excitatory amino acids
- Glutamate receptor antagonists – membrane stabilizing effect
- Riluzole (Na^{+}), Ca^{++} and K^{+} channel blockers – decrease axonal Ca^{++} overload
- Erythropoetin - activates neurotrophic, antiapoptotic, antioxidant, and anti-inflammatory pathways
- Cyclosporine A - inhibiting mitochondrial permeability transition, lipid peroxidation and free radical formation
- Minocycline - can inhibit excitotoxicity, oxidative stress, caspase-dependent and caspase-independent pathways of neuronal death

Emerging Therapies

- Cell Transplantation Strategies
  - Activated Autologous Macrophages
  - Human Embryonic Stem Cells and Oligodendrocyte Progenitor Cells
  - Schwann Cells and Peripheral Nerve Grafting
- Axonal Regeneration
  - Phosphodiesterase inhibitors
- Removal & Blockade of inhibitory substrates
  - Chondroitinase ABC – inhibits formation of glial scar

Surgical Management

Role of Early Surgical Decompression

- Substantial experimental evidence suggests that persistent compression of the spinal cord is a potentially reversible form of secondary injury
- There is no level I studies:
  - There is no clear definitions of early vs. late surgery
  - Every spinal cord injury is unique
  - Its not possible to design a randomized control trial due to ethical consideration
- Multiple animal studies have shown a positive effect of early decompression
- Multiple evidence-based reviews also show positive effect of early decompression – particulary ones published recently as overall patient care has significantly improved
- Lengths of stay, ICU/resource utilization, and economic factors may show potential benefits from early surgery.

Intuitively, it makes sense to operate early but there is paucity of data to support this

Summary

- Spinal cord injury is a devastating injury with a significant social impact
- Treatment modalities are geared towards decreasing the damage done to the spinal cord during the “second hit”
- Early decompression and stabilization is encouraged for better chances at functional recovery
- A multimodal team approach – surgeon, anaesthesiologist, intensivists, nursings, physical and occupational therapy, speech therapist all play a vital role in improvement in patient outcomes
- Ongoing research on various pharmacologic agents is the key