Spinal Cord Injury

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- No disclosures

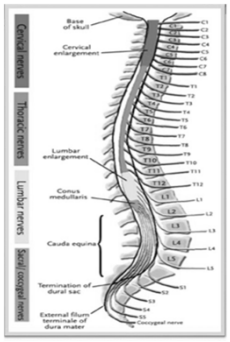
Objective

- To analyze the Anatomy of the Spine
- To evaluate the Pathology of the Spine
- ASIA Exam: International Standards for Classification of SCI
- Functional Prognosis/Outcomes of Complete vs. Incomplete SCI
- To identify Clinical SCI Syndromes and to discuss their prognoses
- Identify SCI Complications

ANATOMY OF THE SPINE

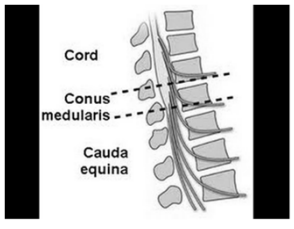
Anatomy

- 33 Vertebrae (31 Pairs of Spinal Nerves)
  - 7 cervical vertebrae (8 pairs cervical SNs)
  - 12 thoracic vertebrae (12 pairs thoracic SNs)
  - 5 lumbar vertebrae (5 pairs lumbar SNs)
  - 5 sacral vertebrae (5 pairs sacral SNs)
  - 4 coccygeal vertebrae (1 pair coccyx SN)
- Spinal nerve exits ABOVE named vertebrae in cervical area
- Spinal nerve exits BELOW named vertebrae at C7 and below

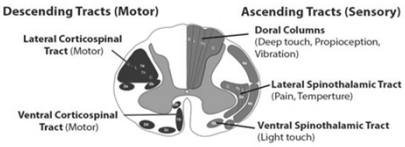


Anatomy

- Spinal Cord= from foramen magnum to L1-L2 vertebral level
- Conus medullaris= terminal portion of cord
- Cauda equina= "horse's tail" at L1-L2

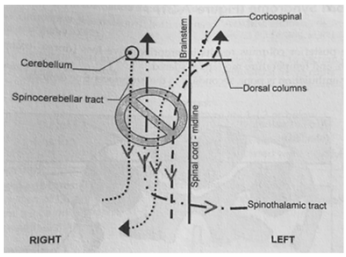


Anatomy



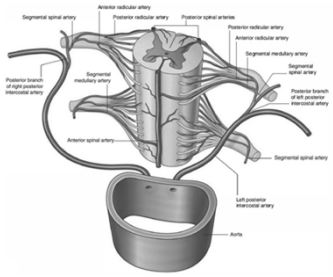
- Corticospinal Tracts= Motor (medial → lateral = cervical → sacral)
- Dorsal Columns= Light touch/Vibration
- Lateral Spinothalamic= Pain/Thermal sensation
- Ventral Spinothalamic= Light touch/ Pressure

Anatomy- Sensory/Motor Pathways



Cuccurullo, SJ. Physical Medicine & Rehabilitation Board Review. 3rd edition.

Anatomy- Blood Supply



- 2 posterior spinal arteries
- 1 posterior spinal artery
- Radicular arteries- branches of local arteries; reinforce the ant and post spinal arteries
- Artery of Adamkiewicz- major blood supply to lumbar and sacral cord
- "Watershed area"- lower thoracic cord due to fewer radicular arteries (T4-T6)

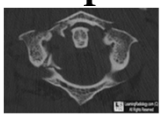
PATHOLOGY OF THE SPINE

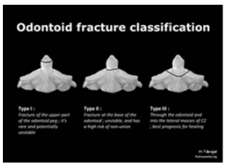
Spine Pathology

- **Traumatic Injuries**
  - Flexion Injuries
    - C5 most common area of compression fracture
    - Anterior wedge shaped vertebra
    - Fragments may project into spinal nerve/cord
  - Extension Injuries
    - C4-C5 most commonly affected
    - May cause central cord syndrome

Fractures of the Spine

- Jefferson fx= C1 burst fx
- Hangman fx = C2 burst fx
- Odontoid fx = Dens fx
- Compression fx
- Chance fx

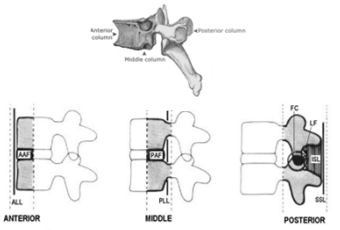




Denis' Three-Column Theory

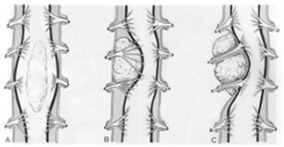
- Anterior- ant longitudinal ligament and ant half of vertebral body
- Middle- post half of vertebral body and post longitudinal ligament
- Posterior- Pedicles, facet joints, supraspinous ligaments

One column injury= stable
Two column injury= unstable
Three column injury= invariably unstable



Spinal Pathology

- Nontraumatic SCI
  - Transverse myelitis
    - Idiopathic inflammatory disorder of the spinal cord
  - Epidural abscess
    - DM, immunocompromised patients
  - Radiation myelopathy
    - Delayed complication of radiation
    - Weakness, Sensation loss, poor prognosis
  - Tumors of the spinal cord
    - Metastatic (lung, breast, prostate CA)
    - Intradural
    - Extradural

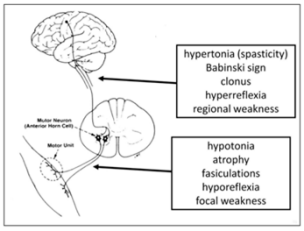


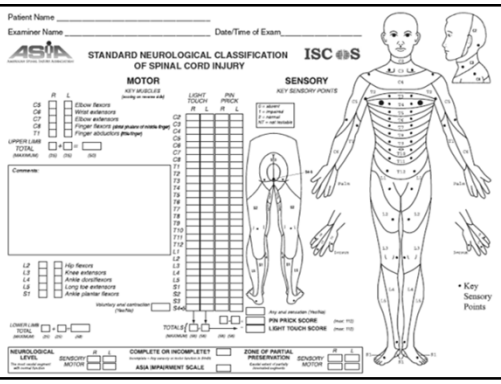
(A) Intradural , Intramedullary , (B) Intradural , Extramedullary , (C) Extradural

SCI CLASSIFICATION ASIA EXAM

SCI Classification

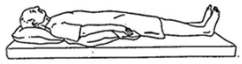
- Terminology
- Quadriplegia- Loss of motor and/or sensory function in cervical segments of spinal cord
- Paraplegia- loss of motor and/or sensory function in thoracic, lumbar, or sacral (NOT CERVICAL) segments of spinal cord
- Upper Motor Neuron Injury- Brain, Spinal Cord
  - Hyperreflexia, pathologic reflexes
- Lower Motor Neuron Injury- Peripheral Nerves
  - Hyporeflexia, muscle atrophy





ASIA SCI Classification (American Spinal Injury Association)

- Performed when patient in supine position
- Best exam at 72 hours
  - May still be in spinal shock before 72 hours
- Repeat exam 1 month after injury for predicting recover



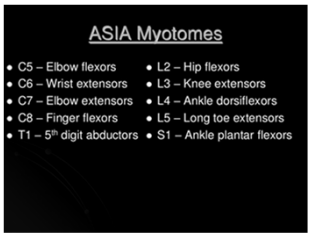
ASIA Exam

- Motor Exam
  - 0-5 Grade
  - 5 key muscles in each extremity
- Sensory Exam
  - 0-2 Grade
  - Pinprick
  - Light touch
- Sacral Testing
  - Voluntary anal contraction
  - Deep anal pressure

Muscle Grading System (ASIA)	
0	Total paralysis
1	Palpable or visible contraction
2	Active movement, full range of motion, gravity eliminated
3	Active movement, full range of motion, against gravity
4	Active movement, full range of motion, against gravity and provides some resistance
5	Active movement, full range of motion, against gravity and provides normal resistance
NT	Patient unable to reliably exert effort or muscle unavailable for testing due to factors such as immobilization, pain on effort or contracture.

ASIA Exam MOTOR

- 10 key myotomes on left and right of body to test
- Motor level of injury: most caudal muscle group that is graded $\geq$ 3/5 with all segments above grade 5/5 strength.
  - Motor level can be determined for each SIDE of body
- For myotomes not tested the motor level is considered to be the same as the sensory level
  - C1-C4
  - T2-L1
  - S2-4/5



ASIA Exam SENSORY

- 28 key dermatomes
- Light touch and Pinprick
- Face used as "normal" point
- Sensory level of injury: most caudal segment of spinal cord with normal 2/2 sensory on BOTH sides
- Test S4-5 dermatome= determines complete vs. incomplete injury

ASIA Exam NEUROLOGICAL LEVEL OF INJURY

- NLI: most caudal segment of spinal cord with both normal sensory and motor function $\geq$3/5
- If no key muscle for that segment, then the sensory level defines the motor level and the NLI

ASIA Exam SACRAL EXAM

- Test for:
  - Voluntary anal contraction
  - Perianal sensation to light touch and pinprick
  - Deep anal pressure

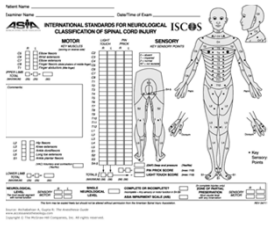
DETERMINES IF INJURY IS COMPLETE OF INCOMPLETE

COMPLETE VS. INCOMPLETE

- COMPLETE SCI
  - NO sacral sparing
  - ASIA A
  - Zone of partial preservation
- INCOMPLETE SCI
  - Sacral sparing
  - ASIA B, C, or D
  - Can have motor/sensory below level or injury, but not called "zone of partial preservation"

ZONE OF PARTIAL PRESERVATION

- ZPP: only in ASIA A complete injuries
  - Record for both left and right sides
  - Motor= motor sparing below motor level
  - Sensory= sensory sparing below sensory level



ASIA Classification

A= Complete Injury	No motor or sensory below in S4-5 segments
B= Incomplete	Sensory but NOT motor preserved below NLI
C= Incomplete	➢ Motor is preserved below NLI ➢ > ½ key muscles below NLI have muscle grade <3/5
D= Incomplete	➢ Motor is preserved below NLI ➢ At least ½ key muscles below NLI have muscle grade ≥3/5
E= Normal	Sensation and motor normal in an SCI patient

ASIA Exam ADDITIONAL INFO

- Use motor level to distinguish between B and C
- Use NLI to distinguish between C and D
- Use non-key muscle groups to determine sensory vs. motor incomplete status (B vs. C)
- Determination that if sensation is abnormal at C2, the level that should be designated is C1

FUNCTIONAL PROGNOSIS/OUTCOMES

FUNCTIONAL PROGNOSIS/OUTCOMES

	BETTER	WORSE
INJURY MECHANISM	✓ Edema ✓ Spinal stenosis ✓ Unilateral facet dislocation	✓ Cord transection ✓ Hemorrhage
NEURO CLASSIFICATION	✓ Incomplete injury ✓ Intact pinprick sensation ✓ Presence of motor level function below NLI	✓ Complete injury

FACTORS IMPACTING PROGNOSIS

- Medical Co-morbidities
- Support system
- Patient motivation
- Resources/Services available

FUNCTIONAL PROGNOSIS

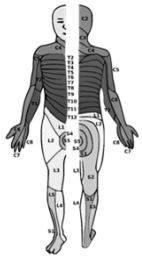
- Complete tetraplegia= most recover 1 motor level
- Starting with grade 1 or 2 muscle strength has a better prognosis than a 0
- If there is strength in the next rostral muscle group, likely will reach antigravity strength by 1 year
- Unlikely to gain functional strength 2 levels below last functional muscle

FUNCTIONAL PROGNOSIS

- More than 90% of incomplete injuries gain 1 motor level in the UEs compared to complete (70-85%)
- 0 muscle grade
  - 25-50% will increase muscle grade to 3 in 1 year
  - 75-100% will increase muscle grade to 1-2 in 1 year
- 1-2 muscle grade
  - 90% will increase to muscle grade 3 in 1 year

FUNCTIONAL OUTCOMES BY ASIA SCORING

- ASIA A→ASIA D 0/5%
- ASIA B (LIGHT TOUCH) → ASIA D 20-25%
- ASIA B (PINPRICK) → ASIA D 40-50%
- ASIA C → ASIA D 60-75%



Whiteneck et al. 1999

PROGNOSIS/OUTCOMES FACTS

- C6= highest level of complete SCI to live independently
- C7= highest level at which they can live independently in most activities at wheelchair level
- C5= highest level for independent driving
- C6= level at which males can intermittent catheterize themselves with setup assistance with adaptive devices

AMBULATION

- T12 and above= usually not community or household ambulators
- L3 and below= best prognosis for community ambulation

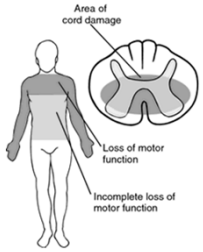
AMBULATION OUTCOMES BASED ON INTIAL ASIA SCORE

- ASIA A initial score= ~3% will get enough strength to ambulate at 1 year
- ASIA B initial score= ~50% will be ambulatory
- ASIA C initial score= ~75% will be ambulatory
- ASIA D initial score= ~95% will be ambulatory

SPINAL CORD SYNDROMES

CENTRAL CORD SYNDROME

- Most common incomplete syndrome
- Weakness in arms > legs
- Variable sensation loss, bowel and bladder dysfunction
- Pathology: corticospinal tract, medial involvement (more cervical than sacral involvement)
- More common with older patients with cervical hyperextension injury
- Prognosis: good for returning to ambulation

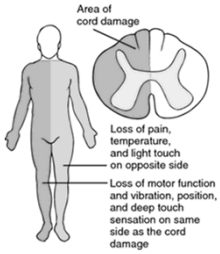


BROWN-SEQUARD SYNDROME

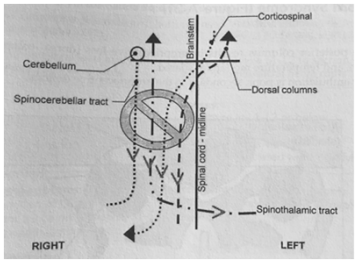
- Hemisection of the cord
- Stabbing, MVC

- Ipsilateral loss
  - Sensation at level
  - Paralysis at level
  - Position sense and vibration BELOW level

- Contralateral loss
  - Pain and temperature BELOW level



BROWN-SEQUARD SYNDROME



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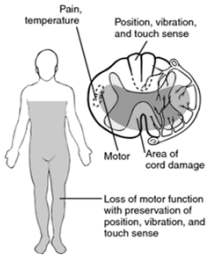
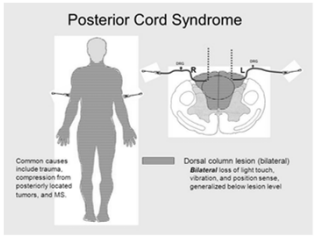
ANTERIOR CORD SYNDROME

- Injury involving anterior 2/3 of cord
- Usually vascular injury
- Preserves posterior columns (position, vibration, touch)
- Loss of motor, pain, temperature, pinprick
- Prognosis: poor for motor recovery



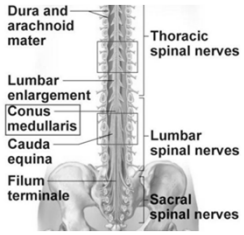
POSTERIOR CORD SYNDROME

- Usually vascular injury (posterior spinal artery to posterior columns)
- Proprioceptive loss (dorsal columns)
- Motor, pain, temperature spared
- Prognosis: for ambulation is poor



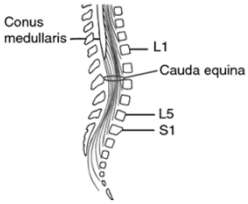
CONUS MEDULLARIS

- Terminal level of spinal cord
- Injury at T12-L2 vertebrae
- Bowel/bladder and sexual dysfunction
- SADDLE ANESTHESIA
- Prognosis: poor for recovery



CAUDA EQUINA SYNDROME

- Injury below L1-2 vertebrae
- LMN injury
- Motor weakness and atrophy of LEs
- Bowel/bladder and sexual dysfunction- AREFLEXIC BOWEL/BLADDER
- Prognosis: better for recovery

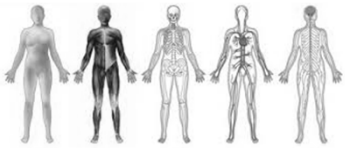


CONUS MEDULLARIS	CAUDA EQUINA
Location: T12-L2 vertebrae	Location: L1-L2 vertebrae
Causes: - Fractures T12-L1 - Tumors - Spina bifida	Causes: - Fractures L1-L2 - Sacral fractures - Fracture to pelvic ring - Spondylosis
Symptoms: - Normal motor - Saddle anesthesia - Pain NOT significant - Symmetrical - Bowel/bladder dysfunction - Hyperreflexia	Symptoms: - Flaccid paralysis - Sensory loss in root distribution - PAINFUL - Asymmetric - +/- Bowel/bladder dysfunction - Hyporeflexia

SCI COMPLICATIONS

SCI AFFECTED SYSTEMS:

- NEUROLOGICAL
- MUSCULOSKELTAL
- CARDIOVASCULAR
- RESPIRATORY
- HEME
- SKIN
- GI/GU
- ENDOCRINE



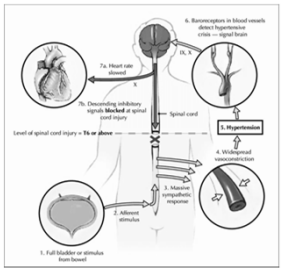
ORTHOSTATIC HYPOTENSION

- ↓ SBP >/= 20mmHg, ↓ DBP >/= 10mmHg upon assumption of upright position.
- Loss of sympathetic vasomotor tone and expanded vascular bed
- Decreases with time as spinal reflexes return
- Treatment:
  - Trendelenburg
  - Elastic stocking/abdominal binder
  - Fluid resuscitation
  - Salt tabs, Midodrine, Florinef

- Sidorov et al, "Orthostatic hypotension in the first month following acute SCI."Spinal Cord 2008.

AUTONOMIC DYSREFLEXIA

- Injuries T6 and above
- The brainstem is unable to send messages through injured cord to decrease sympathetic outflow and allow vasodilation to splanchnic bed
- Signs: HA, sweating above SCI, flushing above SCI, Elevated BP, piloerection, pupillary constriction, sinus congestion



AUTONOMIC DYSREFLEXIA

- TREATMENT:
  1. **SIT PATIENT UPRIGHT AND LOOSEN TIGHT CLOTHING**
  2. **REMOVE NOXIOUS STIMULUS- FLUSH INDWELLING CATHETER, CATHETERIZE PATIENT IF NEEDED**
  3. **MONITOR BP Q2-5 MINUTES FOR AT LEAST 2 HOURS**
  4. **MEDICATIONS INTIIATED IF BP ELEVATED**
  5. **CHECK FOR OTHER SOURCES OF NOXIOUS STIMULI**

  Medications for BP: nitropaste, clonidine, procardia

RESPIRATORY COMPLICATIONS

- Atelectasis, PNA, Respiratory failure
- Inability to clear secretions and adequately ventilate lungs
- 84% of respiratory complications with C1-C4
- 60% incidence with lower level injuries

- Jackson et al, "Incidence of respiratory complications following SCI." Arch Phys Med Rehabil 1994.

DVT

- Acute SCI incidence= 47-100% (without prophylaxis)
- Highest risk in first 2 weeks
- Risk declines after 8 weeks
- Risk factors:
  - Complete injury
  - Male
  - >60 (higher rates of PE)

- Maung et al, "Risk of VTE after SCI: not all levels are the same." J Trauma 2011.

DVT: DURATION OF PROPHYLAXIS

- **"We recommend that anticoagulant thromboprophylaxis continue at least eight weeks after injury in SCI patients with limited mobility."**

2015 update guidelines/Consortium for Spinal Cord Medicine

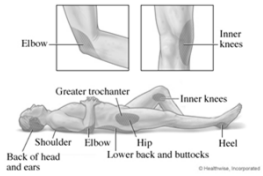
- **"Prevention of Venous Thromboembolism in Individuals with Spinal Cord Injury: Clinical Practice Guidelines for Health Care Providers, 3rd ed"**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4981016/

HETEROTOPIC OSSIFICATION

- HO= formation of mature bone in soft tissues and around joints
- Incidence: 16-53% SCI patients
- Most common in hips/knee/shoulder/elbow
- Symptoms: warmth, soft tissue swelling, decreased ROM, low grade fever, joint effusion
- Diagnosis: bone scan first
- Prophylaxis: Etidronate
- Treatment: ROM, Etidronate, NSAIDs, Radiation therapy, Surgery

PRESSURE ULCERS

- Most common location in SCI patients in first 2 years is SACRUM, followed by ischium, heels, and trochanters
- After 2 years, ISCHIAL TUBEROSITIES are the most common site
- Children up to age 13, the OCCIPUT is the most common site

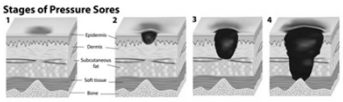


PRESSURE ULCERS

- PREVENTION!!
- Decreased duration of pressure-reposition q2 hours
- Weight shift in wheelchair q 20-30 minutes when sitting
- Proper mattress/bed overlay
- Proper offloading cushion and WC seating
- Pressure mapping

PRESSURE ULCERS

- At risk due to loss of sensation, loss of motor
- Prevent: Offload
- Treatment: Dressings, wound vac, HBO, E Stim
  - Nutritional supplementation (protein, Vit C, zinc, copper)
  - Surgery (myocutaneous flaps, surgical debridement)

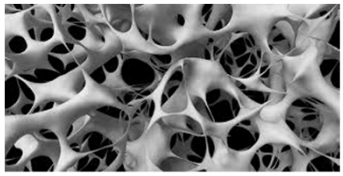


PAIN IN SCI

- Nociceptive Pain- more common than neuropathic pain
  - Shoulder joint- most common
- Neuropathic pain- 60-70% of patients
  - Burning, tingling, cold
  - Treatment: pregabalin, TCAs, anticonvulsants (gabapentin), Topical capsaicin/lidocaine/diclofenac

METABOLIC COMPLICATIONS IN SCI

- HYPERCALCEMIA
- HYPERCALCIURIA
- OSTEOPOROSIS
- FRACTURES
- HYPERGLYCEMIA AND METABOLIC SYNDROMES



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