

SPINAL CORD INJURY & NEUROGENIC SHOCK

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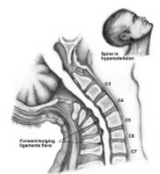
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DISCLOSURES

- none

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PATHOPHYSIOLOGY



hyperextension

- Two phases of injury
- Primary
 - SCI from traumatic mechanical force
 - Impact + persistent force
 - Impact plus transient compression (hyperextension)
 - Distraction (vertebral elements pulled apart)
 - Laceration (penetrating trauma)
- Secondary injury to spinal cord from microvascular, biochemical, cellular processes (hypotension, hypoxia, hemorrhage, ischemia reperfusion, glutamate release, intracellular calcium levels, fluid and electrolyte disturbances, edema, apoptosis, and inflammation)
- Management of SCI targets preventing, decreasing the secondary insults

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PATHOPHYSIOLOGY CONTINUED

- Neurogenic shock (T6 and above)
- D/T sympathectomy during injury causes loss of supraspinal control of sympathetic nervous system
- Unopposed parasympathetic nervous system works independently and activates vagus nerve which then leads to bradycardia and potentially atrio-ventricular nodal block in addition to hypotension.
- Hypotension and hypoperfusion worsen secondary insult to cord = poorer outcomes
- Neurogenic shock is a form of distributive shock (excessive vasodilation, similar to sepsis)- characteristic finding is bradycardia.
- Typical patient is hypotensive with warm, dry skin (d/t vasodilation)
- Shock lasts 1-3 weeks!

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AVOID PNEUMBRA

- Edema, elevated cord pressure and injuries to vessels all contribute to continued ischemia of cord
- In comes augmentation of MAPs is a neuroprotective strategy (level III evidence)

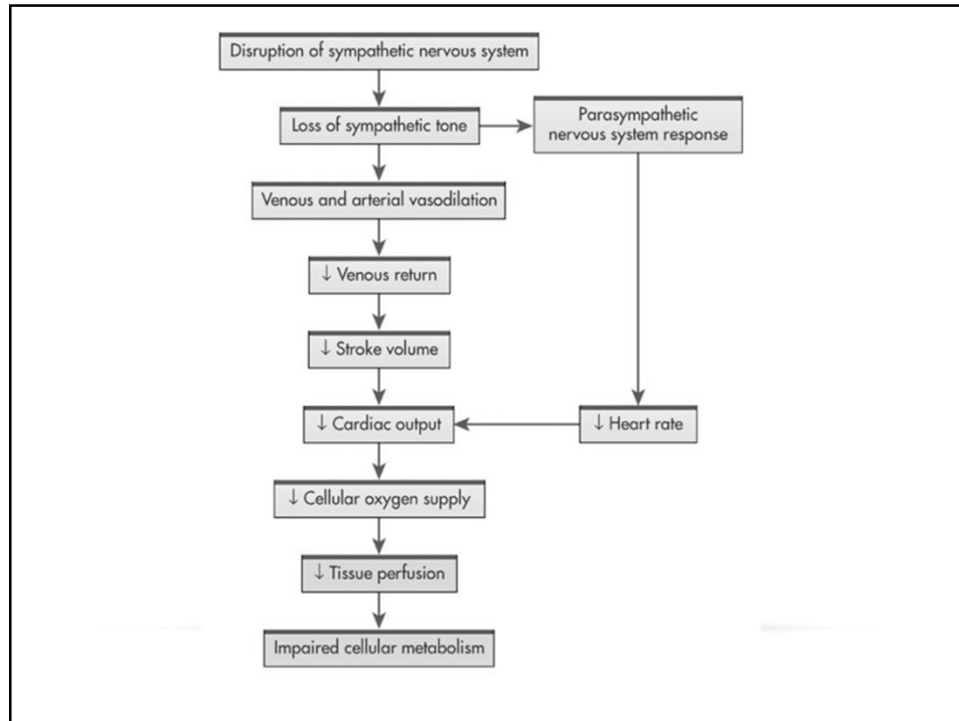
Ahuja, 2017)

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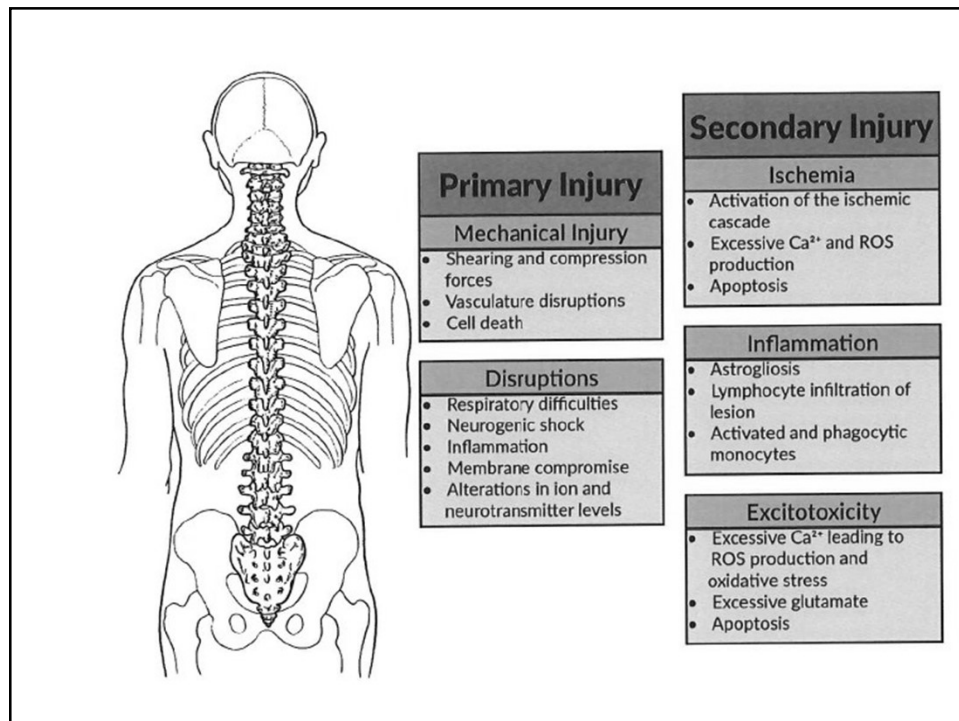
Neurogenic Shock

Hypotension - Decrease in Blood Pressure
Bradycardia - Slow heart rate
Warm, dry extremities
Peripheral vasodilation and venous pooling
Poikilothermia (Cold Body)
Decreased cardiac output (with cervical or high thoracic injury)

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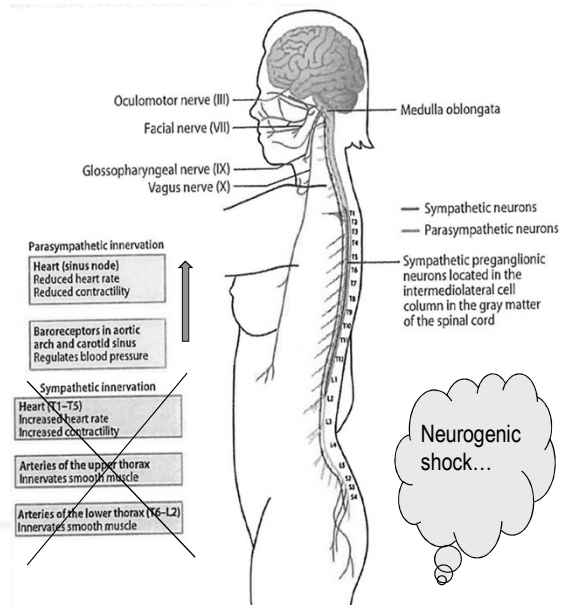
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ANS



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PARASYMPATHETIC/SYMPATHETIC NERVOUS SYSTEM



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INTERVENTIONS

- 1st fluid resuscitate this shock to euvoemia
- 2nd use pressors and inotropes or both

Vasoactive Agents Used to Treat Neurogenic Shock^a

Agent	Alpha Activity	Beta Activity	Considerations
Norepinephrine	+++	++	Probably the preferred agent
Phenylephrine	++	None	May worsen bradycardia
Dopamine			
Low dose (3–10 mcg/kg/min)	+	++	May lead to inadvertent diuresis at low dose
High dose (10–20 mcg/kg/min)	++	+++	
Epinephrine	+++	++	Rarely needed
Dobutamine	None	+++	May cause hypotension if not euvoemic

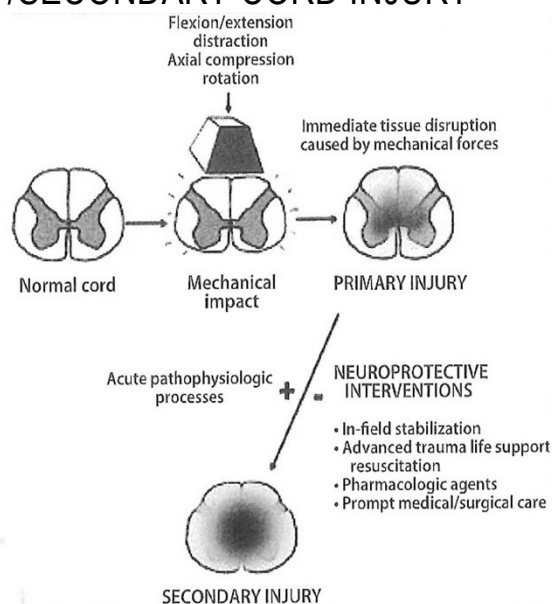
Stein et al, 2012

Consider oral alpha agonist drugs: pseudoephedrine and midodrine in subacute setting.

Updated references Shank, 2017

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PRIMARY/SECONDARY CORD INJURY



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ATLS FIRST

- Treat other life threatening injuries FIRST!!!
- Airway- always secure airway in complete SCI >C5, respiratory distress, hypoxemia, severe respiratory acidosis
- May lose airway in cervical spine injuries from edema, hematoma, oropharyngeal bleeding
- C3-5 injured patients may lose diaphragmatic innervation, chest, abdomen wall strength may lose ability for adequately oxygenate and ventilate
- Complete injuries >C3 will arrest pre hospital- absent diaphragm function
- Consider airway control in all cervical and high thoracic injuries if skeptical about ability to cough, clear secretions, aspiration risk, atelectasis
- Watch for "quad" breathing (chest in during inspiration, abdomen out sharply)

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INTUBATION INDICATIONS TRAUMATIC CERVICAL SPINE INJURY

► 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)

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Muscles of the Respiratory System

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

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ABCDEs

- Disability
- Major motor/sensation deficits on PE
- Spinal precautions
- Detailed exam of motor and sensation
 - (ASIA scoring @ 72 hrs has most prognostic value, also helps risk stratify for possible complications)
- Exposure/environment

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ASIA

- American Spinal Injury Association scale
- Tool focuses on motor, sensory, rectal tone, rectal sensation
- 0-5 strength scale for 10 muscle groups bilaterally
- Sensation 0=none, 1= altered, 2=normal
- Complete or incomplete
 - ASIA A- motor and sensory complete
 - ASIA B- motor complete, sensory incomplete
 - ASIA C- motor incomplete <grade 3 strength
 - ASIA D- motor incomplete >3/= grade 3 strength
 - ASIA E- normal
- Sacral sparing indicated long tracts within cord are preserved and implies INCOMPLETE SCI
- If no sacral sparing- considered COMPLETE with poorer prognosis for recovery.
- Spinal shock may confound accuracy of initial evaluation and may last 4-6 weeks.

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ASIA INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI) **ISCOS**

Patient Name _____ Date/Time of Exam _____
 Examiner Name _____ Signature _____

RIGHT

MOTOR KEY MUSCLES

UER (Upper Extremity Right)

Elbow flexors C5

Wrist extensors C6

Elbow extensors C7

Finger flexors C8

Finger abductors (little finger) T1

LER (Lower Extremity Right)

Hip flexors L2

Knee extensors L3

Ankle dorsiflexors L4

Long toe extensors L5

Ankle plantar flexors S1

(VAC) Voluntary anal contraction (Yes/No) ☐

RIGHT TOTALS (MAXIMUM)

UER ☐ + UEL ☐ = UEMS TOTAL ☐ (50)

LER ☐ + LEL ☐ = LEMS TOTAL ☐ (50)

MOTOR SUBSCORES

MAX (25) (25) = UEMS TOTAL (50)

Key Sensory Points

LEFT

MOTOR KEY MUSCLES

UEL (Upper Extremity Left)

Elbow flexors C5

Wrist extensors C6

Elbow extensors C7

Finger flexors C8

Finger abductors (little finger) T1

LEL (Lower Extremity Left)

Hip flexors L2

Knee extensors L3

Ankle dorsiflexors L4

Long toe extensors L5

Ankle plantar flexors S1

(DAP) Deep anal pressure (Yes/No) ☐

LEFT TOTALS (MAXIMUM)

UER ☐ + UEL ☐ = UEMS TOTAL ☐ (50)

LER ☐ + LEL ☐ = LEMS TOTAL ☐ (50)

MOTOR SUBSCORES

MAX (25) (25) = UEMS TOTAL (50)

SENSORY KEY SENSORY POINTS

Light Touch (LT) Pin Prick (PP) PPR

RIGHT

C2 C3 C4

T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 L1 L2 L3 L4 L5 S1 S2 S3 S4-S

LEFT

C2 C3 C4

T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 L1 L2 L3 L4 L5 S1 S2 S3 S4-S

SENSORY SUBSCORES

LTR ☐ + LTL ☐ = LT TOTAL ☐ (112)

PPR ☐ + PPL ☐ = PP TOTAL ☐ (112)

NEUROLOGICAL LEVELS

1. SENSORY ☐ R ☐ L ☐

2. MOTOR ☐ R ☐ L ☐

3. NEUROLOGICAL LEVEL OF INJURY (NLI) ☐

4. COMPLETE OR INCOMPLETE? ☐

5. ASIA IMPAIRMENT SCALE (AIS) ☐

ZONE OF PARTIAL PRESERVATION

(In complete injuries only)

Must include level with any preservation

SENSORY ☐ R ☐ L ☐

MOTOR ☐ R ☐ L ☐

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Muscle Function Grading

0 = total paralysis
 1 = palpable or visible contraction
 2 = active movement, full range of motion (ROM) with gravity eliminated
 3 = active movement, full ROM against gravity
 4 = active movement, full ROM against gravity and moderate resistance in a muscle specific position
 5 = (normal) active movement, full ROM against gravity and full resistance in a functional muscle position expected from an otherwise unimpaired person
 5* = (normal) active movement, full ROM against gravity and sufficient resistance to be considered no mal if identified inhibiting factors (i.e. pain, disease) were not present
 NT = not testable (i.e. due to immobilization, severe pain such that the patient cannot be graded, amputation of limb, or contracture of > 50% of the normal range of motion)

Sensory Grading

0 = Absent
 1 = Altered, either decreased/impairment sensation or hypersensitivity
 2 = Normal
 NT = Not testable

Non Key Muscle Functions (optional)

May be used to assign a motor level to differentiate AIS B vs. C

Movement	Root level
Shoulder: Flexion, extension, abduction, adduction, internal and external rotation	C5
Elbow: Supination	
Elbow: Pronation	C6
Wrist: Flexion	
Finger: Flexion at proximal joint, extension	C7
Thumb: Flexion, extension and abduction in plane of thumb	
Finger: Flexion at MCP joint	C8
Thumb: Opposition, adduction and abduction perpendicular to palm	
Finger: Abduction of the index finger	T1
Hip: Adduction	L2
Hip: External rotation	L3
Hip: Extension, abduction, internal rotation	L4
Knee: Flexion	
Ankle: Inversion and eversion	
Toe: MP and IP extension	
Hallux and Toe: DIP and PIP flexion and abduction	L5

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-S5.

B = Sensory incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5 (light touch or pin prick at S4-S5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor incomplete. Motor function is preserved below the neurological level, and more than half of key muscle functions below the neurological level of injury (NLI) have a muscle grade less than 3 (grades 0-2).

D = Motor incomplete. Motor function is preserved below the neurological level, and at least half (half or more) of key muscle functions below the NLI have a muscle grade ≥ 3 .

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.


** For an individual to receive a grade of C or D, i.e. motor incomplete status, they must have either (1) voluntary and sphincter contraction or (2) focal sensory sparing, i.e. testing of motor function more than three levels below the motor level for that side of the body. The International Standards at this time allow even one key muscle function more than 3 levels below the motor level to be used in determining motor incomplete status (AIS C versus D).

NOTE: When assessing the extent of motor sparing below the level for distinguishing between AIS B and C, the motor level on each side is used, whereas to differentiate between AIS C and D based on proportion of key muscle functions with strength grade 3 or greater the neurological level of injury is used.


Steps in Classification

The following order is recommended for determining the classification of individuals with SCI.

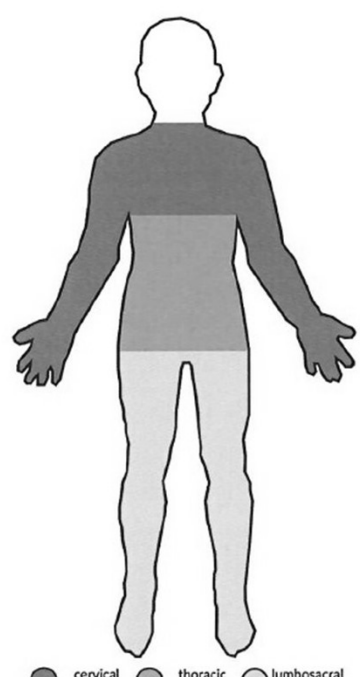
- Determine sensory levels for right and left sides.**
 The sensory level is the most caudal, intact dermatome for both pin prick and light touch sensation.
- Determine motor levels for right and left sides.**
 Defined by the lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5).
 Note: in regions where there is no response to test, the motor level is presumed to be the same as the sensory level, if testable motor function above that level is also normal.
- Determine the neurological level of injury (NLI).**
 This refers to the most caudal segment of the cord with intact sensation and voluntary (3 or more) muscle function strength, provided that there is normal (pinprick) sensory and motor function caudally respectively.
 The NLI is the most cephalad of the sensory and motor levels determined in steps 1 and 2.
- Determine whether the injury is Complete or incomplete.**
 (It is absence or presence of sacral sparing)
 If voluntary and contraction = No AND all S4-S5 sensory scores = 0 AND deep anal pressure = No, then injury is Complete.
 (Otherwise, injury is Incomplete).
- Determine ASIA Impairment Scale (AIS) Grade:**
 Is injury Complete? If YES, AIS=A and can record ZPP (lowest dermatome or myelome on each side with some preservation)
 If YES, AIS=B
 Is injury Motor Complete? If YES, AIS=B
 (Involuntary and contraction OR motor function more than three levels below the motor level on a given side, if the patient has sensory incomplete classification)
 Are at least half (half or more) of the key muscles below the neurological level of injury graded 3 or better?
 If YES, AIS=D
 If NO, AIS=C
 If sensation and motor function is normal in all segments, AIS=E
 Note: AIS E is used in follow-up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact; the ASIA Impairment Scale does not apply.



INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY



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● cervical ● thoracic ● lumbosacral

Cervical Spinal Cord Injury

Hallmarks of Cervical SCI

- Characteristic SCI pathology
- Loss of gray and white matter
- Severing of ascending and descending axonal tracts
- Possibility for regeneration due to axons being severed closer to their originating cell body

Impairments by Segment

C1-C3: head and neck movement, sympathetic nervous system, voluntary respiration; complete paralysis

C4: shoulder movement, upper and lower limb and torso function, respiration

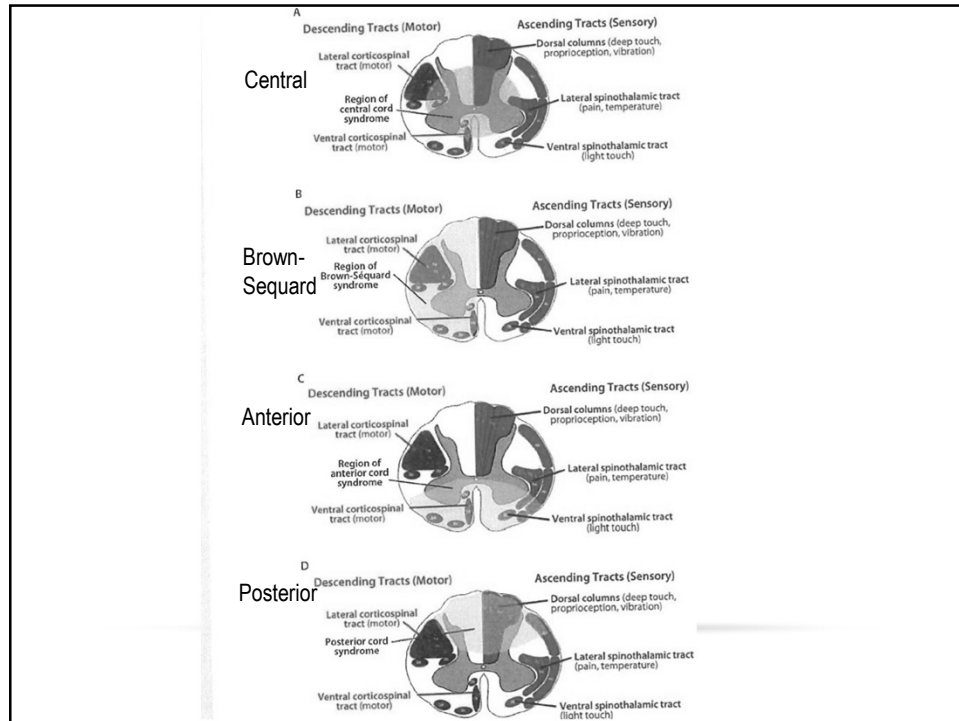
C5-C6: triceps, wrists, fingers, torso and lower limbs

C7-C8: upper limb and upper torso movement, lower torso and limbs

Need for Cervical-Specific Therapies

- Cervical SCI accounts for over 50% of SCI, accounts for less than 20% of SCI models
- Segmental changes in recovery
- Anatomy may make regeneration more plausible
- Quadriplegics rate restoration of hand and arm function as top priority

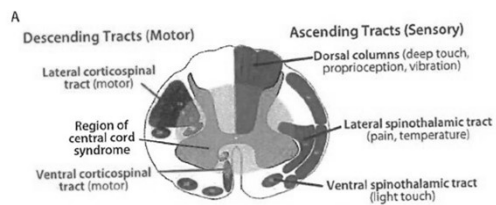
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CENTRAL CORD

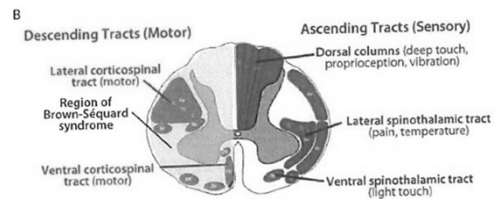
- Most common
- Older patients with underlying cervical stenosis
- Hyperextension, usually without fracture
- Buckling of ligamentum flavum- bruises cord
- Sparing of lower extremity strength is characteristic (upper extrem motor fibers are most medial in the spinal tract)



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BROWN-SEQUARD

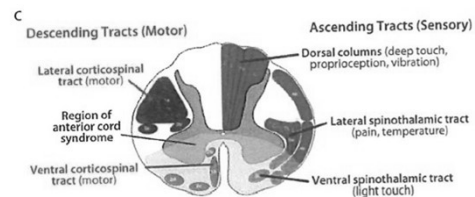
- Hemiplegia with ipsilateral loss of light touch and proprioception with contralateral loss of pain and temperature sensation
- d/t traumatic hemisection of cord from penetrating injury (knife, missile, or lateral mass fx)



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ANTERIOR CORD SYNDROME

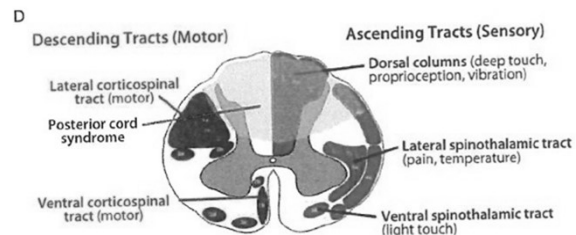
- Rare in trauma
- More common from ischemia (disruption of anterior spinal artery)
- Axial compression and burst fracture with retropulsion of the vertebral body and bone fragments into the anterior portion of the cord
- Symptoms: spares sensory pathways, interrupts pain, temperature, light touch
- Poor prognosis



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POSTERIOR CORD SYNDROME

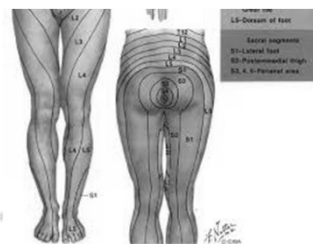
- Loss of proprioception
- Preserves motor function, pain, temperature sensation and light touch
- Atypical in trauma, usually occurs from vascular compromise to cord



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CAUDA EQUINA

- Caused from retropulsion of fracture fragments in the lumbar/sacral region resulting in spinal nerve root compression
- Symptoms include back and lower extremity pain, sensory loss, bowel and bladder dysfunction, saddle anesthesia
- Reduced or absent perianal and perineal sensation, decreased rectal tone and contraction
- Negative "anal wink"



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SPINAL STINGER

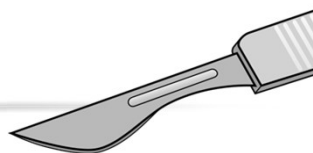
- AKA- Spinal concussion
- SCIWORA-Spinal cord injury without radiographic abnormality
- Complete on incomplete
- Transient dysfunction that resolves
- Most common from sports injuries
- Treatment is supportive and focuses on prevention of recurrent injury



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SURGICAL INTERVENTION

- Anatomic reduction of the spinal column in the setting of SCI is indicated in the situation of any neuro deterioration, facet dislocation, or bilateral locked facets.
- Closed anatomic reduction should be performed as soon as possible for the awake patient with fracture or dislocation injuries of the cervical spine.
- MRI is recommended prior.
- Open reduction should be performed if unable to reduce with closed approach.
- Goals: stabilize spine, decompress canal, prevent further neurologic injury.
- Goal of decompression within 24 hours may improve outcomes (cervical spine) is now the standard of care (STASCIS- surgical timing in acute spinal cord injury study).
- No consensus for thoracolumbar spine yet.



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DRUG THERAPIES

- No pharmacologic therapy to date has been found to be effective in mitigation of neuro effects of SCI.
- For decades steroids were used, now it is no longer used. Risks outweigh benefits (infections, GI hemorrhage, hyperglycemia, death)
- GM1 ganglioside- initial thought this drug would improve motor function- now recommended to NOT use.
- GM11 and other hormones studied, show no benefit in clinical trials
- Ongoing clinical trials other drugs
- Other therapies like stem cell transplant and therapeutic hypothermia continue to be studied.

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COMPLICATIONS

- Pulmonary- hygiene including: Chest physiotherapy, secretion clearance devices, bronchodilators, mucolytics, respiratory muscle training, assisted breathing, assisted coughing devices and techniques, dedicated weaning protocols, VAP bundle, early tracheostomy (intake ASIA score <10 100% predicts need for trach...laparoscopically implanted diaphragm pacing system)
- Cardiac- Bradycardia- tx in symptomatic patients only (use levophed or dopamine, consider enteral albuterol). Acute-atropine. Pacer if persistent.
- VTE- mechanical asap, + chemical after 72hrs of injury x 3 months. IVC filter only if contraindicated (TBI)
- Skin- turn schedule, frequent assessment including under braces, pressure reduction beds, care of pressure points,

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COMPLICATIONS CONT...

- Bowel- aggressive regimen. Bowel program. Daily supp.
- Bladder- neurogenic bladder, foley, bladder training (straight cath schedule Q 4-6 hrs decreases risk of UTI)
- Hyperglycemia- avoid! (infection, wound healing, etc)
- Nutrition- enteral nutrition within 72 hrs (hypermetabolism), swallow evals.
- Stress ulcer- prophylaxis- high risk for ulcer and bleed
- High risk of depression, chronic pain syndrome, issues with neurogenic pain
 - 5x increase risk of suicide

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COMPLICATIONS CONT...

- Autonomic dysreflexia- not typically an acute complications (usually occurs after spinal shock resolves >6 weeks after injury)
 - Cervical and high thoracic injuries (>T6)
 - Noxious stimuli (fecal impaction or bladder distention) occurs below level of injury, causes increase in SBP d/t hyperactive thoracic sympathetic reflex activity, loss of supraspinal sympathetic control and lack of parasympathetic response.
 - Defined as >20% increase in SBP with change in HR and 1 of the following: diaphoresis, piloerection, facial flushing, headache, blurred vision, nasal congestion.
 - If left untreated can lead to malignant HTN, intracranial hemorrhage, retinal detachment, seizure and death.
 - Try to avoid! If occurs remove the stimuli (check foley, fecal impaction, bed linens, pain)
 - May need to tx with calcium channel blocker or nitrate

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REHAB

- Consult PT/OT/ST
- Social Work/Discharge planning consult on admission
 - Assess patient needs and appropriate settings for continued care with care team
 - Educate on goals and plan of care
 - Resources
 - Insurance benefits
 - Apply for medicaid, guardianship
- Referral Options
 - Skilled nursing facility
 - AWH inpatient rehab
 - Spinal cord injury rehab centers
 - Froedtert-Milwaukee, other centers in WI and surrounding states

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