

CLASSIFICATION OF SCI

IMPORTANT DEFINITIONS

Types of Injuries

Tetraplegia

- Replaces quadriplegia
- Impairment or loss of motor and/or sensory function in the cervical segments of SC due to damage of neural elements within spinal canal
- Results in impairment of function in arms, trunk, legs, pelvic organs
- Does not include brachial plexus lesions or injury to peripheral nerves outside neural canal

Paraplegia

- Impairment or loss of motor and/or sensory function in thoracic, lumbar, or sacral segments of SC
- Trunk, legs, pelvic organs may be involved, arm function spared
- Refers to cauda equina and conus medullaris injuries, but not to lumbosacral plexus lesions or injury to peripheral nerves outside the neural canal

Other Definitions

Dermatome

Area of skin innervated by the sensory axons within each segmental nerve (root)

Myotome

Collection of muscle fibers innervated by the motor axons within each segmental nerve (root)

UPPER MOTOR NEURON INJURY vs. LOWER MOTOR NEURON INJURY

Upper Motor Neuron Injury	Lower Motor Neuron Injury
Supply: Begins in the prefrontal motor cortex, travels through the internal capsule and brainstem, and projects into the spinal cord	Supply: Begins with the anterior horn cells of the spinal cord and includes the peripheral nerves
Upper Motor Neuron Findings	Lower Motor Neuron Findings
Increased muscle stretch reflexes Babinski response Detrusor sphincter dyssynergia (depending on level of lesions)	Hyporeflexia Flaccid weakness Significant muscle wasting

Note: Lesions of the upper lumbar vertebral bodies can present with a mixture of upper and lower neuron findings

NEUROLOGIC LEVEL, SENSORY LEVEL, AND MOTOR LEVEL OF INJURY:

(Hoppenfeld, 1977)

Lesions are classified according to a *neurologic, motor, and sensory level of injury*. They are further divided into complete and incomplete lesions.

1. Sensory level of injury

- Most caudal segment of the SC with normal (2/2) sensory function on both sides of the body for pinprick, and light touch
- For the sensory examination there are 28 key sensory *dermatomes*, each tested separately for *light touch* (with a cotton tip applicator) and *pinprick* (with a safety pin)

Scores:	0	Absent
	1	Impaired
	2	Normal

The face is used as the normal control point.

For pinprick testing: The patient must be able to differentiate the sharp and dull edge of a safety pin.

Scores:	0	Not able to differentiate between the sharp and dull edge
	1	The pin is not felt as sharp as on the face, but able to differentiate sharp from dull
	2	Pin is felt as sharp as on the face

For light touch, a cotton tip applicator is compared to the face sensation

Scores:	2	Normal—same as on face
	1	Impaired—less than on the face
	0	Absent

 It is very important to test the S4/S5 dermatome for light touch and pinprick

2. Motor level of injury

- Most caudal key muscle group that is graded three-fifths or greater with the segments above graded five-fifths in strength.
- A possible score of 100 can be obtained when adding the muscle scores of the key muscle groups (25 points per extremity).

There are 10 key myotomes on the left and right side of the body:

Myotome	Index Muscle	Action
C5	Biceps brachialis	Elbow flexors
C6	Extensor carpi radialis	Wrist extensors
C7	Triceps	Elbow extensors
C8	Flexor digitorum profundus	Finger flexors (FDP of middle finger)
T1	Abductor digiti minimi	Small finger abductor
L2	Iliopsoas	Hip flexors
L3	Quadriceps	Knee extensors
L4	Tibialis anterior	Ankle dorsiflexors
L5	Extensor hallucis longus	Long toe extensors
S1	Gastrocnemius	Ankle plantarflexors

Manual Muscle Testing Grading System

- 0 No movement
- 1 Palpable movement or visible contraction
- 2 Active movement through full range of motion with gravity eliminated
- 3 Active movement through full range of motion against gravity
- 4 Active movement against moderate resistance through full range of motion
- 5 Normal strength based on age, sex, and body habitus

3. Neurologic level of injury

- Most caudal segment of the spinal cord with both normal sensory and motor function on both sides of the body, determined by the sensory and motor levels
- Since the level may be different from side to side, it is recommended to record each side separately

4. Skeletal level of injury


- Level where the greatest vertebral damage is noted by radiographic evaluation

COMPLETE VS. INCOMPLETE LESIONS

Complete injury (Waters 1991)

- Absence of sensory and motor function in the lowest sacral segment
- The term *Zone of Partial Preservation* is only used with *complete lesions*
- Refers to the dermatomes and myotomes *caudal* to the neurological level of injury that remain partially innervated

Incomplete injury

- Partial preservation of sensory and/or motor functions below the neurological level, which includes the lowest sacral segment. Sacral sensation and motor function are assessed.
-  *Sacral Sparing* —voluntary anal sphincter contraction or sensory function (light touch, pinprick at the S4–S5 dermatome, or anal sensation on rectal examination) in the lowest sacral segments.
- Due to preservation of the periphery of the SC
- Indicates incomplete injury
- Sacral sparing indicates the possibility of SC recovery, with possible partial or complete return of motor power
- There is also the possibility of return of bowel and bladder function
- The concept of sacral sparing in the incomplete SCI is important because it represents at least partial structural continuity of the white matter long tracts (i.e., corticospinal and spinothalamic tracts). Sacral sparing is evidenced by perianal sensations (S4–S5 dermatome), and rectal motor function. Sacral sparing represents continued function of the lower sacral motor neurons in the conus medullaris and their connections via the spinal cord to the cerebral cortex.

ASIA IMPAIRMENT SCALE: CLASSIFIES COMPLETE AND INCOMPLETE INJURIES:

A = Complete: No motor or sensory function is preserved in the sacral segments

B = Incomplete: Sensory but not motor function is preserved below the neurological level and includes sacral segments


C = Incomplete: Motor function preserved below the neurological level; more than half the key muscles below the neurological level have a muscle grade less than 3

D = Incomplete: Motor function preserved below the neurological level; at least half the key muscles below the neurological level have a muscle grade of 3 or more

E = Normal: Motor and sensory function

Assigning an ASIA Level (Figure 7–15)

1. Examine 10 index muscles bilaterally
2. Examine 28 dermatomes for pinprick and light touch
3. Complete rectal exam to assess sensation and volitional sphincteric contraction
4. Determine left and right motor levels

5. Determine left and right sensory levels
6.  Assign final motor and sensory levels
7. Determine neurological level, which is the most caudal segment with normal motor and sensory function
8. Categorize injury as complete or incomplete by ASIA impairment scale (A,B,C,D,E)
9. Calculate motor and sensory score
10. Determine zone of partial preservation if complete injury ("A" on impairment scale)

CLINICAL EFFECTS OF SCI: DIVIDED INTO TWO STAGES

1. Spinal Shock–Areflexia
2. Heightened Reflex Activity

1. Stage of Spinal Shock

- Reflex arc is not functioning
- Loss of motor function is accompanied by atonic paralysis of the bladder, bowel, gastric atony
- All the muscles below the level of the lesion become flaccid and hyporeflexic
- Loss of sensation below the level of the lesion
- Temporary loss or depression of all spinal reflex activity below the level of the lesion
- Autonomic function below the level of the lesion is also impaired
- Temporary loss of piloerection, sweating, vasomotor tone in the lower parts of the body
- Believed to be due to a sudden and abrupt interruption of descending excitatory influences

Duration: Lasts from 24 hours to 3 months after injury. Average is 3 weeks.

Minimal reflex activity is noted usually with the return of the bulbocavernosus reflex and the anal wink reflex

Bulbocavernosus reflex (male ♂): (Figure 7–16)

- The bulbocavernosus reflex arc is a simple sensory-motor pathway that can function without using ascending or descending white-matter, long-tract axons.
- Usually the first reflex to return after spinal shock is over. If the level of the reflex arc is both physiologically and anatomically intact, the reflex will function in spite of complete spinal cord disruption at a higher level.
- Indicates that reflex innervation of bowel and bladder is intact
- Performed by squeezing the penis and noting stimulation of anal sphincter contraction
- At this time the bladder can be expected to contract on a reflex basis (although clinically this rarely occurs)
- Bowel will empty as a result of reflex induced by fecal bulb or rectal suppository stimulation

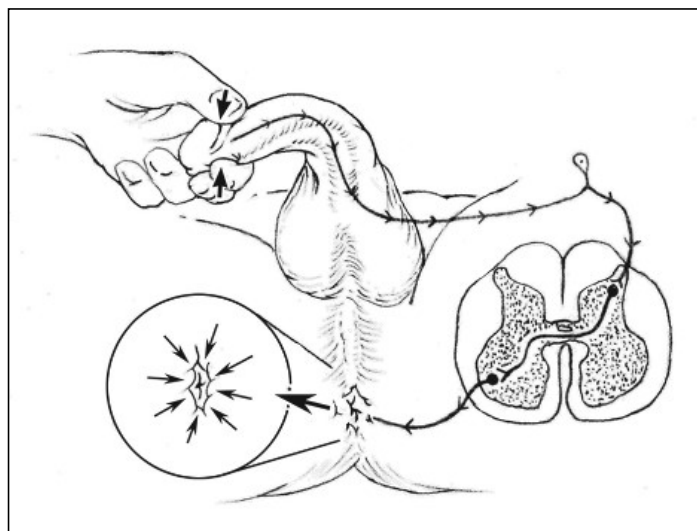


FIGURE 7–16. The bulbocavernosus reflex.

Perianal Sphincter Reflex (anal wink)

- Perianal stimulation causes contraction of the anal sphincter
- Indicates that reflex innervation of the bowel and bladder is intact

2. Stage of Increased Reflex Activity

- As the spine recovers from shock, the reflex arc functions without inhibitory or regulatory impulses from the brain, creating local spasticity and clonus
- Reflexes become stronger, and come to include additional and more proximal muscles
- Pattern of higher flexion is noted
- Dorsiflexion of the big toe (Babinski sign)
- Fanning of the toes
- Achilles reflex returns, then patellar
- Bladder starts to present contractions at irregular intervals with release of urine
- Reflex defecation

ASIA NEUROLOGICAL EXAMINATION TWO COMPONENTS—SENSORY AND MOTOR

Localizing Level of Injury and Asia Classification (Asia, 1996), (Mayard and Bracken, 1997)

ASIA Key Sensory Levels (Figure 7–17)

- C2: Occipital protuberance
- C3: Supraclavicular fossa
- C4: Superior AC Joint
- C5: Lateral side of the antecubital fossa
- C6: Thumb (and index finger)
- C7: Middle finger
- C8: Little finger
- T1: Medial ulnar side of antecubital epicondyle
- T2: Apex of axilla
- T3: Third intercostal space (IS)
- T4: Nipple line – fourth IS
- T5: Fifth intercostal space - fifth IS
- T6: Xiphoid – sixth IS
- T7: Seventh intercostal space – seventh IS
- T8: Eighth intercostal space – eighth IS
- T9: Midway between T8 and T10 – ninth IS
- T10: Umbilicus – tenth IS
- T11: Eleventh intercostal space – eleventh IS
- T12: Inguinal ligament at midpoint
- L1: Half the distance between T12 and L2
- L2: Midanterior thigh
- L3: Medial fem condyle
- L4: Medial malleolus
- L5: Dorsum of foot at third MTP joint
- S1: Lateral heel
- S2: Popliteal fossa in the midline
- S3: Ischial tuberosity
- S4 and S5: Perianal area (taken as one level)

ASIA Key Motor Levels

- C1–C4: Use sensory level and diaphragm to localize lowest neurological level
- C5: Elbow flexors
- C6: Wrist extensors
- C7: Elbow extensors
- C8: Finger flexors (FDP of middle finger)
- T1: ABD digiti minimi (small finger abductor)
- T2–L1: Use sensory level
- L2: Hip flexors
- L3: Knee extensors
- L4: DF ankle dorsiflexors
- L5: Long toe extensors
- S1: Plantar flexors

Reflexes

- S1S2: Gastrocnemius (ankle jerk)
- L3L4: Quadriceps (knee jerk)
- C5C6: Biceps, brachioradialis
- C7C8: Triceps, finger flexors
- L5: Medial hamstring

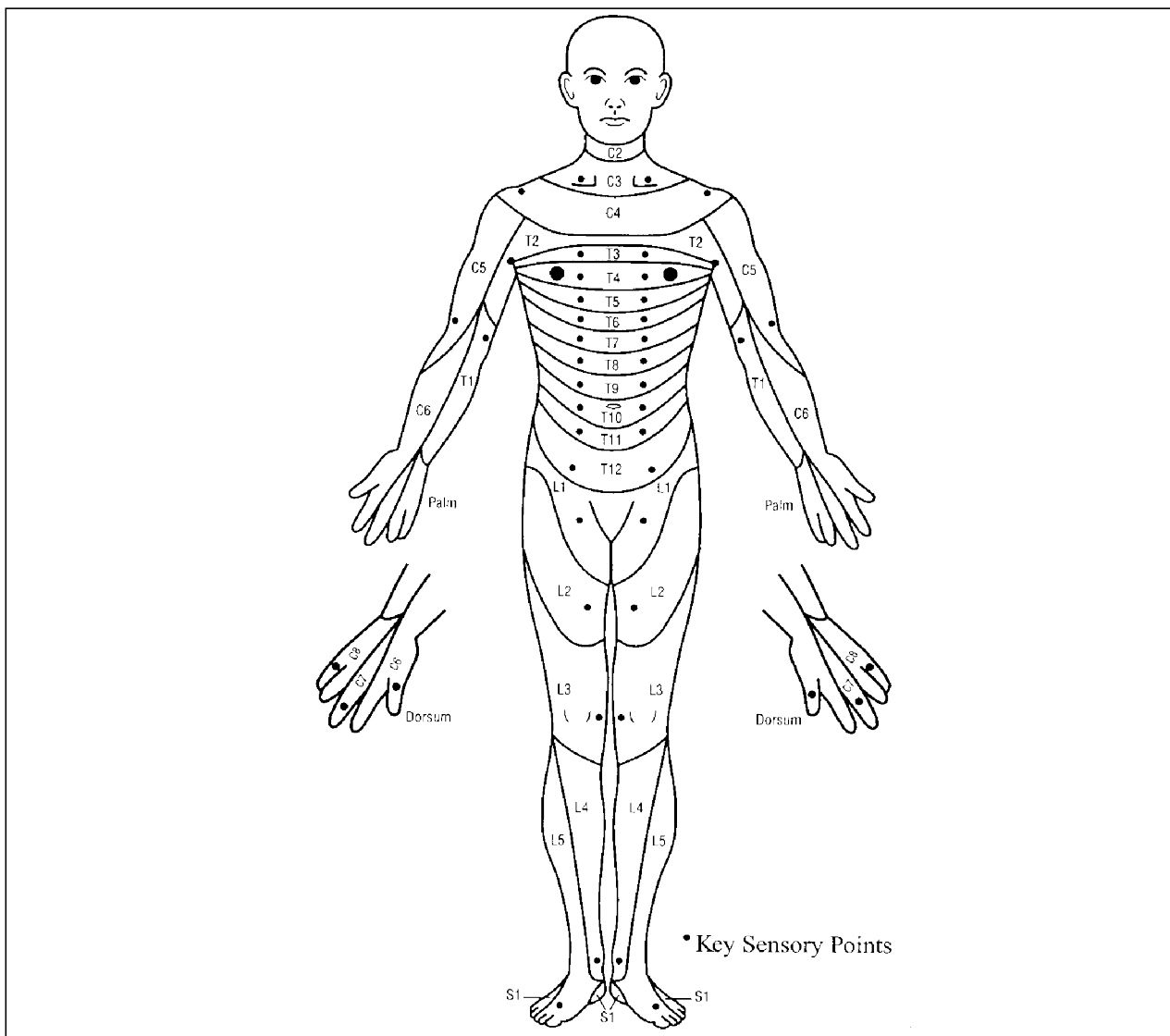



FIGURE 7–17. ASIA key sensory levels. © American Spinal Injury Association, 1996, with permission.

INCOMPLETE SPINAL CORD INJURY SYNDROMES

 **Central cord syndrome** (Figure 7–18) This is the most common syndrome.

- Results from an injury involving the center of the spinal cord
- It is predominantly a white matter peripheral injury
- Intramedullary hemorrhage is not common
- It may occur at any age, but is more common in older patients
- Produces sacral sensory sparing, greater motor weakness in the upper limbs than the lower limbs. Anatomy of the corticospinal tracts is such that the cervical distribution is medial and sacral distribution is more lateral. Since the center of the SC is injured, upper extremities are more affected than lower extremities.
- Patients may also have bladder dysfunction, most commonly urinary retention
- Variations in sensory loss below the level of the lesion

Recovery: Lower extremities recover first and to a greater extent. This is followed by improvement in bladder function, then proximal upper extremity, and finally intrinsic hand function. (Roth et al., 1990)

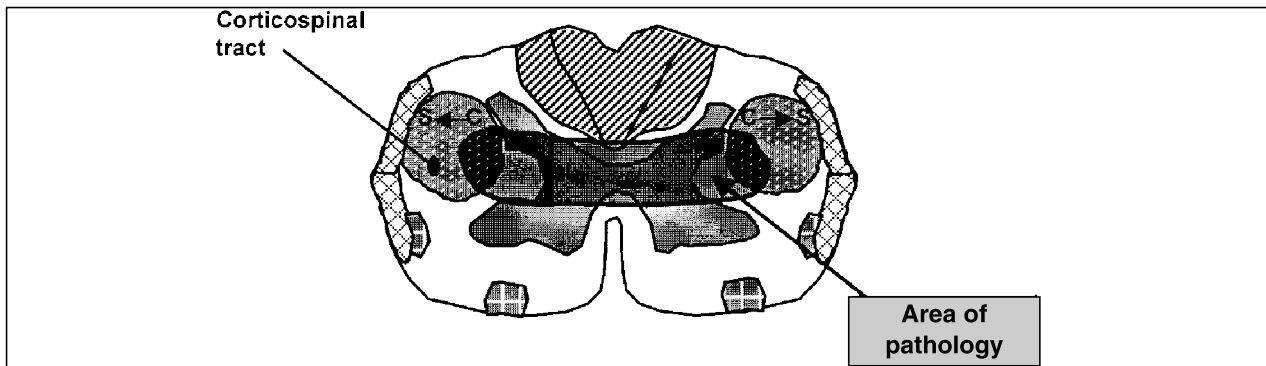


FIGURE 7-18. Central Cord Syndrome. (Transverse section of the spinal cord—refer to Figure 7-2 for anatomical landmarks).

Brown-Sequard Syndrome: (Figure 7-19, 7-20) Constitutes 2%-4% of all traumatic SCI

- Results from a lesion that causes spinal hemisection
- (Ipsilateral) focal injury to the spinal cord causes deficits distal to the site of the lesion. Because tracts cross at different locations, deficits affect different sides, i.e.
- Ipsilateral—motor and proprioception deficits
- Contralateral—pain and temperature deficits
- Associated with stabbing and gunshot wounds
- Patients have ipsilateral motor and proprioceptive loss, and contralateral loss of pain and temperature

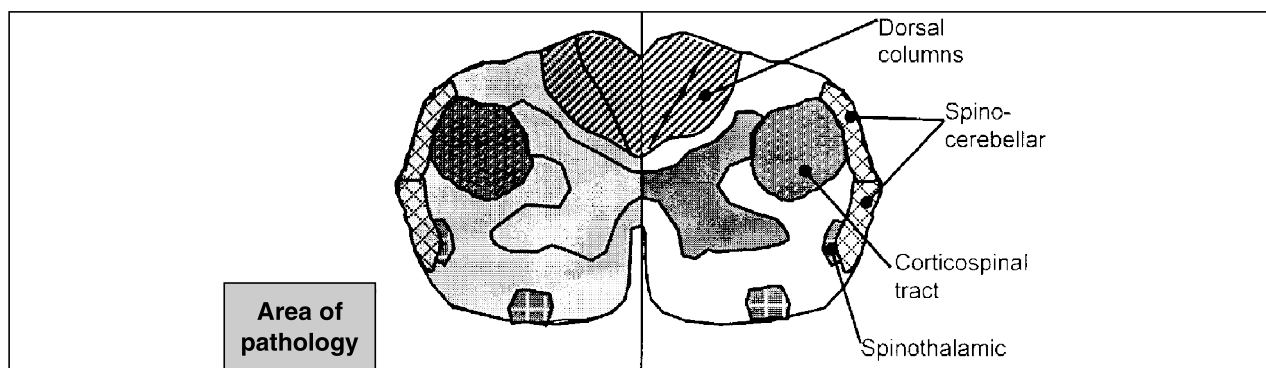


FIGURE 7-19. Brown-Sequard Syndrome. (Transverse section of the spinal cord—refer to Figure 7-2 for anatomical landmarks).

Result

Ipsilateral:

Motor and proprioceptive deficits (right sided)

Contralateral:

Pain and temperature deficits (left sided)

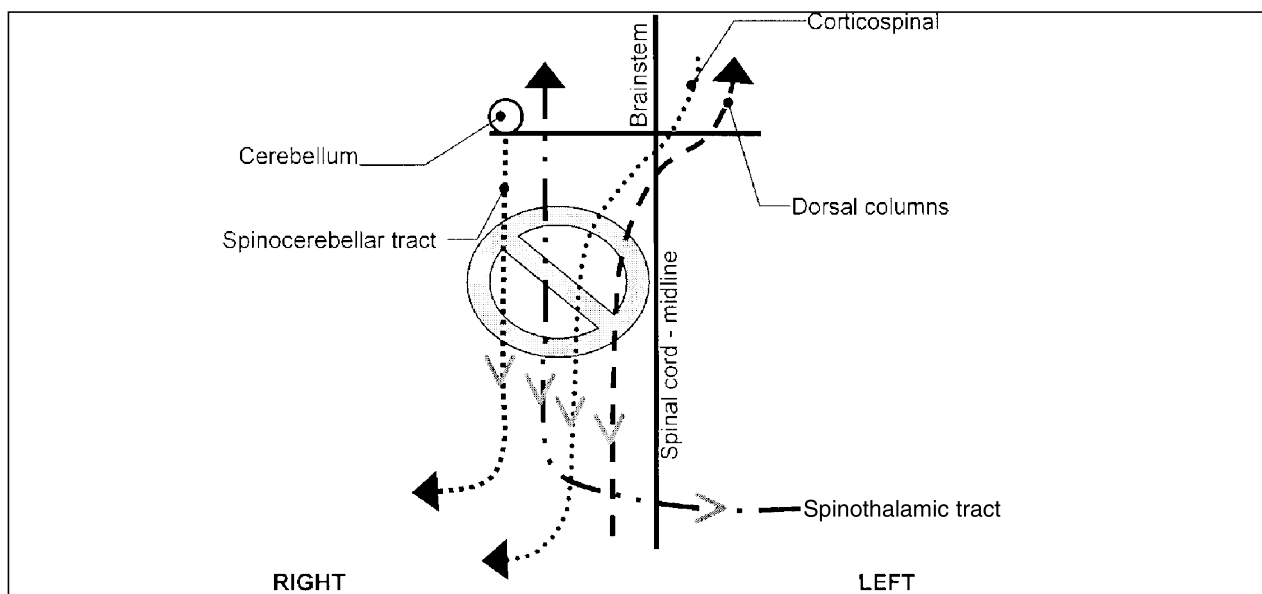


FIGURE 7–20. Brown-Sequard syndrome lesion: depicts point of injury, i.e. right-sided gunshot or knife wound. Follow tracts distal from the point of injury. Result is ipsilateral motor and proprioceptive deficits (right-sided) contralateral pain and temperature deficits (left-sided).

Anterior Cord Syndrome: (Figure 7–21)

Caused by:

A lesion involving the anterior two thirds of the spinal cord preserving the posterior columns, such as:

Anterior spinal artery lesions, direct injury to the anterior spinal cord, bone fragments or a retropulsed disc

Polyarteritis nodosa, angioplasty, aortic and cardiac surgery, and embolism, can result in injury to the anterior two-thirds of the spinal cord (Ditunno, 1992)

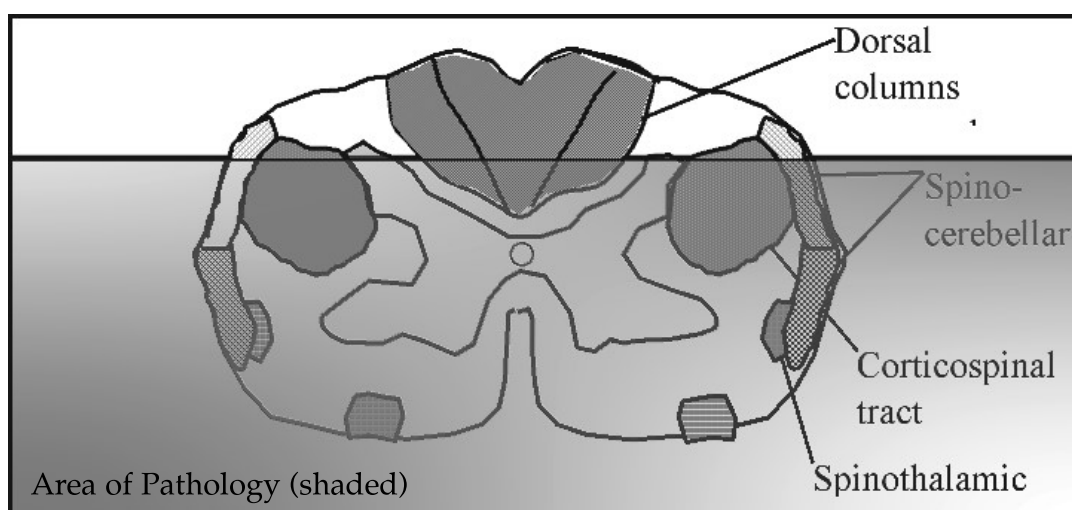


FIGURE 7–21. Anterior cord syndrome. (transverse section of the spinal cord—refer to Figure 7–2 for anatomic landmarks).

Result:

Variable loss of motor function (corticospinal tract) and sensitivity to pain and temperature, pinprick sensation, (spinothalamic tract) with preservation of proprioception and light touch

Recovery:

There is only 10%–20% chance of muscle recovery in most cases. (Kirshblum, 1998)

Of those who recover, coordination and muscle power is poor.

Posterior Cord Syndrome (Figure 7–22)

- Least frequent syndrome
- Injury to the posterior columns results in proprioceptive loss (dorsal columns)
- Pain, temperature, touch are preserved. Motor function is preserved to varying degrees.

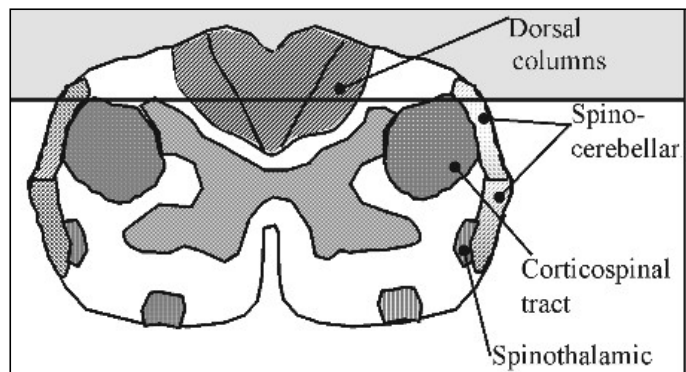


FIGURE 7–22. Posterior cord syndrome. (transverse section of the spinal cord—refer to Figure 7–2 for anatomical landmarks).

Conus Medullaris Syndrome

- Injury to the sacral cord (conus) and lumbar nerve roots within the spinal canal, usually results in areflexic bladder and bowel, and lower limbs (in low-level lesions) i.e., lesions at B in Figure 7–23.
- If it is a high conus lesion, bulbocavernous reflex and micturition may be present, i.e., lesions at A in Figure 7–23.

Cauda Equina Syndrome:

- Injury to the lumbosacral nerve roots within the neural canal, results in areflexic bladder, bowel, lower limbs, i.e., lesions at C in Figure 7–23.
- Bulbocavernous reflex absent

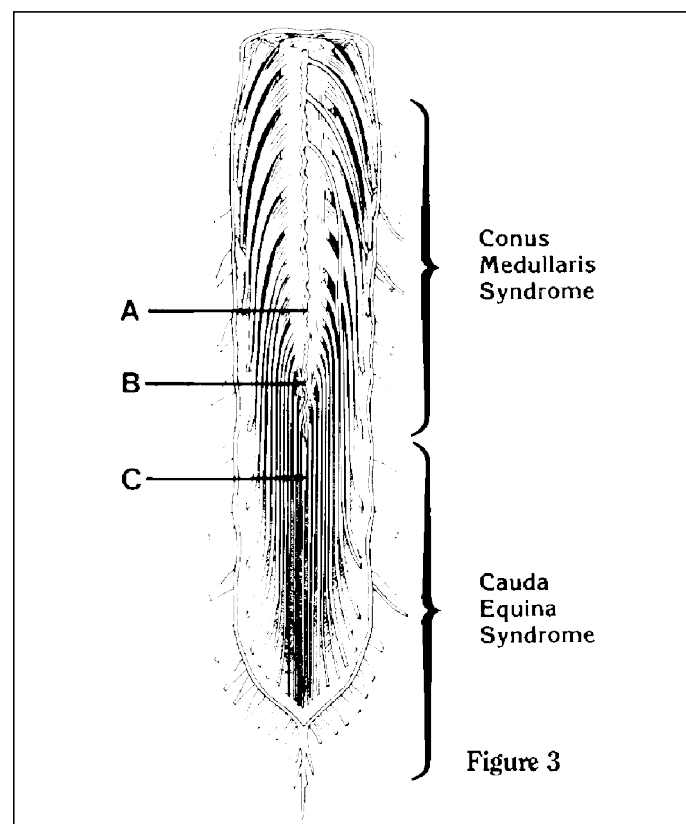




FIGURE 7–23. Distal spinal cord: Conus Medullaris Syndrome. **A:** high lesion. **B:** low lesion. Cauda Equina Syndrome: **C:** Lesion of the lumbosacral nerve roots. © American Spinal Injury Association, 1996, with permission.

Table 7-2 Conus Medularis vs. Cauda Equina Syndrome

CONUS MEDULLARIS L1–L2 vertebral level Injury to Sacral Cord (S1–S5)	CAUDA EQUINA SYNDROME L2–sacrum vertebral level Injury to Lumbosacral Nerve Roots
Location: L1–L2 vertebral level injury of sacral cord (S1–S5) and lumbar roots	Location: L2–sacrum vertebral level Injury to lumbosacral nerve roots
Causes: <ul style="list-style-type: none"> • L1 fracture • Tumors, gliomas • Vascular injury • Spina bifida, tethering of the cord 	Causes: <ul style="list-style-type: none"> • L2 or below fracture • Sacral fractures • Fracture of pelvic ring • Can be associated with spondylosis
Resultant Signs and Symptoms: <ol style="list-style-type: none"> 1. Normal motor function of lower extremities unless S1–S2 motor involvement (since only involves S1–S5) Areflexic lower extremities If lumbar root involvement results in a lower motor neuron lesion (LMN) 2. Saddle distribution sensory loss (touch is spared) 3. No pain 4. Symmetric abnormalities 5. Severe bowel, bladder, sexual dysfunction Areflexic bowel Areflexic bladder 6. If it is a high conus lesion, bulbocavernosus reflex may be present 	Resultant Signs and Symptoms: <ol style="list-style-type: none"> 1. Flaccid paralysis of lower extremities of involved Lumbosacral nerve roots Areflexic LE—results in a LMN Lesion 2. Sensory loss in root distribution 3. Pain 4. Abnormalities predominate on one side (asymmetric) 5. High cauda equina lesions (lumbar roots) Spare bowel and bladder Lower lesions (S3–S5) can involve bowel and bladder and sexual dysfunction 6. Bulbocavernosus reflex is absent (in low cauda equina [sacral] lesions)
EMG: Normal EMG (except for external sphincter or S1, S2 involvement)	EMG: Findings show multiple root level involvement Px: Good

TABLE 7-3. Functional Potential Outcomes for Cervical SCI (Complete) Patients (Kirshblum, 1998)

	C3–C4	 C5	 C6	C7	C8–T1
Feeding	May be able with adapted equipment	*BFO Independent with equipment after set up	Independent with equipment	Independent	Independent
Grooming	Dependent	Independent with equipment after set up	Independent with equipment	Independent with equipment	Independent
UE Dressing	Dependent	Requires assistance	Independent	Independent	Independent
LE Dressing	Dependent	Dependent	Requires assistance	May be independent with equipment	Independent
Bathing	Dependent	Dependent	Independent with equipment	Independent	Independent
Bed Mobility	Dependent	Requires assistance	Independent with equipment	Independent	Independent
Weight Shifts	Independent with power Dependent in manual	Requires assistance	Independent	Independent	Independent
Transfers	Dependent	Requires assistance	Possible independent with transfer board	Independent with or without board except floor transfer	Independent
W/C Propulsion	Independent with power Dependent in manual	Independent with power Short distances in manual with lugs or plastic rims on level surfaces	Independent manual with plastic rims on level surfaces	Independent except curbs	Independent
Driving	Unable	Unable	Specially adapted van	Car with hand controls or adapted van	Car with hand controls or adapted van
Bowel and Bladder	Dependent	Dependent	Independent—bowel assists—bladder	Independent	Independent

📖 THE HIGHEST COMPLETE SCI LEVEL THAT CAN LIVE INDEPENDENTLY WITHOUT THE AID OF AN ATTENDANT IS A C6 COMPLETE TETRAPLEGIA.

- This patient would have to be *extremely motivated*
- Feeding is accomplished with a universal cuff for utensils
- Transfers require stabilization of elbow extension with forces transmitted from shoulder musculature through a closed kinetic chain
- Bowel care is performed using a suppository insertion wand or other apparatus for digital stimulation
- Outcome studies of a subset of patients with motor and sensory complete C6 SCI revealed the following percentage of patients were independent for key self-care tasks:

Feeding—16%

Upper body dressing—13%

Lower body dressing—3%

Grooming—19%

Bathing—9%

Bowel Care—3%

Transfers—6%

Wheelchair propulsion—88%

📖 C7 level is the *usual* level for achieving independence.

■

MEDICAL COMPLICATIONS OF SCI

**Important Levels to Remember:**

T6 and above: Individuals with SCI are considered to be at risk for

1. Autonomic Dysreflexia
2. Orthostatic Hypotension

T8: If lesion above T8, patient cannot regulate and maintain normal body temperature
(Note: an easy way to remember this level is to spell the word *temp eight ture.*)

Central temperature regulation in the brain is located in the hypothalamus.

ORTHOSTATIC HYPOTENSION (see Table 7-4) (Corbett, 1971)

State of transient reflex depression

Cause: Lack of sympathetic outflow, triggered by tilt of patient > 60 degrees

Lesion T6 or above

T1–L2 responsible for:

Tachycardia, vasoconstriction and increased arterial pressure

Heart and blood vessels supplied by T1–T7

Mechanism

- Upright position causes decrease in blood pressure (BP)
- Carotid body baroreceptors sense decrease in BP, which would usually increase sympathetic outflow.