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SPINAL CORD INJURIES

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EPIDEMIOLOGY OF SPINAL CORD INJURY (SCI)

In USA: 30–60 new injuries per million pop. /year
🕮 **Incidence (new cases):** 10,000 new cases of SCI/year
🕮 **Prevalence (total # of existing cases):** 200,000–250,000 cases
Gender: 82% male vs. 18% female
Age: 🕮 Average age at injury: 31.7 years of age
🕮 Patients injured after 1990 had an average age at time of injury of 34.8 years
56% of SCIs occur among persons in the 16–30 year age group
Children 15 years of age or younger account for only 4.5% of SCI cases
Persons older than 60 years of age account for 10% of SCI cases
Falls are the most common cause of SCI in the elderly
Motor vehicle accidents (MVAs) are the second most common cause of SCIs in the elderly
Causes: MVAs: 44%
Violence (most are gunshot): 24%
Falls: 22%
Sports (most are diving): 8%
Other: 2%
Time of Injury: Season: Summer (highest incidence in July)
Day: Weekends (usually Saturday)
Time: Night
Characteristics of Injury: Tetraplegia: C5 is most common level of injury
Paraplegia: T12 is most common level of injury
Type of injury: Tetraplegia: 51.9%
Paraplegia: 46.27%
Incomplete tetraplegia: 29.6%
Complete paraplegia: 28.1%
Incomplete paraplegia: 21.5%
Complete tetraplegia: 18.5%
Complete or substantial recovery by time of discharge: 0.7%
Persons for whom this information is not available: 0.7%

Demographics:

There is a close association between risk of SCI and a number of indications of social class, all of which have profound implications for rehabilitation:

- SCI patients have fewer years of education than their uninjured counterparts
- SCI patients are more likely to be unemployed than non-SCI pts.
- SCI patients are more likely to be single (i.e. never married, separated, divorced)

🕮 Note: Postinjury marriages (injured and then married) survive better than preinjury marriages (injured after marriage)

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ANATOMY

The vertebral column (Figure 7–1) consists of:

7	cervical
12	thoracic
5	lumbar
5	sacral
4	coccyx

Spinal Cord:

Located in upper two-thirds of the vertebral column

The terminal portion of the cord is the conus medullaris, which becomes cauda equina (horse's tail) at approximately the L2 vertebrae

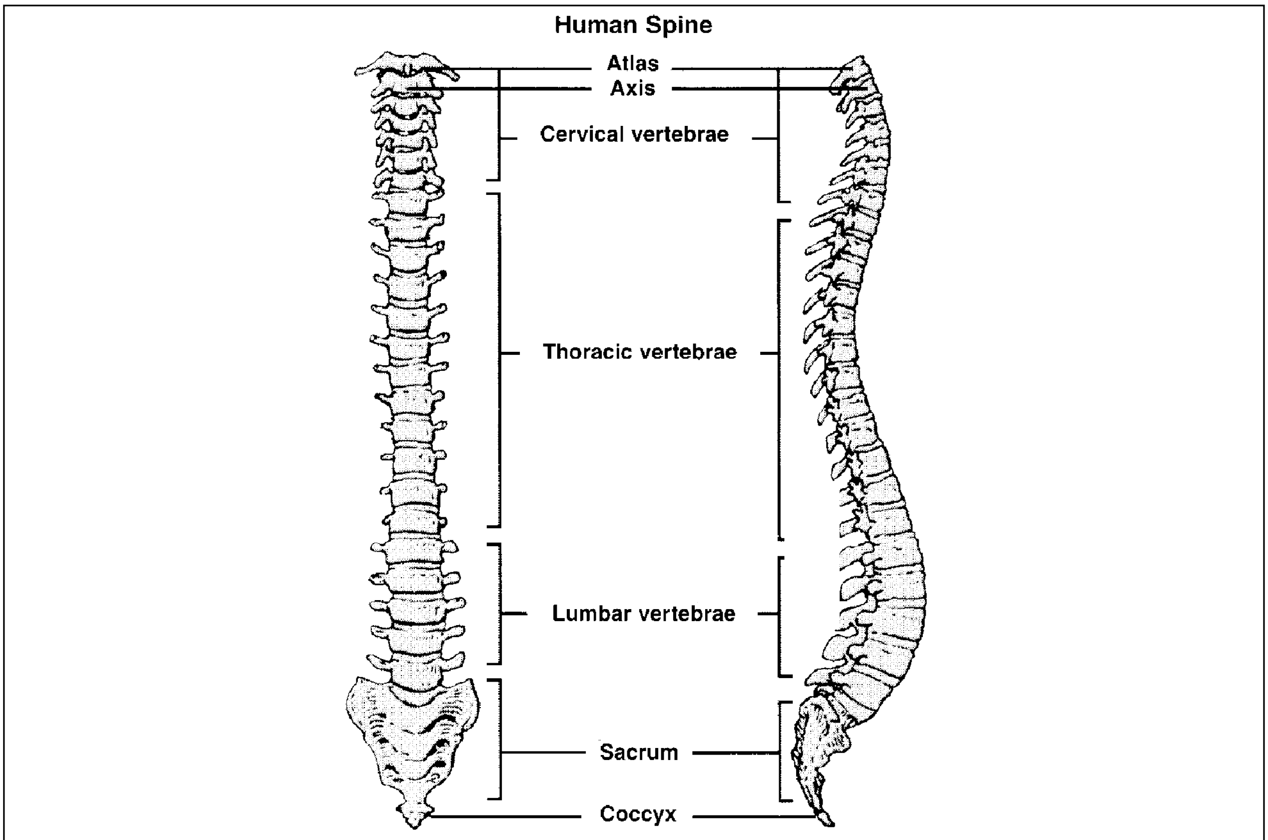

FIGURE 7–1. Human Vertebral Column. (From Nesathurai S. The Rehabilitation of People With Spinal Cord Injury: A House Officer's Guide. © Boston Medical Center for the New England Regional Spinal Cord Injury Center. Boston, MA: Arbuckle Academic Publishers, with permission).

The spinal cord has an inner core of gray matter, surrounded by white matter. The white matter consists of nerve fibers, neuroglia, and blood vessels. The nerve fibers form spinal tracts, which are divided into ascending, descending, and intersegmental tracts. The location and function of various tracts are shown below (Figure 7–2).

LONG TRACTS IN THE SPINAL CORD			
Key	**Tract**	**Location**	**Function**
	Fasciculus gracile: dorsal columns (posterior)	**Medial dorsal column**	**Proprioception from the leg Light touch Vibration**
Same as above	**Fasciculus cuneate: dorsal columns (posterior)**	**Lateral dorsal column**	**Proprioception from the arm Light touch Vibration**
	Spinocerebellar	**Superficial lateral column**	**Muscular position and tone, unconscious proprioception**
	Lateral spinothalamic	**Ventrolateral column**	**Pain and thermal sensation**
	Ventral spinothalamic	**Ventral column**	**Tactile sensation of crude touch and pressure**
	Lateral corticospinal tract (pyramidal)	**Deep lateral column**	**Motor: Medial (cervical)-Lateral (sacral) C ⟶ S (motor neuron distribution)**
	Anterior corticospinal tract	**Medial ventral column**	**Motor: Neck and trunk movements**

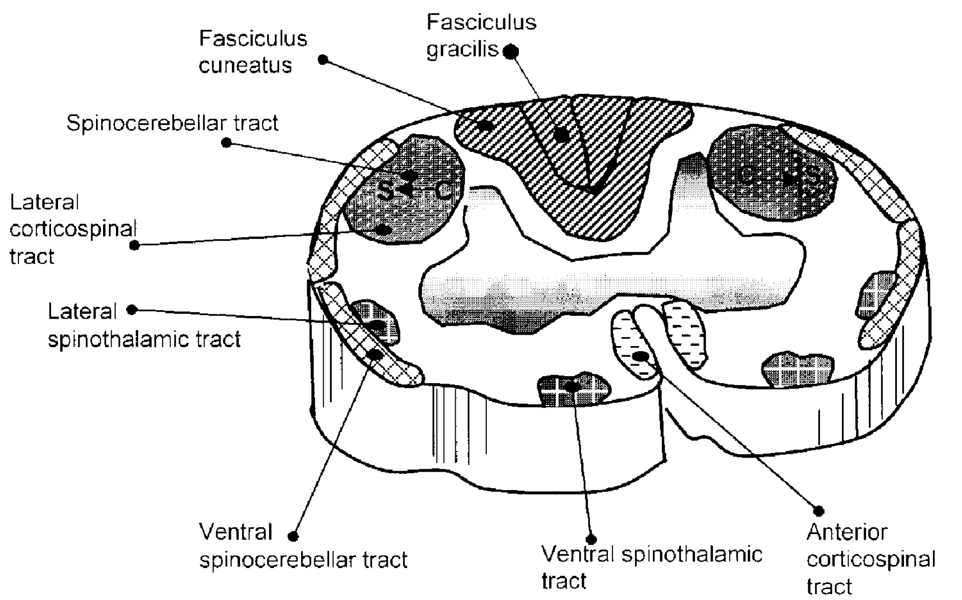

FIGURE 7–2. Transverse section of the spinal cord (use key above for long tracts location and function).

MAJOR ASCENDING AND DESCENDING PATHWAYS IN THE SPINAL CORD (A SCHEMATIC VIEW)

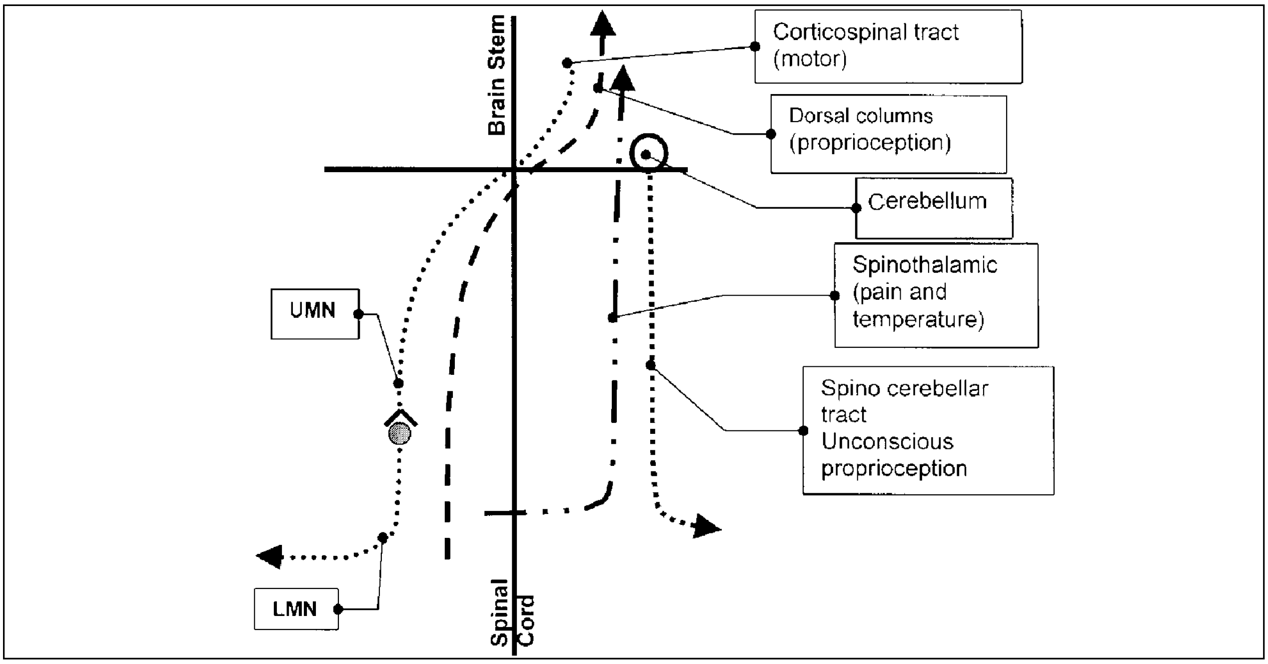

FIGURE 7–3. A Schematic View: The major long tracts in the spinal cord (ascending and descending arrows depict direction).

Note where tracts cross in relation to brain stem (Figure 7–3)

- Corticospinal tract crosses at brain stem to contralateral side, then descends
- Spinocerebellar tract does not cross; remains ipsilateral as it descends
- Spinothalamic tract crosses low to contralateral side, then ascends
- Dorsal columns ascends, crosses at brain stem to contralateral side

Descending Pathways

- The corticospinal tract (motor pathways) extends from the motor area of the cerebral cortex down through the brainstem, crossing over at the junction between the spinal cord and brainstem. The corticospinal pathway synapses in the anterior horn (motor grey matter) of the spinal cord just prior to leaving the cord. This is important for motor neurons above the level of this synapse [connecting anterior horn and anterior horn are termed upper motor neurons (UMN) whereas those below this level (peripheral neurons) are termed lower motor neurons (LMN)]. Cerebral lesions result in contralateral defects in general.
- The spinocerebellar tract (unconscious proprioception) remains ipsilateral. Cerebral lesions produce ipsilateral malfunctioning.

Ascending Pathways

- Spinothalamic tract (pain and temperature) enters the spinal cord, crosses over to the opposite half of the cord almost immediately (actually within 1–2 spinal cord vertebral segments), ascends to the thalamus on the opposite side, and then moves on the cerebral cortex. A lesion of the spinothalamic tract will result in loss of pain-temperature sensation contralaterally below the level of the lesion.

- Dorsal columns (proprioception vibration) initially remains on the same side of the spinal cord that it enters, crossing over at the junction between the spinal cord and brainstem. The synaptic areas just prior to this crossing are nucleus cuneatus and nucleus gracilis. Their corresponding spinal cord pathways are termed fasciculus gracilis and fasciculus cuneatus. Fasciculus gracilis and fasciculus cuneatus are collectively termed posterior (dorsal) columns. A lesion of the posterior columns results in the loss of proprioception and vibration ipsilaterally below the level of the lesion.

Blood Supply of the Spinal Cord (Figure 7–4)

- Posterior Spinal Arteries arise directly or indirectly from the vertebral arteries, run inferiorly along the sides of the spinal cord, and provide blood to the posterior third of the spinal cord
- Anterior Spinal Arteries arise from the vertebral arteries, uniting to form a single artery, which runs within the anterior median fissure. They supply blood flow to the anterior two-thirds of the spinal cord
- Radicular Arteries reinforce the posterior and anterior spinal arteries. These are branches of local arteries (deep cervical, intercostal, and lumbar arteries). They enter the vertebral canal through the intervertebral foramina
- The artery of Adamkiewicz or the arteria radicularis magna is the name given to the lumbar radicular artery. It is larger and arises from an intersegmental branch of the descending aorta in the lower thoracic or upper lumbar vertebral levels (between T10 and L3) and anastomoses with the anterior spinal artery in the lower thoracic region. The lower thoracic region is referred to as the watershed area. It is the major source of blood to the lower anterior two-thirds of the spinal cord
- The Veins of the Spinal Cord drain mainly into the internal venous plexus

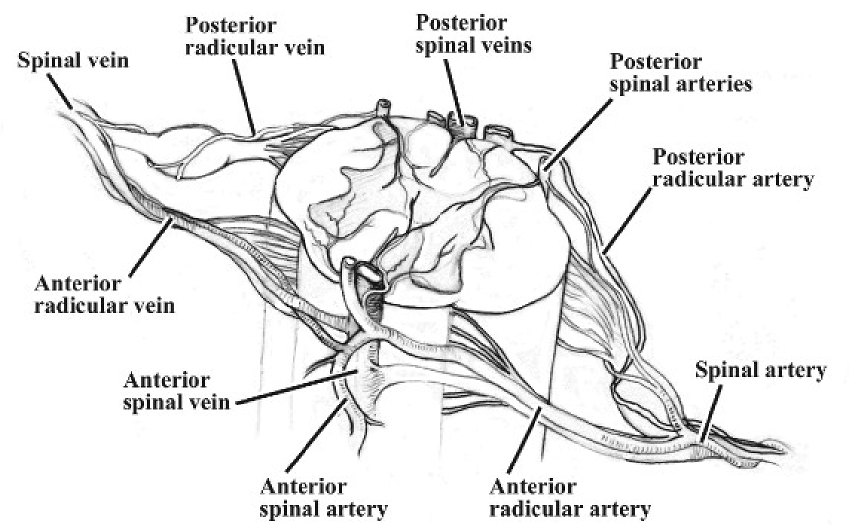

FIGURE 7–4. Arterial and venous supply to the spinal cord. (transverse section).

SPINAL PATHOLOGY

TYPES OF CERVICAL SPINAL CORD INJURY: PATHOLOGY

Compression Fractures—slight flexion of the neck with axial loading (Figure 7–5)

(Bohlmann, 1979)

- C5 is the most common compression fracture of the cervical spine
- Force ruptures the plates of the vertebra, and shatters the body. Wedge shaped appearing vertebra on X-ray.
- May involve injury to the nerve root and/or cord itself
- Fragments may project into spinal canal
- Stable ligaments remain intact

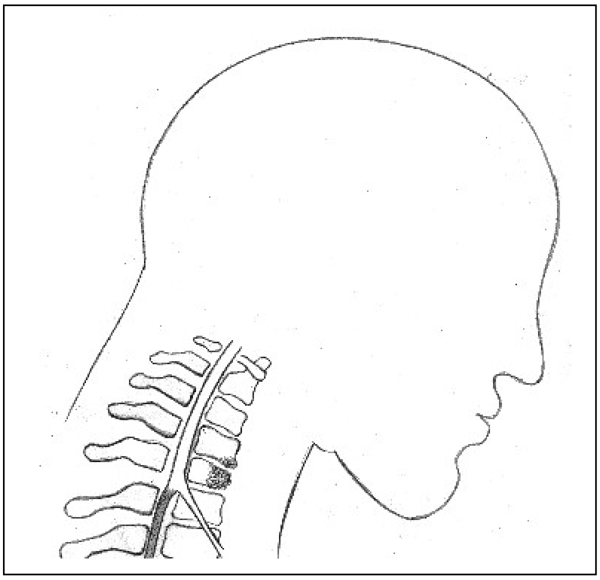

FIGURE 7–5. Cervical compression fracture.

Flexion-Rotation Injuries

Unilateral facet joint dislocations (Figure 7–6)

- Vertebral body < 50% displaced on X-ray
- Unstable (if the posterior ligament is disrupted)
- Narrowing of the spinal canal and neural foramen
- C5–C6 most common level
- Also note that flexion and rotation injuries may disrupt the intervertebral disc, facet joints, and interspinous ligaments with little or no fracture of the vertebrae
- Approximately 75% have no neurological involvement because the narrowing is not sufficient to affect the spinal cord
- If injury results, it is likely an incomplete injury

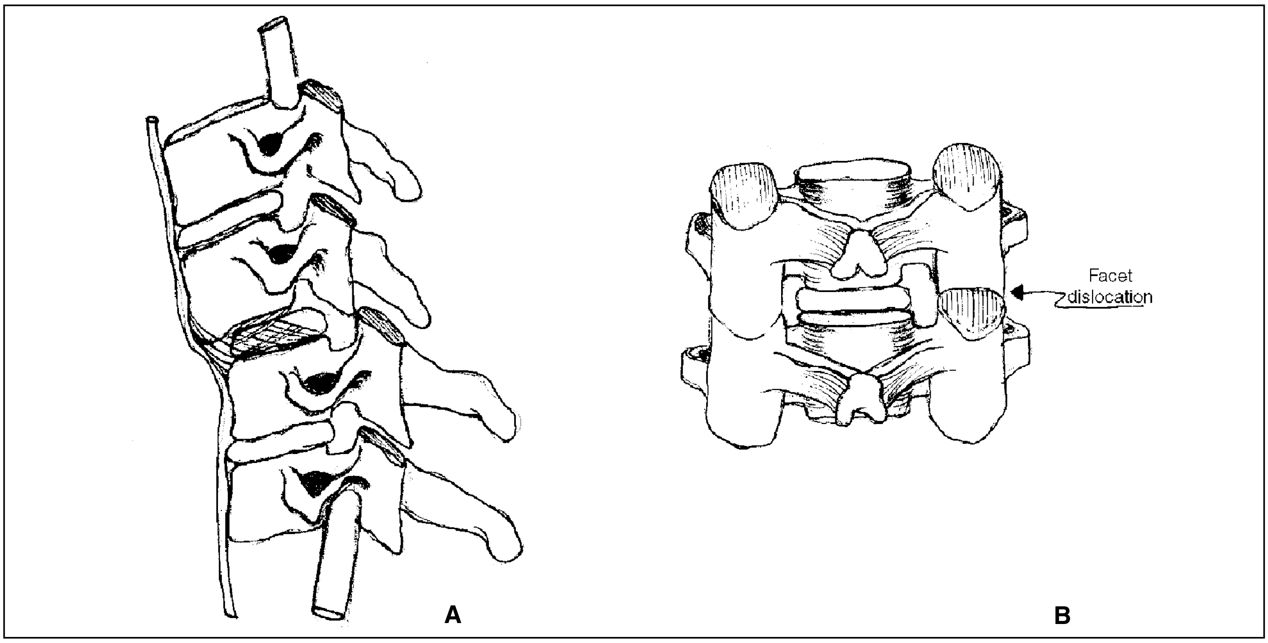

FIGURE 7–6. Unilateral facet joint dislocation. **A:** lateral view. Note: there is less than 50% anterior dislocation of the vertebral body. **B:** posterior view.

Flexion Injuries
Bilateral facet joint dislocations (Figure 7–7)

- Vertebral body > 50% displaced on X-ray
- Both facets dislocate
- Unstable; secondary to tearing of the ligaments
- Most common level is C5–C6 because of increased movement in this area
- More than 50% anterior dislocation of the vertebral body causes significant narrowing of the spinal canal
- Spinal cord is greatly compromised
- 85% suffer neurologic injuries
- Likely to be a complete injury

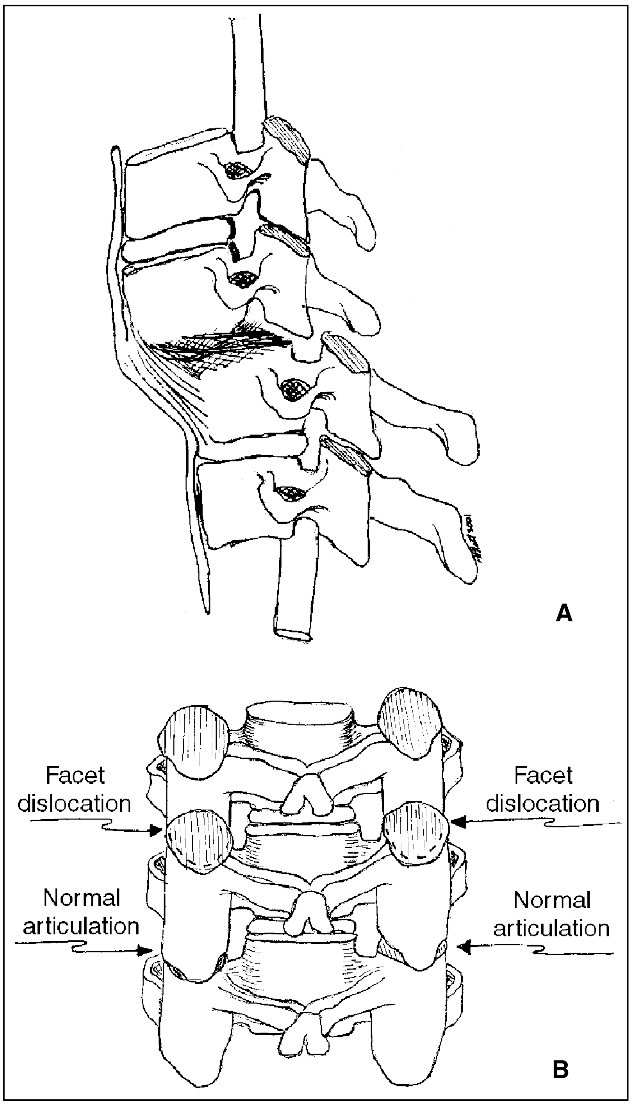

FIGURE 7–7. Bilateral facet joint dislocation. **A:** lateral view. Note: there is greater Than 50% anterior dislocation of the vertebral body. **B:** posterior view.

Hyperextension Injuries (Figure 7–8)

- Can be caused by acceleration-deceleration injuries such as MVA
- Soft tissue injury may not be seen in radiologic studies
- Stable; anterior longitudinal ligament is disrupted
- Spinal cord may be involved
- Can be seen in hyperextension of the C-spine and appear as Central Cord syndrome. This most commonly occurs in older persons with degenerative changes in the neck.
- Clinically: UE motor more involved than LE. Bowel, bladder, and sexual dysfunction occur to various degrees.
- C4–C5 is the most common level

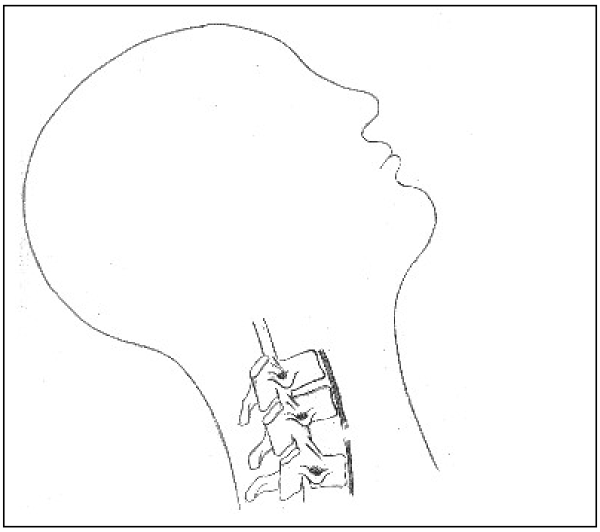

FIGURE 7–8. Cervical spine hyperextension injury.

TABLE 7-1. Spinal Cord and Pathology Associated with Mechanism of Injury

Types of Spinal Injury: Pathology			
Mechanism of Injury	**Stability**	**Possible Resultant Injury**	**Most Common Level**
Compression Axial loading (i.e., diving)	Stable Ligaments remain intact	Crush fracture w/ fragmentation of vertebral body and projection of bony spicules into canal	**C5**
Flexion Rotation Injury Unilateral dislocation	Unstable (if posterior ligament disrupted) Vertebral body <50% displaced on Xray	Spinal cord not severely compromised; likely to be incomplete injury	**C5–C6**
Flexion Bilateral dislocation	Unstable (if post ligament disrupted) Vertebral body <50% displaced on X-ray	Ant. dislocation of C-spine with compression of spinal cord; spinal cord greatly compromised; likely to be complete injury	**C5–C6**
Hyper Extension Injury Central Cord syndrome	Stable; Anterior longitudinal ligament may be disrupted	Hyperextension of C-spine clinically: UE weaker than LE; likely to be incomplete injury	C4 C5

🕮 **Spinal Compression 2°** to metastatic disease

Majority of tumors affecting the SC are metastatic in origin
95% are extradural in origin involving the vertebral bodies
Results in compression of the anterior aspect of the spinal cord
70% of spinal mets occur in the thoracic spine

CERVICAL BRACING (also see Prosthetics & Orthotics Chapter)

Removable Cervical Orthoses:		**Nonremovable Cervical Orthoses:**
Least restrictive:	Soft collar	Halo is the most restrictive cervical orthosis of all cervical orthoses.
↓	Philadelphia collar	
	SOMI brace	
	Four poster	
Most restrictive:	Minerva brace	

🕮 **Cervical Bracing**

The Minerva brace is the most restrictive removable brace, followed by the four poster, then SOMI.
Philly collar is less restrictive, and soft collar is the least restrictive of the listed braces.
Halo is the most restrictive, but not removable.
See P & O section for more in-depth discussion of spinal bracing.

COMPLETE vs. INCOMPLETE LESIONS

🕮 **Complete lesions are most commonly secondary to the following**

1. Bilateral cervical facet dislocations
2. Thoracolumbar flexion-rotation injuries
3. Transcanal gunshot wounds

🕮 **Incomplete injuries are most commonly secondary to the following**

1. Cervical spondylosis—falls
2. Unilateral facet joint dislocations
3. Noncanal penetrating gunshot/stab injuries

OTHER FRACTURES OF THE SPINE

Cervical Region:

Jefferson Fracture: (Figure 7–9)
- Burst fracture of the C1 ring
- Mechanism: axial loading causing fractures of anterior and posterior parts of the atlas
- If the patient survives, there are usually no neurologic findings with treatment

Hangman Fracture: (Figure 7–10)
- C2 burst fracture
- Body is separated from its posterior element, decompresses cord (No SCI)
- If the patient survives, there are only transient neurologic findings with appropriate Tx

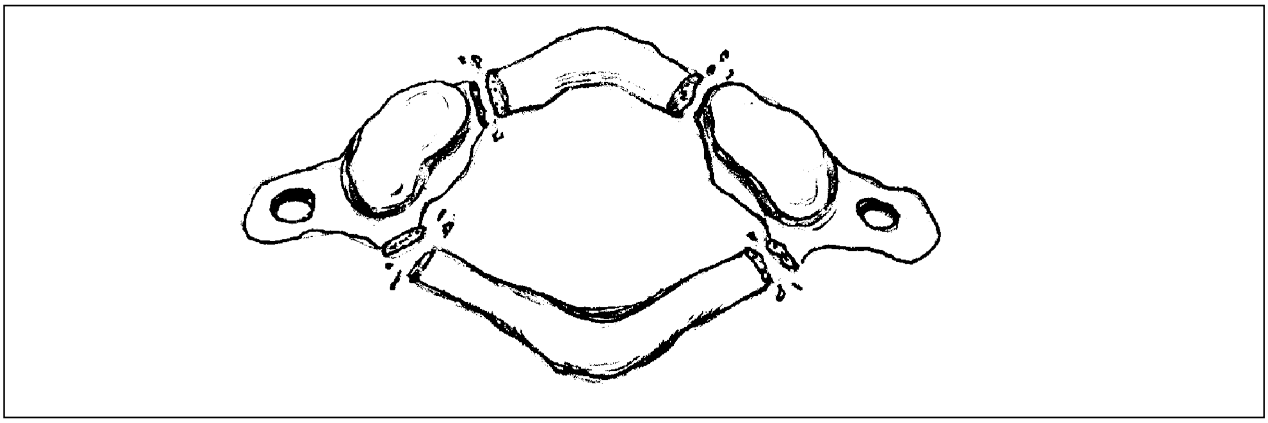

FIGURE 7–9. Jefferson fracture (Superior view).

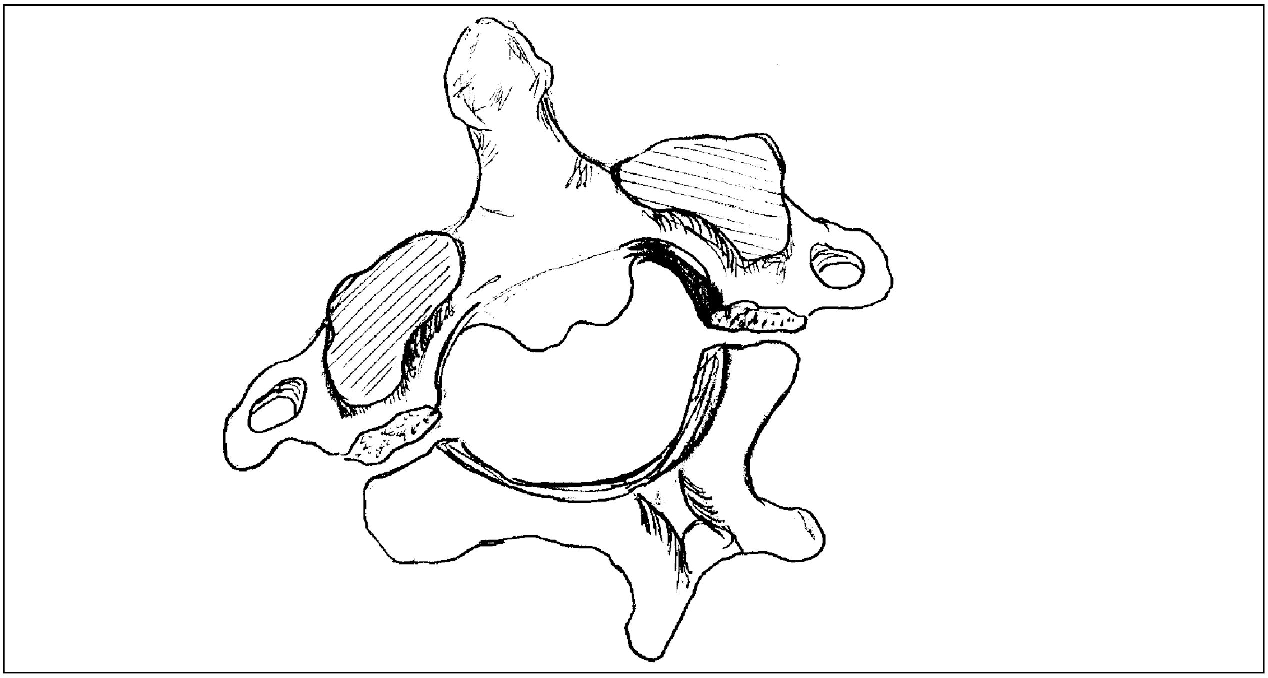

FIGURE 7–10. Hangman fracture. (Superior posterior view).

Odontoid Fracture (Figure 7–11, 7–12)

- C2 odontoid is fractured off at its base
- Commonly results from trauma
- Patient usually survives
- Usually only transient neurologic signs with appropriate Tx

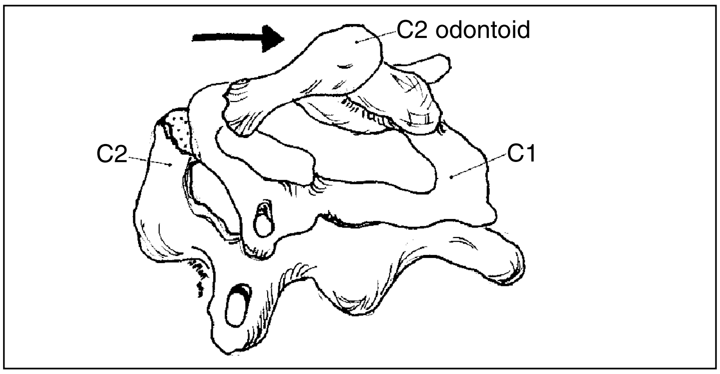

FIGURE 7–11. Odontoid fracture. Illustration by Heather Platt, 2001.

Thoraco Lumbar Region

🕮 Chance Fracture (Figure 7–13)

- Most commonly seen in patients wearing lap seat belts
- Transverse fracture of lumbar spine through body and pedicles, posterior elements
- Chance fractures are seldom associated with neurologic compromise unless a significant amount of translation is noted on the lateral radiographs

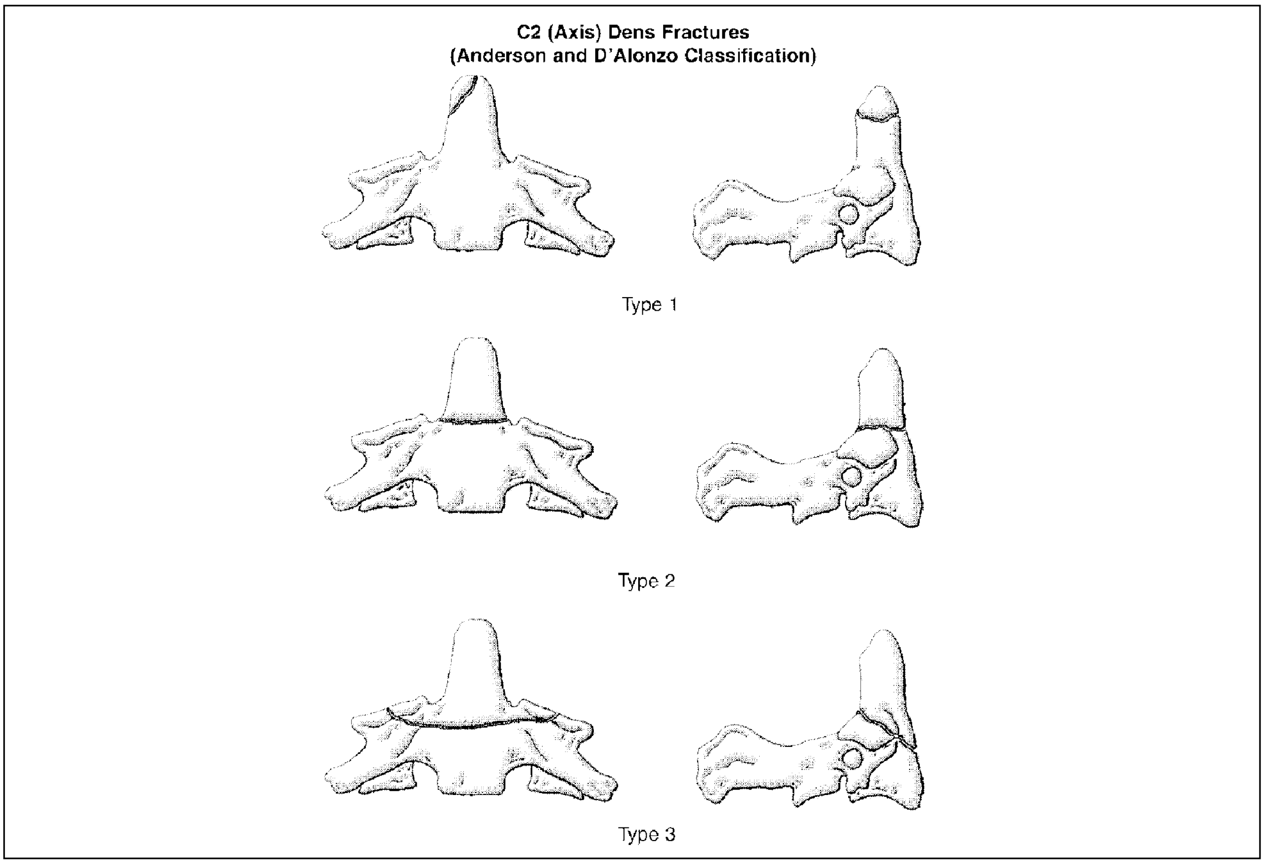

FIGURE 7–12. Type 1: Oblique fracture through upper part of the dens; treatment is with rigid cervical orthosis such as Philadelphia collar. **Type 2:** Fracture at the junction of the odontoid process and the vertebral body; if displacement is less than 5 mm and angulated less than 15 degrees, then halo is appropriate; otherwise operative treatment with C1 to C2 fusion or screw fixation. **Type 3:** Fracture extends down through vertebral body; treatment is with halo. (From Nesathurai S. The Rehabilitation of People With Spinal Cord Injury: A House Officer's Guide. © Boston Medical Center for the New England Regional Spinal Cord Injury Center. Boston, MA: Arbuckle Academic Publishers, with permission).

🕮 **Vertebral Body Compression Fracture (anterior wedge fracture) (Figure 7–14)**

- Mechanism: most common injuries caused by axial compression with or without flexion: vertebrae body height is reduced—may cause thoracic kyphosis (Dowager hump)
- Spontaneous vertebral compression fractures are stable injuries—ligaments remain intact

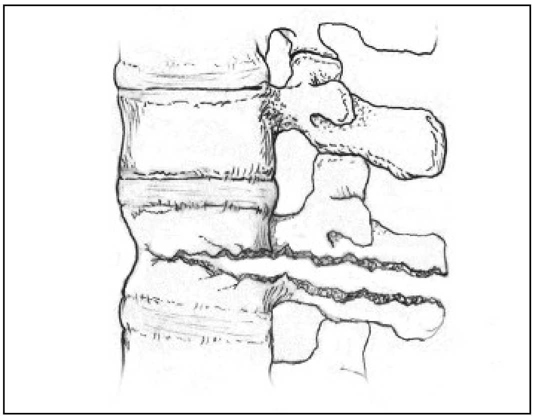

FIGURE 7–13. Chance Fracture.

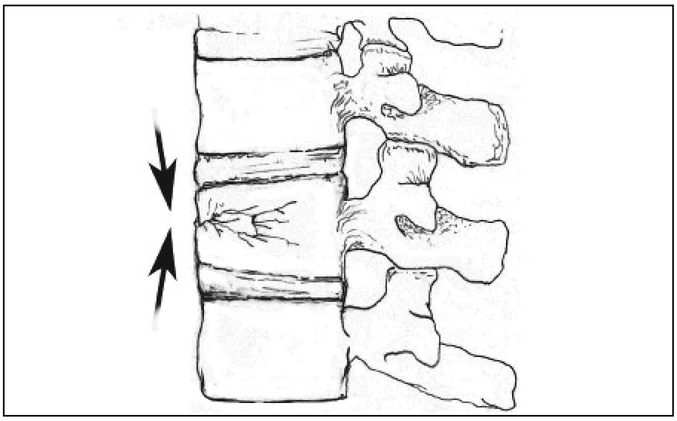

FIGURE 7–14. Vertebral Body Compression Fracture.

SCIWORA – SPINAL CORD INJURY WITHOUT RADIOLOGIC ABNORMALITY

This condition is commonly seen in young children and older adults

Children

- **Mechanism of injury in children include**
  Traction in a breech delivery
  Violent hyperextension or flexion
- **Predisposing factors in children include**
  Large head-to-neck size ratio
  Elasticity of the fibrocartilaginous spine
  Horizontal orientation of the planes of the cervical facet joints

Older Adults

- **Mechanism of injury in the elderly includes**
  A fall forward and a blow on the head causing an acute central cord syndrome; the ligamentum flavum may bulge forward into the central canal and narrow the sagittal diameter as much as 50%

- Note: Delayed onset or paralysis may occur due to vascular mechanism or edema accumulation at the injury site, although this is uncommon
- Essential history in a person with head or neck pain includes identifying any neurological symptoms
- Flexion/Extension films should be done cautiously only after static neck films have been cleared by a radiologist and only if there are no neurologic symptoms or severe pain present
- Empiric use of a 24-hour cervical collar with repeat films at resolution of cervical spasm is warranted

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.