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1- Spinal Cord Anatomy

- Nervous System Overview

- Nervous system
 - central nervous system
 - includes the
 - brain
 - spinal cord
 - spinal cord ends at L3 at birth, and L1 at maturity
 - peripheral nervous system
 - contains the
 - cranial nerves
 - peripheral nerves
 - autonomic nervous system
 - sympathetic system
 - a total of 22 ganglia (3 cervical, 11 thoracic, 4 lumbar, 4 sacral)
 - cervical ganglia
 - the three cervical include the stellate, middle , and superior
 - the middle ganglion is most at risk at the level of C6 where it lies close to the medial border of the longus colli muscles
 - injury to the middle ganglion/sympathetic chain will lead to Horner's syndrome
 - parasympathetic nervous system
 - hypogastric plexus
 - formed by S2, S3, S4 parasympathetic fibers and lumbar sympathetic fibers (splanchnic nerves)

- Spinal Cord Overview

- Spinal cord extends from brainstem to inferior border of L1
 - conus medullaris
 - is termination of spinal cord
 - filum terminale

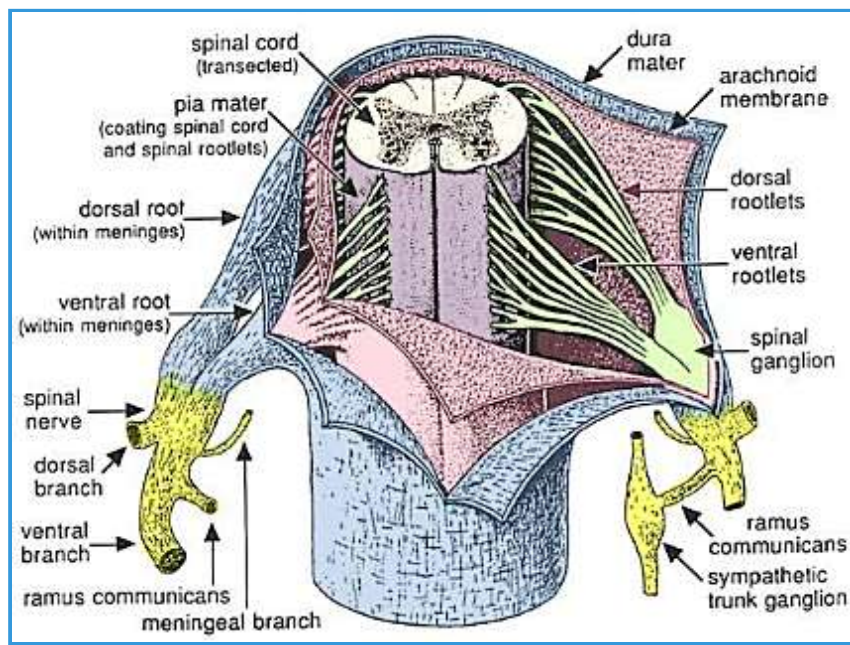
- is residual fragment of spinal cord that extends from conus medullaris to sacrum.
- thecal sac
 - the dural surrounded sac that extends from the spinal cord and contains CSF, nerve roots and the cauda equina
- cauda equina
 - nerve roots and filum terminale surrounded by dura that extend from the spinal cord

• Embryology of the spinal cord

- Neural Tube
 - becomes spinal cord
 - formed from the primitive Streak, which turns into the primitive (midsagittal) groove > which turns into the Neural Tube
 - failure of the neural tube to close leads to
 - anencephaly when it fails to close cranially
 - spinal bifida occulta, meningocele, myelomeningocele when it fails to close distally
- Neural crest
 - forms dorsal to neural tube
 - becomes the
 - peripheral nervous system
 - pia mater
 - spinal ganglia
 - sympathetic trunk
- Notocord
 - forms ventral to neural tube
 - becomes
 - vertebral bodies
 - intervertebral discs
 - nucleus pulposus from cells of notocord
 - annulus from sclerotomal cells associated with resegmentation

• Layers of the spinal cord

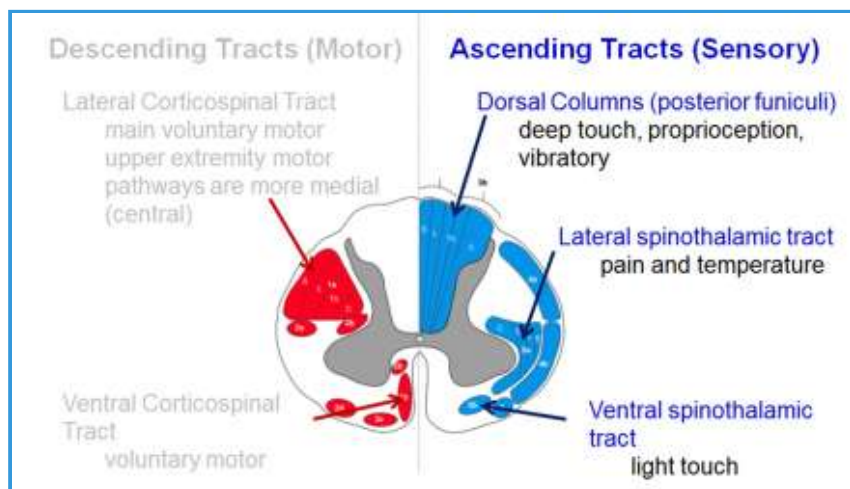
- Layers of the spinal cord include the



- dura mater (outside)
- arachnoid
- pia mater (inside)

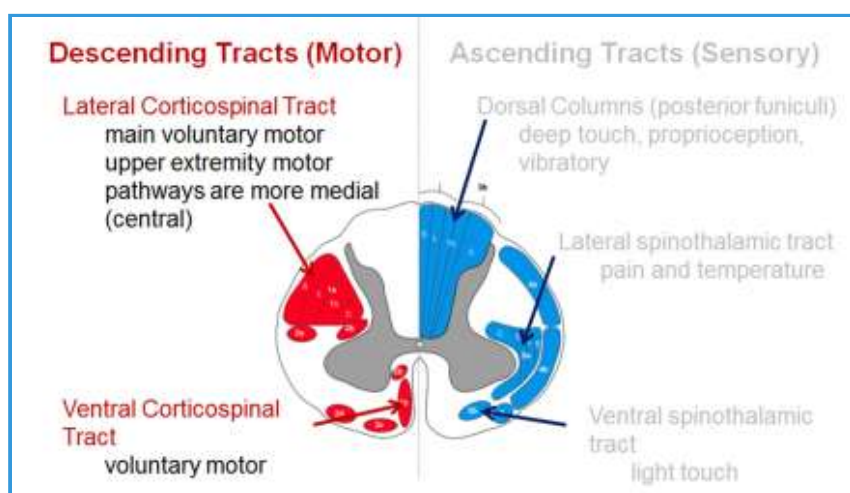
• Spinal Cord Functional Tracts

○ Ascending Tracts (Sensory)



- dorsal columns (posterior funiculi)
 - deep touch, proprioception, vibratory
- lateral spinothalamic tract
 - pain and temperature
 - site of chordotomy to alleviate intractable pain
- ventral spinothalamic tract
 - light touch

○ Descending Tracts (Motor)

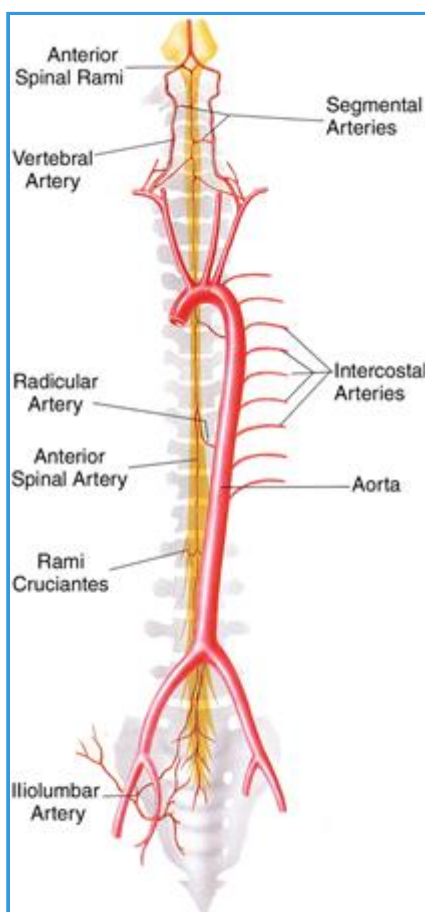


- lateral corticospinal tract
 - main voluntary motor

- upper extremity motor pathways are more medial(central) which explains why a central cord injury affects the upper extremities more than the lower extremities
- ventral corticospinal tract
 - voluntary motor

• Blood Supply

- Spinal cord blood supply provided by
 - anterior spinal artery
 - primary blood supply of anterior 2/3 of spinal cord, including both the lateral corticospinal tract and ventral corticospinal tract
 - posterior spinal artery (right and left)
 - primary blood supply to the dorsal sensory columns
 - Artery of Adamkiewicz



- the largest anterior segmental artery
- typically arises from left posterior intercostal artery, which branches from the aorta, and supplies the lower two thirds of the spinal cord via the anterior spinal artery
- significant variation exists
 - in 75% it originates on the left side between the T8 and L1 vertebral segments

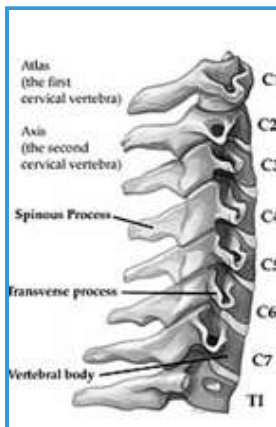
• Cerebral Spinal Fluid

- Function
 - a colorless fluid that occupies the subarachnoid space surrounding the brain, spinal cord, and ventricular system

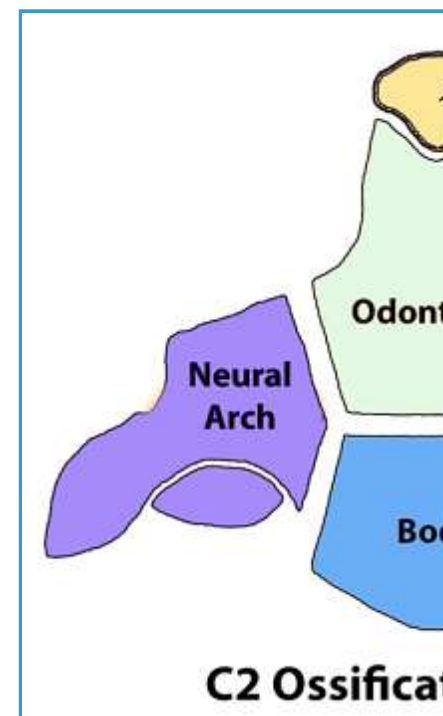
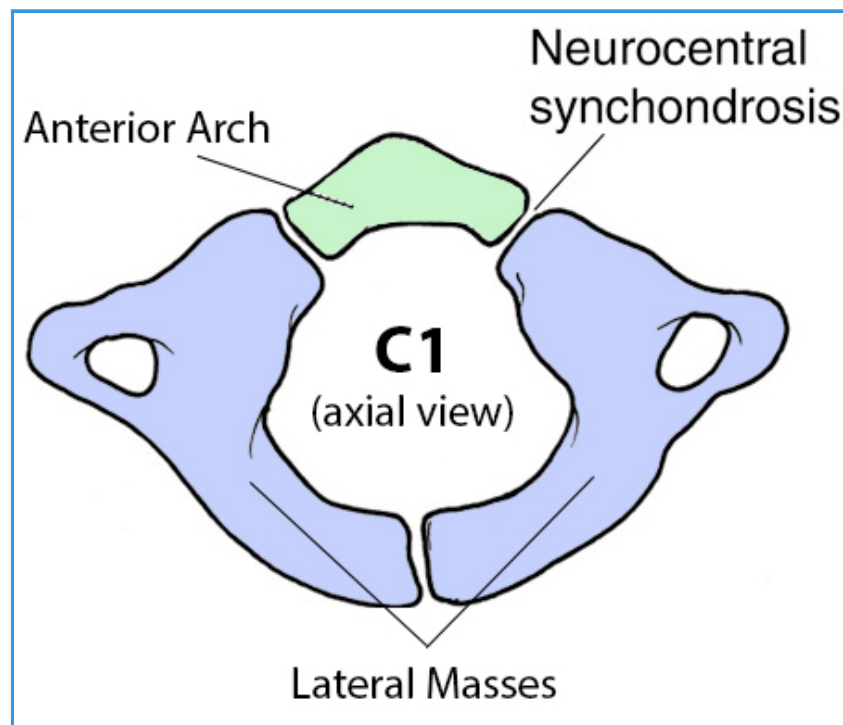
- the subarachnoid space is between the arachnoid mater and pia mater
 - provides mechanical and immunological protection for the brain, spinal cord, and thecal sac
- Production
 - location
 - most human cerebrospinal fluid (CSF) is produced by the choroid plexus in the third, fourth, and lateral ventricles of the brain.
 - CSF is an ultrafiltrate of blood plasma through the permeable capillaries of the choroid plexus
 - volume
 - total CSF volume between brain, spinal cord, and thecal sac is ~150 mL
 - CSF formation occurs at rate of ~500mL per day
 - thus the total amount of CSF is turned over 3-4 times per day
- Nerve Root Anatomy
 - Cervical spine
 - nerve roots exit above corresponding pedicle
 - C5 nerve root exits above the C5 pedicle
 - nerve root travel horizontally to exit
 - there is an extra C8 nerve root
 - that does not have a corresponding vertebral body
 - Thoracic spine
 - nerve root travel below corresponding pedicle
 - T1 exits below T1 pedicle
 - T12 exits below T12 pedicle
 - Lumbar spine
 - nerve roots descend vertically before exiting
 - nerve root travel below corresponding pedicle
 - L1 exits below L1 pedicle
 - L5 exits below L5 pedicle

2- Cervical Spine Anatomy

Images



		Bifid Spinous Process	Transverse Foramen / Vert?	Flexion/ Extension	Rotation	Lateral Bend
C1	Occiput-C1			50	4	8
C2	C1 (Atlas)	None	Yes / Yes			
C3	C2 (Axis)	Yes	Yes / Yes	10	50	0
C4	C3	Yes	Yes / Yes			
C5	C4	Yes	Yes / Yes			
C6	C5	Yes	Yes / Yes	60 (10/level)	60 (10/level)	60 (12/level)
C7	C6	Yes	Yes / Yes			
T1	C7 (VP)	No (95%)	Yes / No			
	Total Motion			110	100	68



- Embryology

- Genetics

- homeobox, or Hox genes direct and regulate processes of embryonic differentiation and segmentation along craniocaudal axis
 - see each segment for embryologic development

- Osteology

- The cervical spine contains 7 vertebral bodies

- C1 (atlas)
 - C2 (axis)
 - C1 to C7
 - have a transverse foramen
 - vertebral artery travels through transverse foramen of C1 to C6
 - C2 to C6
 - have bifid spinous process
 - C7
 - despite having a transverse foramen, the vertebral artery does NOT travel through it in the majority of individuals
 - there is no C8 vertebral body although there is a C8 nerve root

- Alignment

- Normal sagittal lordosis (measured from C2 to C7)

- Spinal Canal

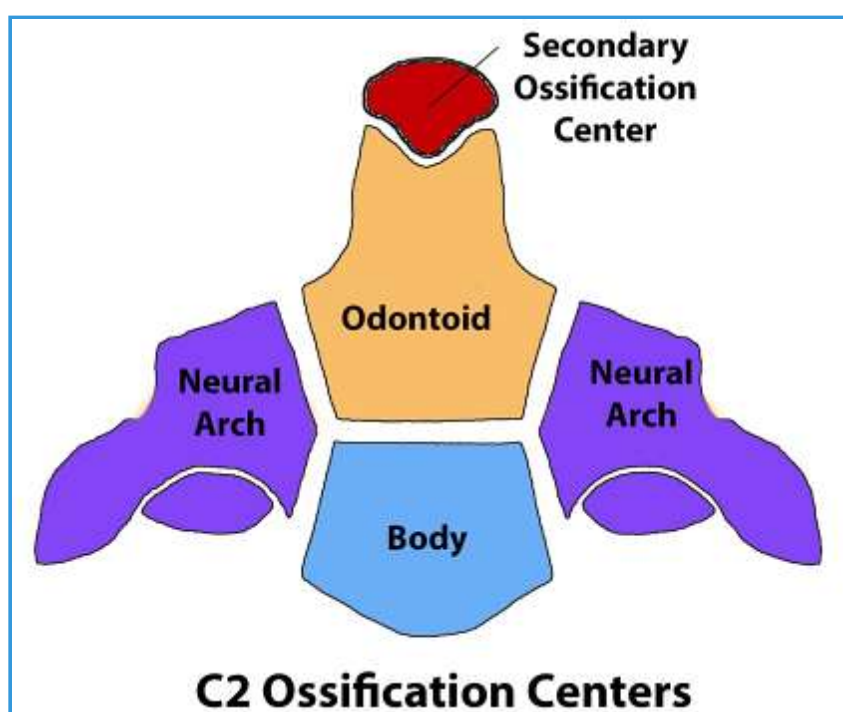
- Spinal canal
 - normal diameter is 17mm
 - <13mm indicates possible cord compression

- Atlas (C1)

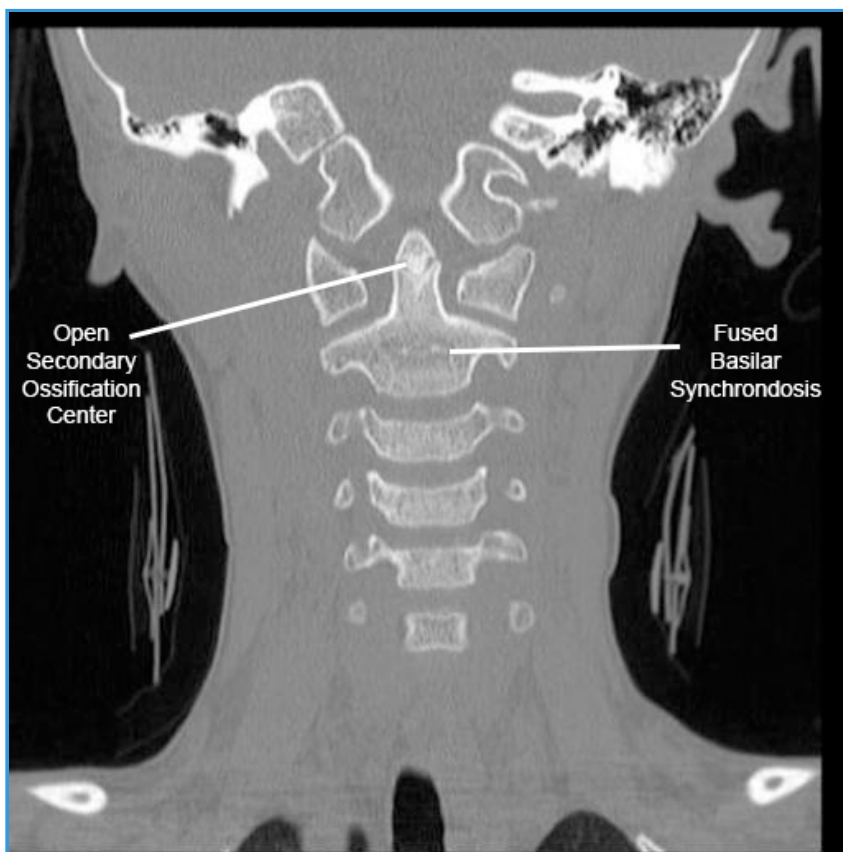
- Has no vertebral body and no spinous process
- Embryology
 - three ossification centers
 - one for each lateral mass (posterior neural arches)
 - lateral masses fuse to body at age 7
 - one for anterior arch
 - anterior arch does not appear until 1 year of age
- Articulations
 - occiput-C1
 - two superior concave facets that articulate with the occipital condyles
 - makes up 50% of neck flexion and extension
 - C1-C2 (see below)

- Axis (C2)

- Axis Osteology
 - axis has odontoid process (dens) and body
 - embryology
 - develops from five ossification centers



- subdental (basilar) synchondrosis is an initial cartilagenous junction between the dens and vertebral body that does not fuse until ~6 years of age



- the secondary ossification center appears at ~ age 3 and fuses to the dens at ~ age 12

○ Axis Kinematics

- C1-C2 (atlantoaxial) articulation
- is a diarthrodial joint that provides

	Bifid Spinous Process	Transverse Foramen present/ Vert. Artery within it	Flexion/ Extension	Rotation	Lateral Bend
Occipitocervical					
Occiput-C1			50	4	8
Atlantoaxial					
C1 (Atlas)	None	Yes/ Yes	10	50	0
C2 (Axis)	Yes	Yes/ Yes			
Subaxial					
C3	Yes	Yes/ Yes			
C4	Yes	Yes/ Yes			
C5	Yes	Yes/ Yes	50 (10/level)	50 (10/level)	60 (12/level)
C6	Yes	Yes/ Yes			
C7 (VP)	No (95%)	Yes/ No			
Total Motion			110	100	68

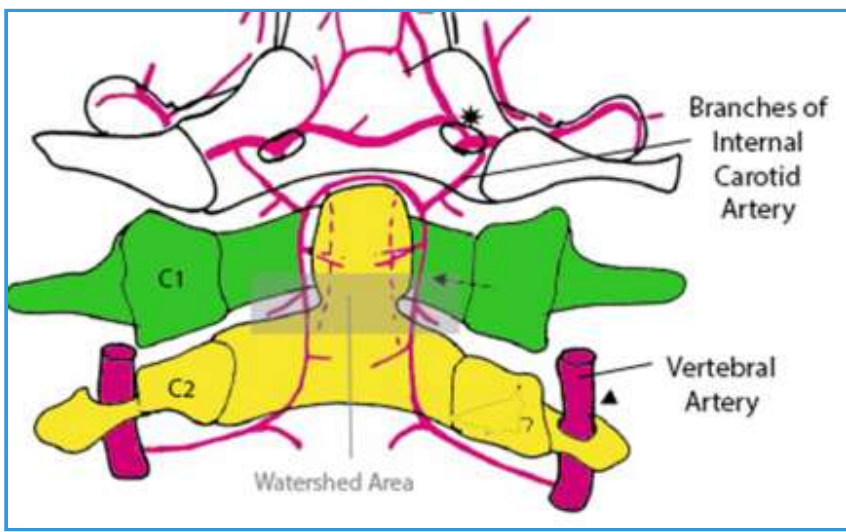
- 50 (of 100) degrees of cervical rotation
- 10 (of 110) degrees of flexion/extension
- 0 (of 68) degrees of lateral bend

■ C2-3 joint

- participates is subaxial (C2-C7) cervical motion which provides
 - 50 degrees of flexion/extension of cervical spine
 - 50 degrees of rotation of cervical spine
 - 60 degrees of lateral bend

○ C2 Blood Supply

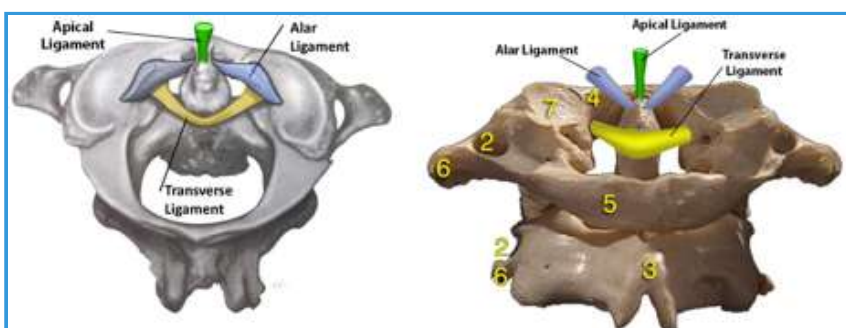
- a vascular watershed exists between the apex and the base of the odontoid



- apex is supplied by branches of internal carotid artery
- base is supplied from branches of vertebral artery
- the limited blood supply in this watershed area is thought to affect healing of type II odontoid fractures.

• Occipital-C1-C2 Ligamentous Complex

- Provided by the odontoid process and its supporting ligaments
 - transverse ligament

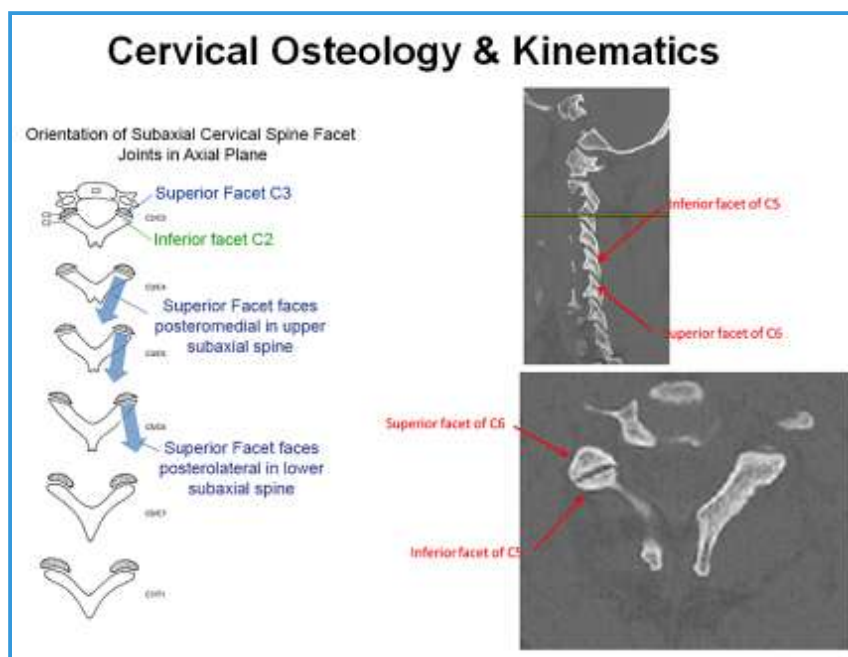


- limits anterior translation of the atlas
- apical ligaments
 - limit rotation of the upper cervical spine
- alar ligaments

- limit rotation of the upper cervical spine

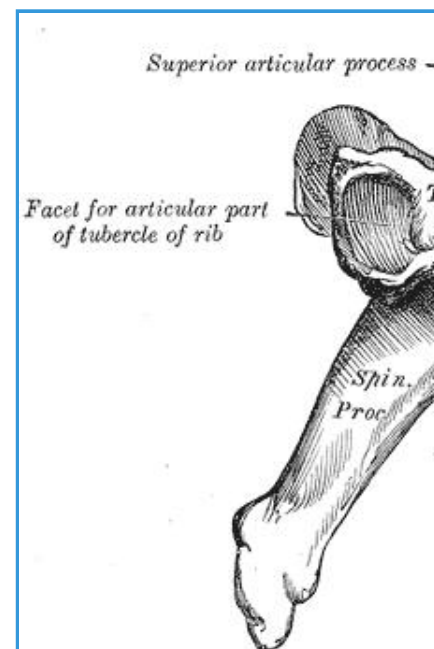
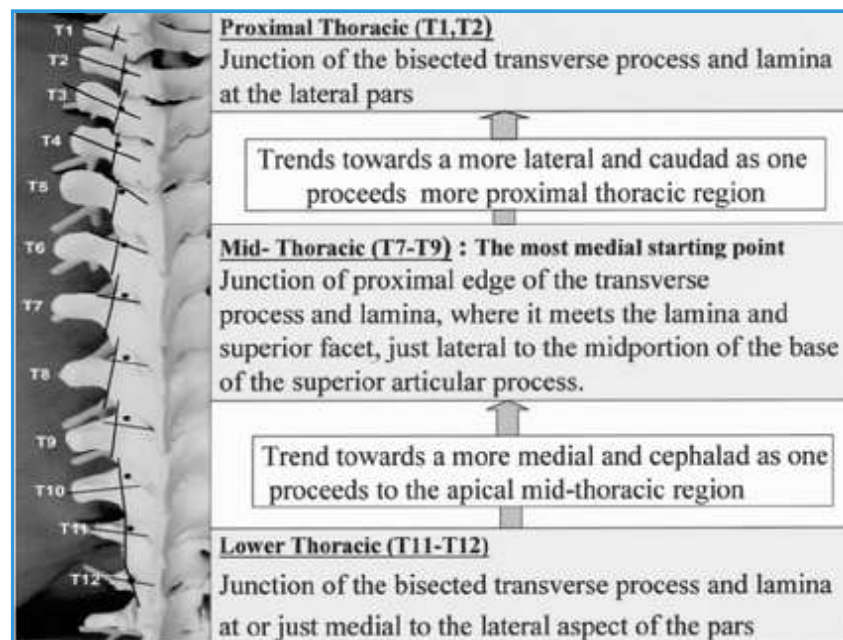
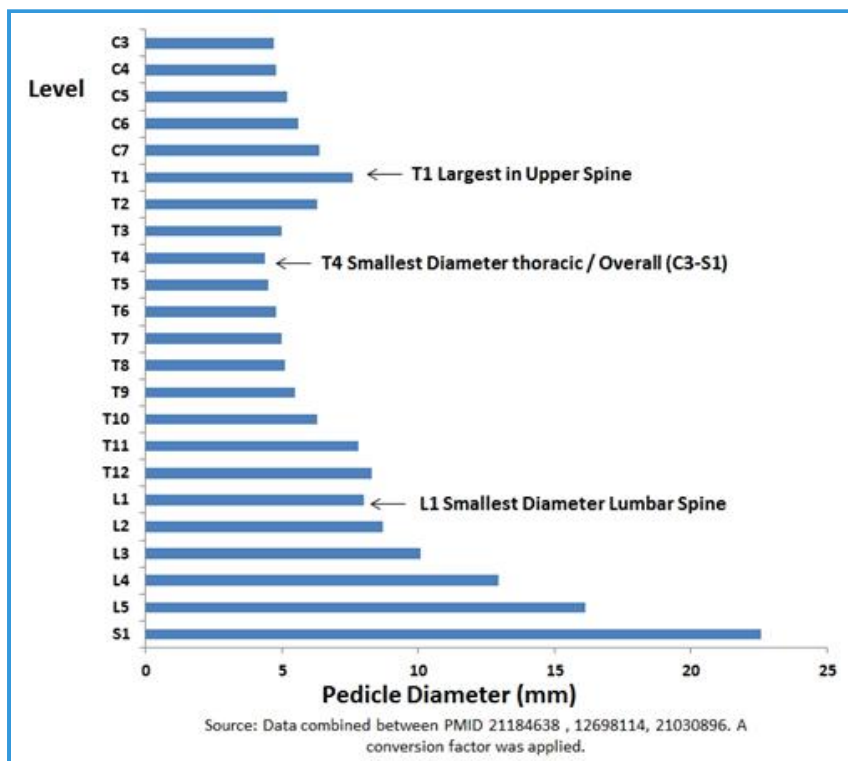
- Subaxial Cervical Spine (C3 to C7)

- C1 to C7
 - have a transverse foramen
 - vertebral artery travels through transverse foramen of C1 to C6
- C2 to C6
 - have bifid spinous process
- C6
 - contains palpable carotid tubercle which is a valuable landmark for anterior approach to cervical spine
- C7
 - nonbifid spinous process
 - despite having a transverse foramen, the vertebral artery does NOT travel through it in the majority of patients
 - there is no C8 vertebral body although there is a C8 nerve root
- The superior articular facets of the subaxial cervical spine (C3-C7) are oriented in a posteromedial direction at C3 and posterolateral direction at C7, with a variable transition between these levels



3- Thoracic Spine Anatomy

Images

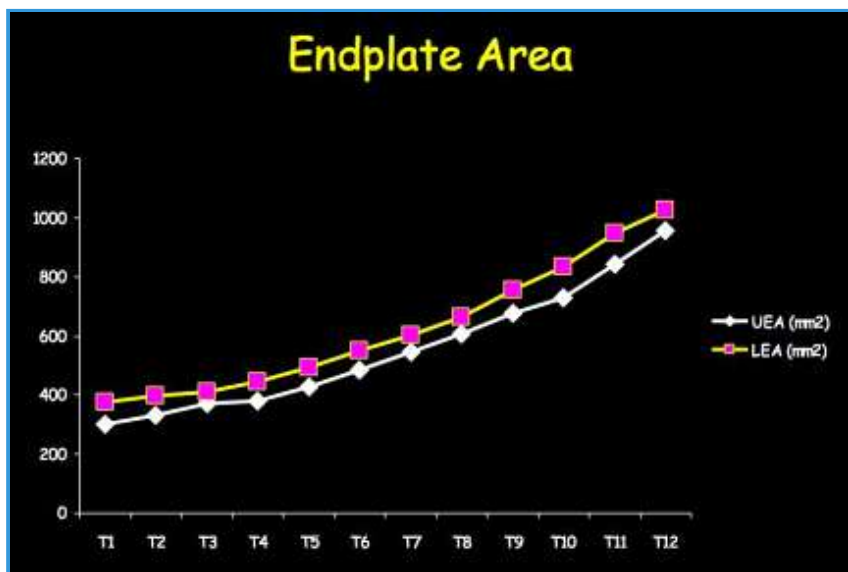


- Alignment

- Sagittal plane alignment
 - normal thoracic kyphosis
 - averages 35° degrees
 - normal range is 20° to 50°

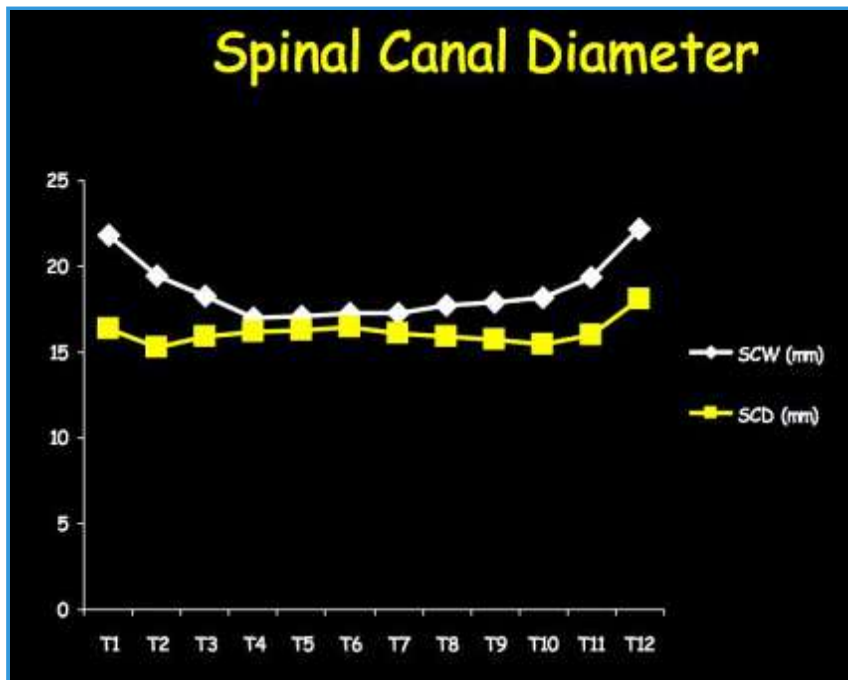
- Osteology

- Vertebral prominens
 - the long prominent spinous process found at C7
- Costal facets
 - articulation between ribs and vertebral segments
 - present on all vertebral bodies and transverse processes from T1 to T9
 - articulation with ribs leads to increased rigidity of thoracic spine (most rigid in axial skeleton)
- Vertebral body size



- increases progressively from T1 to T12

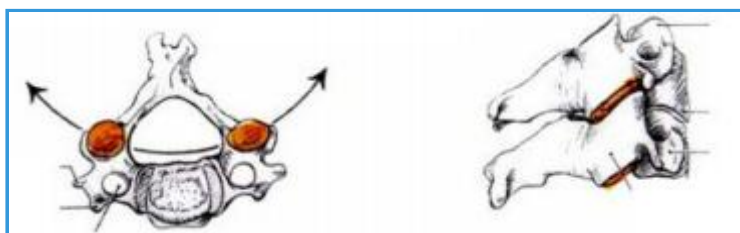
- Spinal canal dimensions



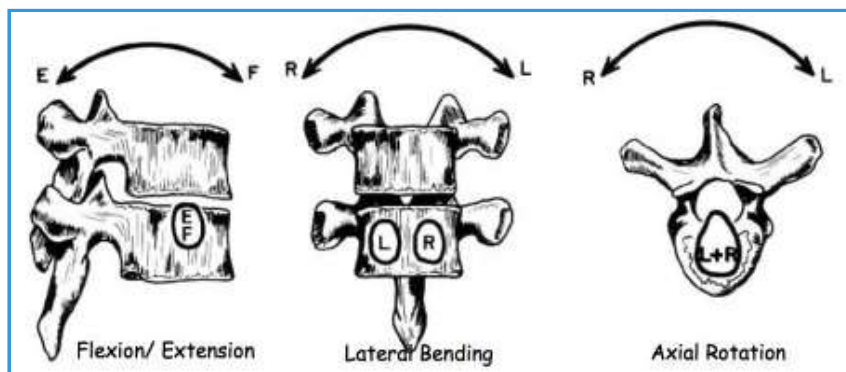
- varies from T1 to T12

- Motion

- The orientation of the facets (zygapophyseal) joints determines the degree and plane of motion at that level
 - varies throughout the spine to meet physiologic function
 - cervical spine (C3-7)
 - planes
 - 0° coronal
 - 45° sagittal (angled superio-medially)



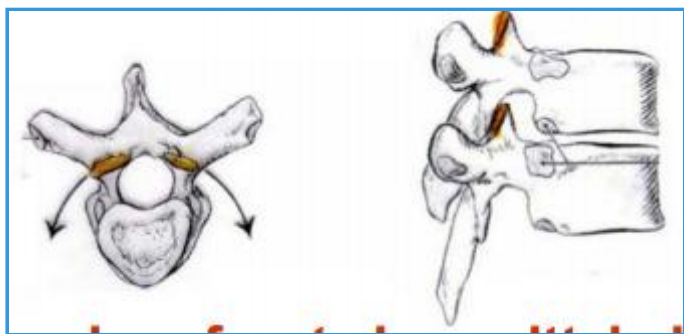
- function
 - allows flexion-extension, lateral flexion, rotation
- thoracic spine
 - planes
 - 20° coronal
 - 55° sagittal (facets in coronal plane)
 - 6 degrees of freedom



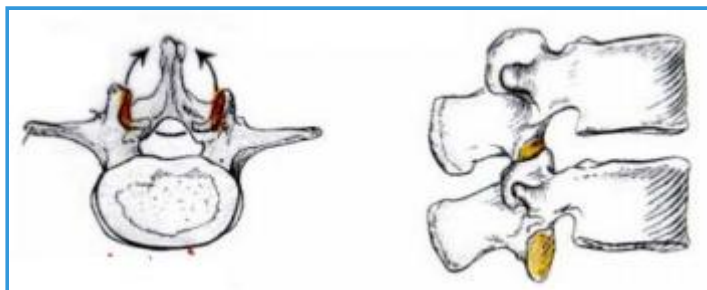
- function
 - allows some rotation, minimal flexion-extension (also limited by ribs)

	upper	middle	lower
- Flexion-Extension	4°	6°	12°
- Lateral bending	12°	12°	14°
- Axial rotation	16°	14°	4°

- prevents downward flexion on heart and lungs



- lumbar spine
 - plane
 - 50° coronal
 - 90° sagittal (facets in sagittal plane)



- function
 - allows flexion-extension, minimal rotation
 - helps increase abdominal pressure

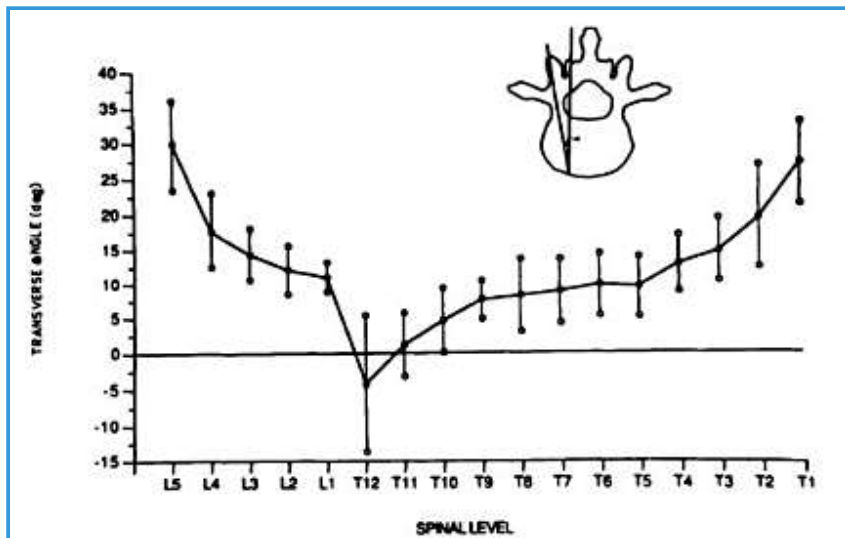
• Thoracic Pedicle Anatomy

- Pedicle diameter
 - the pedicle wall is twice as thick medially as laterally
 - T4 has the narrowest pedicle diameter (on average)
 - T7 can be irregular and have a narrow diameter on the concave side in AIS
 - T12 usually has larger pedicle diameter than L1
- Pedicle length

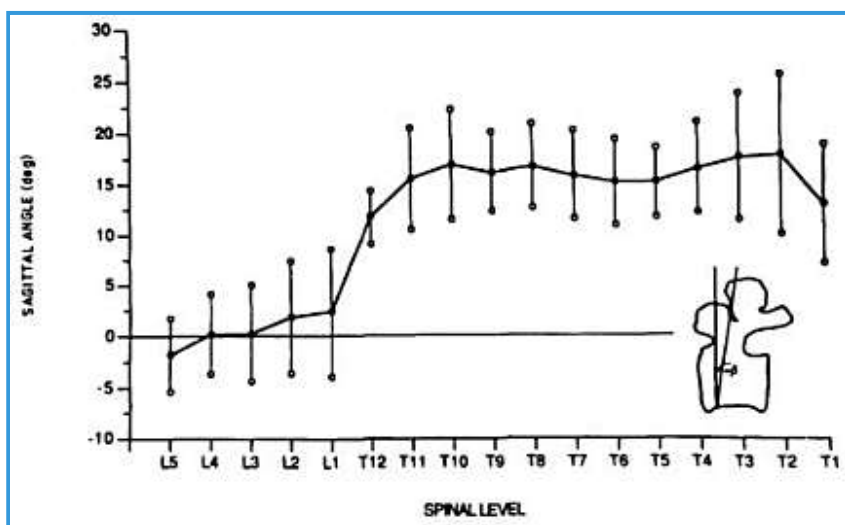
- pedicle length decreases from T1 to T4 and then increases again as you move distal in the thoracic spine
 - T1: 20mm
 - T4: 14mm (shortest pedicle)
 - T10: 20 mm

- Pedicle angle

- transverse pedicle angle



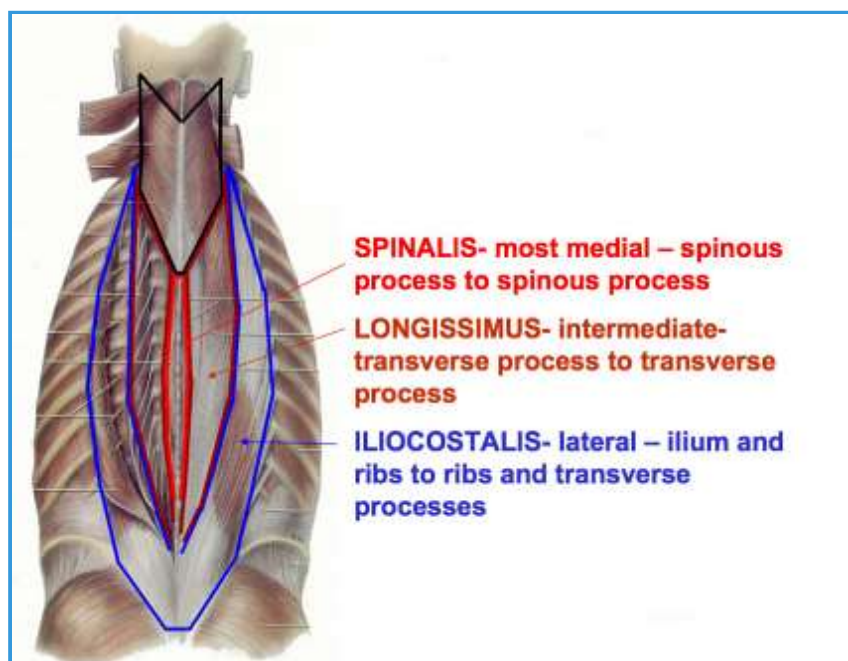
- varies from 10deg (mid thoracic spine) to 30deg (L5)
- sagittal pedicle angle



- 15-17deg cephalad for majority of thoracic spine
- neutral (0deg) for lumbar spine except L5 (caudal)

- Erector Spinae Muscles

- Characteristics

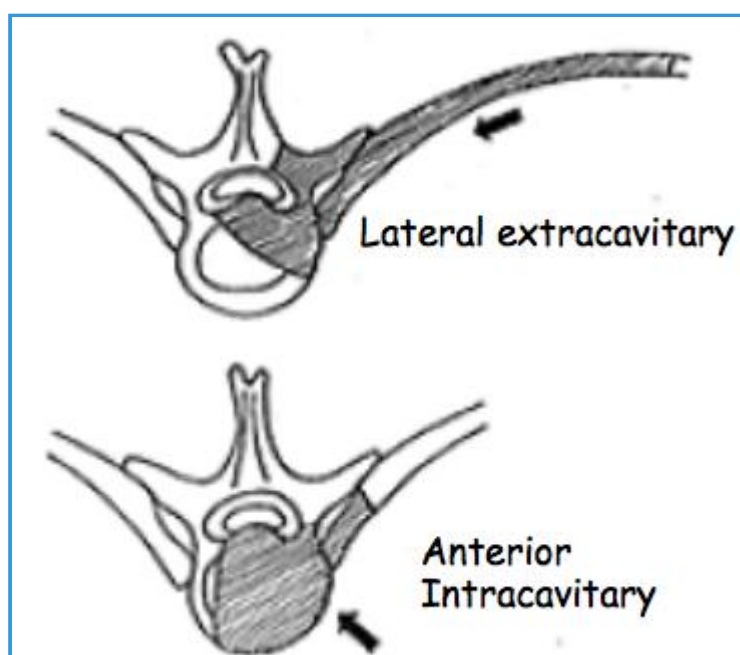
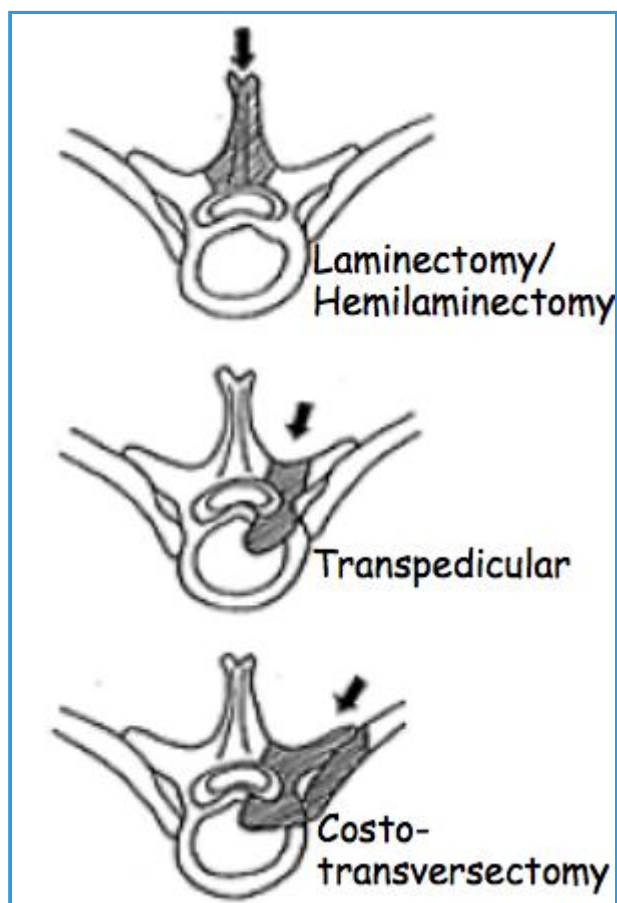


- functions to extend the trunk
- located dorsal to vertebral column

- innervated by dorsal rami of spinal nerves
- Erector spinae muscles include
 - spinalis
 - most medial
 - origin and insertion: spinous process to spinous process
 - longissimus
 - intermediate
 - origin and insertion: transverse process to transverse process
 - iliocostalis
 - most lateral
 - origin: ilium and ribs
 - insertion: ribs and transverse process

• Surgical Approaches

- Surgical approaches for thoracic disc herniation

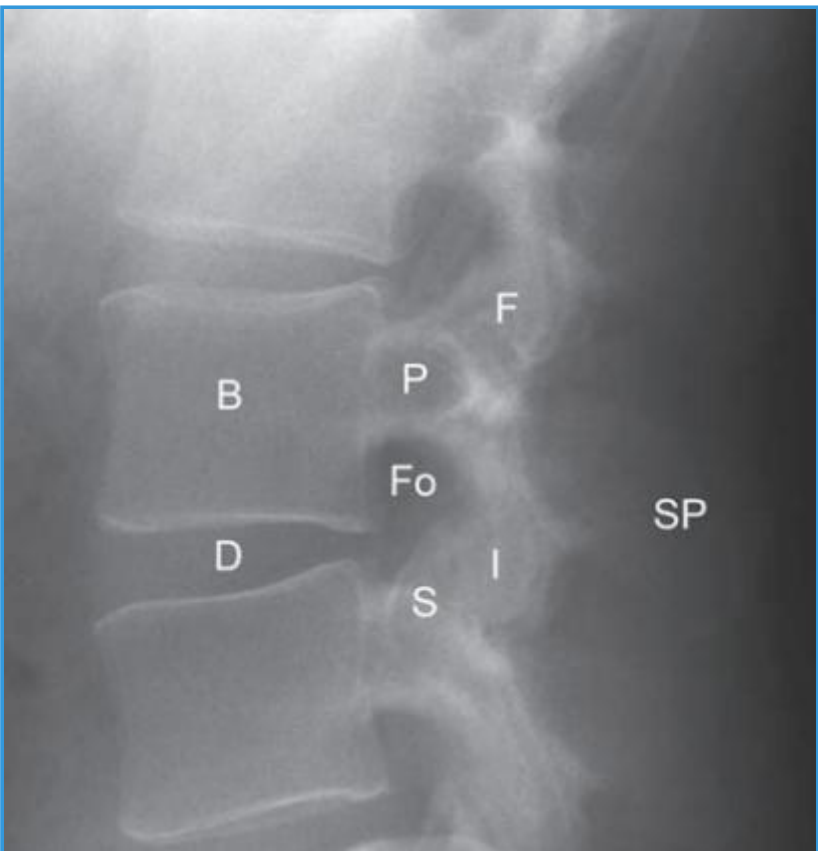
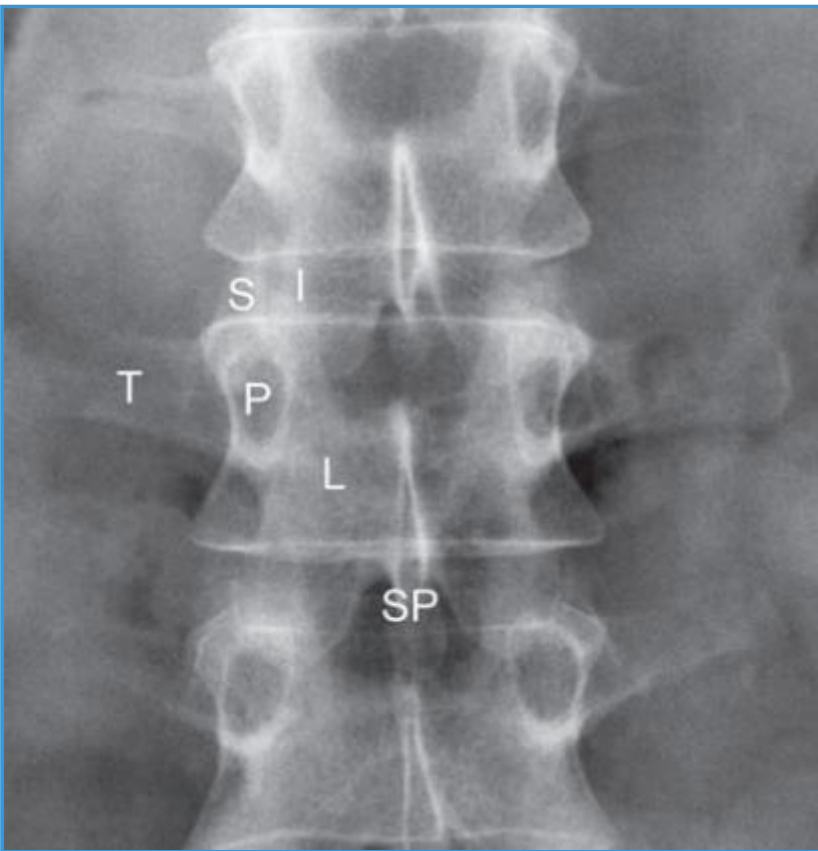


- laminectomy/hemilaminectomy
- transpedicular
- costotransversectomy

- lateral extracavitary
- anterior intracavitary
 - thoracotomy
 - VATS (video assisted thoracoscopic surgery)

4- Lumbar Spine Anatomy

- Alignment
 - Sagittal plane
 - lumbar lordosis
 - average of 60 degrees
 - normal range is 20 to 80 degrees
 - apex of lordosis at L3
 - disc spaces responsible for most of lordosis
- Lumbar Osteology
 - Lumbar spine has the largest vertebrae bodies in the axial spine
 - Components of vertebral bodies

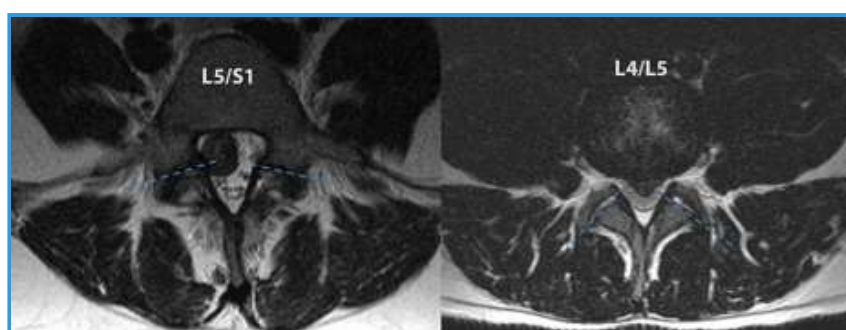
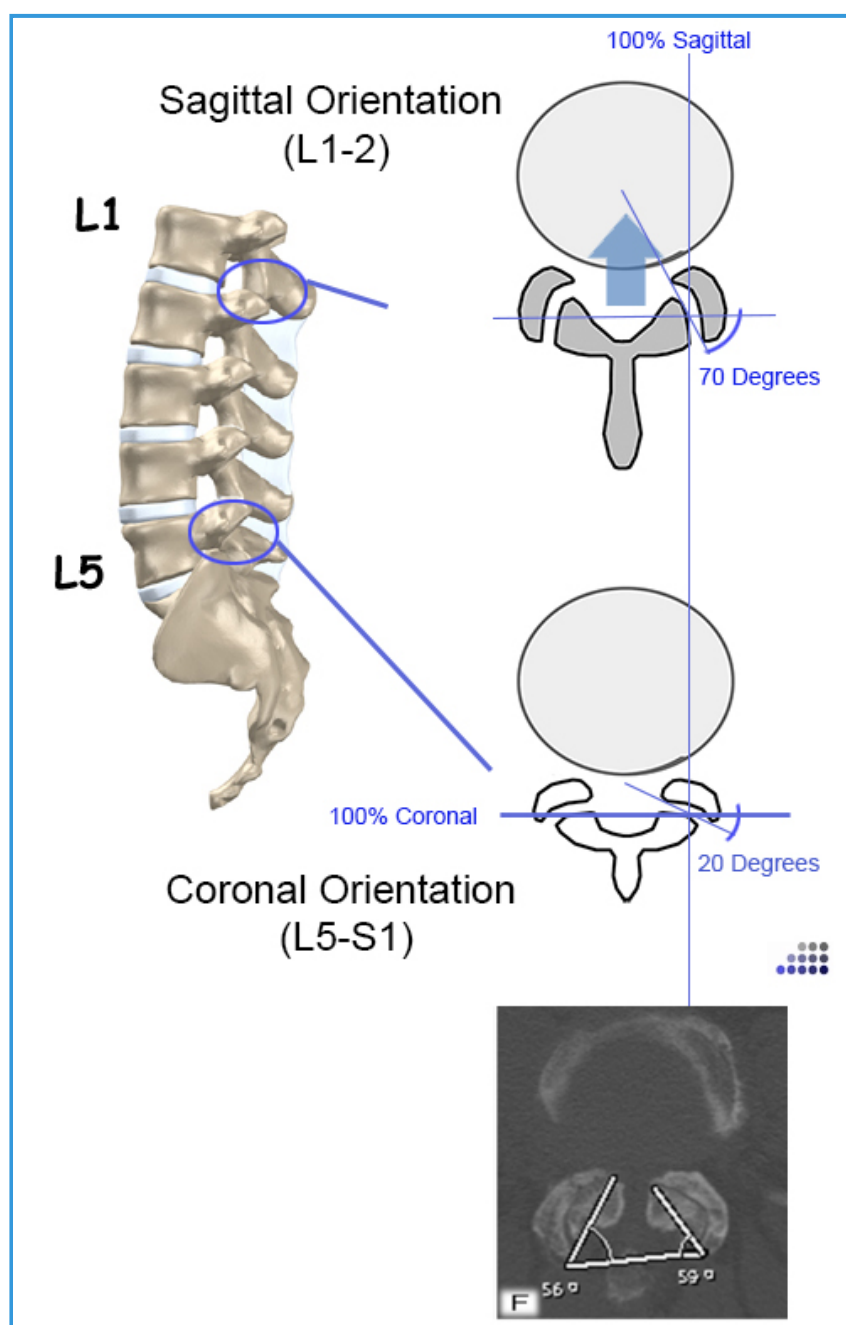


- anterior vertebral body
- posterior arch
 - formed by
 - pedicles
 - pedicles project posteriorly from posterolateral corners of vertebral bodies
 - lamina
 - lamina project posteromedially from pedicles, join in the midline
- spinous process
- transverse process
- mammillary processes
 - separate ossification centers
 - project posteriorly from superior articular facet
- pars interarticularis
 - mass of bone between superior and inferior articular facets
 - site of spondylolysis



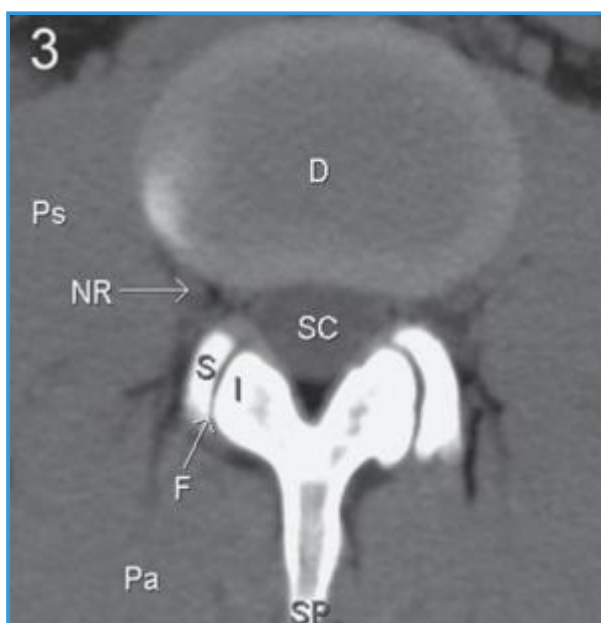
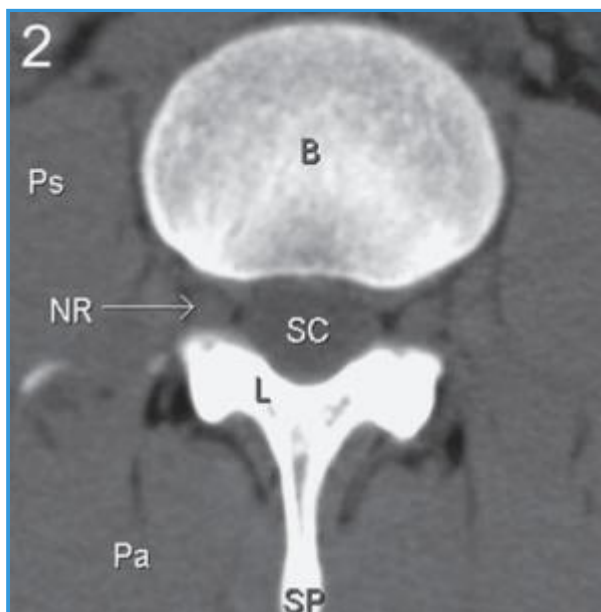
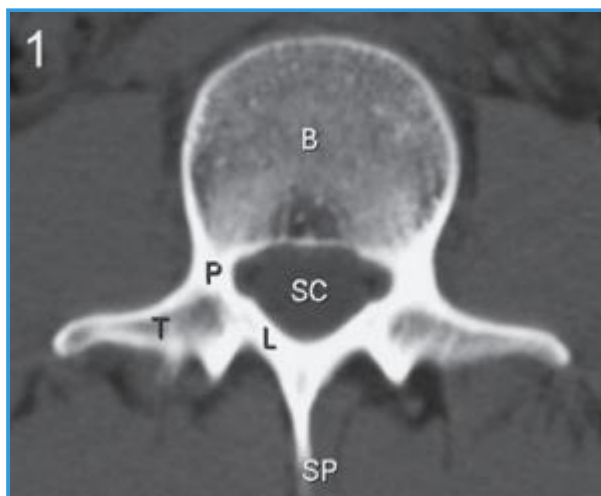
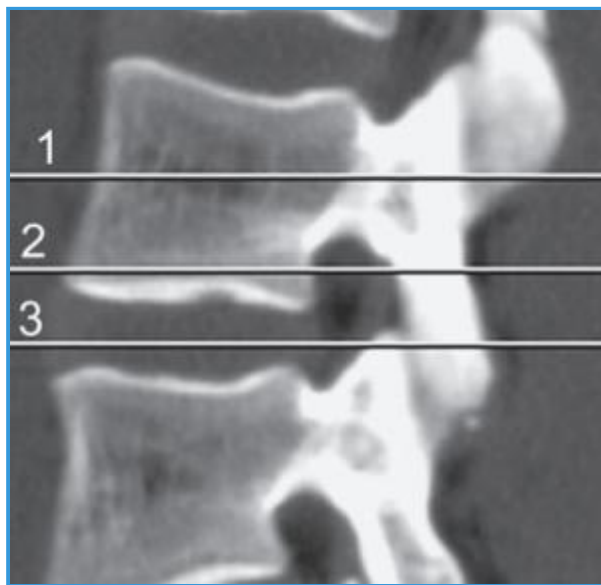
○ Articulations

- intervertebral disc
 - act as an articulation above and below
- facet joint (zygapophyseal joint)
 - formed by superior and inferior articular processes that project from junction of pedicle and lamina
 - facet orientation
 - facets become more coronal as you move inferior



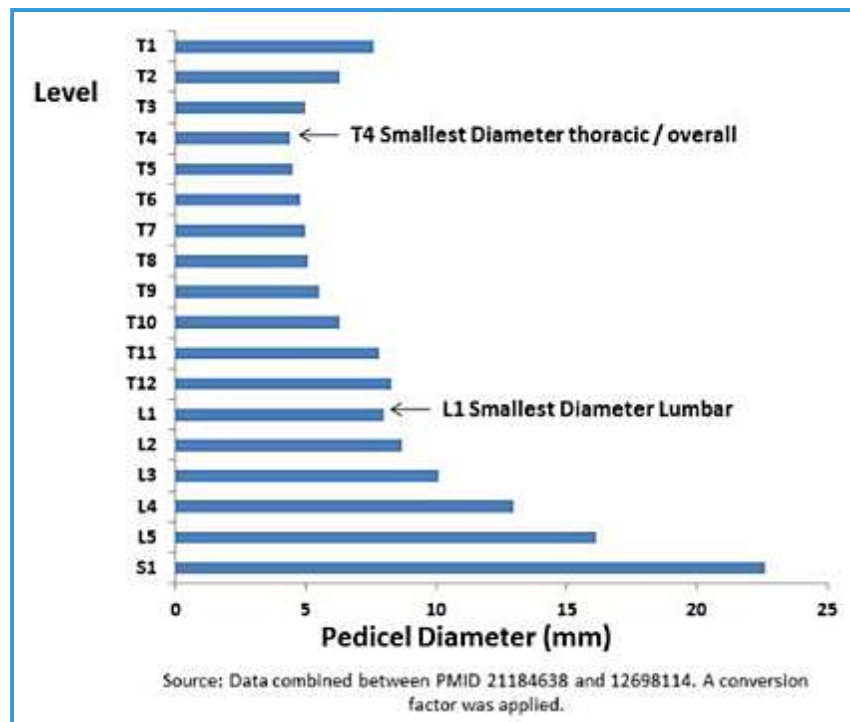
- Lumbar Pedicle Anatomy

- Landmarks



- midpoint of the transverse process used to identify midpoint of pedicle in superior-inferior dimension
 - lateral border of pars used to identify midpoint in medial-lateral dimension
 - Pedicle angulation

- pedicles angulate more medial as you move distal
 - L1: 12 degrees
 - L5: 30 degrees
 - S1: 39 degrees
- Pedicle diameter



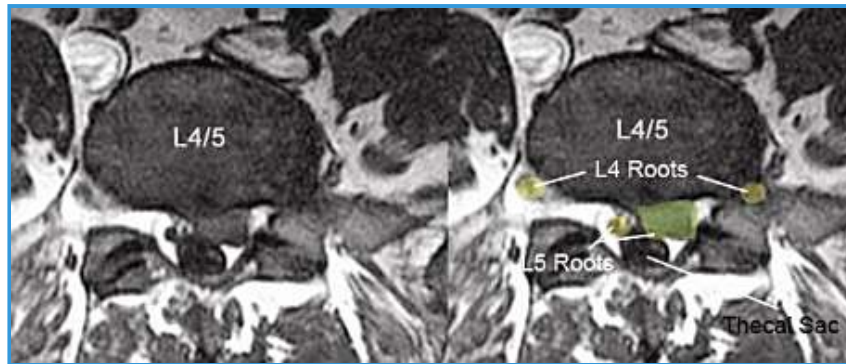
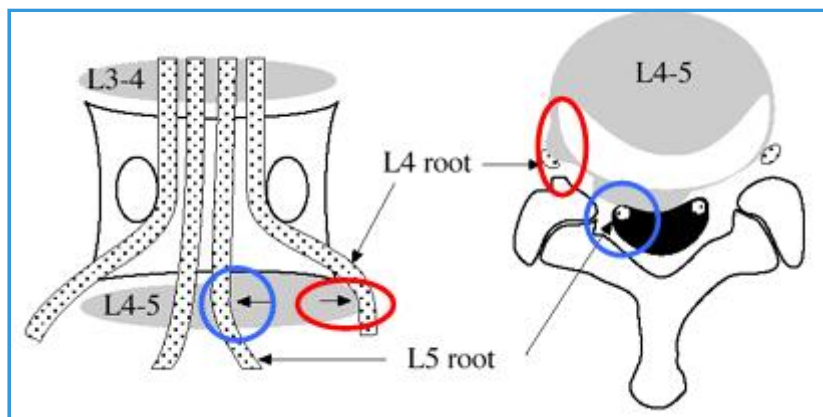
- L1 has smallest diameter in lumbar spine (T4 has smallest diameter overall)
- S1 has average diameter of ~19mm

• Lumbar Blood Supply

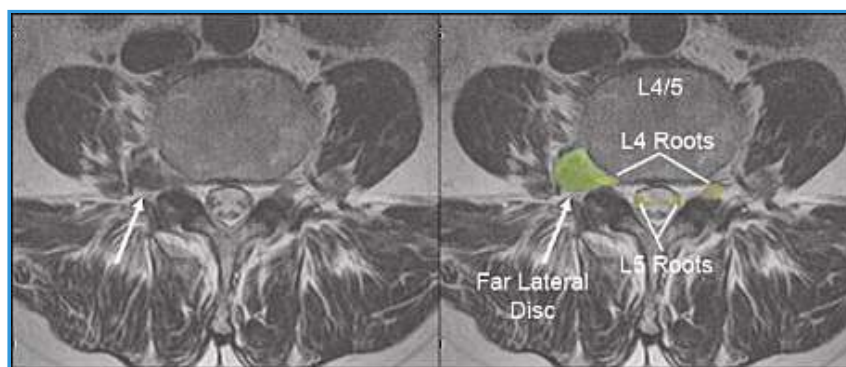
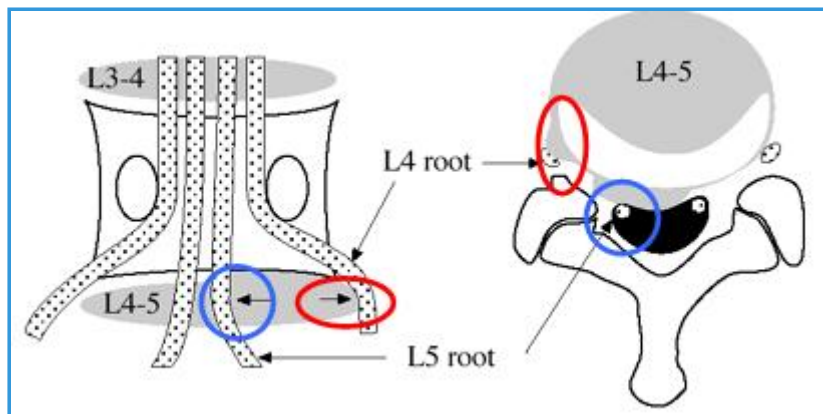
- Lumbar vertebral bodies supplied by
 - segmental arteries
 - dorsal branches supply blood to the dura & posterior elements

• Lumbar Neurologic Structures

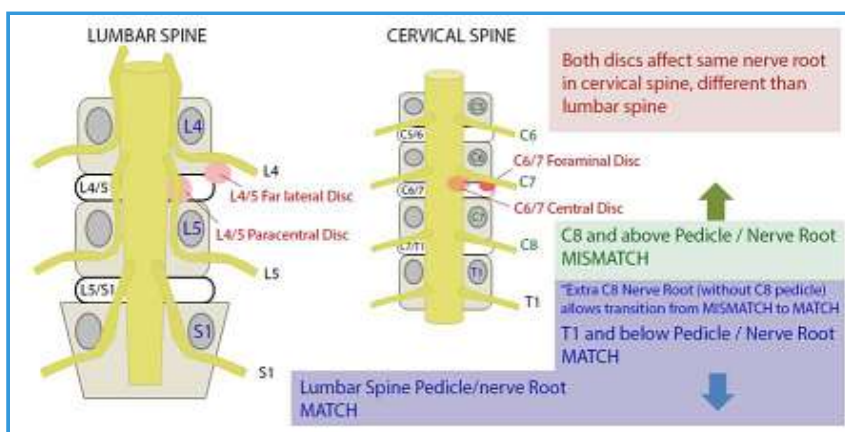
- Nerve roots
 - anatomy
 - nerve root exits foramen under same numbered pedicle
 - central herniations affect traversing nerve root



- far lateral herniations affect exiting nerve root

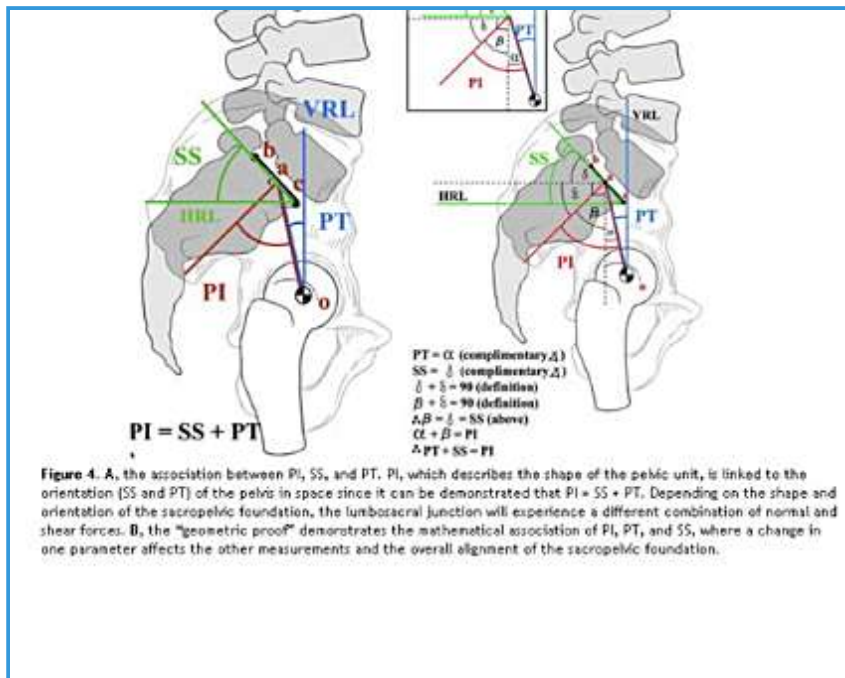


- dorsal rami
 - supplies muscles, skin
- ventral rami
 - supplies anteromedial trunk
- key difference between cervical and lumbar spine is

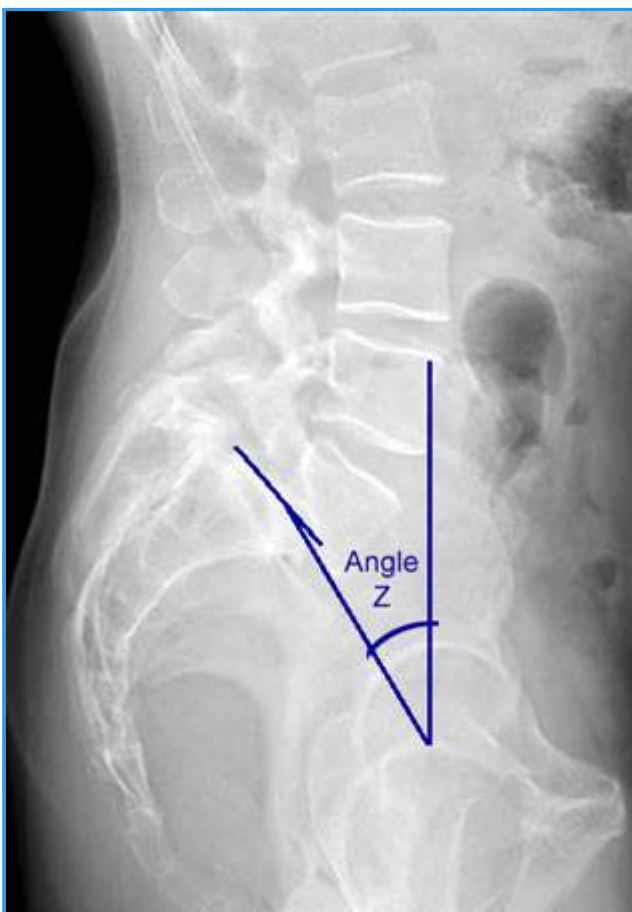


- pedicle/nerve root mismatch
 - cervical spine C6 nerve root travels under C5 pedicle (mismatch)
 - lumbar spine L5 nerve root travels under L5 pedicle (match)
 - extra C8 nerve root (no C8 pedicle) allows transition
- horizontal (cervical) vs. vertical (lumbar) anatomy of nerve root

- a second line is drawn perpendicular to a line drawn along the S1 endplate, intersecting the point in the center of the S1 endplate
- the angle between these two lines is the pelvic incidence (see angle X in figure above)
- correlates with severity of disease
- pelvic incidence has direct correlation with the Meyerding-Newman grade

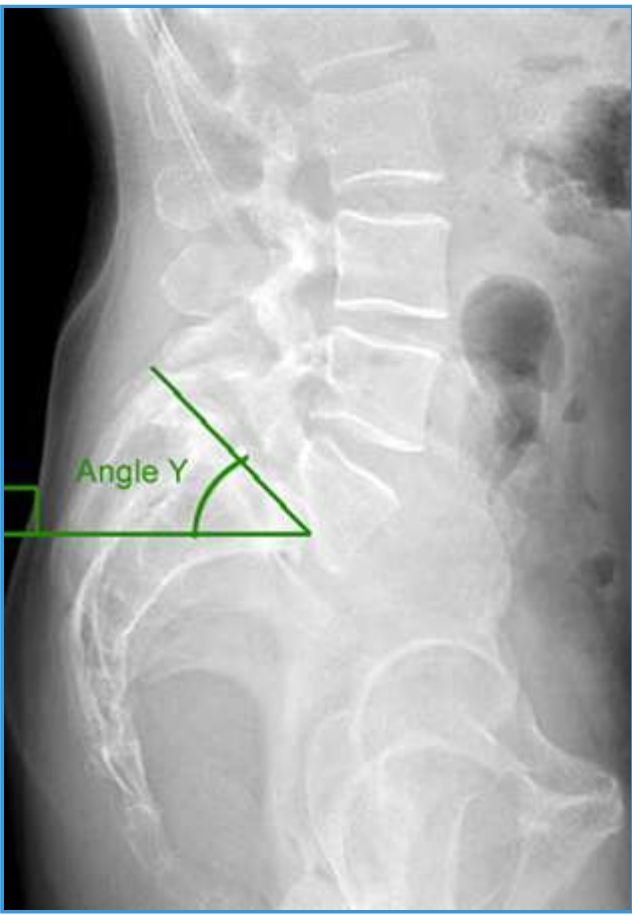


○ Pelvic tilt



- pelvic tilt = pelvic incidence - sacral slope
- a line is drawn from the center of the S1 endplate to the center of the femoral head
- a second vertical line (parallel with side margin of radiograph) line is drawn intersecting the center of the femoral head
- the angle between these two lines is the pelvic tilt (see angle Z in figure above)

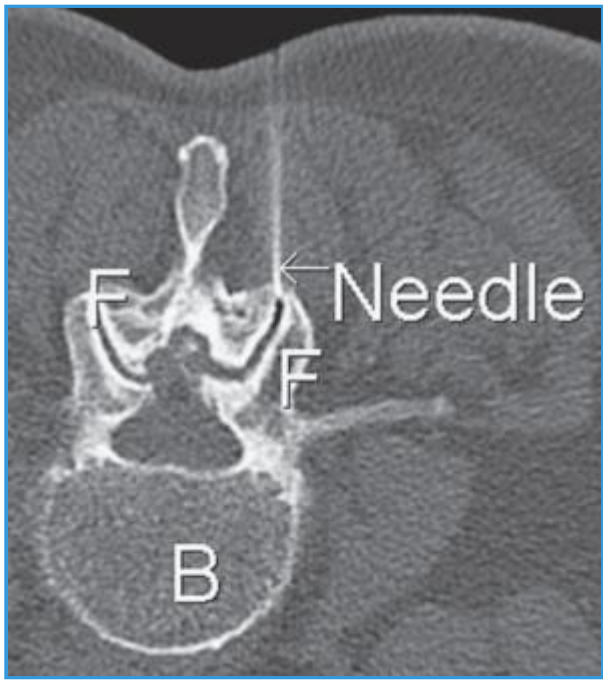
○ Sacral slope



- sacral slope = pelvic incidence - pelvic tilt
- a line is drawn parallel to the S1 endplate
- a second horizontal line (parallel to the inferior margin of the radiograph) is drawn
- the angle between these two lines is the sacral slope (see angle Y in the figure above)

• Image-Guided Interventions

- Overview
 - performed using CT or fluoroscopic guidance
 - 22G-25G needle usually used for injection of local anesthetic and corticosteroid
- Selective Nerve Root Injections
 - indications
 - unilateral radicular symptoms
 - used for therapeutic and diagnostic purposes
 - technique
 - transforaminal (outside-in) technique usually used
- Facet joint injection
 - indications



- to confirm facet joint as pain generator (diagnostic)
- also a therapeutic procedure

○ Epidural injection

- indications



- lumbar spinal stenosis

○ Discography



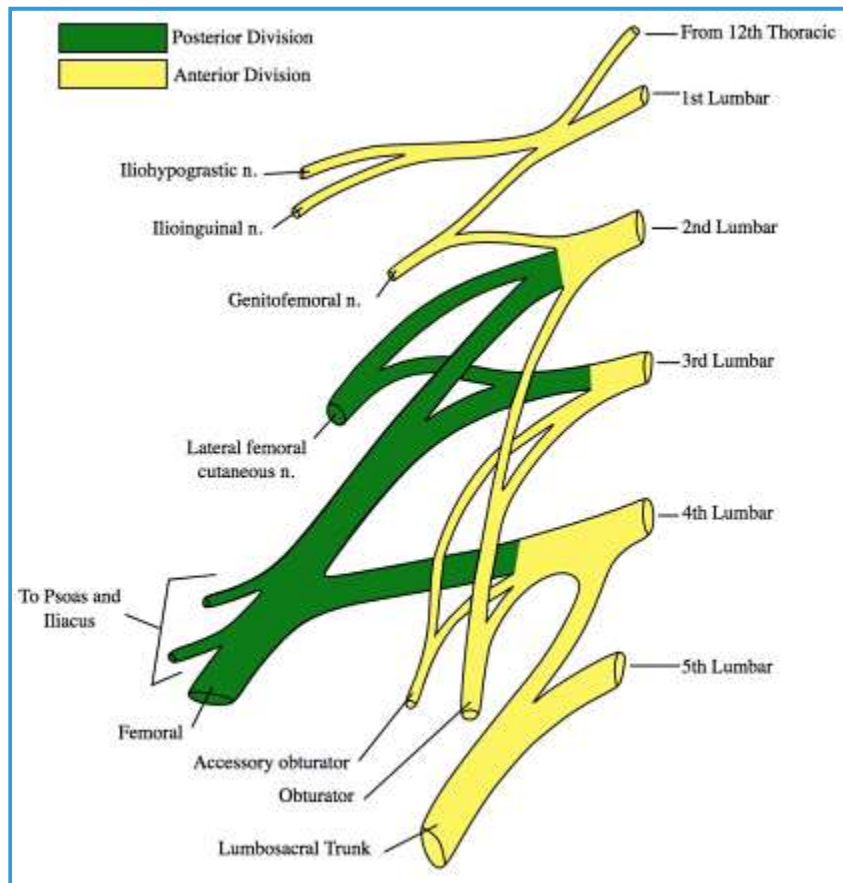
- indications
 - very controversial

- to prove that pain arises from the intervertebral disc ("concordant pain") rather than other sources ("discordant pain")
- technique
 - small amount of dilute contrast injected into the disc and pain response is recorded
 - contrast helps assess disc morphology and diagnose annular tears

• Surgical Approaches

- Posterior
 - posterior midline approach
 - can be used for PLIF or TLIF
 - Wiltse paraspinal approach
- Anterior Lateral
 - retroperitoneal (anterolateral) approach
 - aorta bifurcation found at L4/5
 - superior hypogastric plexus on L5 body
 - damage causes retrograde ejaculation
 - also referred to as
 - transpsoas approach
 - direct lateral
 - patient position
 - lateral
 - usually performed on left side due to increased strength of aorta to injury
 - target levels
 - ideal for access for
 - L1/2
 - L2/3
 - L3/4
 - less ideal access
 - L4/5
 - highest risk of iatrogenic nerve injury to lumbar plexus and resulting hip flexion and knee extension weakness
 - T12/L1
 - will need to remove rib and take down diaphragm)
 - anatomic risks
 - lumbar plexus
 - moves dorsal to ventral moving down the lumbar spine

- ilioinguinal and iliohypogastric nerves



- may be injured during retroperitoneal approach resulting in groin paresthesias and abdominal paresis
- segmental arteries
 - need to be stabled or tied off corpectomy performed
- aorta
 - important to place anterior retractors so damage to aorta is prevented

5- Spine Biomechanics

• Introduction

○ Functional spinal unit

- the cephalad and caudad vertebral body as well as the intervertebral disc and the corresponding facet joints
- function is to provide physiologic motion and protect neural elements
- intradiscal pressure depends on position

Activity	Intradiscal Pressure (kPa)	Compressive Force (N)	% Weight Above L3-L4
Standing	270	380	100%+
Twisting	480	670	180%
Lateral Bending	620	870	230%
Flexion	710	990	260%
Extension	720	1,010	270%
Flexion + 40 N in Each Hand	1,620	2,270	600%

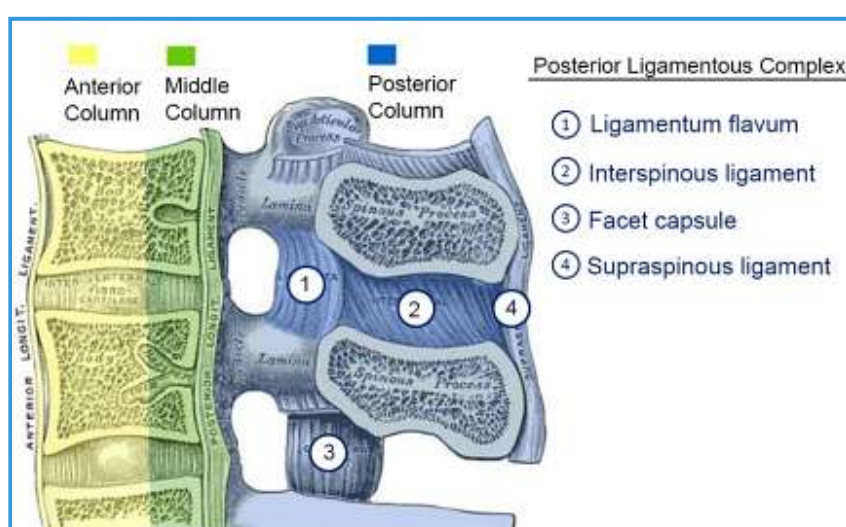
○ Spinal stability

- defined when, under physiologic loading, there is neither abnormal strain or excessive motion in the FSU
 - maintained by
 - FSU
 - muscular tension
 - abdominal and thoracic pressure
 - rib cage support

• Three Column Theory

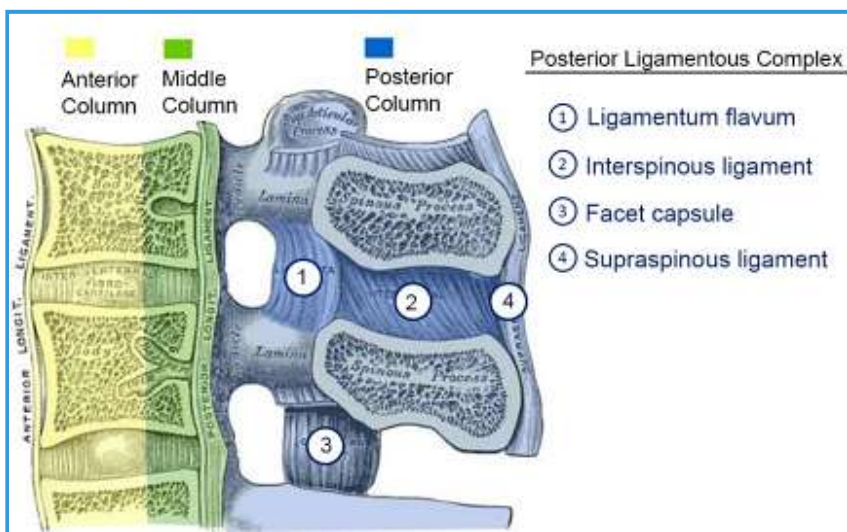
○ Denis three column system

- clinical relevance
 - only moderately reliable in determining clinical degree of stability
- definitions
 - anterior column

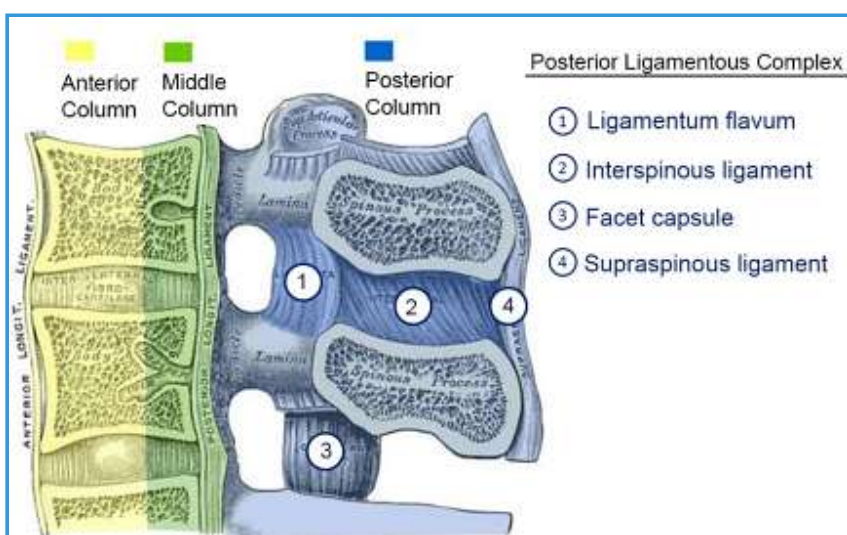


- anterior longitudinal ligament (ALL)

- anterior 2/3 of vertebral body and annulus
- middle column



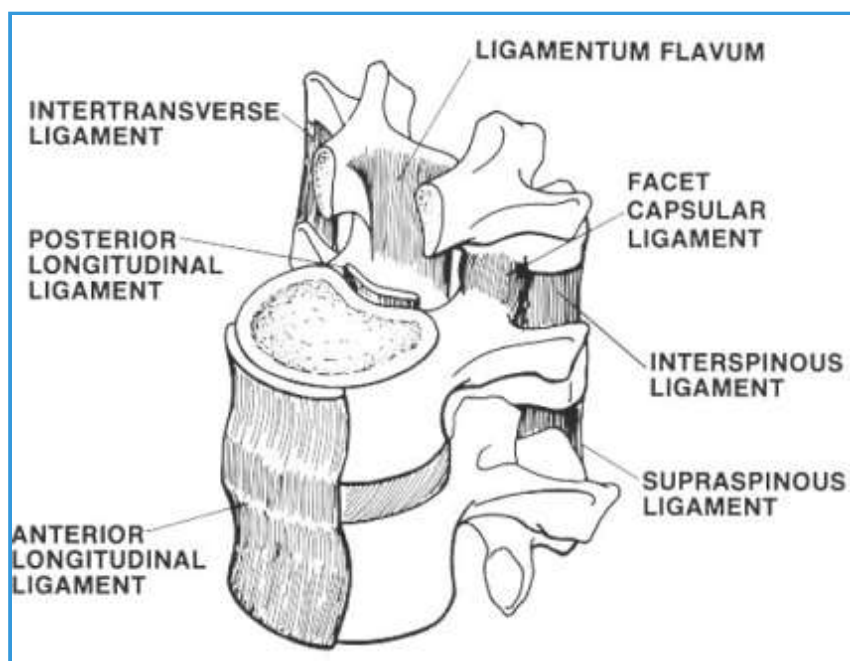
- posterior longitudinal ligament (PLL)
- posterior 1/3 of vertebral body and annulus
- posterior column



- pedicles
- facets
- ligamentum flavum
- spinous process
- posterior ligament complex (PLC)
- instability defined by
 - injury to middle column
 - as evidenced by widening of interpedicular distance on AP radiograph
 - loss of height of posterior cortex of vertebral body
 - disruption of posterior ligament complex combined with anterior and middle column involvement

• Ligaments

- FSU is surrounded by 10 ligaments with the functions:

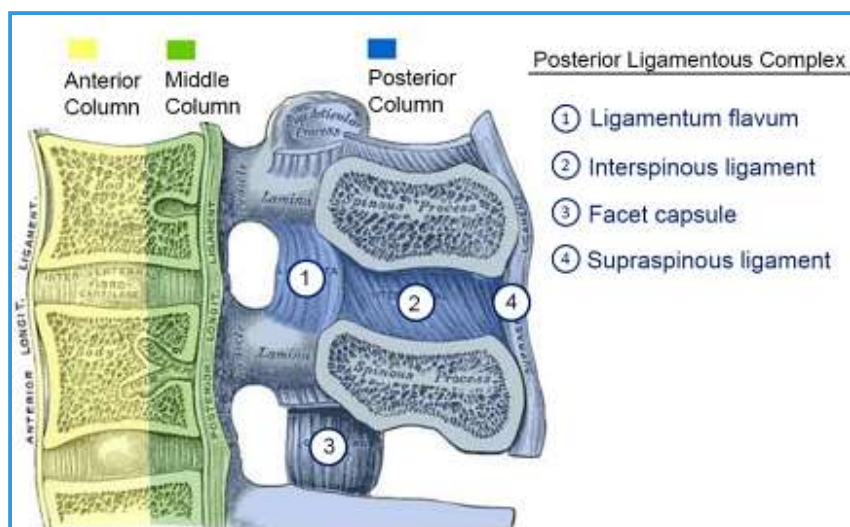


- protecting neural structures by restricting motion of the FSU
- absorb energy during high speed motions
- Contents
 - all ligaments are composed of type I collagen except ligamentum flavum (mostly elastin)
 - are viscoelastic, with nonlinear behavior

Ligament	Failure Load (N)	Failure Strength (MPa)	Failure Strain (%)	Maximum <i>In Vivo</i> Strain (%)
ALL	450	11.6	37	13 (flexion)
PLL	324	11.5	26	13 (extension)
LF	285	8.7	26	15 (flexion)
CL	222	7.6	12	17 (torsion)
ISL	125	3.2	13	28 (flexion)
SSL	150	5.4	33	31 (flexion)

• Posterior Ligamentous Complex

- Integrity of PLC now considered to be one of the most critical predictor of spinal fracture stability



- one of three primary factors in TLICS scoring system. TLICS measures as
 - intact
 - suspect/indeterminant
 - ruptured
- Anatomy
 - consists of
 - supraspinous ligament
 - interspinous ligament
 - ligamentum flavum

- facet capsule

- Evaluation

- determining the integrity of the PLC can be challenging
- conditions where PLC is ruptured
 - bony chance fracture
 - widening of interspinous distance
 - progressive kyphosis with nonoperative treatment
 - facet diastasis
- conditions where ambiguity
 - MRI shows signal intensity between spinous process

- Treatment

- nonoperative
 - according to TLICS, if PLC is intact (+0 points) in a compression (+1 point) burst fx (+1 point) in a patient without neurologic deficits (+0 points) than the patient should be treated nonoperatively
 - total score = 2 points (score < 4 points = nonoperative)
- operative
 - according to TLICS, if PLC is ruptured (+3 points) in a compression (+1 point) burst fx (+1 point) in a patient without neurologic deficits (+0 points) than the patient should be treated with surgery
 - total score = 5 points (score > 4 points = operative)

- Spinal Balance

- Sagittal balance

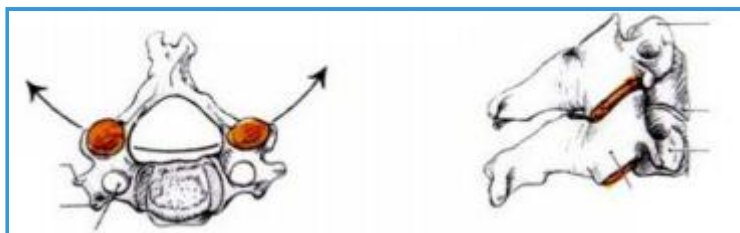


- is due to the normal cervical lordosis, thoracic kyphosis and lumbar lordosis.
 - cervical lordosis
 - normal range 20-40°
 - thoracic kyphosis
 - average 35°
 - normal range 20-50°
 - lumbar lordosis
 - average 60°
 - normal range 20-80°
 - as much as 75% of lumbar lordosis occurs between L4 and S1 with 47% occurring at L5/S1
- normal alignment

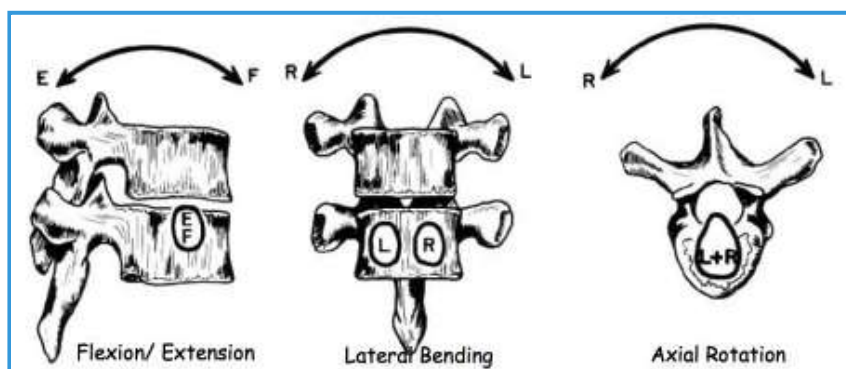
- the vertical axis runs from the center of C2 to the anterior border of T7 to the middle of the T12/L1 disc, posterior to the L3 vertebral body, and crosses the posterior superior corner of the sacrum.
- on radiograph this is estimated by a plumb line dropped from the center of C7 to the posterior-superior corner of S1
- negative sagittal balance
 - the axis is posterior to the sacrum and occurs in patients with lumbar hyperlordosis
- positive sagittal balance
 - The axis is anterior to the sacrum and occurs in patients with hip flexion contracture or flat-back syndrome

• Motion

- The orientation of the facets (zygapophyseal) joints determines the degree and plane of motion at that level
 - varies throughout the spine to meet physiologic function
 - cervical spine (C3-7)
 - planes
 - 0° coronal
 - 45° sagittal (angled superio-medially)



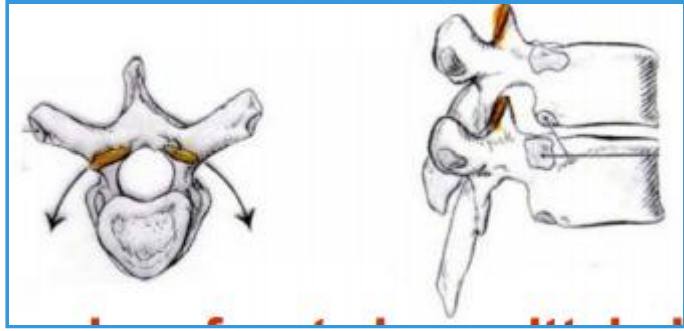
- function
 - allows flexion-extension, lateral flexion, rotation
- thoracic spine
 - planes
 - 20° coronal
 - 55° sagittal (facets in coronal plane)
 - 6 degrees of freedom



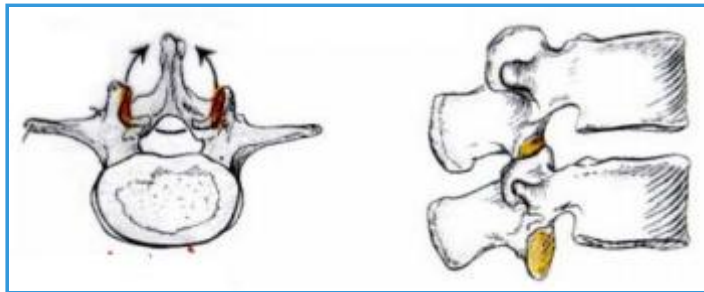
- function
 - allows some rotation, minimal flexion-extension (also limited by ribs)

	upper	middle	lower
- Flexion-Extension	4°	6°	12°
- Lateral bending	12°	12°	14°
- Axial rotation	16°	14°	4°

- prevents downward flexion on heart and lungs



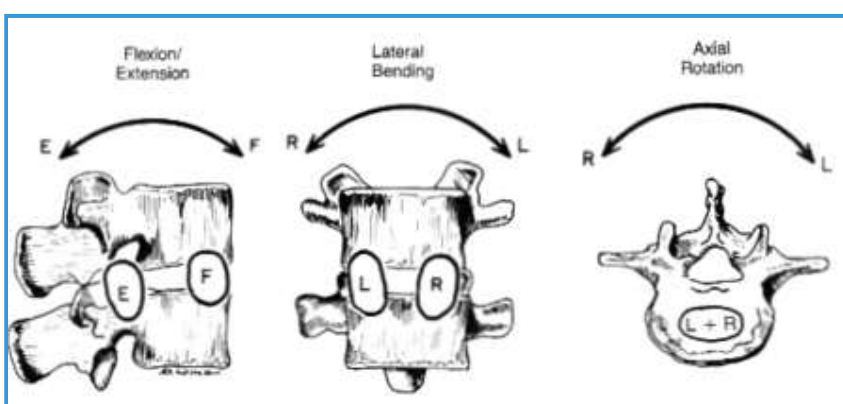
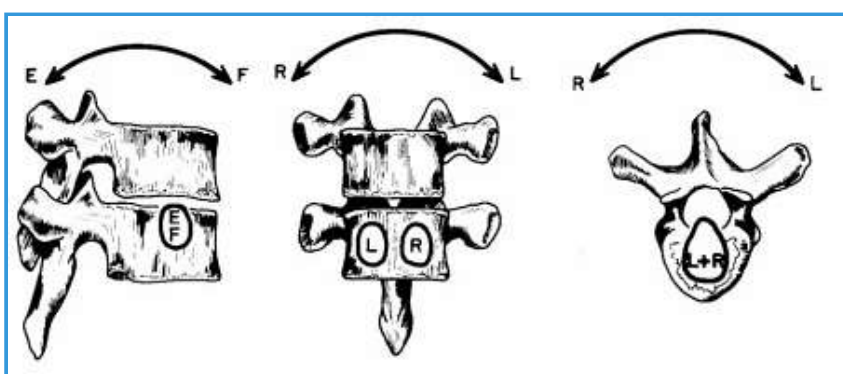
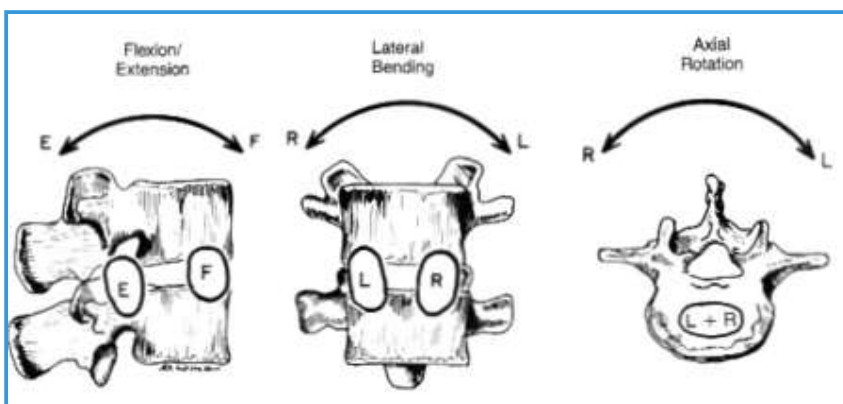
- lumbar spine
 - plane
 - 50° coronal
 - 90° sagittal (facets in sagittal plane)



- function
 - allows flexion-extension, minimal rotation
 - helps increase abdominal pressure

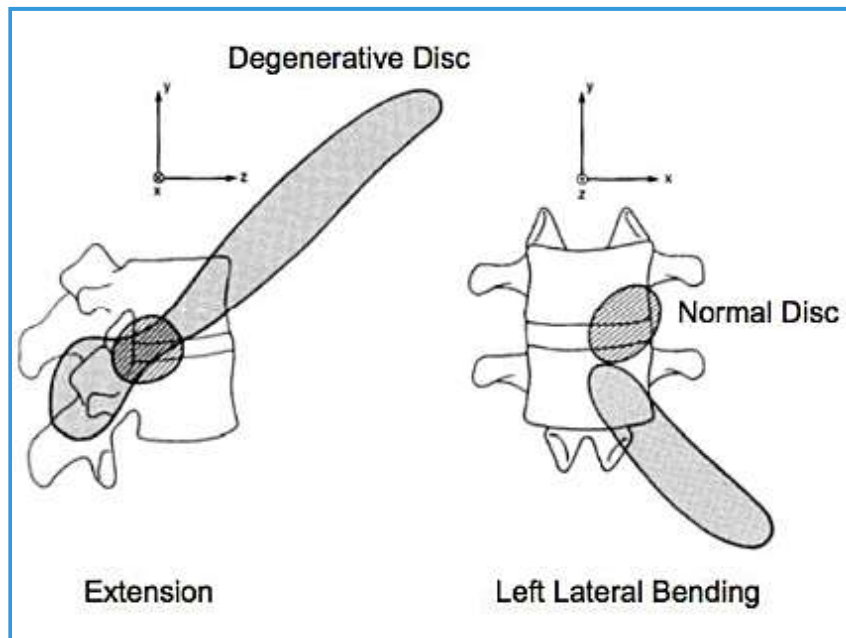
○ Instantaneous axis of rotation (IAR)

- axis about which the vertebra rotates at some instant in time



- normal FSU

- is confined to a small area within the FSU
- abnormal FSU (e.g. degenerate disc)
 - shifts outside the physical space of the FSU



- is enlarged dramatically

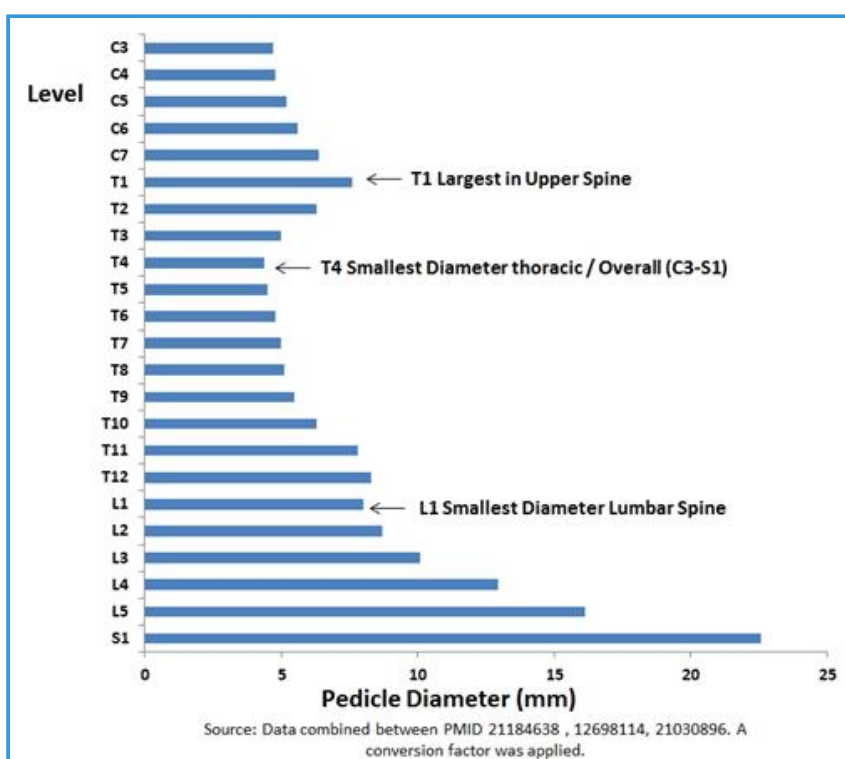
• Pedicle Anatomy

○ Cervical

- C2
 - viable for pedicle screw placement
- C3-C6
 - pedicle small making pedicle screw instrumentation difficult
 - lateral mass screws placed at C3-C6 as alternative
- C7
 - viable for pedicle screw placement

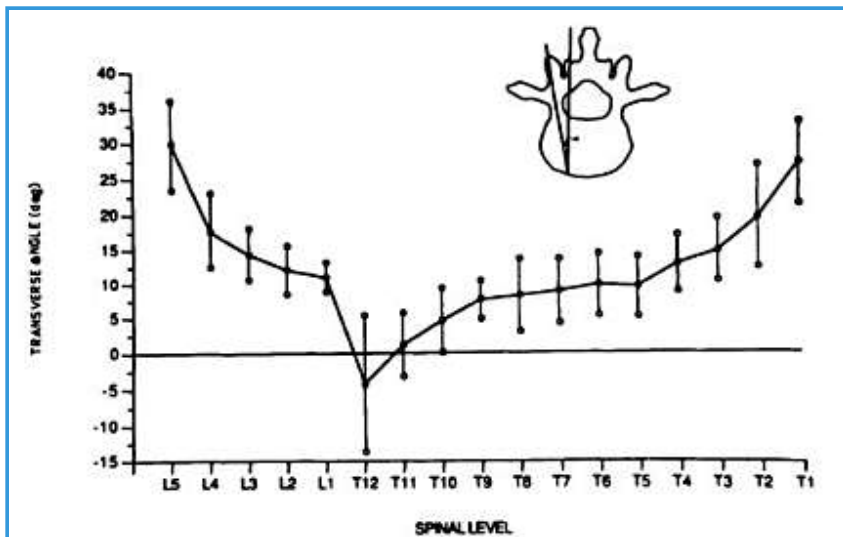
○ Thoracic

- pedicle diameter

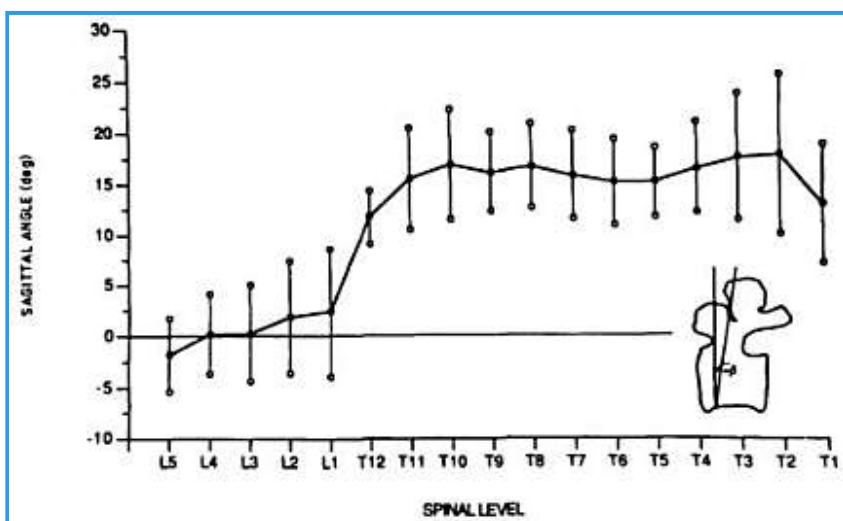


- the pedicle wall is twice as thick medially as laterally
- T4 has the narrowest pedicle diameter (on average)
- T7 can be irregular and have a narrow diameter on the concave side in AIS

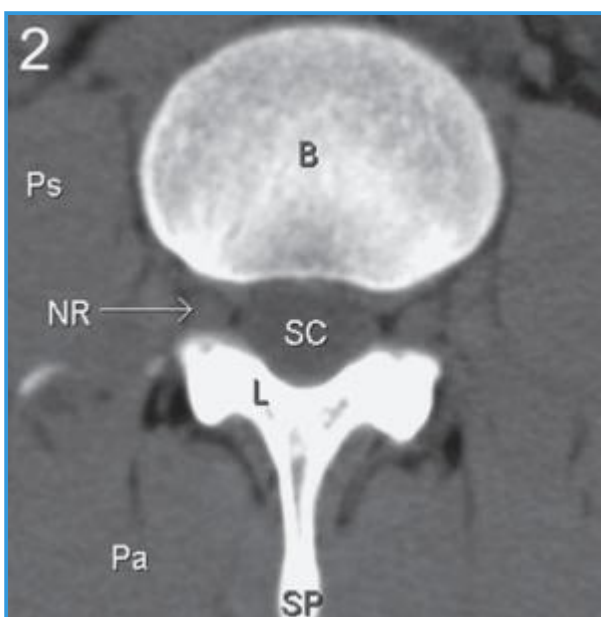
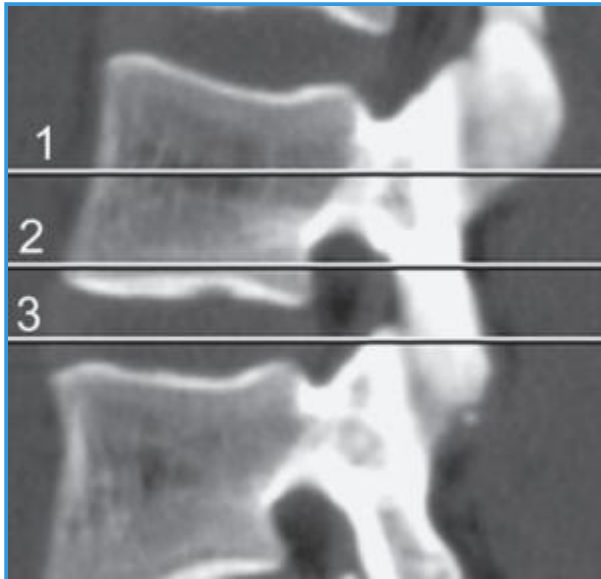
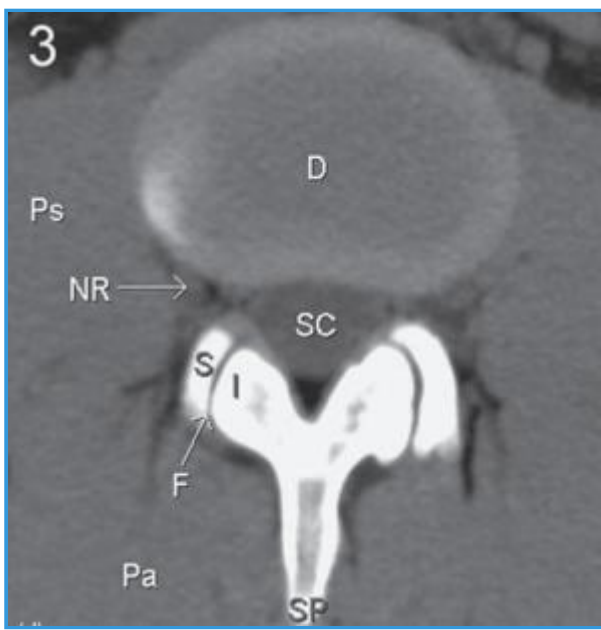
- T12 usually has larger pedicle diameter than L1
- pedicle length
 - pedicle length decreases from T1 to T4 and then increases again as you move distal in the thoracic spine
 - T1: 20mm
 - T4: 14mm (shortest pedicle)
 - T10: 20 mm
- pedicle angle
 - transverse pedicle angle



- varies from 10deg (mid thoracic spine) to 30deg (L5)
- sagittal pedicle angle



- 15-17deg cephalad for majority of thoracic spine
- neutral (0deg) for lumbar spine except L5 (caudal)
- Lumbar-Sacral
 - landmarks

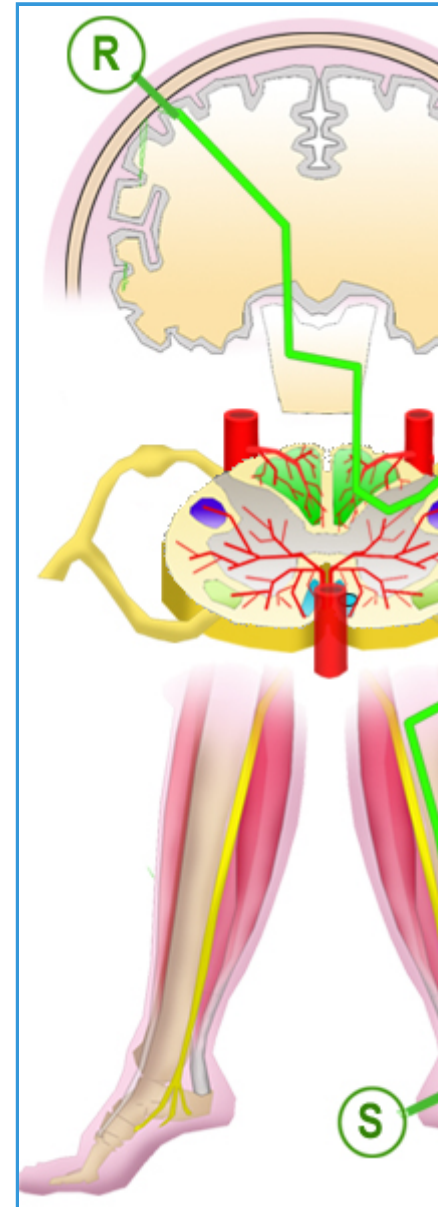
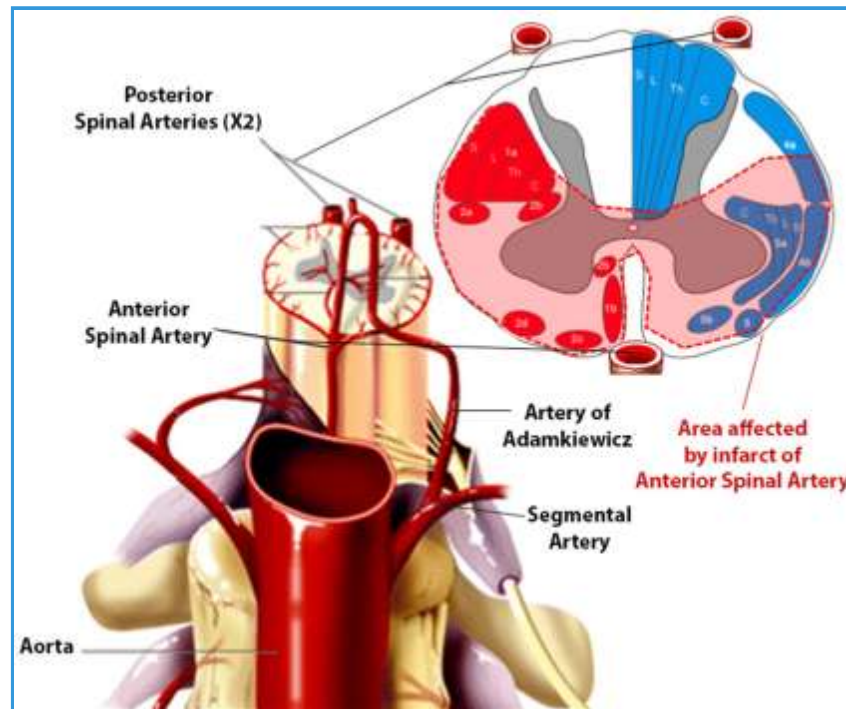
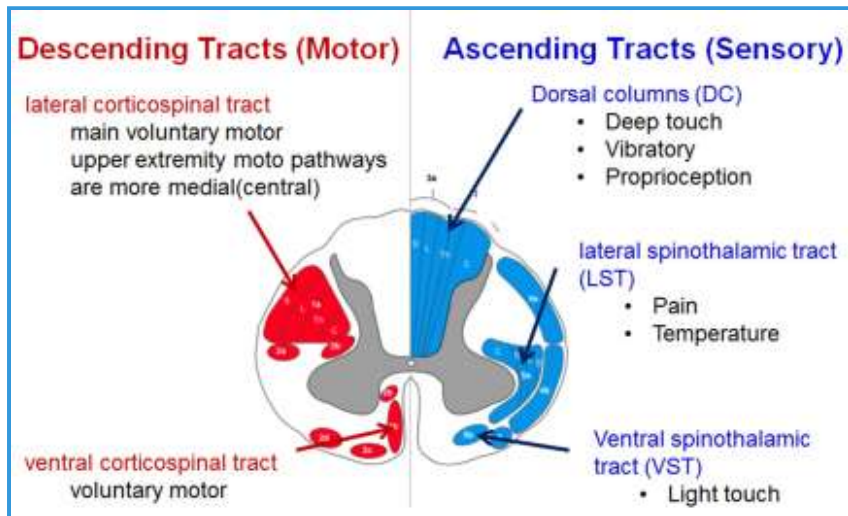


- midpoint of the transverse process used to identify midpoint of pedicle in superior-inferior dimension
- lateral border of pars used to identify midpoint in medial-lateral dimension
- pedicle angulation
 - pedicles angulate more medial as you move distal
 - L1: 12 degrees
 - L5: 30 degrees

- S1: 39 degrees
- pedicle diameter
 - L1 has smallest diameter in lumbar spine
 - S1 has average diameter of ~19mm

6- Spinal Cord Monitoring

Images



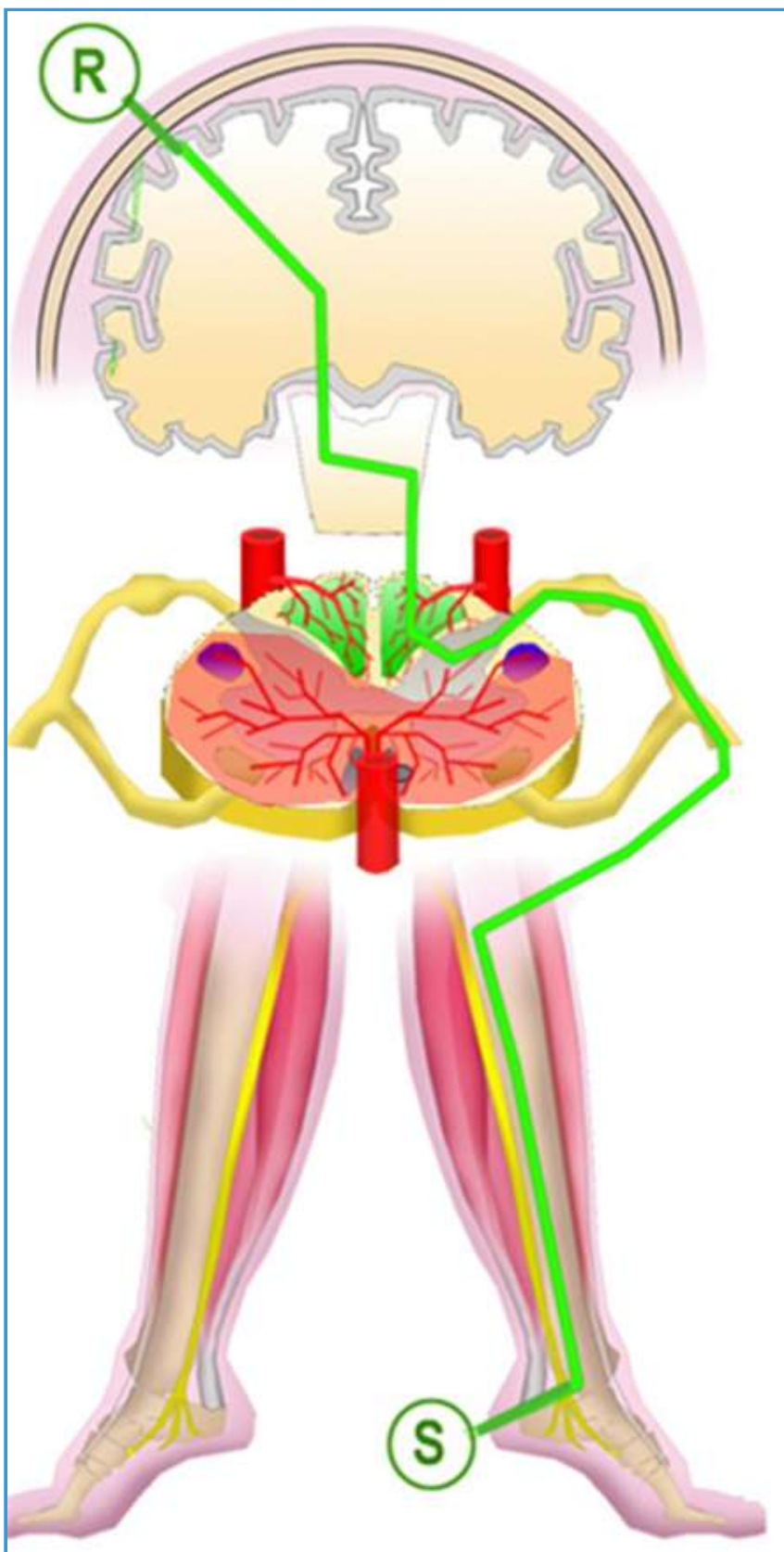
• Forms

- Spinal cord monitoring is a method to detect injury to the spinal cord during operative procedures.
 - most common forms are
 - EMG (electromyography)
 - SEP (somatosensory evoked potentials)
 - 25% sensitive, 100% specific
 - MEP (motor evoked potentials)
 - 100% sensitive, 100% specific

• Anatomy

- Spinal cord pathways
 - sensory (afferent)
 - dorsal column
 - spinothalamic tract
 - motor (efferent)

- lateral corticospinal tract
 - ventral corticospinal tract
- Blood supply
 - consists of
 - anterior spinal artery
 - primary blood supply of anterior 2/3 of spinal cord, including both the lateral corticospinal tract and ventral corticospinal tract
 - posterior spinal artery (right and left)
 - primary blood supply to the dorsal sensory columns
- Sensory evoked potentials (SEPs)
 - Function
 - monitor integrity of dorsal column sensory pathways of the spinal cord
 - Technique
 - signal initiation
 - lower extremity usually involves stimulation of posterior tibial nerve behind ankle
 - upper extremity usually involve stimulation of ulnar nerve
 - signal recording
 - transcranial recording of somatosensory cortex
 - Advantages
 - reliable and unaffected by anesthetics
 - Disadvantages
 - not reliable for monitoring the integrity of the anterior spinal cord pathways



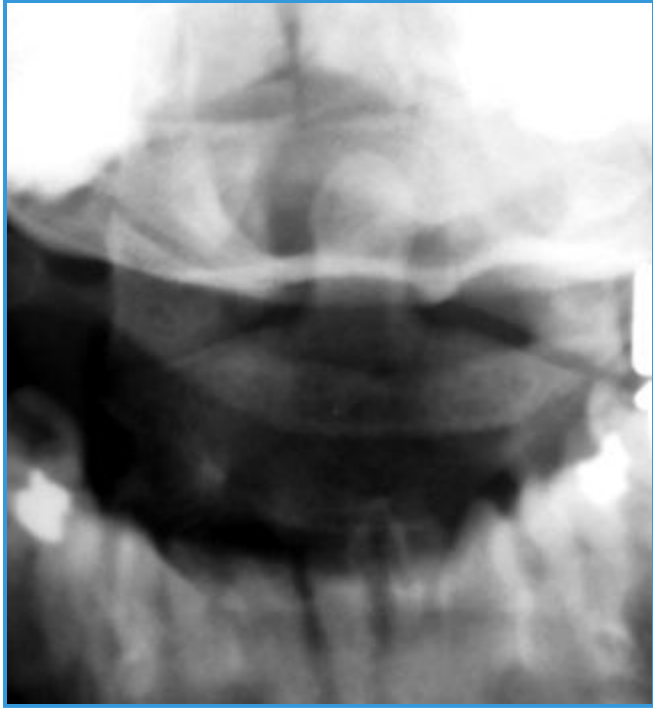
- reports exist in literature of an ischemic injury leading to paralysis despite normal SEP monitoring during surgery
- Intraoperative considerations
 - loss of signals during distraction mandates immediate removal of device and repeated assessment of monitoring signals
 - decrease in amplitude of 50% and/or 10% prolongation in latency is considered a significant change
- Motor Evoked Potential (MEP)
 - Function
 - monitor integrity of lateral and ventral corticospinal tract of the spinal cord
 - Technique
 - signal initiation
 - transcranial stimulation of motor cortex
 - signal recording

- muscle contraction in extremity (gastroc, soleus, EHL of lower extremity)
- Advantages
 - effective at detecting a ischemic injury (loss of anterior spinal artery) in anterior 2/3 of spinal cord
- Disadvantages
 - often unreliable due to effects of anesthesia
- Intraoperative considerations
 - loss of signals during distraction mandates immediate removal of device and repeated assessment of monitoring signals
 - greater than 100 V increase in threshold is suggestive of an early injury
 - >50% decrease in MEP amplitude is considered significant
- Mechanical Electromyography (spontaneous)
 - Introduction
 - monitor integrity of specific spinal nerve roots
 - Technique
 - concept
 - microtrauma to nerve root during surgery causes depolarization and a resulting action potential in the muscle that can be recorded
 - contact of a surgical instrument with nerve root will lead to "burst activity" and has no clinical significance
 - significant injury or traction to a nerve root will lead to "sustained train" activity, which may be clinically significant
 - signal initiation
 - mechanical stimulation (surgical manipulation) of nerve root
 - signal recording
 - muscle contraction in extremity
 - Advantages
 - allows monitoring of specific nerve roots
 - Disadvantages
 - may be overly sensitive (e.g., sustained train activity does not necessarily reflect nerve root injury)
- Electrical Electromyography (triggered)
 - Introduction
 - allows detection of a breached pedicle screw
 - Technique

- concept
 - bone conducts electricity poorly
 - an electrically stimulated pedicle screw that is confined to bone will not stimulate the nerve root
 - if there is a breach in a pedicle, stimulation of the screw will lead to activity of that specific nerve root
- signal initiation
 - electrical stimulation of placed pedicle screw
- signal recording
 - muscle contraction in extremity
 - thresholds <8 mA may be indicative of breach
- Advantages
 - allows monitoring of specific nerve roots
- Disadvantages
 - may be overly sensitive (e.g., sustained train activity does not necessarily reflect nerve root injury)

7- Cervical Spine Trauma Evaluation

Images



- Introduction
 - All trauma patients have a cervical spine injury until proven otherwise
 - Cervical spine clearance defined as confirming the absence of cervical spine injury
 - important to clear cervical spine and remove collar in an efficient manner
 - delayed clearance associated with increased complication rate
 - cervical clearance can be performed with
 - physical exam
 - radiographically
 - Missed cervical spine injuries
 - may lead to permanent disability
 - careful clinical and radiographic evaluation is paramount
 - high rate of missed cervical spine injuries due to
 - inadequate imaging of affected level
 - loss of consciousness
 - multisystem trauma
 - cervical spine injury necessitates careful examination of entire spine
 - noncontiguous spinal column injuries reported in 10-15% of patients
- History

- Details of accident
 - energy of accident
 - higher level of concern when there is a history of high energy trauma as indicated by
 - MVA at > 35 MPH
 - fall from > 10 feet
 - closed head injuries
 - neurologic deficits referable to cervical spine
 - pelvis and extremity fractures
 - mechanism of accident
 - e.g., elderly person falls and hits forehead (hyperextension injury)
 - e.g., patient rear-ended at high speed (hyperextension injury)
 - condition of patient at scene of accident
 - general condition
 - degree of consciousness
 - presence or absence of neurologic deficits
- Identify associated conditions and comorbidities
 - ankylosing spondylitis (AS)
 - diffuse idiopathic skeletal hyperostosis (DISH)
 - previous cervical spine fusion (congenital or acquired)
 - connective tissue disorders leading to ligamentous laxity

• Physical Exam

- Useful for detecting major injuries
- Primary survey
 - airway
 - breathing
 - circulation
 - visual and manual inspection of entire spine should be performed
 - manual inline traction should be applied whenever cervical immobilization is removed for securing airway
 - seat belt sign (abdominal ecchymosis) should raise suspicion for flexion distraction injuries of thoracolumbar spine
- Secondary survey
 - cervical spine exam
 - remove immobilization collar
 - examine face and scalp for evidence of direct trauma

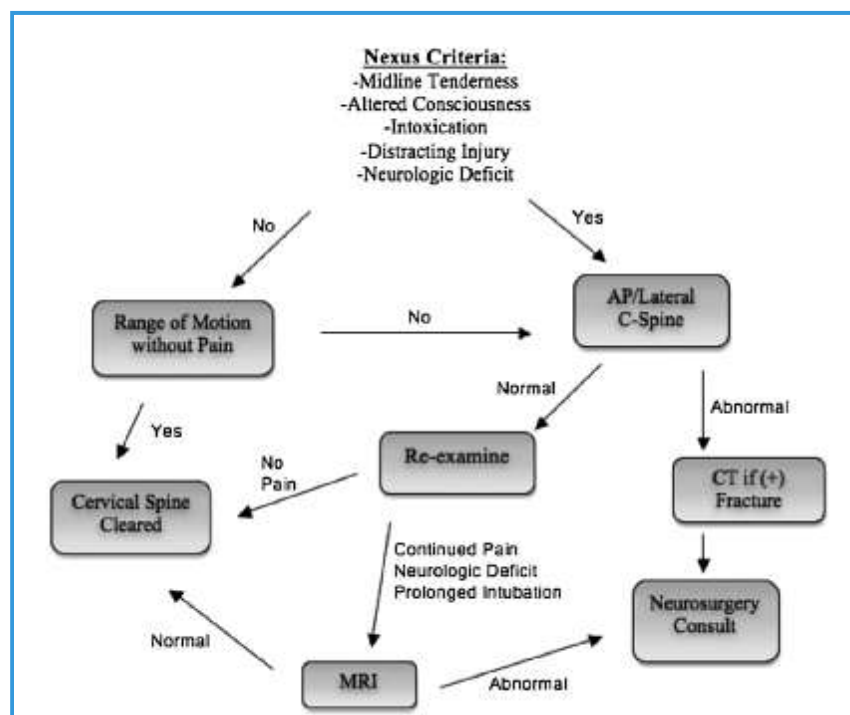
- inspect for angular or rotational deformities in the holding position of the patient's head
 - rotational deformity may indicate a unilateral facet dislocation
- palpate posterior cervical spine looking for tenderness along the midline or paraspinal tissues
 - absence of posterior midline tenderness in the awake, alert patient predicts low probability of significant cervical injury



- log roll patient to inspect and palpate entire spinal axis
- perform careful neurologic exam

• Clinical Cervical Clearance

- Removal of cervical collar WITHOUT radiographic studies allowed if
 - patient is awake, alert, and not intoxicated AND
 - has no neck pain, tenderness, or neurologic deficits AND
 - has no distracting injuries
- Utilizing updated clinical practice guidelines and Nexus criteria for pediatric C-spine clearance



- less radiation exposure with reduced CT scans for C-spine clearance

• Radiographic Cervical Clearance

- Indications for obtaining radiographic clearance
 - intoxicated patients OR
 - patients with altered mental status OR Cervical Conditions
 - neck pain or tenderness present OR
 - distracting injury present
- Methods
 - radiographs

- lateral
 - must include inferior endplate of C7
- open-mouth odontoid
- AP
- CT scan
 - must include superior endplate of T1

- Treatment

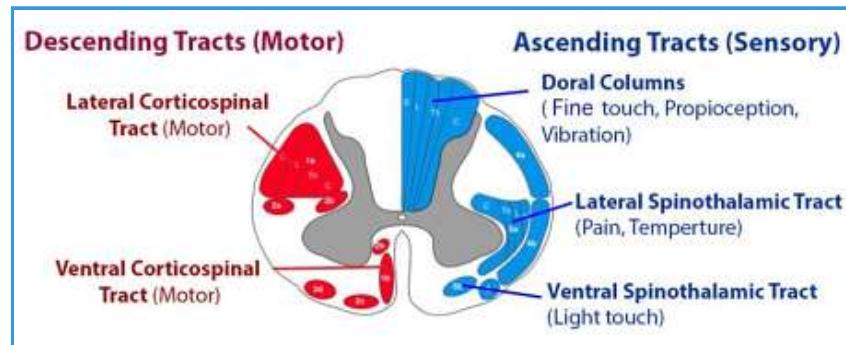
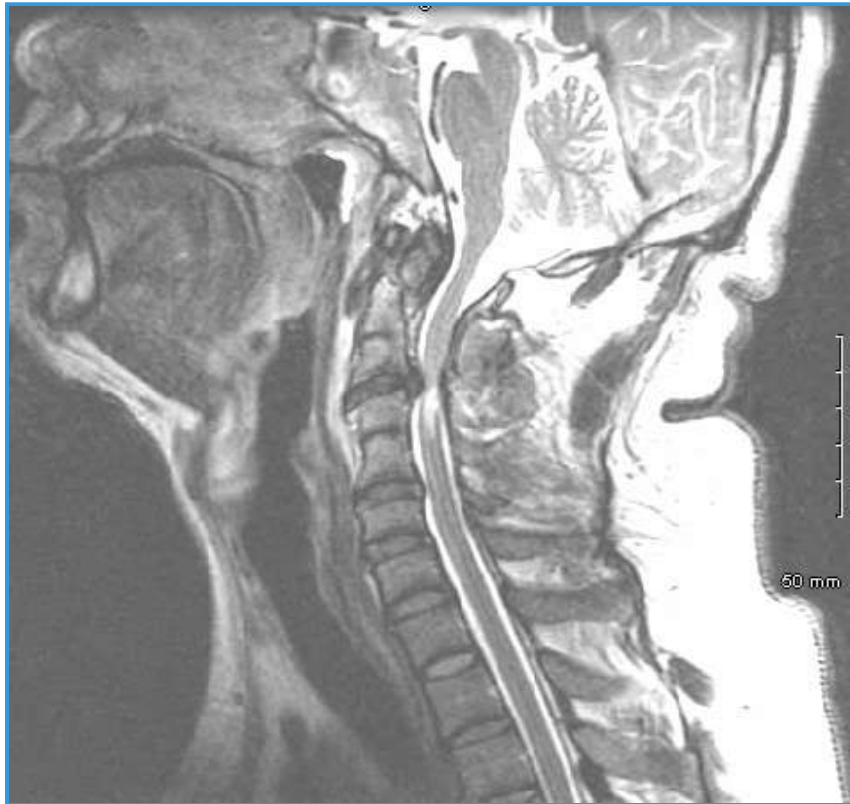
- Nonoperative
 - **cervical collar**
 - indications
 - initiated at scene of injury until directed examination performed
 - **early active range of motion**
 - indications
 - "whiplash-like" symptoms and
 - cleared from a serious cervical injury by exam or imaging

- Complications

- Delayed clearance associated with increased complication rate including
 - increased risk of aspiration
 - inhibition of respiratory function
 - decubitus ulcers in occipital and submandibular areas
 - possible increase in intracranial pressure
- Mortality increased in geriatric patients

8- Incomplete Spinal Cord Injuries

Images



- Introduction
 - Defined as spinal cord injury with some preserved motor or sensory function below the injury level including
 - voluntary anal contraction (sacral sparing)
 - sacral sparing critical to separate complete vs. incomplete injury
 - OR palpable or visible muscle contraction below injury level
 - OR perianal sensation present
- Epidemiology
 - Incidence
 - 11,000 new cases/year in US
 - 34% incomplete tetraplegia
 - central cord syndrome most common
 - 17% incomplete paraplegia
 - remaining 47% are complete
- Anatomy
 - Descending Tracts (motor)
 - lateral corticospinal tract (LCT)
 - ventral corticospinal tract
 - Ascending tracts (sensory)

- dorsal columns
 - fine touch
 - vibration
 - proprioception
- lateral spinothalamic tract (LST)
 - pain
 - temperature
 - gross sensation
- ventral spinothalamic tract (VST)
 - light touch

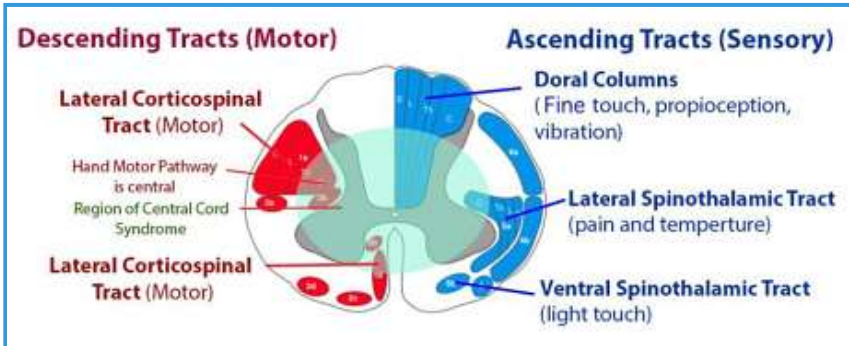
•
 Classification

- Clinical classification
 - anterior cord syndrome (see below)
 - Brown-Sequard syndrome
 - central cord syndrome
 - posterior cord syndrome
- ASIA classification
 - method to scale

■ ASIA Impairment Scale		
■ A	■ No motor or sensory function is preserved in the sacral segments S4-S5.	■ Complete
■ B	■ Sensory function preserved but not motor function is preserved below the neurological level and includes the sacral segments S4-S5.	■ Incomplete
■ C	■ Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3 .	■ Incomplete
■ D	■ Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more .	■ Incomplete
■ E	■ Motor and sensory functions are normal.	■ Normal

•
 Central Cord Syndrome

- Epidemiology
 - incidence
 - most common incomplete cord injury



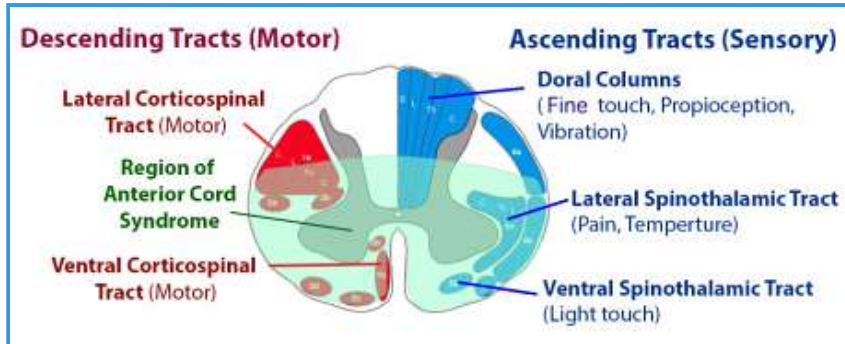
- demographics

- often in elderly with minor extension injury mechanisms
 - due to anterior osteophytes and posterior infolded ligamentum flavum
- Pathophysiology
 - believed to be caused by spinal cord compression and central cord edema with selective destruction of lateral corticospinal tract white matter
 - anatomy of spinal cord explains why upper extremities and hand preferentially affected
 - hands and upper extremities are located "centrally" in corticospinal tract
- Presentation
 - symptoms
 - weakness with hand dexterity most affected
 - hyperpathia
 - burning in distal upper extremity
 - physical exam
 - loss
 - motor deficit worse in UE than LE (some preserved motor function)
 - hands have more pronounced motor deficit than arms
 - preserved
 - sacral sparing
 - late clinical presentation
 - UE have LMN signs (clumsy)
 - LE has UMN signs (spastic)
- Treatment
 - nonoperative vs. operative
 - extremely controversial
- Prognosis
 - final outcome
 - good prognosis although full functional recovery rare
 - <50 years of age associated with greatest neurologic recovery
 - usually ambulatory at final follow up
 - usually regain bladder control
 - upper extremity and hand recovery is unpredictable and patients often have permanent clumsy hands
 - recovery occurs in typical pattern
 - lower extremity recovers first
 - bowel and bladder function next

- proximal upper extremity next
- hand function last to recover

• Anterior Cord Syndrome

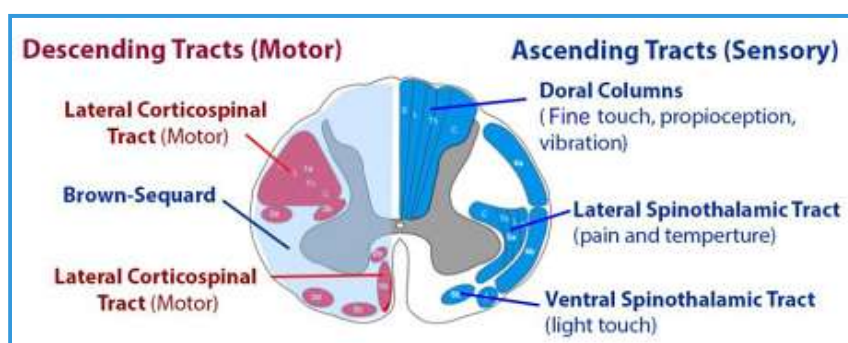
- A condition characterized by
 - motor dysfunction



- dissociated sensory deficit below level of SCI
- Pathophysiology
 - injury to anterior spinal cord caused by
 - direct compression (osseous) of the anterior spinal cord
 - anterior spinal artery injury
 - anterior 2/3 spinal cord supplied by anterior spinal artery
- Mechanism
 - usually result of flexion/ compression injury
- Exam
 - lower extremity affected more than upper extremity
 - loss
 - LCT (motor)
 - LST (pain, temperature)
 - preserved
 - DC (proprioception, vibratory sense)
- Prognosis
 - worst prognosis of incomplete SCI
 - most likely to mimic complete cord syndrome
 - 10-20% chance of motor recovery

• Brown-Sequard Syndrome

- Caused by complete cord hemitransection

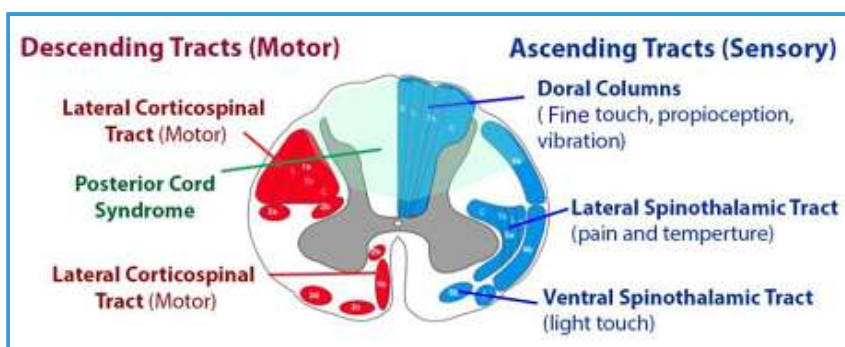


- usually seen with penetrating trauma

- Exam
 - ipsilateral deficit
 - LCS tract
 - motor function
 - dorsal columns
 - proprioception
 - vibratory sense
 - contralateral deficit
 - LST
 - pain
 - temperature
 - spinothalamic tracts cross at spinal cord level (classically 2-levels below)
- Prognosis
 - excellent prognosis
 - 99% ambulatory at final follow up
 - best prognosis for function motor activity

• Posterior Cord Syndrome

- Introduction
 - very rare



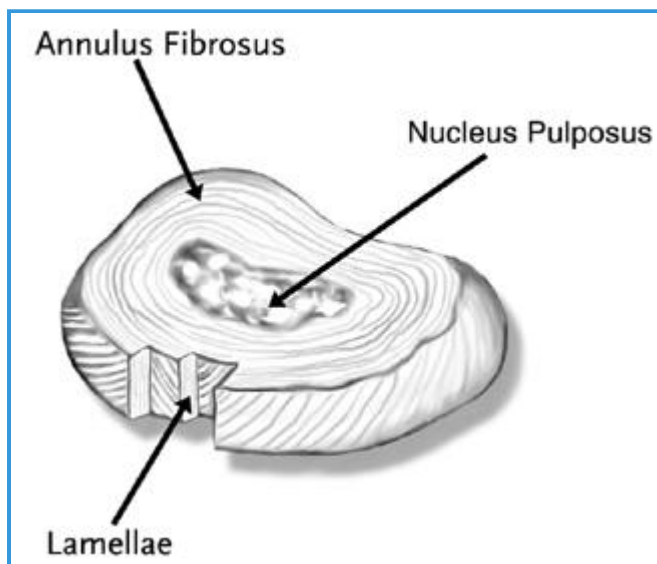
- Exam
 - loss
 - proprioception
 - preserved
 - motor, pain, light touch

• Prognosis

- Most important prognostic variable relating to neurologic recovery is completeness of the lesion (severity of neurologic deficit)

9- Intervertebral Disc

Images



- Anatomy

- Function

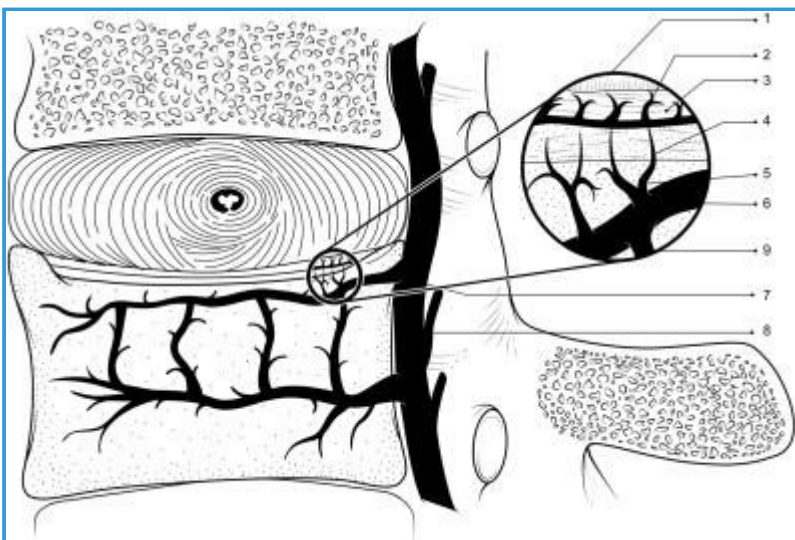
- allows spinal motion and provides stability
 - links adjacent vertebral bodies together
 - responsible for 25% of spinal column height

- Composition

- annulus fibrosus
 - outer structure that encases the nucleus pulposus
 - composed of type I collagen that is obliquely oriented, water, and proteoglycans
 - characterized by high tensile strength and its ability to prevent intervertebral distraction
 - remains flexible enough to allow for motion
 - high collagen / low proteoglycan ratio (low % dry weight of proteoglycans)
 - fibroblast-like cells
 - responsible for producing type I collagen and proteoglycans
 - nucleus pulposus
 - central portion of the intervertebral disc that is surrounded by the annulus fibrosis
 - composed of type II collagen, water, and proteoglycans
 - approximately 88% water
 - hydrophilic matrix is responsible for height of the intervertebral disc
 - characterized by compressibility

- a hydrated gel due to high polysaccharide content and high water content (88%)
 - proteoglycans interact with water and resist compression
 - Aggrecan is a proteoglycan primarily responsible for maintaining water content of the disc
 - viscoelastic matrix distributes the forces smoothly to the annulus and the end plates
- low collagen / high proteoglycan ratio (high % dry weight of proteoglycans)
- chondrocyte-like cells
 - responsible for producing type II collagen and proteoglycans
 - survive in hypoxic conditions

○ Blood Supply



- the disk is avascular with capillaries terminating at the end plates
- nutrition reaches nucleus pulposus through diffusion through pores in the endplates
 - annulus is not porous enough to allow diffusion

○ Innervation

- the dorsal root ganglion gives rise to the sinuvertebral nerve which innervates the superficial fibers of annulus
 - no nerve fibers extend beyond the superficial fibers
- neuropeptides thought to participate in sensory transmission include
 - substance P
 - calcitonin
 - VIP
 - CPON

○ Fixation

- attached to vertebral bodies by hyaline cartilage

• Disc Biomechanics

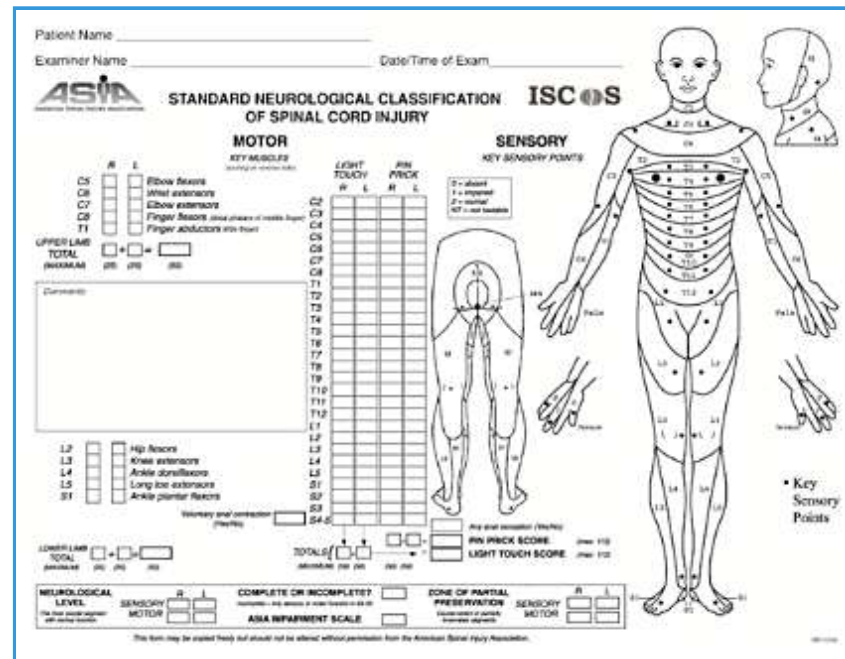
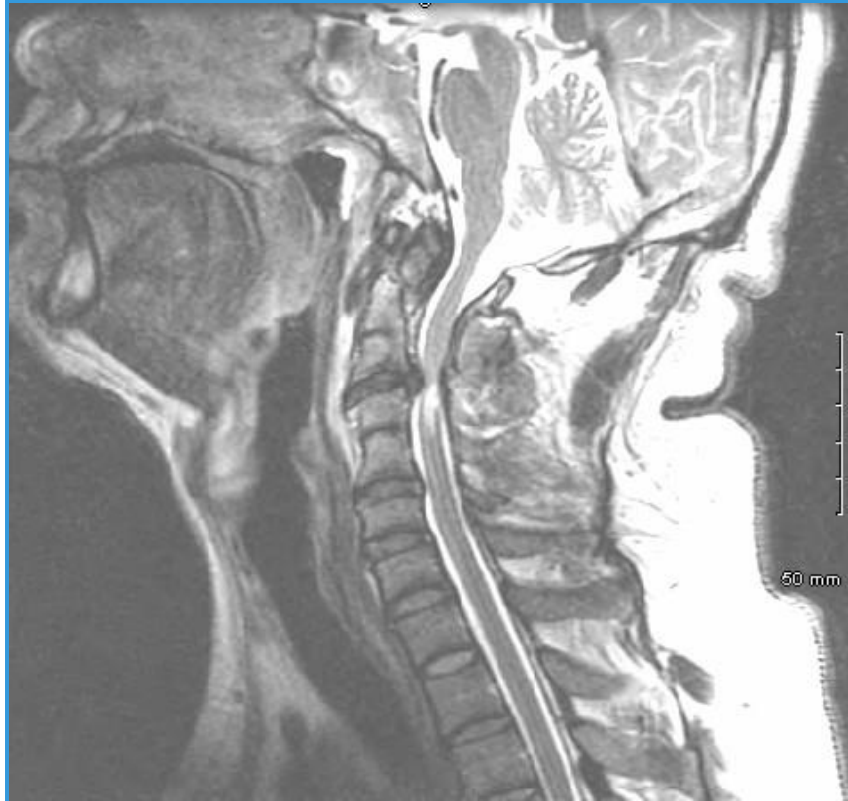
○ Disc

- viscoelastic characteristics
 - demonstrates creep which allows for deformity over time
 - demonstrates hysteresis which allows for energy absorption with repetitive axial compression
 - this property decreases with time
- Stresses
 - annulus fibrosus
 - highest tensile stresses
 - nucleus pulposus
 - highest compressive stress
 - intradiscal pressure is position dependent
 - pressure is lowest when lying supine
 - pressure is intermediate when standing
 - pressure is highest when sitting and flexed forward with weights in the hands
 - when carrying weight, the closer the object is to the body the lower the pressure
- Stability
 - following subtotal discectomy, extension is most stable loading mode
- Pathoanatomy
 - Disc Herniation
 - herniated disks are associated with a spontaneous increase in the production of
 - osteoprotegerin (OPG)
 - interleukin-1 beta
 - receptor activator of nuclear factor-kB ligand (RANKL)
 - parathyroid hormone (PTH)
 - Disc aging leads to an overall loss of water content and conversion to fibrocartilage . Specifically there is a
 - decrease in
 - nutritional transport
 - water content
 - absolute number of viable cells
 - proteoglycans
 - pH
 - increase in
 - an increase keratin sulfate to chondroitin sulfate ratio

- lactate
- degradative enzyme activity
- density of fibroblast-like cells
 - fibroblast-like cells reside in the annulus fibrosus only
- no change in
 - absolute quantity of collagen

10- Spinal Cord Injuries

Images



- Epidemiology

- Incidence

- 11,000 new cases/year in US
 - 34% incomplete tetraplegia
 - central cord syndrome most common
 - 25% complete paraplegia
 - 22% complete tetraplegia
 - 17% incomplete paraplegia

- Demographics

- bimodal distribution
 - young individuals with significant trauma
 - older individuals that have minor trauma compounded by degenerative spinal canal narrowing

- Anatomic location

- 50% in cervical spine

- Etiology

- Mechanism

- MVA causes 50%
 - falls
 - GSW

- iatrogenic
 - it is estimated that 3-25% of all spinal cord injuries occur after initial traumatic episode due to improper immobilization and transport.
 - Pathophysiology
 - primary injury
 - damage to neural tissue due to direct trauma
 - irreversible
 - secondary injury
 - injury to adjacent tissue due to
 - decreased perfusion
 - lipid peroxidation
 - free radical / cytokines
 - cell apoptosis
 - methylprednisone used to prevent secondary injury by improving perfusion, inhibiting lipid peroxidation, and decreasing the release of free radicals
 - Associated conditions
 - acute phase conditions (see below)
 - spinal shock
 - neurogenic shock
 - associated injuries
 - closed head injuries
 - noncontiguous spinal fractures
 - vertebral artery injury
 - risk factors for vertebral artery injury include
 - atlas fractures
 - facet dislocations
 - most people with unilateral injury remain asymptomatic
 - imaging
 - magnetic resonance angiography is least invasive method
 - treatment
 - stenting only if patient is symptomatic from basilar arterial insufficiency
- Relevant Anatomy
 - See Spinal Cord Anatomy
 - Classification

- Descriptive
 - tetraplegia
 - injury to the cervical spinal cord leading to impairment of function in the arms, trunk, legs, and pelvic organs
 - paraplegia
 - injury to the thoracic, lumbar or sacral segments leading to impairment of function in the trunk, legs, and pelvic organs depending on the level of injury. Arm function is preserved
 - complete injury
 - an injury with no spared motor or sensory function below the affected level.
 - patients must have recovered from spinal shock (bulbocavernosus reflex is intact) before an injury can be determined as complete
 - classified as an ASIA A
 - incomplete injury
 - an injury with some preserved motor or sensory function below the injury level
 - incomplete spinal cord injuries include
 - anterior cord syndrome
 - Brown-Sequard syndrome
 - central cord syndrome
 - posterior cord syndrome
 - conus medullaris syndromes
 - cauda equina syndrome

• ASIA Classification

○

■ ASIA Impairment Scale			
		■ Motor	■ <i>Sensory</i>
■ A	■ Complete	■ No motor function	■ Complete deficit
■ B	■ Incomplete	■ No motor function	■ Incomplete deficit
■ C	■ Incomplete	■ Motor function partially preserved: more than half of key muscles below the neurological level have a muscle grade less than 3 .	■ Incomplete deficit
■ D	■ Incomplete	■ Motor function is partially preserved - at least half of key muscles below the neurological level have a muscle grade of 3 or more .	■ Incomplete deficit
■ E	■ Normal	■ Normal motor	■ Normal sensory

• Acute Phase Conditions

- Neurogenic shock
 - characterized by hypotension & relative bradycardia in patient with an acute spinal cord injury
 - potentially fatal
 - mechanism
 - circulatory collapse from loss of sympathetic tone
 - disruption of autonomic pathway within the spinal cord leads to
 - lack of sympathetic tone
 - decreased systemic vascular resistance
 - pooling of blood in extremities
 - hypotension
 - treatment
 - Swan-Ganz monitoring for careful fluid management
 - pressors to treat hypotension
- Spinal shock
 - defined as temporary loss of spinal cord function and reflex activity below the level of a spinal cord injury.
 - characterized by
 - flaccid areflexic paralysis
 - bradycardia & hypotension (due to loss of sympathetic tone)
 - absent bulbocavernosus reflex
 - reflex characterized by anal sphincter contraction in response to squeezing the glans penis or tugging on an indwelling Foley catheter
 - timing
 - variable but usually resolves within 48 hours
 - at its conclusion spasticity, hyperreflexia, and clonus slowly progress over days to weeks
 - mechanism
 - neurophysiologic in nature
 - neurons become hyperpolarized and unresponsive to stimuli from brain
 - evaluation
 - important because one cannot evaluate neurologic deficit until spinal shock phase has resolved
 - end of spinal shock indicated by return of the bulbocavernous reflex
 - conus or cauda equina injuries may lead to permanent loss of the bulbocavernous reflex

- ruled out when
 - bulbocavernous reflex present
 - 48 hours has elapsed from time of injury
- stages of spinal shock
 - Phase 1 - hyporeflexic
 - 0 to 48 hours
 - areflexia/hyporeflexic
 - Phase 2 - initial reflex return
 - 1-2 days
 - polysynaptic reflexes return (bulbocavernous reflex)
 - monosynaptic (patellar) remain absent
 - Phase 3 - initial hyperreflexia
 - 1-4 weeks
 - Phase 4 - spasticity
 - 1 to 12 months
 - characterized by altered skeletal performance

■ Spinal vs. Neurogenic vs. Hypovolemic Shock			
■	■ <i>Spinal shock</i>	■ <i>Neurogenic shock</i>	■ <i>Hypovolemic shock</i>
■ BP	■ Hypotension	■ Hypotension	■ Hypotension
■ Pulse	■ Bradycardia	■ Bradycardia	■ Tachycardia
■ Reflexes / Bulbocavernosus Reflex	■ Absent	■ Variable/independent	■ Variable/independent
■ Motor	■ Flaccid Paralysis	■ Variable/independent	■ Variable/independent
■ Time	■ ~48-72 hours immediately after spinal cord injury	■ ~48-72 hours immediately after spinal cord injury	■ Following excessive blood loss
■ Mechanism	■ Peripheral neurons become temporarily unresponsive to brain stimuli.	■ Disruption of autonomic pathway leads to loss of sympathetic tone and decreased systemic vascular resistance.	■ Decreased preload leads to decreased cardiac output.

- Evaluation
 - Field treatment
 - treatment of potential spinal cord injuries begins at the accident scene with proper spinal immobilization
 - immobilization
 - immobilization should include a rigid cervical collar and transport on a firm spine board with lateral support devices

- patient should be rolled with standard log roll techniques with control of cervical spine
 - spine boards should be used for transport only and patients should be removed when clinically safe
 - decubitus ulcers can occur after only 30-60 minutes on a backboard
 - athletes
 - in the setting of sports-related injuries helmets and shoulder pads should be left on until arrival at the hospital OR until experienced personnel can perform simultaneous removal of helmet and shoulder pads in a controlled situation
- Initial evaluation
 - primary survey
 - airway
 - breathing
 - SCI above C5 likely to require intubation
 - circulation
 - initial survey to inspect for obvious injuries of head and spine
 - visual and manual inspection of entire spine should be performed
 - seat belt sign (abdominal ecchymoses) should raise suspicion for flexion distraction injuries of thoracolumbar spine
 - secondary survey
 - cervical spine exam
 - remove immobilization collar
 - examine face and scalp for evidence of direct trauma
 - inspect for angular or rotational deformities in the holding position of the patient's head
 - rotational deformity may indicate a unilateral facet dislocation
 - palpate posterior cervical spine looking for tenderness along the midline or paraspinal tissues
 - absence of posterior midline tenderness in the awake, alert patient predicts low probability of significant cervical injury
 - log roll patient to inspect and palpate entire spinal axis
 - perform careful neurologic exam
 - cervical spine clearance
- Initial Medical Treatment
 - Medical / Prevention

- **DVT prophylaxis**
 - indications
 - most patients
 - contraindications include
 - coagulopathy
 - hemorrhage
 - modalities
 - low-molecular weight heparin
 - rotating bed
 - pneumatic compression stocking
 - **cardiopulmonary management**
 - careful hemodynamic monitoring and stabilization is critical in early treatment
 - hypotension should be avoided
 - implement immediate aggressive pulmonary protocols
 - **decubitus ulcer prevention**
- Steroids
 - high dose methylprednisone
 - indications
 - current indications
 - current literature and available guidelines recommend against administration due to
 - lack of clear clinical benefit
 - risk of complications
 - historical indications
 - nonpenetrating SCI within 8 hours of injury recommended by NASCIS III
 - historical contraindications include
 - GSW
 - pregnancy
 - under 13 years
 - > 8 hours after injury
 - brachial plexus injuries (peripheral nerve injuries)
 - technique
 - load 30 mg/kg over 1st hour (2 grams for 70kg man)
 - drip 5.4 mg/kg/hr drip
 - for 23 hours if started < 3 hrs after injury
 - for 47 hours if started 3-8 hours after injury
 - outcomes

- may leads to improved root function at level of injury
 - associated with significant complications
- monosialotetrahexosylganglioside (GM-1)
 - indications
 - remains controversial
 - large multicenter RCT did not show long term benefit
 - some evidence of faster recovery
- Reduction
 - **acute closed reduction with axial traction**
 - indications
 - alert and oriented patient with neurologic deficits and compression due to fracture/dislocation
 - bilateral facet dislocation with spinal cord injury in alert and oriented patient is most common reason to perform acute reduction with axial traction
 - technique
 - reasons to abort
 - overdistracton
 - worsening neurologic exam
 - failure to obtain reduction
- Hypothermia
 - systemic and local
 - evidence is weak and limited
 - currently not recommended due to increased complications
 - coagulopathy
 - sepsis
 - pneumonia
 - rebound hypertension
 - arrhythmias

• Definitive Treatment

- Nonoperative
 - **bracing and observation**
 - indications
 - most GSWs
 - exceptions listed below
- Operative
 - **surgical decompression and stabilization**

- indications
 - most incomplete SCI (except GSW)
 - decompress when patient hits neurologic plateau or if worsening neurologically
 - decompression may facilitate nerve root function return at level of injury (may recover 1-2 levels)
 - most complete SCI (except GSW)
 - stabilize spine to facilitate rehab and minimize need for halo or orthosis
 - decompression may facilitate nerve root function return at level of injury (may recover 1-2 levels)
 - consider for tendon transfers
 - e.g. Deltoid to triceps transfer for C5 or C6 SCI
 - GSW with
 - progressive neurological deterioration with retained bullet within the spinal canal
 - cauda equina syndrome (considered a peripheral nerve)
 - retained bullet fragment within the thecal sac
 - CSF leads to the breakdown of lead products that may lead to lead poisoning

- Rehabilitation

- Goals
 - goal is to assess and identify mechanisms for reintegration into community based on functional level and daily needs
 - patients learn transfer techniques, self care retraining, mobility skills
- Restoring hand function
 - hand function is often limiting factor for many patients
 - tendon transfers can be used to restore function to paralyzed arms and hands by giving working muscles different jobs
- Modalities
 - functional electrical stimulation is a technique that uses electrical currents to stimulate and activate muscles affected by paralysis

○

■ Spinal cord injury level and Function		
■ <i>Level</i>	■ <i>Patient Function</i>	■
■ C1-C3	■ Ventilator-dependent with limited talking. ■ Electric wheelchair with head or chin control	■
■ C3-C4	■ Initially ventilator-dependent, but can become independent ■ Electric wheelchair with head or chin control	■
■ C5	■ Ventilator independent ■ Has biceps, deltoid, and can flex elbow, but lacks wrist extension and supination needed to feed oneself ■ Independent ADL's; electric wheelchair with hand control , minimal manual wheelchair function	■
■ C6	■ C6 has much better function than C5 due to ability to bring the hand to mouth and feed oneself (wrist extension and supination intact) ■ Independent living; manual wheelchair with sliding board transfers , can drive a car with manual controls	■
■ C7	■ Improved triceps strength ■ Daily use of a manual wheelchair with independent transfers	■
■ C8-T1	■ Improved hand and finger strength and dexterity ■ Fully independent transfers	■
■ T2-T6	■ Normal UE function ■ Improved trunk control ■ Wheelchair-dependent	■
■ T7-T12	■ Increased abdominal muscle control ■ Able to perform unsupported seated activities; with extensive bracing walking may be possible	■
■ L1-L5	■ Variable LE and B/B function ■ Assist devices and bracing may be needed	■
■ S1-S5	■ Various return of B/B and sexual function ■ Walking with minimal or no assistance	■

● Prognosis

○ Complete Injuries

- improvement of one nerve root level can be expected in 80% of patients
- improvement of two nerve root levels can be expected in 20% of patients
- only 1% have complete recovery at time of hospital diagnosis
- ASIA A injuries have the least chance for marked recovery and the highest lifetime healthcare costs

○ Incomplete Injuries

- trends of improvement include
 - the greater the sparring, the greater the recovery

- patients that show more rapid recovery have a better prognosis
 - when recovery plateaus, it rarely resumes improvement
- Conus medullaris syndrome
 - has a better prognosis for recovery than more proximal lesions

• Complications

- Skin problems
 - treatment is prevention
 - start in ER
 - do not leave on back board
 - start log rolling early
 - proper bedding
- Venous Thromboembolism
 - prevent with immediate DVT prophylaxis
- Urosepsis
 - common cause of death
 - strict aseptic technique when placing catheter
 - don't let bladder become overly distended
- Sinus bradycardia
 - most common cardiac arrhythmia in acute stage following SCI
- Orthostatic hypotension
 - occurs as a result of lack of sympathetic tone
- Autonomic dysreflexia
 - potentially fatal
 - presents with headache, agitation, hypertension
 - caused by unchecked visceral stimulation
 - check foley
 - disimpact patient
 - radiographs of lower extremity if there is concern for undiagnosed fracture
- Major depressive disorder
 - ~11% of patients with spinal cord injuries suffer from MDD
 - MDD in spinal cord injury patients is highly associated with suicidal ideation in both the acute and chronic phase.

• Prognosis

- Only 1% have complete recovery at time of hospital diagnosis

- conus medullaris syndrome has a better prognosis for recovery than more proximal lesions

11- Pediatric Cervical Trauma Overview

Images



- Epidemiology
 - Incidence
 - pediatric cervical spine injuries are uncommon
 - account for 60% of spinal injuries in the pediatric population
 - 3% of pediatric patients with cervical spine injury will present with neurologic deficits
 - Anatomic location
 - at or above C3
 - 87% of injuries at C3 or above in children < 8 years
 - below C3
 - after 8 years of age, lower cervical injuries are more common (adult injury patterns)
- Etiology
 - Pathophysiology
 - mechanism
 - motor vehicle accidents

- are most common mechanism
 - airbags should be turned off in children riding in the front passenger seat and weighing less than 80lbs
- falls
 - may be cause of injury in toddlers and school aged patients
- sports related injuries
 - may lead to cervical trauma in adolescents
- pathoanatomy
 - in patients below 8 years of age the cervical spine is more susceptible to injury due to
 - larger head size relative to the trunk
 - increased physiologic motion due to
 - horizontally oriented facet joints
 - elevated ligamentous laxity
 - weaker muscles
- Associated conditions
 - neurologic injury
 - 33% of patients will present with neurologic deficits
 - solid organ involvement
 - other organs may be involved in ~40% of patients with spinal trauma

• Anatomy

- Normal physiologic motion
 - the pediatric spinal column can stretch up to 5 cm without rupture
 - increased physiologic motion due to
 - horizontally oriented facet joints
 - elevated ligamentous laxity

• Presentation

- Physical exam
 - complete exam
 - is critical secondary to high incidence of associated injuries
 - always suspect cervical spine injuries when patients present with head trauma and facial fractures
 - careful neurologic exam
 - need to document sensation (including sacral sparing), motor function and presence of reflexes

- repeat exams are warranted considering that 20% of patients with spinal fractures may have normal examinations
- examinations can be difficult in unconscious patients

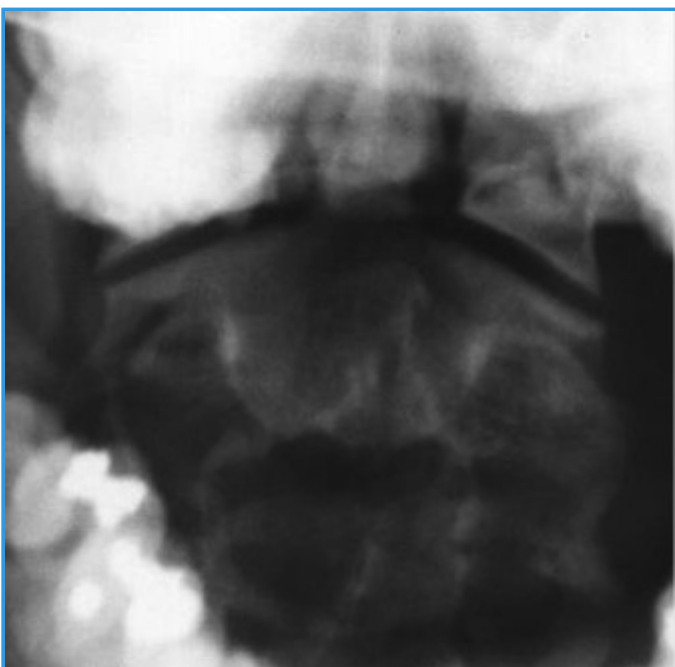
- Imaging

- Radiographs

- overview
 - pediatric cervical spine imaging interpretation complicated by
 - hypermobility
 - unique vertebral configurations
 - incomplete ossification
 - presence of apophyses
 - radiographic findings that could be considered abnormal in an adult, may be normal in a pediatric patient
 - mandatory trauma radiographs include
 - AP



- odontoid open mouth



- cross table lateral



- normal findings include
 - prevertebral swelling $< 2/3$ of adjacent vertebral width
 - smooth contour lines of
 - anterior vertebral bodies
 - posterior vertebral bodies
 - spinolaminar line (inside lamina)
 - tips of spinous process
 - parallel facet joints
 - normal retropharyngeal space
 - < 6 mm at C2
 - < 22 mm at C6
 - retrotracheal space < 14 mm
 - atlanto-dens interval < 5 mm in children and < 3 mm adolescents
 - absent vertebral body wedging
 - 7% of normal children have a wedge shaped C3 vertebral body
 - absence of cervical lordosis
 - loss of cervical lordosis may be found in 14% of normal children
 - C2-3 or C3-4 pseudosubluxation < 4 mm
 - considered normal as long as the posterior laminar line is contiguous
- additional xrays (optional)
 - oblique
 - can help visualize facet disruption
 - flexion-extension

- problematic and should only be performed under physician supervision
- CT scan
 - useful to identify
 - fractures of upper cervical spine
 - atlantoaxial rotatory subluxation
 - can help to assess the degree of spinal canal compromise
- MRI
 - indications
 - useful in obtunded patients or patients with closed head injuries
 - findings
 - can help to assess the degree of spinal canal compromise
- Treatment
 - Nonoperative
 - **initial Immobilization**
 - indications
 - all pediatric cervical spine trauma
 - modalities
 - on pediatric spine board with head "cutout" to compensate for large head size
 - commercial collars often do not fit properly, may use sandbags
 - using an adult backboard for pediatric patients creates a dangerous level of cervical flexion
 - transporting patients less than 8 years of age requires a spine board with occipital depression or enough thoracic elevation to align the cervical and thoracic segments of the spine
 - **observation**
 - indications
 - pseudosubluxation C2-3
 - **collar immobilization**
 - some common indications include
 - stable odontoid fractures
 - atlantoaxial instability
 - acute atlantoaxial rotatory displacement (AARD)
 - stable subaxial cervical spine trauma
 - modalities
 - rigid collar vs. soft collar (depends on injury, often controversial)

- **halo immobilization**

- some common indications include
 - unstable odontoid fractures
 - occipitocervical instability
 - atlantoaxial instability
 - subacute atlantoaxial rotatory displacement (AARD)
 - C1 fractures (Jefferson fractures)
 - unstable subaxial cervical spine trauma

- **surgical stabilization**

- some common indications
 - unstable cervical spine with spinal cord injury
 - atlantoaxial instability
 - chronic atlantoaxial rotatory displacement (AARD)

- **Prognosis**

- Mortality

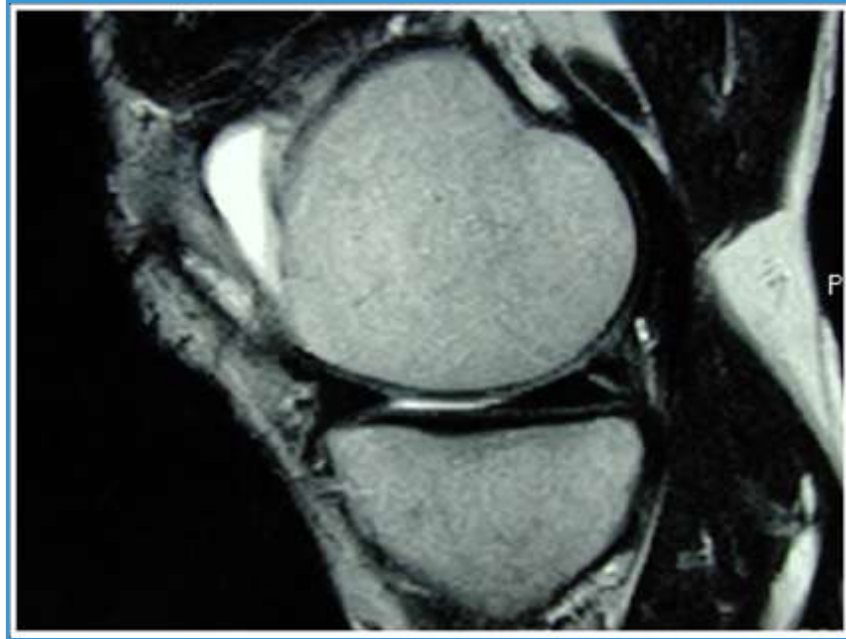
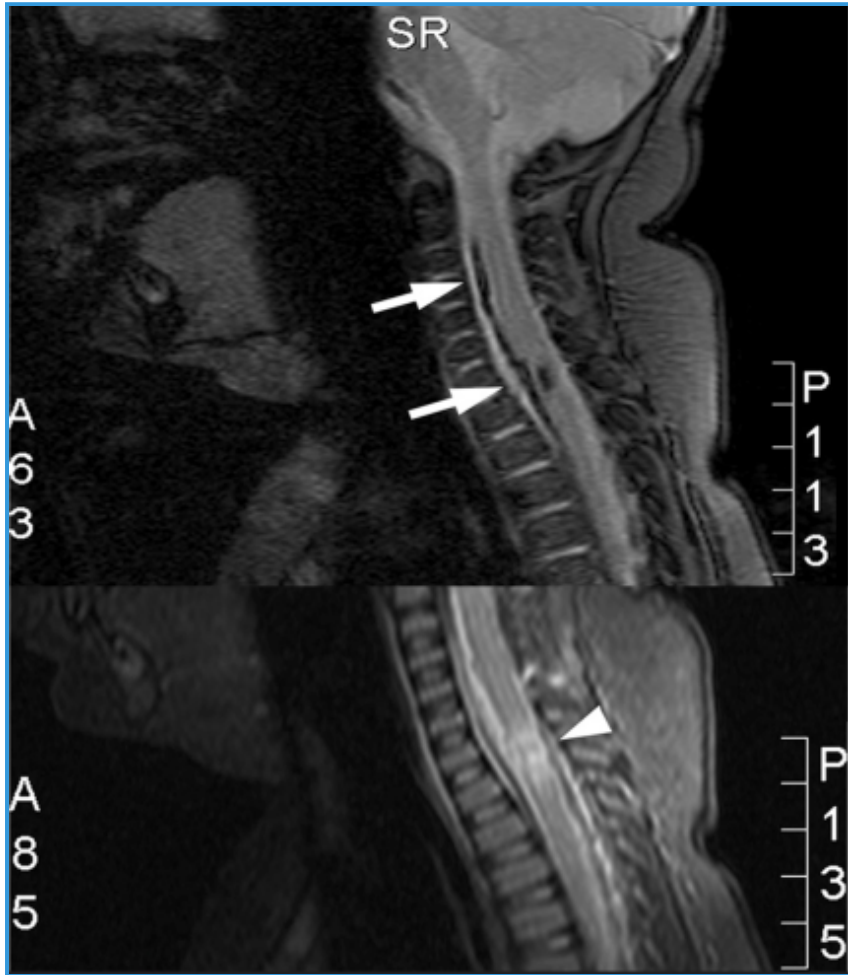
- higher mortality rate at C3 or above
 - injuries at C1 lead to a mortality rate of 17%
 - injuries at C4 lead to a mortality rate of ~4%

- Neurologic injury

- spinal cord injury is more common/lethal in patients younger than 8 years old
- prognosis for recovery is better than patients older than 8 years old

12- Pediatric Spinal Cord Injury

Images



- Epidemiology

- Incidence
 - 2-5% of all spinal cord injuries
 - 83% involve the cervical spine
- Demographics
 - male:female ratio of approx.1.5:1
 - cervical spine injuries more common in children aged <8 years due to large head-to-body ratio
 - thoracolumbar spine injuries more common in children aged >8 years
- Anatomic location
 - upper cervical spine injuries (C1-4) are more common than lower cervical spine injuries (C5-7)

- Etiology

- Pathophysiology
 - mechanism of injury includes:
 - motor vehicle accidents (most common)
 - falls from height
 - sport-related injuries

- child abuse
 - sledding and ATV (high risk for thoracolumbar spine injury)
- Orthopedic considerations
 - pattern of injury
 - cervical spine
 - occipitoatlantal, atlantoaxial dislocation
 - atlantoaxial rotatory fixation
 - odontoid fracture
 - subaxial ligamentous injuries
 - spinal cord injury without radiographic abnormality (SCIWORA)
 - thoracolumbar spine
 - compression fracture (most common)
 - burst fracture
 - flexion-distraction injury
 - combined fracture-dislocation
- Associated conditions
 - head injuries (>30%)
 - intra-thoracic injuries
 - intra-abdominal injuries

• Anatomy

- Spinal Cord
 - spinal cord ends at L3 in the newborn
 - migrates cephalad during childhood to end at L1 - L2
 - reaches adult size by the age of 10
- Osteology
 - vertebral bodies undergo chondrification around the 5th or 6th week gestation
 - ossification occurs throughout adolescents
 - deforming forces are commonly translated through the relatively weak physeal cartilage of maturing vertebral bodies
- Biomechanics
 - greater flexibility of the pediatric spinal column compared to adults is due to:
 - increased ligamentous laxity of the spine
 - immature supporting structures
 - thoracolumbar facets are more shallow and horizontal

- the nucleus pulposus has greater water content and less collagen crosslinking, which allows for a greater ability to dissipate force

- Classification

- Pediatric Glasgow Coma Scale

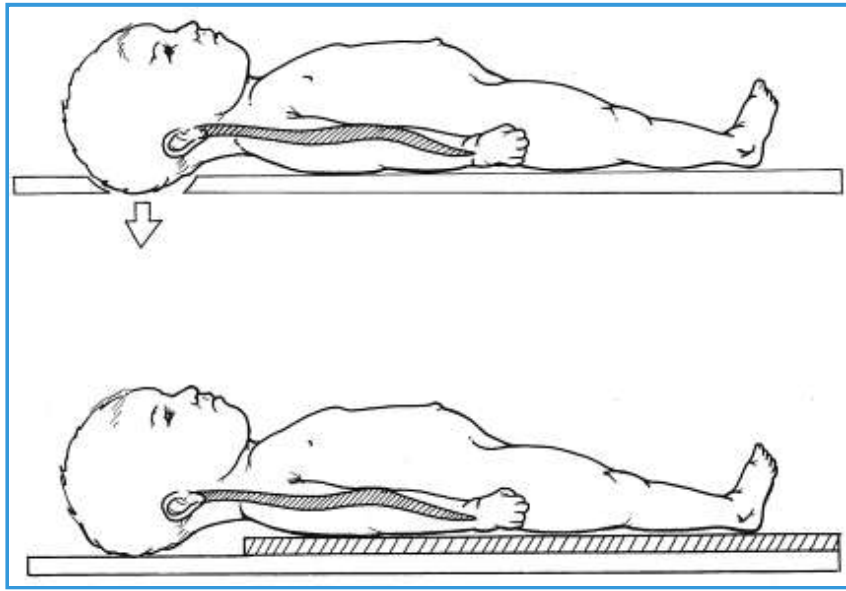
- Best Motor Response
 - 6 - Normal spontaneous movement
 - 5 - Withdrawals to touch
 - 4 - Withdrawals to pain
 - 3 - Flexion is abnormal
 - 2 - Extension, either spontaneous or to painful stimulus
 - 1 - None (flaccid)
 - Best Verbal Response
 - 5 - Smiles, oriented to sound, follows objects, interacts
 - 4 - Cries but is consolable, inappropriate interactions
 - 3 - Inconsistently consolable, moaning
 - 2 - Inconsolable, agitated
 - 1 - No vocal response
 - Best Eye Opening
 - 4 - Spontaneously
 - 3 - To verbal stimulation or to touch
 - 2 - To pain
 - 1 - No response

- Evaluation

- Primary survey

- formation of a multi-disciplinary pediatric trauma team
 - assessment as per Advanced Trauma and Life Support(ATLS) protocol for children
 - Airway
 - Breathing
 - Cardiovascular support
 - use of the Broselow pediatric emergency tape may be used for estimating children's weight in the pediatric patient during trauma resuscitation
 - Disability
 - spinal precautions with cervical spine immobilization and log-roll procedures should be performed

- pediatric spine board or an adult spine board with a torso pad/head cut out should be used to prevent flexion of the cervical spine



- evaluate neurologic response using the Pediatric Glasgow Coma Scale

- Exposure

○ Secondary survey

- trauma specific history
 - mechanism of injury, last meal, PMHx, Allergies, medications
- full neurological examination
 - motor and sensory examination by myotome and dermatome, respectively
 - rectal and genital examination
 - bulbocavernosus reflex, when appropriate
- physical examination
 - inspection and palpation of the entire spine and paraspinous region
 - note step-offs, crepitus, bruising, pain, or open injuries
 - head-to-toe assessment for associated injuries

• Imaging

○ Radiographs

- recommended views
 - AP and cross table lateral views of the C-T-L spine
- additional views
 - swimmer's view
 - open-mouth view
 - AP view of chest and pelvis
 - flexion-extension views
- findings
 - malalignment
 - fracture
 - relatively high chance of multilevel spinal involvement

- dislocation
- CT
 - indications
 - poly-trauma
 - high energy injuries
 - high clinical suspicion of spine injury
 - altered mental status
 - head and facial injuries
 - findings
 - risk of radiation overexposure in young children
 - not to be used as a spine screening examination
- MRI
 - indications
 - neurological deficits without radiographic abnormalities
 - limits ionizing radiation exposure
 - findings
 - spinal cord injury
 - soft-tissue edema
 - inferior to CT for evaluating osseous anatomy

- Treatment

- Nonoperative
 - **pain control and activity as tolerated**
 - indications
 - stable fracture patterns
 - apophyseal fractures
 - spinous process fractures
 - transverse process fractures
 - **activity modification and spinal immobilization**
 - indications
 - cervical collar immobilization (8 to 12 weeks)
 - fracture patterns
 - stable odontoid fractures
 - atlantoaxial instability
 - acute atlantoaxial rotatory displacement (AARD)
 - stable subaxial cervical spine trauma
 - thoracolumbosacral braces (8 to 12 weeks)
 - fracture patterns

- compression fractures (<50% anterior height loss)
 - burst fracture (<50% retropulsion, no neurological deficit)
 - purely osseous flexion-distraction fracture
- modalities
 - cervical collar
 - rigid collar vs. soft collar (depends on injury, often controversial)
 - halo collar
 - considered for unstable cervical spine fractures
 - thin calvaria increases risk of skull penetration
- Operative
 - **surgical stabilization of cervical spine**
 - indications
 - occipitocervical instability
 - atlantoaxial instability
 - subaxial instability
 - techniques
 - occipitocervical fusion
 - transarticular screws
 - pedicle screws with rigid loops and plate or rod constructs
 - **surgical stabilization of thoracolumbar spine**
 - indications
 - unstable burst fracture
 - spinal cord compression
 - irreducible fracture-dislocation
 - ligamentous flexion-distraction injury
 - techniques
 - pedicle instrumentation one to two levels above and below injury

- Complications

- Complete neurological deficits
- Progressive spinal deformity
- Poor wound healing with operative treatment
- Cauda equina syndrome

- Prognosis

- Natural history of disease
 - most spinal cord injuries in children are incomplete

- all injuries need to be followed to maturity due to risk of spinal column deformities
- Neurologic injury
 - spinal cord injury is more common/lethal in patients younger than 8 years old
 - prognosis for recovery is better than patients older than 8 years old

13- Atlas Fractures And Transverse Ligament Injuries

- Summary

- Atlas Fractures & Transverse Ligament Injuries are traumatic injuries usually caused by high-energy trauma with axial loading in young patients (Jefferson Fracture) or low-energy falls in elderly. Due to the capacious nature of the spinal canal at this level these injuries usually present with neck pain without neurological deficits.
- Diagnosis is often missed with plain radiographs so a CT scan may be required to make the diagnosis. An open-mouth odontoid radiograph is useful to evaluate for disruption of the transverse ligament which leads to lateral displacement of the lateral masses relative to each other.
- Stable injuries can be treated with immobilization in a cervical collar. Unstable injuries require either halo-vest immobilization or surgical stabilization with a fusion.

- Epidemiology

- Incidence
 - make up ~7% of cervical spine fractures
 - atlas fractures make up to 25% of the injuries of the craniovertebral junction
 - 1-3% of all spinal injuries
 - commonly missed due to inadequate imaging of occipitocervical junction
- Demographics
 - bimodal age distribution
 - early adulthood (20-30s)
 - high-energy axial loading mechanism
 - elderly
 - low-energy, ground-level fall
 - predisposed to injury from
 - osteoarthritic bone changes
 - limited mobility
 - gait imbalance

- ETIOLOGY

- Pathophysiology

- mechanism

- most commonly associated with high-energy injury mechanisms
 - ~85% of cases associated with MVC
 - ground level falls in elderly patients
 - osteoporosis predisposes to low energy fractures
 - injury biomechanics
 - hyperextension
 - forehead blow injury
 - posterior arch remains static
 - anterior arch continues to move
 - posterior arch injury
 - higher occurrence with low-energy falls
 - higher association with odontoid fractures
 - 30% less energy requirement to cause atlas fracture when cervical spine is in extension compared to neutral
 - lateral compression
 - anterior arch fractures
 - lateral distraction
 - comminuted lateral mass fracture
 - axial compression
 - blow to the vertex
 - leads to Jefferson burst fracture

- Associated conditions

- spine fracture
 - 50% have an associated spine injury
 - 40% associated with axis fx
 - closed head injuries
 - neurologic injury
 - risk of neurologic injury is low
 - due to large space for the spinal cord at this level
 - injuries tend to increase the area available for spinal cord at C1

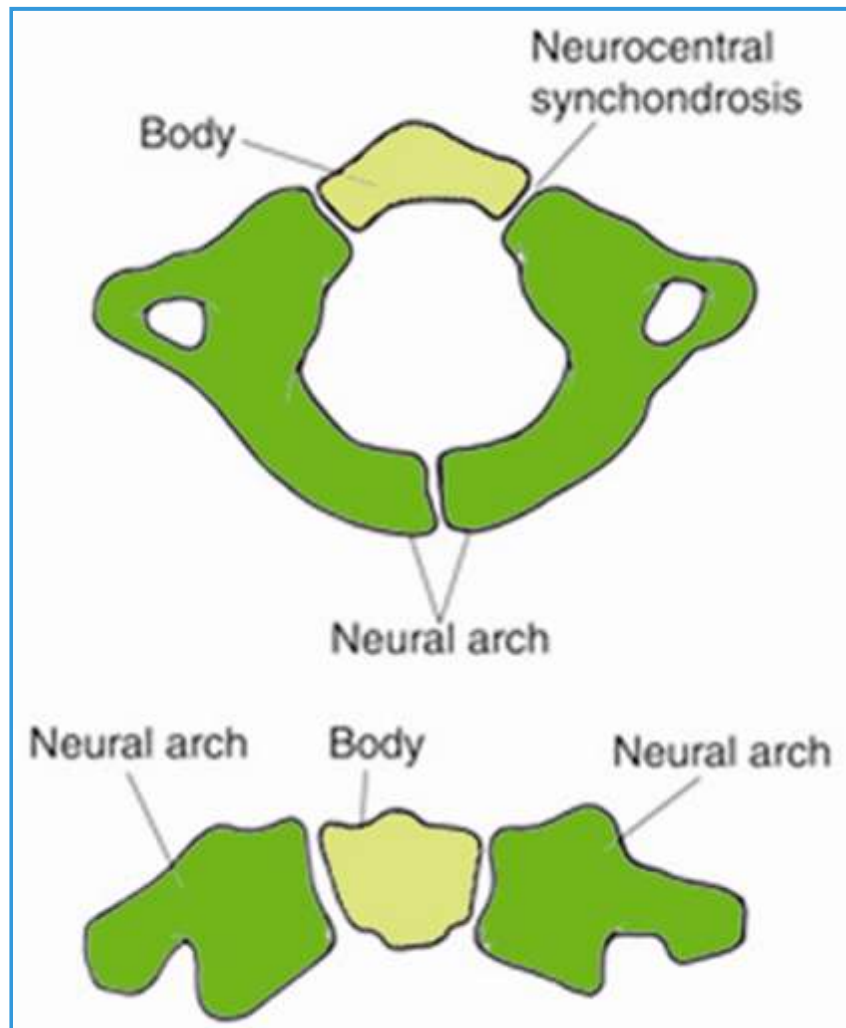
- Anatomy

- Bony anatomy

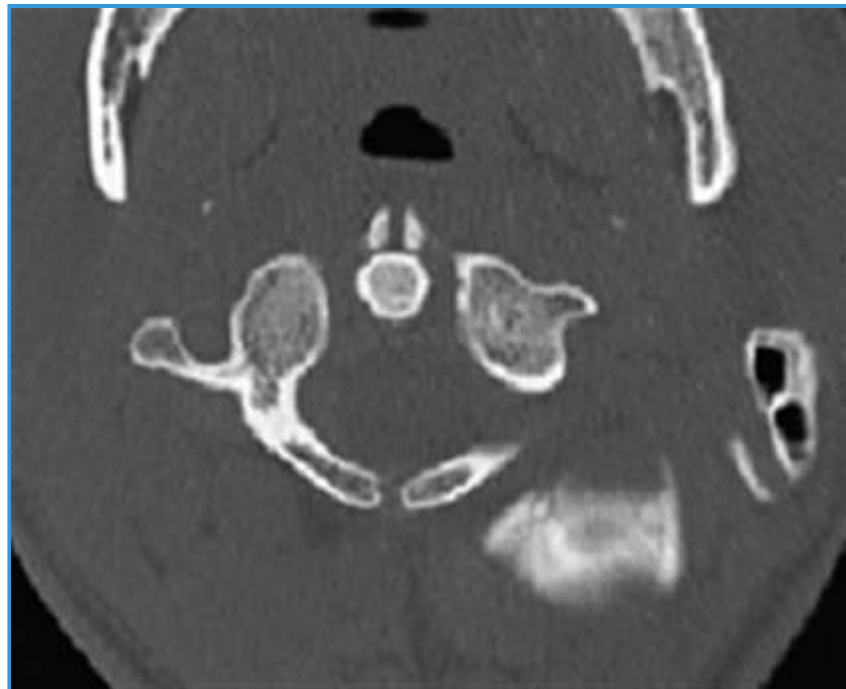
- Atlas osteology

- atlas (C1) is a ring containing two articular lateral masses

- it lacks a vertebral body or a spinous process
- embryology
 - forms from 3 ossification centers



- anatomic variation
 - incomplete formation of the posterior arch is a relatively common anatomic variant and does not represent a traumatic injury

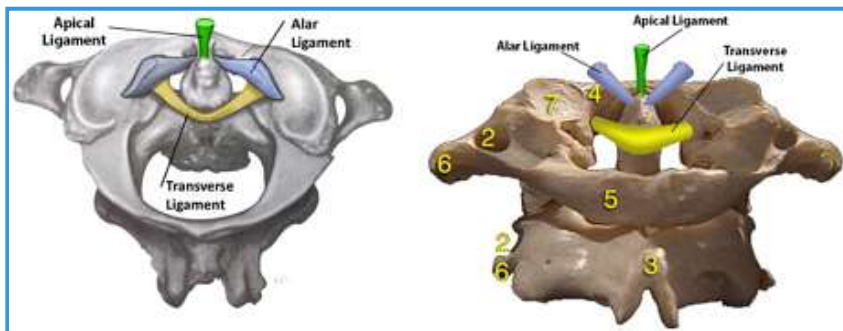


- C1 transverse foramen
 - houses vertebral artery
 - makes acute posteromedial bend around Occ-C1 joint and crosses sulcal groove
 - sulcal groove is a common site for posterior arch injuries/fractures

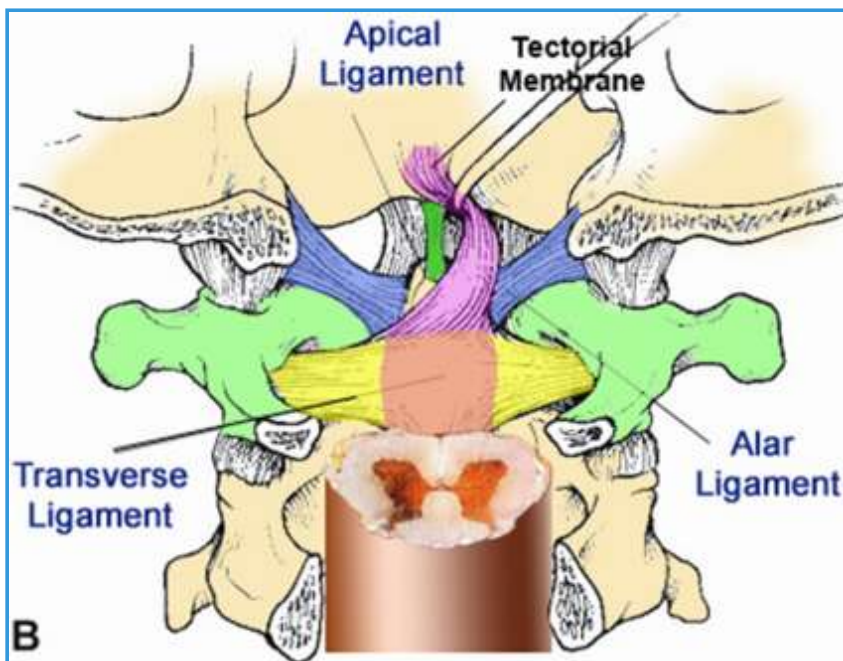
○ Ligamentous anatomy

- occipital-cervical junction and atlantoaxial junction are coupled
- intrinsic ligaments are located within the spinal canal, provide most of the ligamentous stability. They include

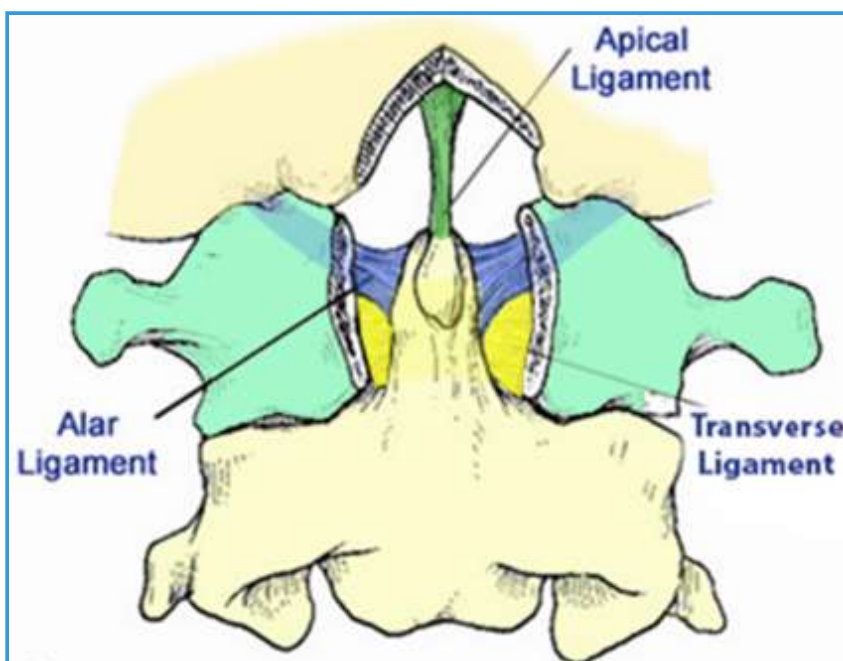
- transverse ligament



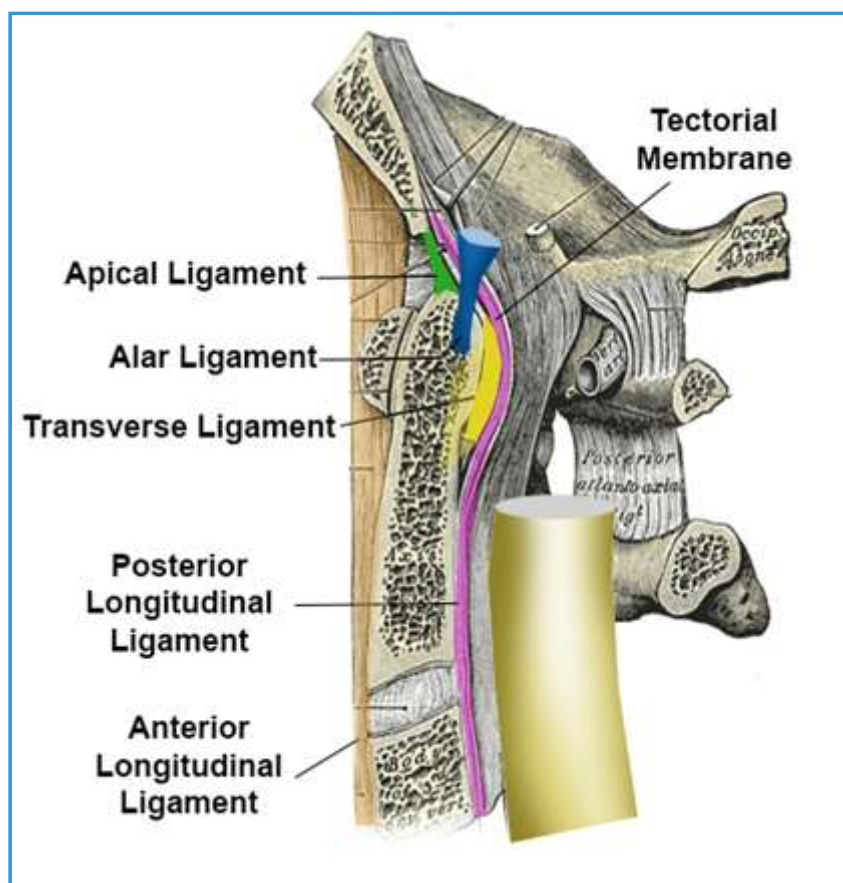
- primary stabilizer of atlantoaxial junction
 - prevents posterior migration of the odontoid into the spinal canal
 - connects the posterior odontoid to the anterior atlas arch, inserting laterally on bony tubercles of the lateral mass
- paired alar ligaments



- connect the odontoid to the occipital condyles
 - relatively strong and contributes to occipitalcervical stability
- apical ligament



- relatively weak midline structure
 - runs vertically between the odontoid and foramen magnum.
- tectorial membrane



- connects the posterior body of the axis to the anterior foramen magnum and is the cephalad continuation of the PLL

○ Articulations

- occipitoatlantal joint (Occ-C1)
 - occipital condyles articulate with C1 superior articular processes
 - provides ~50% of cervical spine flexion and extension range of motion
 - true synovial joint
 - contains anterior and posterior joint capsules
- atlantoaxial joints (C1-2)
 - facet joints
 - articulation between the inferior facet of C1 and superior facet of C2
 - biconcave synovial joint
 - atlantodens joint
 - synovial joint
 - articulation between the dens (C2) and the anterior arch of the atlas
 - enable ~50% of cervical spine rotation

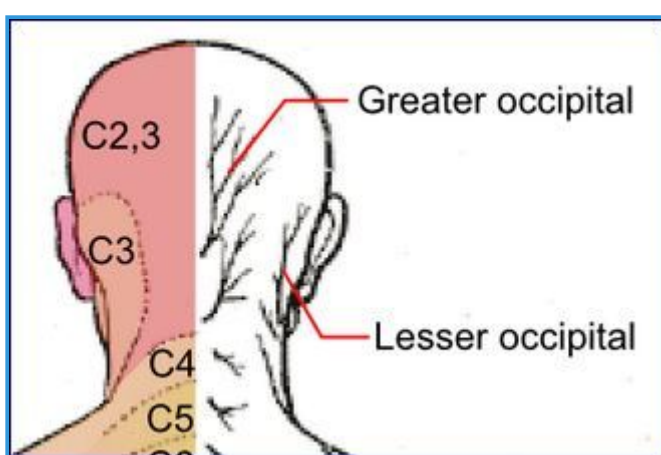
● Classification

Landells Atlas Fractures Classification		
Type 1	- Isolated anterior or posterior arch fracture. - Most common injury pattern "Plough" fracture is an isolated anterior arch fracture caused by a force driving the odontoid through the anterior arch. - Stable injury - Treat with hard collar.	
Type 2	- Jefferson burst fracture with bilateral fractures of anterior and posterior arch resulting from an axial load. - Stability determined by the integrity of transverse ligament. - If intact, treat with a hard collar. - If disrupted, halo vest (for bony avulsion) or C1-2 fusion (for intrasubstance tear) (see Dickman classification below).	
Type 3	- Unilateral lateral mass fx. - Stability determined by the integrity of the transverse ligament. - If stable, treat with a hard collar. - If unstable, halo vest.	
Dickman Transverse Ligament Injuries Classification		
Type 1	- Intrasubstance tear . - Treat with C1-2 fusion.	
Type 2	- Bony avulsion at tubercle on C1 lateral mass . - Treat with halo vest (successful in 75%)	

- Presentation

- History
 - high-energy injury
 - MVC
 - fall from ladder
 - ground level fall
 - elderly patients
- Symptoms

- neck pain
- cervical spinal muscle spasms
- limited neck motion
- C2 neuralgia/palsy
 - occipital neuralgia
 - occipital numbness
 - occipital alopecia (rare)
- vertebral artery dissection
 - loss of consciousness
 - double vision
 - vertigo
- Physical exam
 - neuro deficits uncommon in isolated C1 fractures
 - associated C2 fractures have a higher risk of neuro deficit
 - vertebral artery injury
 - vertigo
 - diplopia
 - blindness
 - ataxia
 - bilateral weakness
 - dysphagia
 - nausea
 - C2 nerve palsy
 - decreased sensation in the occipital region



- neck flexion and extension weakness

• Imaging

- Radiographs

Atlas Fracture & Transverse Ligament Injuries

Stability Depends on Transverse Ligament

- Transverse ligament is injured if
 - ADI > 3mm
 - sum of lateral mass displacement is > 8.1mm

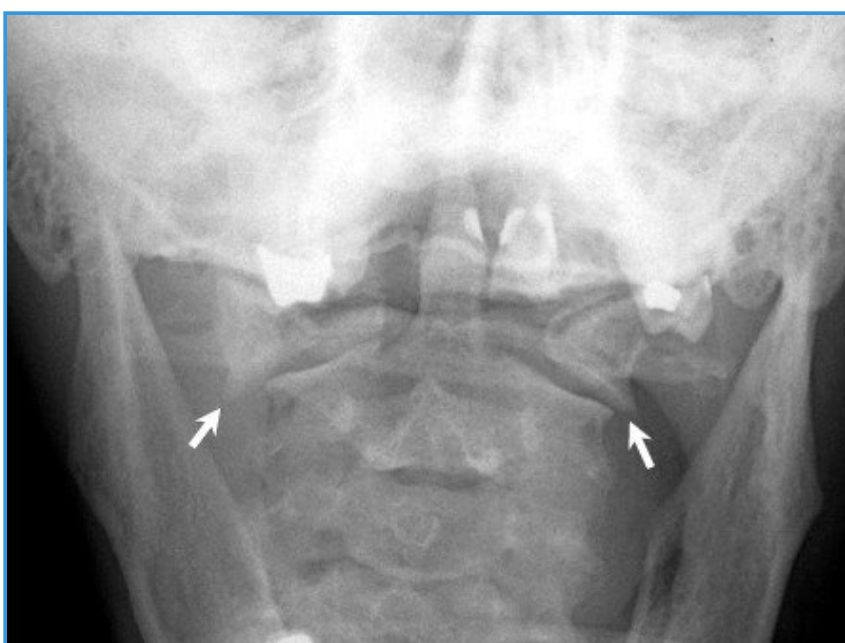
SUPERIOR VIEW OF C1 ON C2

Proper treatment of "unstable" Jefferson fracture remains controversial. 2013 OITE = fusion. Some experts = hard collar

- recommended views
 - lateral radiographs



- oblique radiographs
 - 60-degree oblique radiographs to identify posterior arch fractures
- open-mouth odontoid

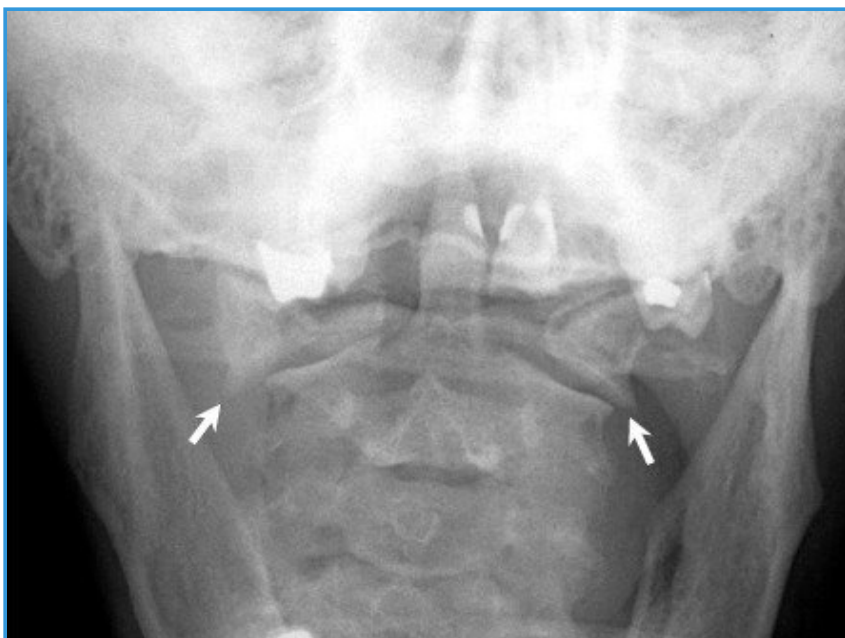


- open-mouth odontoid view important to identify atlas fractures
- optional views
 - flexion-extension views
 - identify late instability following nonoperative treatment
- findings
 - increased widening of C1 lateral masses compared to C2 (LMD)

- increased distance of the atlantodental interval (ADI)
- fracture involving the posterior or anterior arch
- concomitant spine injuries
 - C2 injuries
 - subaxial spine injuries
 - occipitocervical distraction/dissociation
- measurements
 - atlantodens interval (ADI)
 - measured on lateral radiographs and flexion-extension views
 - $< 3 \text{ mm}$ = normal in adult ($< 5 \text{ mm}$ normal in child)
 - $3\text{-}5 \text{ mm}$ = injury to transverse ligament with intact alar and apical ligaments
 - $> 5 \text{ mm}$ = injury to transverse, alar ligament, and tectorial membrane



- sum of lateral mass displacement (LMD)

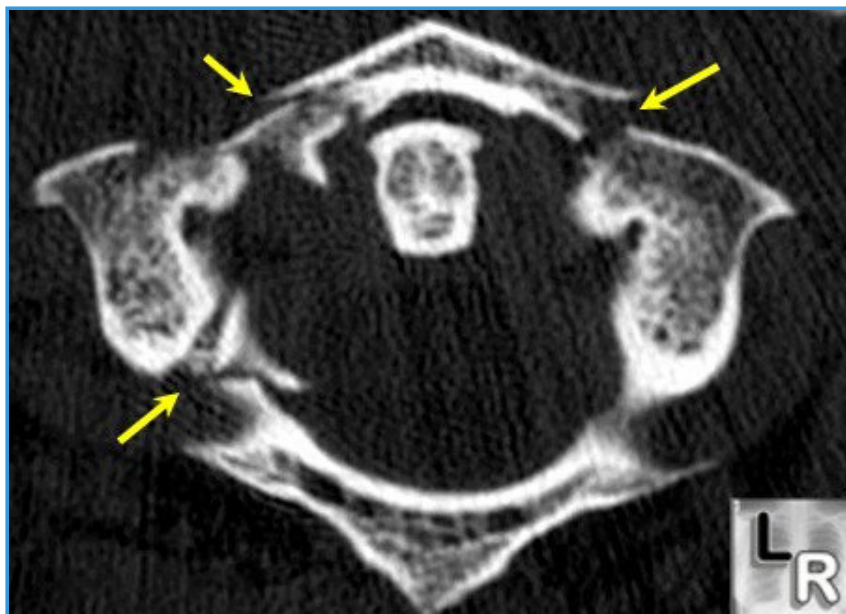


- measured on open-mouth odontoid views
 - if sum of lateral mass displacement is $> 6.9 \text{ mm}$ (rule of Spence) or 8.1 mm with radiographic magnification (rule of Heller) then a transverse ligament rupture is assured and the injury pattern is considered unstable

- retropharyngeal soft tissue
 - measured on lateral radiographs
 - increased thickening of retropharyngeal soft tissue (>9.5 mm) suggests an anterior arch injury
- sensitivity
 - radiographs have a lower sensitivity of detecting unstable atlas fractures than CT and MRI

○ CT

- indications
 - should be ordered for every case of suspected cervical spine injury
 - study of choice to delineate fracture pattern and identify associated injuries in the cervical spine



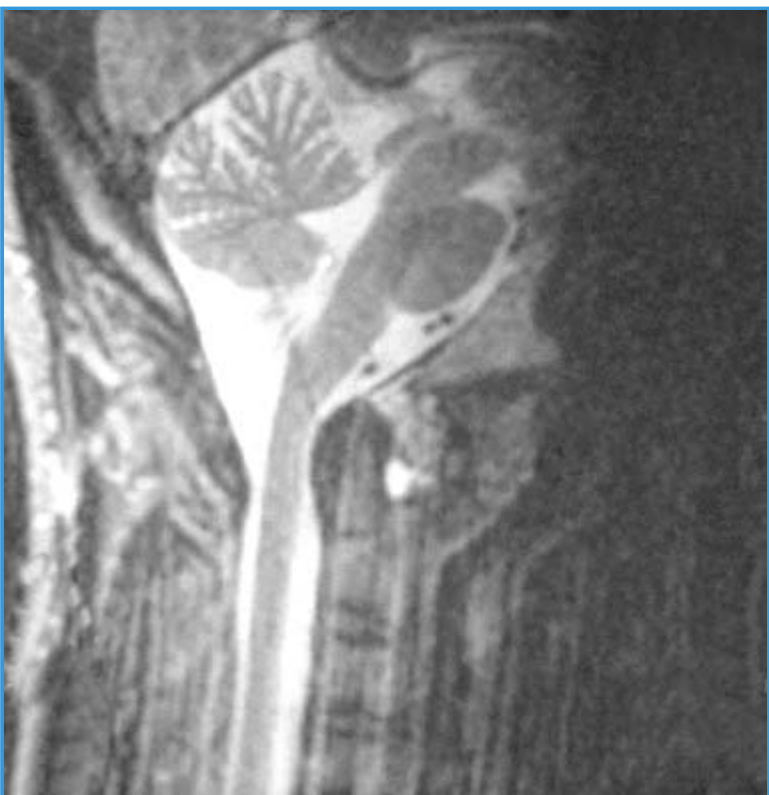
- good study to assess for pseudospread of the atlas in pediatric patients



- thin slices parallel to the C1 arch
 - represents asymmetric growth of the atlas compared to the axis
 - greater atlantal overhang of the lateral masses
- views
 - sagittal reconstructions
 - occult horizontal fractures of the anterior arch
 - axial reconstructions
 - identify Dickman II injuries to the TAL

- coronal reconstructions
 - determine total lateral mass displacement
- angiogram
 - assess the presence of a vertebral artery injury
- findings
 - fractures involving the anterior and posterior ring
 - lateral mass fractures
 - increased radial displacement of the C1 fracture fragments (unstable)
 - bone avulsion injuries of the tubercle (TAL insertion)
 - sagittal split fractures of the lateral mass
- sensitivity
 - highly sensitive at detecting fractures
 - lower sensitivity than MRI at detecting TAL injuries

○ MRI



- indications
 - should be ordered in any case there is a confirmed fracture of the atlas
 - rule out associated unstable ligamentous injuries
- views
 - sagittal and coronal views
 - increased T2 signal in the TAL suggests intrasubstance injury



- findings
 - TAL injuries
 - increased T2 signal intensity in the TAL on the sagittal and coronal views
 - spinal cord injury
 - edema
 - increased T2 signal intensity in the spinal cord
 - hematoma
 - depends on age of injury

Stage	Time	Component	T ₁	T ₂
Hyperacute	<24 h	Oxyhaemoglobin	Hypointense	Hyperintense
Acute	1-3 days	Deoxyhaemoglobin	Isointense	Hypointense
Subacute-early	3-7 days	Intracellular methaemoglobin	Hyperintense	Hypointense
Subacute-late	1-2 weeks	Extracellular methaemoglobin	Hyperintense	Hyperintense
Chronic	>2 weeks	Haemosiderin	Hypointense	Hypointense

- prevertebral soft tissue swelling
 - increased prevertebral soft tissue T2 signal intensity at C1-2
- more sensitive at detecting injury to transverse ligament



- increased T2 signal intensity in the TAL is suggestive of injury

• Treatment

- Nonoperative
 - **hard collar vs. halo immobilization for 6-12 weeks**
 - indications
 - stable Type I fx (intact transverse ligament)
 - stable Jefferson fx (Type II) (intact transverse ligament)
 - stable Type III (intact transverse ligament)
 - Dickman type II TAL injuries
 - technique
 - controversy exists around optimal form of immobilization
 - hard cervical collar
 - typically used in stable fracture patterns with intact transverse ligament
 - halo vest
 - typically used in the transverse ligament is compromised
 - reduce with halo traction before immobilization
 - immobilization for 3 months
 - require post treatment flexion-extension radiographs to assess for late instability
- Operative
 - **posterior C1-C2 fusion vs. occipitocervical fusion**
 - indications
 - unstable Type II (controversial)
 - unstable Type III (controversial)
 - Dickman type I TAL injuries
 - combined C1 and C2 fractures
 - most often type II odontoid and hangman's fractures
 - higher association with neurologic injury
 - some authors prefer Occ-C2 fusion as opposed to C1-2 fusion
 - no significant downside and lower risk of revision surgery
 - technique
 - may consider preoperative traction to reduce displaced lateral masses
 - **C1 internal fixation**
 - indications
 - C1 lateral mass split fractures (controversial)
 - described in a few small case series
 - preserves C1-2 motion
 - technique
 - anterior and posterior techniques described

- transoral approach
- further randomized trials needed to ascertain role of this treatment

• Techniques

○ Posterior C1-C2 fusion

- preserves motion compared to occipitocervical fusion
- fixation
 - C1 lateral mass - C2 pedicle screw construct (Harm's technique)
 - may be sufficient if adequate purchase with C1 lateral mass screws
 - 10° medial screw trajectory protects the internal carotid artery
 - C1-2 transarticular screw placement
 - sublaminar wiring
 - not commonly performed in isolation
 - need intact posterior arch

○ Occipitocervical fusion (C0-C2)

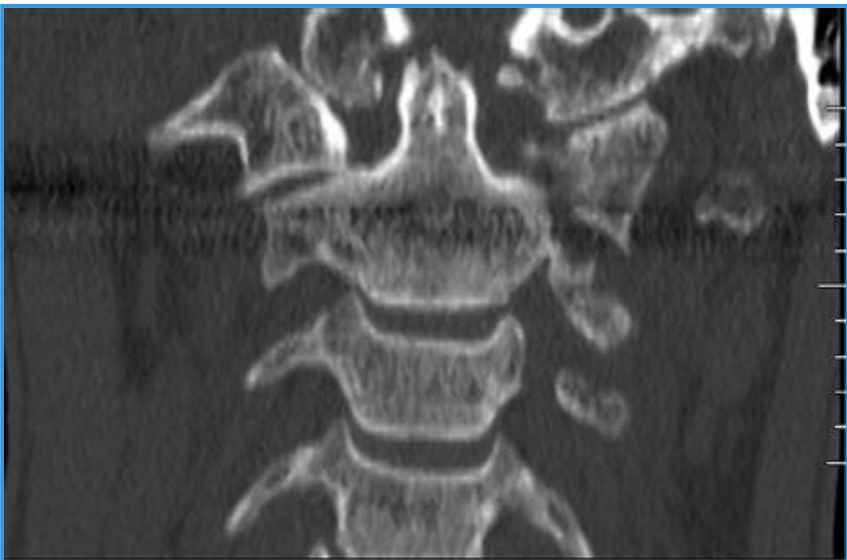
- used when unable to obtain adequate purchase of C1 (comminuted C1 fracture)
- leads to significant loss of motion

		Bifid Spinous Process	Transverse Foramen present/ Vert. Artery within it	Flexion/ Extension	Rotation	Lateral Bend
Occipitocervical	Occiput-C1			50	4	8
	C1 (Atlas)	None	Yes/ Yes	10	50	0
Atlantoaxial	C2 (Axis)	Yes	Yes/ Yes			
	C3	Yes	Yes/ Yes			
Subaxial	C4	Yes	Yes/ Yes			
	C5	Yes	Yes/ Yes	50 (10°level)	50 (10°level)	60 (12°level)
	C6	Yes	Yes/ Yes			
	C7 (VP)	No (95%)	Yes/ No			
Total Motion				110	100	68

- fixation
 - occipital plate
 - C1 lateral mass screws
 - C2 pedicle screws
- C1 internal fixation
 - anterior and posterior approaches described
 - standard posterior approach
 - fixation
 - plate and screw construct
 - screw and rod construct
 - screws alone

- Complications

- Vertebral artery injury
 - rare complication with displaced posterior ring fractures
 - fractures involving the sulcal groove
- Neurologic injury
 - rare in isolated atlas fractures
 - radial displacement of fracture increased the surface area of the spinal canal'
- Cock robin deformity



- displaced unilateral sagittal split lateral mass fracture
 - occipital condyle settles onto the C2 superior articular facet
 - treat with occipitocervical fusion +/- osteotomy to correct the deformity
- Nonunion
 - ~20% of cases treated nonoperatively
- Neck pain
 - present in 20-80% of patients after immobilization
- Delayed C-spine clearance
 - higher rate of complications in patients with delayed C-spine clearance so it is important to clear expeditiously
- Pseudoarthrosis
- Stiffness
 - loss of ~50% of cervical rotation with C1-2 arthrodesis

- loss of ~50% cervical flexion with Occ-C2 arthrodesis
- Infection
 - a complication of surgical treatment
 - higher infection rates in patients treated with posterior approaches
- Prognosis
 - Natural history (conservative treatment)
 - 8-20% complaints of neck stiffness
 - 14-80% complaints of neck pain
 - ~34% complaints of activity limitations
 - contact athletes may not return to play
 - Prognostic variables
 - stability dependent on degree of injury and healing potential of transverse ligament
 - worse long-term patient reported outcomes in fractures with >7 mm of displacement

14- Odontoid Fracture

- Summary

- Odontoid Fractures are relatively common fractures of the C2 (axis) dens that can be seen in low energy falls in elderly patients and high energy traumatic injuries in younger patients.
- Diagnosis can be made with standard lateral and open-mouth odontoid radiographs. Some fractures may be difficult to visualize on Xrays and require a CT scan to diagnose. MRI is rarely indicated as these fractures are usually not associated with neurologic symptoms.
- Treatment may be nonoperative or operative depending on the Anderson and D'Alonzo type and risk factors for nonunion. Patient older than 80 have a high morbidity and mortality regardless of nonoperative or operative treatment.

- Epidemiology

- Incidence
 - most common fracture of the axis
 - account for 10-15% of all cervical fractures
 - most common cervical spine fractures in the elderly
- Demographics
 - occur in bimodal fashion in elderly and young patients
 - elderly
 - common, often missed, and caused by simple falls
 - associated with increased morbidity and mortality compared to younger patients with this injury
 - young patients
 - result from blunt trauma to head leading to cervical hyperflexion or hyperextension
 - children
 - rare and almost occur at site of basilar synchondrosis

- Etiology

- Pathophysiology

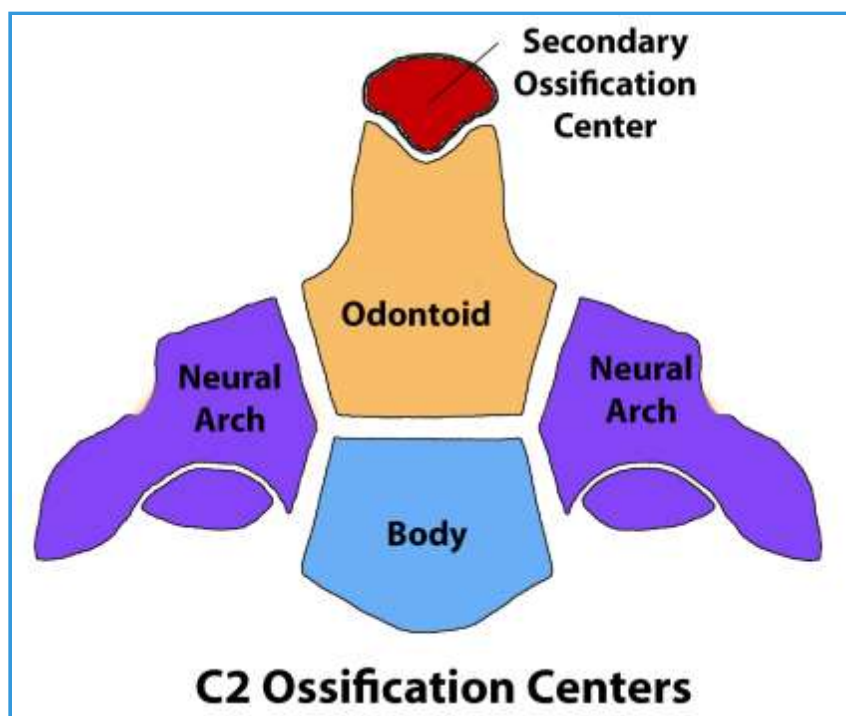
- mechanism
 - displacement may be anterior (hyperflexion) or posterior (hyperextension)
 - anterior displacement
 - is associated with transverse ligament failure and atlanto-axial instability
 - posterior displacement
 - caused by direct impact from the anterior arch of atlas during hyperextension
 - biomechanics
 - a fracture through the base of the odontoid process severely compromises the stability of the upper cervical spine.
- Associated conditions
 - Os odontoideum



- etiology
 - previously thought to be due to failure of fusion at the base of the odontoid
 - evidence now suggests it may represent the residuals of an old traumatic process
- imaging
 - appears like a type II odontoid fx on xray
- treatment
 - observation

• Anatomy

- Osteology
 - axis has odontoid process (dens) and body
 - contains a transverse foramen which vertebral artery travels through
 - embryology
 - develops from five ossification centers



- subdental (basilar) synchondrosis
 - is an initial cartilaginous junction between the dens and vertebral body that does not fuse until ~6 years of age
- secondary ossification center
 - appears at ~ age 3 and fuses to the dens at ~ age 12

○ Arthrology

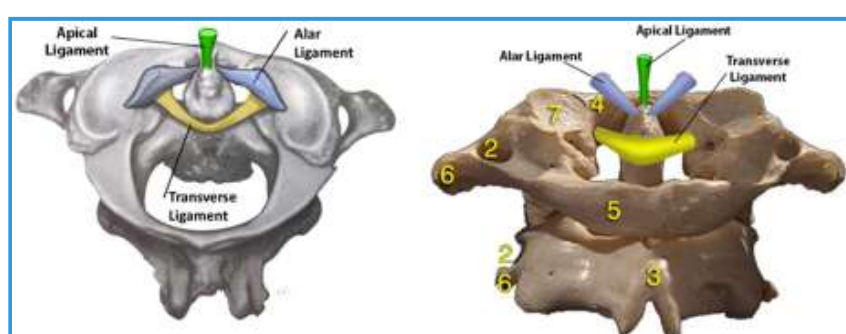
- C1-Dens
 - anterior dens articulates with anterior arch of C1
- C1-C2 articulation
 - is a diarthrodial joint

	Bifid Spinous Process	Transverse Foramen present/ Vert. Artery within it	Flexion/ Extension	Rotation	Lateral Bend
Occipitocervical					
Occiput-C1			50	4	8
Atlantoaxial					
C1 (Atlas)	None	Yes / Yes	10	50	0
C2 (Axis)	Yes	Yes / Yes			
Subaxial					
C3	Yes	Yes / Yes			
C4	Yes	Yes / Yes			
C5	Yes	Yes / Yes	50 (10/level)	50 (10/level)	60 (12/level)
C6	Yes	Yes / Yes			
C7 (VP)	No (95%)	Yes / No			
Total Motion			110	100	68

- C2-3 joint
 - participates in subaxial (C2-C7) cervical motion

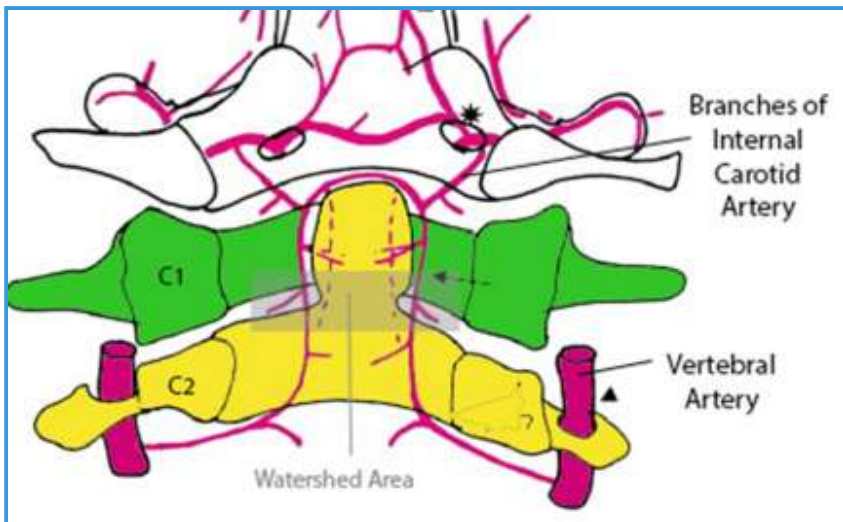
○ Ligaments

- occipital-C1-C2 ligamentous stability
- provided by the odontoid process and its supporting ligaments
 - transverse ligament



- primary stabilizer of atlantoaxial joint
- limits anterior translation of the atlas

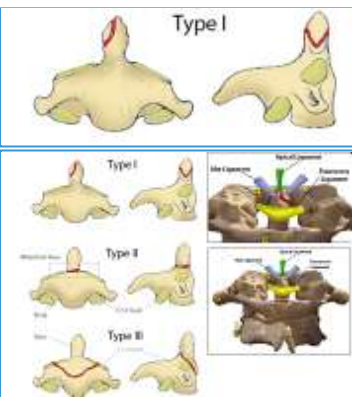
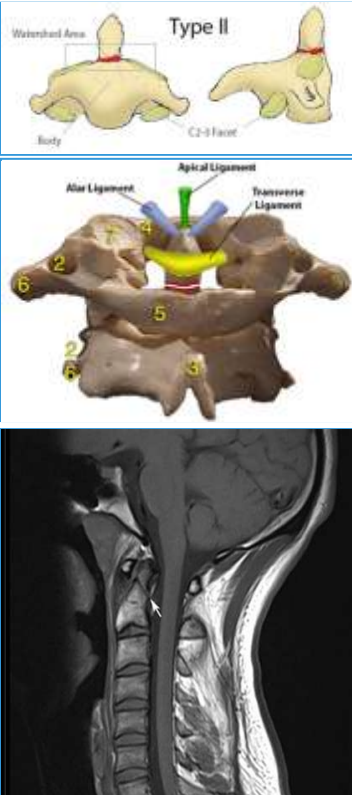
- apical ligaments
 - limit rotation of the upper cervical spine
- alar ligaments
 - limit rotation of the upper cervical spine
- Blood Supply
 - a vascular watershed exists between the apex and the base of the odontoid

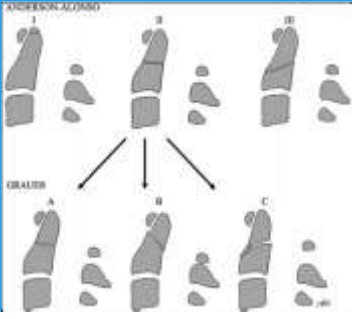
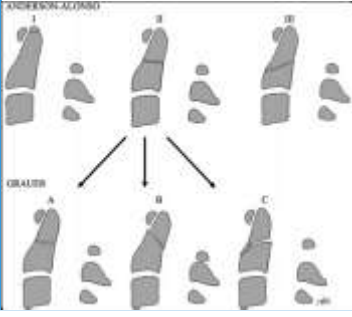
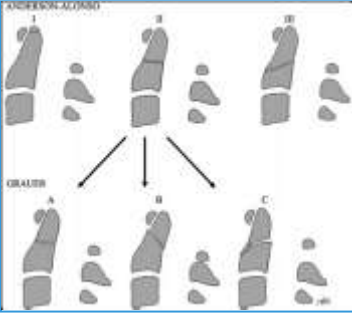


- apex
 - supplied by branches of internal carotid artery
- base
 - supplied from branches of vertebral artery
- the limited blood supply in this watershed area is thought to affect healing of type II odontoid fractures.
- Kinematics

○ ■ Normal Cervical Kinematics			
■	■ Flexion/Extension	■ Rotation	■ Lateral Bend
■ Occipitocervical joint (OC)	■ 50	■ 4	■ 8
■ Atlantoaxial joint (C1-2)	■ 10	■ 50	■ 0
■ Subaxial Spine (C3-7)	■ 50	■ 50	■ 60
■ Total Motion (degrees)	■ 110	■ 100	■ 68

• Classification

○ ■ Anderson and D'Alonzo Classification		
■ Type I	■ Oblique avulsion fx of tip of odontoid. Due to avulsion of alar ligament. Although rare, atlantooccipital instability should be ruled out with flexion and extension films.	■ 
■ Type II	■ Fracture through waist (high nonunion rate due to interruption of blood supply).	■ 
■ Type III	■ Fx extends into cancellous body of C2 and involves a variable portion of the C1-C2 joint.	■ 

■ Grauer Classification of Type II Odontoid fractures		
■ Type IIA	■ Nondisplaced/minimally displaced with no comminution. Treatment is external immobilization	■ 
■ Type IIB	■ Displaced fracture with fracture line from anterosuperior to posteroinferior. Treatment is with anterior odontoid screw (if adequate bone density).	■ 
■ Type IIC	■ Fracture from anteroinferior to posterosuperior, or with significant comminution. Treatment is with posterior stabilization.	■ 

• Presentation

- Symptoms
 - neck pain
 - worse with motion, especially rotation
 - dysphagia
 - may be present when associated with a large retropharyngeal hematoma
- Physical exam
 - neurologic deficits
 - very rare due to large cross-section area of spinal canal at this level

• Imaging

- Radiographs
 - required views
 - AP, lateral, open-mouth odontoid view of cervical spine
 - optional views
 - flexion-extension radiographs are important to diagnose occipitocervical instability in Type I fractures and Os odontoideum
 - instability defined as
 - atlanto-dens-interval (ADI)
 - > 10mm
 - space available for cord (SAC)
 - < 13mm
 - findings

- fx pattern best seen on open-mouth odontoid

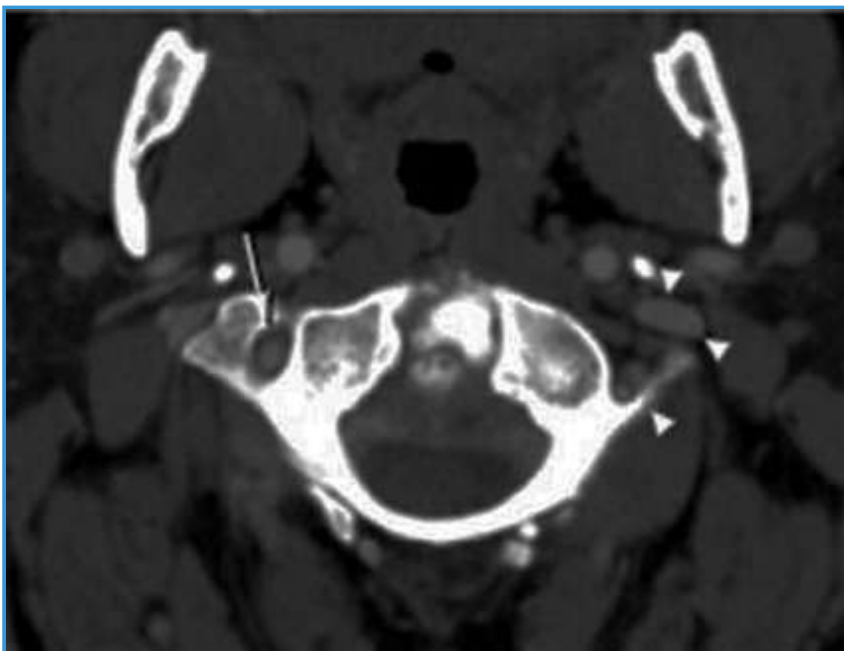


- CT

- study of choice for fracture delineation and to assess stability of fracture pattern

- CT angiogram

- required to determine location of vertebral artery prior to posterior instrumentation procedures



- MRI

- indicated if neurologic symptoms present



- Treatment

○ ■ Treatment Overview Table	
■ Type I	■ Collar
■ Type II (age < 40)	■ Halo Vest
■ Type II (40-80)	■ Surgery
■ Type II (> 80 years)	■ Collar
■ Type III	■ Collar

○ Nonoperative

■ **observation alone**

■ indications

■ Os odontoideum

- assuming no neurologic symptoms or instability

■ **hard cervical orthosis**

■ indications

■ Type I

■ Type II in elderly who are not surgical candidates

- union is unlikely, however a fibrous union should provide sufficient stability except in the case of major trauma

■ Type III

- no evidence to support Halo over hard collar

■ technique

- typically worn for 6-12 weeks

■ **halo immobilization**

■ indications

■ Type II young patient with no risk factors for nonunion

■ contraindications

■ elderly patients

- do not tolerate halo (may lead to aspiration, pneumonia, and death)

■ technique

- typically work for 6-12 weeks

○ Operative

■ **posterior C1-C2 fusion**

■ indications

■ Type II fractures with risk factors for nonunion

- indicated in patient 50-80

■ Type II/III fracture nonunions

- Os odontoideum with neurologic deficits or instability

■ **anterior odontoid screw**

- indications
 - Type II fractures with risk factors for nonunion AND
 - acceptable alignment and minimal displacement (reduction obtained)
 - anterior oblique fracture pattern



- fracture line is perpendicular to screw trajectory
 - patient body habitus must allow proper screw trajectory
 - outcomes
 - associated with higher failure rates than posterior C1-2 fusion
- **transoral odontoidectomy**
 - indications
 - severe posterior displacement of dens with spinal cord compression and neurologic deficits
 - rarely performed due to high complication rate
 - C1 laminectomy typically provides sufficient decompression of the spinal canal and is preferred

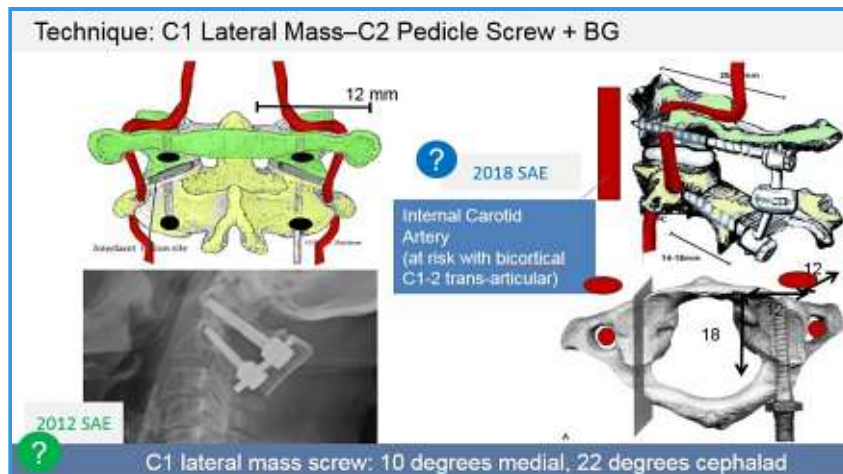
• Techniques

○ **Halo immobilization**

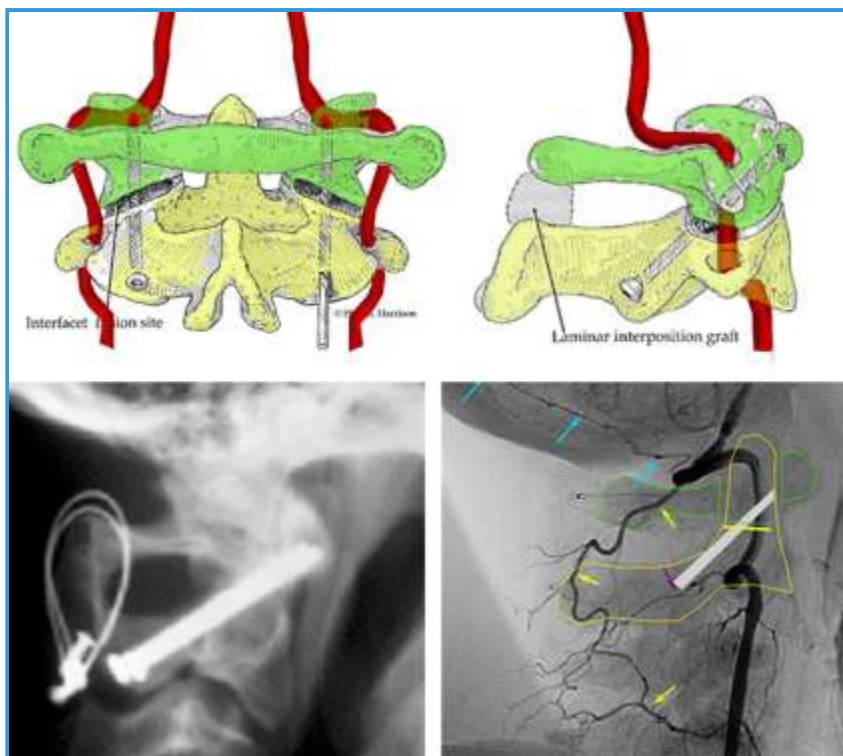
- complications
 - pin site infection
 - initial superficial pin infection can be treated with tightening and oral antibiotics

○ **C1-C2 posterior fusion**

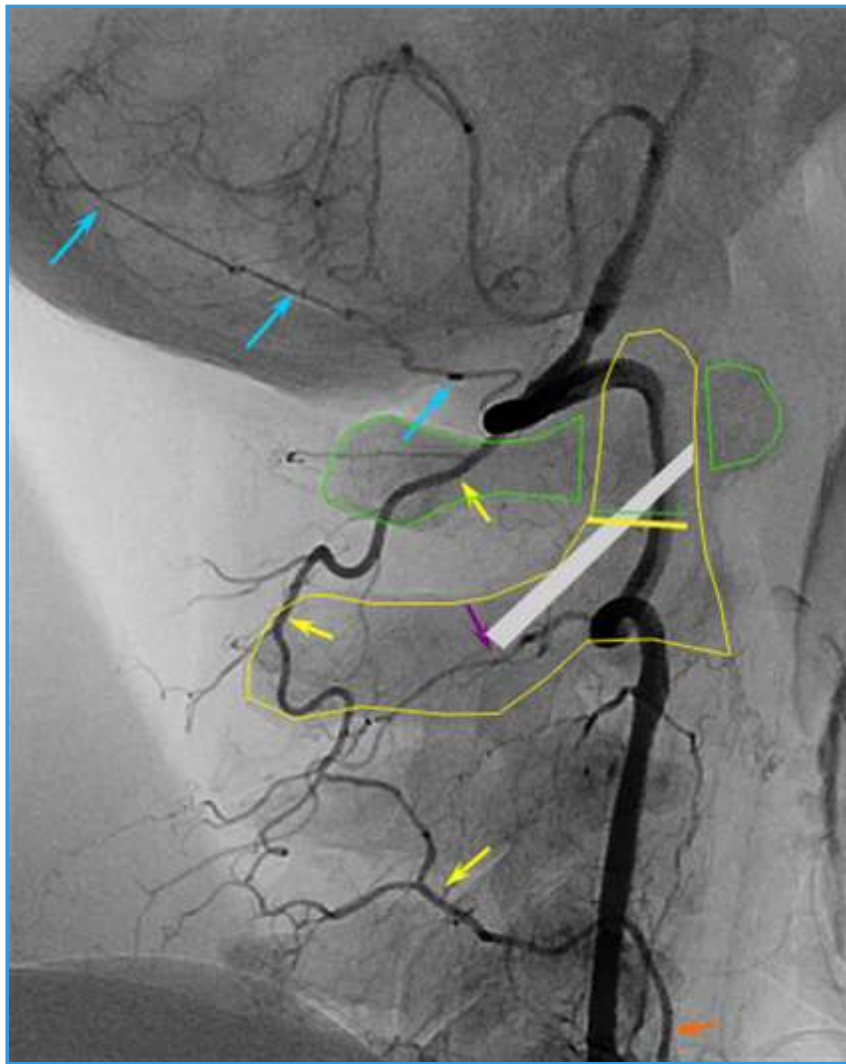
- approach
 - posterior midline cervical approach
- stabilization technique
 - sublaminar wiring techniques (Gallie or Brooks)
 - require postoperative halo immobilization and rarely used
 - posterior C1-C2 segmental fixation



- C1 lateral mass screws
 - 10 degrees medial, 22 degrees cephalad
 - avoid perforation of anterior cortex of C1 lateral mass due to potential internal carotid artery injury
- C2 fixation options include
 - C2 laminar screws
 - C2 pedicle screws
 - C2 pars screws (most common)
- posterior C1-C2 transarticular screws construct

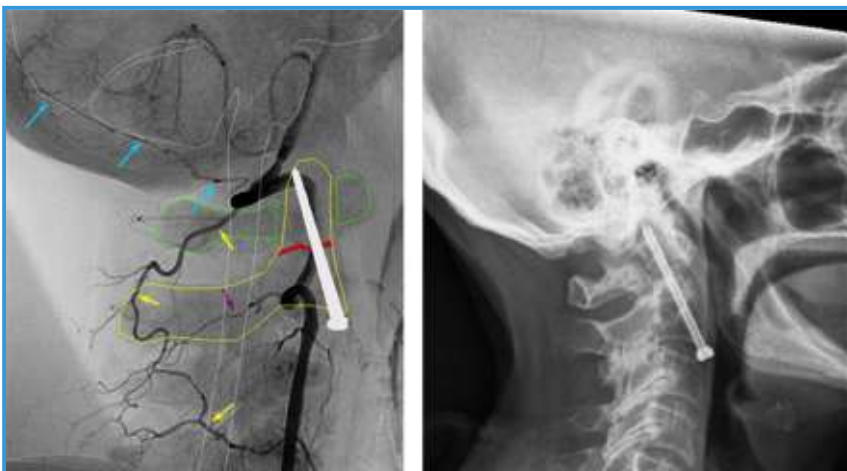


- contraindicated in patients with an aberrant vertebral artery



- outcomes
 - C1-C2 fusion will lead to 50% loss of neck motion
 - Higher fusion rate in elderly compared to anterior fusion

- **Anterior odontoid screw**



- approach
 - anterior approach to cervical spine
- technique
 - single screw adequate
- pros & cons
 - associated with higher failure rate than posterior C1-2 fusion
 - advantage is preservation of atlantoaxial motion

- **Transoral odontoidectomy**

- technique
 - usually combined with posterior stabilization procedure

- **Complications**

- Nonunion
 - overall incidence

- 33% (up to as high as 88% in some studies)
- risk factors
 - Type II fractures with
 - posterior displacement (> 2 mm)
 - strongest predictor of nonunion
 - age > 40 years
 - ≥ 5 mm displacement (>50% nonunion rate)
 - delay in treatment (> 4 days)
 - angulations > 10°
 - smoker
- Mortality
 - overall patient > 80 year of age do poorly with operative or nonoperative treatment
 - especially with halo orthosis

15- Cervical Facet Dislocations And Fractures

- Summary

- Cervical Facet Dislocations and Fractures represent a spectrum of traumatic injury with a varying degree of cervical instability and risk of spinal cord injury.
- Diagnosis can be confirmed with radiographs or CT scan. An MRI should be performed before surgery to identify an associated disk herniation.
- Treatment usually involves closed or open reduction followed by surgical stabilization.

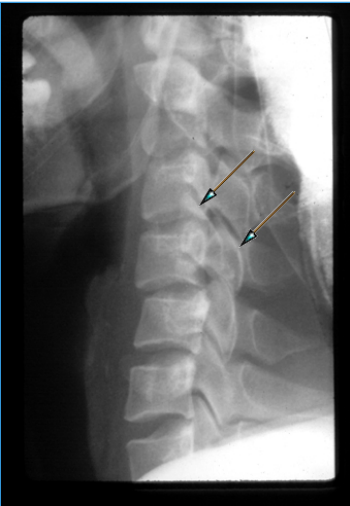
- Epidemiology

- Demographics
 - high energy trauma in young
 - motor vehicle accidents and motor cycle accidents
 - high speed deceleration injury
 - contact sports injuries
 - low energy trauma in elderly
- Anatomic location
 - 17% of all injuries are fractures of C7 or dislocation at the C7-T1 junction
 - this reinforces the need to obtain radiographic visualization of the cervicothoracic junction

- Etiology

- Pathoanatomy
 - represent spectrum of osteoligamentous pathology that includes
 - facet fractures
 - more frequently involves superior facet
 - may be unilateral or bilateral
 - decreases the threshold for facet dislocation
 - loss of tethering effect of interlocked facets
 - unilateral facet dislocation

- most frequently missed cervical spine injury on plain xrays
 - leads to ~25% subluxation on xray
 - associated with monoradiculopathy that improves with traction
 - inferior facet of the cephalad vertebrae encroaches the neuroforamina
 - bilateral facet dislocation
 - leads to ~50% subluxation on xray
 - often associated with significant spinal cord injury (~80% of cases)
 - mechanism
 - flexion and distraction forces +/- an element of rotation
 - rotational moment associated with unilateral facet dislocation
- Associated injuries
 - head injuries
 - noncontiguous spinal injuries
 - often occurs in the thoracolumbar, cervicothoracic, and occipitocervical junction
 - appendicular injuries
- Classification
 - Descriptive classification (subaxial cervical spine injuries)
 - includes
 - compression fracture
 - burst fraction
 - flexion-distraction injury
 - facet dislocation (unilateral or bilateral)
 - facet fracture
 - more commonly used in clinical setting

■ Allen and Ferguson Classification (of subaxial cervical spine injuries)		
■	- Typically used for research and not in a clinical setting - Based solely on static radiographs and mechanisms of injury	■
1. Flexion-compression		
2. Vertical compression		
3. Flexion-distraction		■
	Stage 1 : Facet sprain with slight subluxation, focal kyphosis <10°	
	Stage 2 : Unilateral facet dislocation	
	Stage 3 : Bilateral facet dislocation with 50% displacement (perched facets)	
	Stage 4 : Complete dislocation (100% displacement)	
4. Extension-compression		

5. Extension-distrraction		
6. Lateral flexion		

• Presentation

○ History

- history of trauma involving flexion-distrraction mechanism
- obtain relevant past history
 - ankylosing spondylitis / DISH
 - previous cervical spine fusion

○ Symptoms

- pain
 - neck pain in setting of flexion-distrraction mechanism
- unilateral dislocation
 - numbness and tingling radiating down a single arm
 - C5/6 presents with numbness in thumb
 - C6/7 presents with numbness in index and middle finger
- bilateral dislocation
 - subjective weakness in b/l upper and lower extremities
 - paresthesias and sensory changes in b/l lower extremities

○ Physical exam

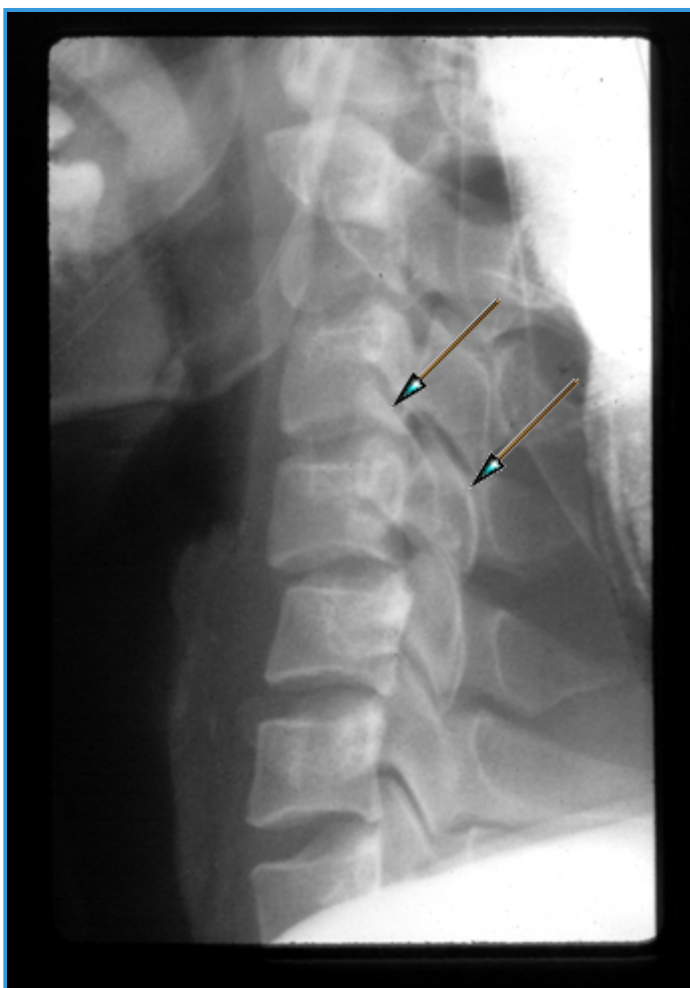
- inspection
 - gross spinal alignment
 - angular deformity may suggest a unilateral facet dislocation
 - scalp and head lacerations or contusions
 - suggest a overlying head injury
- monoradiculopathy
 - seen in patients with unilateral dislocations
 - C5/6 unilateral dislocation
 - presents with a C6 radiculopathy
 - weakness to wrist extension
 - numbness and tingling in the thumb

- C6/7 unilateral dislocation
 - presents with a C7 radiculopathy
 - weakness to triceps and wrist flexion
 - numbness in index and middle finger
- spinal cord injury symptoms
 - seen with bilateral dislocations
 - symptoms worsen with increasing subluxation
 - perform thorough neurologic examination
 - assess motor and sensory status
 - neurologic reflexes
 - document findings via ASIA scoring

• Imaging

○ Radiographs

- views
 - ap, lateral, oblique, open-mouth odontoid
- findings
 - lateral shows subluxation of vertebral bodies
 - unilateral dislocations lead to ~ 25% subluxation



- bilateral facet dislocation leads to ~ 50% subluxation on xray



- loss of disc height might indicated retropulsed disc in canal
- widening of the interspinous distance
- hypolordosis, especially at the injury level
- soft tissue swelling
- additional views
 - flexion-extension lateral radiographs
 - indications
 - required whenever facet fracture seen due to possibility of spontaneous reduction and occult instability

○ CT scan

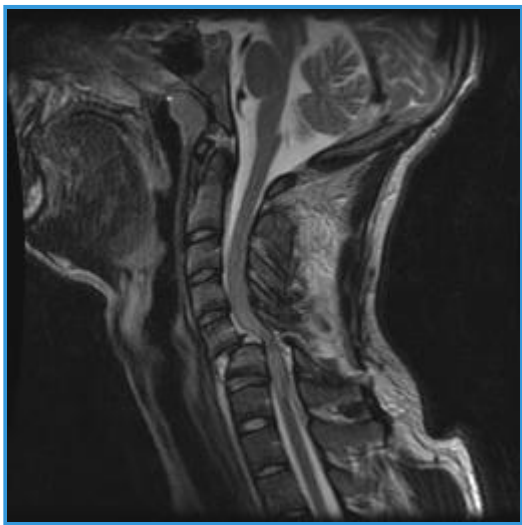


- indications
 - most cases require a CT scan
- findings
 - bony anatomy of the injury
 - malalignment or subtle subluxation of facet
 - facet fracture
 - associated fractures of the pedicle or lamina

○ MRI

- indications
 - acute facet dislocation in patient with altered mental status
 - must be performed emergently followed by open reduction and stabilization
 - failed closed reduction and before open reduction to look for disc herniation

- any neurologic deterioration is seen during closed reduction
- any patient going to OR for surgical stabilization needs an MRI in advance
- timing (controversial)
 - timing of MRI depends on severity and progression of neurologic injury
 - an MRI should always be performed prior to open reduction or surgical stabilization
 - if a disc herniation is present with compression on the spinal cord, then you must go anterior to perform a anterior cervical discectomy
- findings
 - disc herniations
 - need to know if large anterior disc is present prior to surgery
 - extent of posterior ligamentous injury
 - disruption of the supraspinous and interspinous ligaments
 - posterior longitudinal ligament and posterior annulus disruption
 - 40% of cases in unilateral dislocation
 - 80% of cases in bilateral dislocation
 - sprain or disruption of the posterior facet capsules
 - spinal cord compression or myelomalacia



- spinal cord hematoma
 - poor prognostic sign for motor recovery

• Differential

- Cervical Lateral Mass Fracture Separation
 - important to identify as cervical lateral mass fracture separations require fusing two levels while a facet dislocation only requires fusing a single level

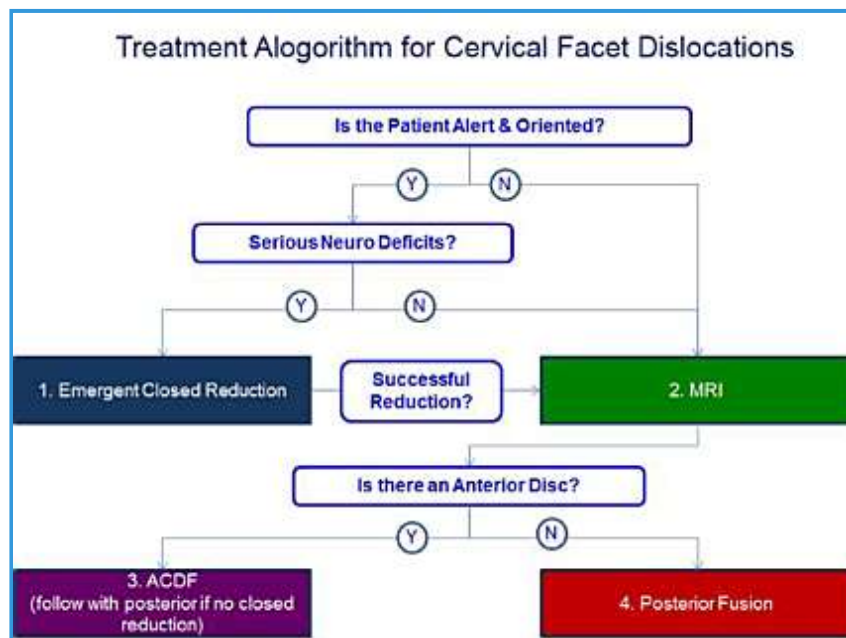
• Treatment

- Nonoperative

- **external immobilization x 6-12 weeks**
 - indications
 - stable facet fracture
 - unilateral reduced facet fractures without radiographic instability and involving <40% of the lateral mass or an absolute height <1 cm
 - must first rule out instability with flexion-extension radiographs
 - technique
 - halo vs. hard orthosis depending on degree of instability and age of patient
 - outcomes
 - >30% rate of subluxation or redislocation
 - increased pain associated with late redislocations
 - high incidence of persistent pain and instability
- Operative
 - **single level instrumented stabilization**
 - indications
 - unstable facet fracture
 - bilateral facet fracture
 - unilateral fracture involving >40% of the lateral mass or an absolute height >1 cm
 - technique
 - if no anterior disc herniation can be performed from anterior or posterior approach
 - **emergent closed reduction, emergent MRI, then urgent surgical stabilization**
 - indications
 - bilateral facet dislocation with deficits in a wake and cooperative patient
 - unilateral facet dislocation with deficits in a wake and cooperative patient
 - for a unilateral dislocation there is no spinal cord injury so urgency is much less than with a bilateral dislocation
 - timing
 - emergent to obtain reduction especially when you have bilateral dislocation
 - once reduction is obtain, and patient in a collar, then obtain MRI emergently. If MRI shows reduction and no significant compression

on spinal cord, then can perform stabilization on urgent (within 24 hours basis)

- technique
 - closed reduction



- usually precedes surgical intervention
 - rarely closed reduction followed by immobilization performed
 - medically frail patients
 - facet dislocations associated with high degree of instability and ligamentous injuries
- technique
 - never perform closed reduction in patient with mental status changes
 - unilateral dislocations are more difficult to reduce but more stable after reduction
 - bilateral dislocation are easier to reduce (PLL torn) but less stable following reduction
- outcomes
 - 26% of patients will fail closed reduction and require open reduction
 - unilateral facet dislocations effectively closed reduced in 25% of cases
- anterior cervical discectomy and fusion (single level)
 - indications
 - large disc herniation present following reduction with compression on the spinal cord or nerve roots
 - if closed reduction is failed, may attempt open reduction from anterior approach by distracting across casper pins with simultaneous rotation
 - 1-level interbody arthrodesis with anterior plating
- posterior reduction & instrumented stabilization

- indications
 - when no anterior disc present
 - bilateral or unilateral facet dislocations that are not reducible from the front or through closed reduction
 - combined anterior decompression and posterior reduction / stabilization
 - indications
 - when disc herniation present that requires decompression in patient that can not be reduced through closed or open anterior technique
- **emergent MRI then emergent open reduction surgical stabilization**
 - indications
 - facet dislocations (unilateral or bilateral) in patient with mental status changes
 - patients who fail closed reduction
 - technique
 - always obtain MRI prior to open reduction and stabilization
 - if disc herniation with presence of spinal cord compression then you must use an anterior approach and do a discectomy

• Techniques

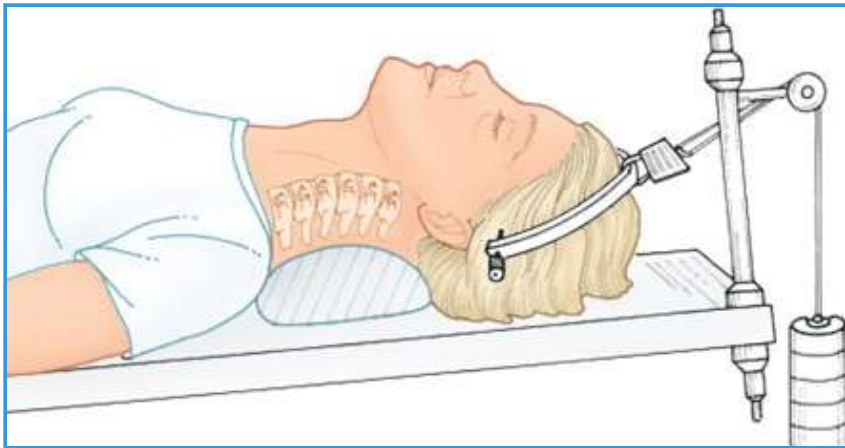
○ **Halo external immobilization**

- technique
 - halo is suboptimal in lower cervical spine and therefore hard orthosis may be satisfactory without complications associated with a halo
 - requires close radiographic follow-up
 - risk of redislocation or subluxation
 - morbidly obese patients may not fit or be adequately stabilized in a halo brace

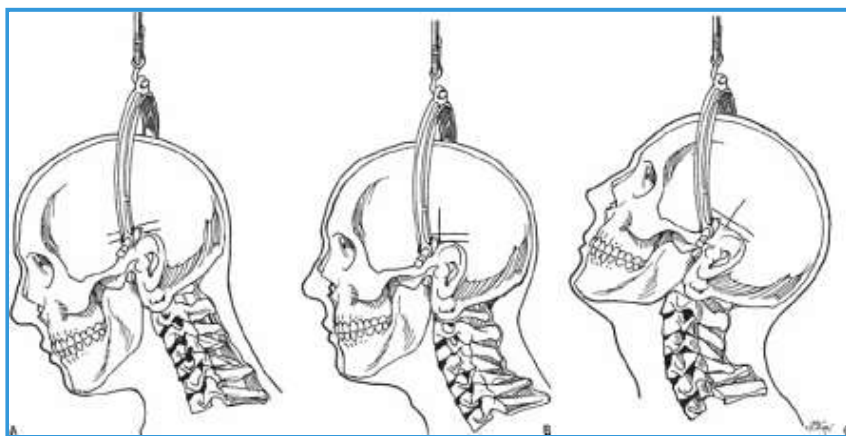
○ **Closed reduction**

- requirements
 - adequate anesthesia
 - sedation
 - supervision of respiratory function
 - serial cross table laterals
 - ability to perform serial neurologic examinations
- technique
 - application of Gardner-Wells tongs

- 1 cm above the pinna and in line with the external auditory meatus
- below the equator of the skull
 - avoids pin migration and slippage
- gradually increase axial traction with the addition of weights
 - usually in 5 to 10 lbs increments
 - can add up to 140 lbs of weight or 70% body weight
 - average weight required for reduction ~9.4 to 9.8 lbs per segment above the injury level
- a component of cervical flexion can facilitate reduction



- flexion moment can be created with pulley system or posterior placement of the Gardner-Wells tongs pins



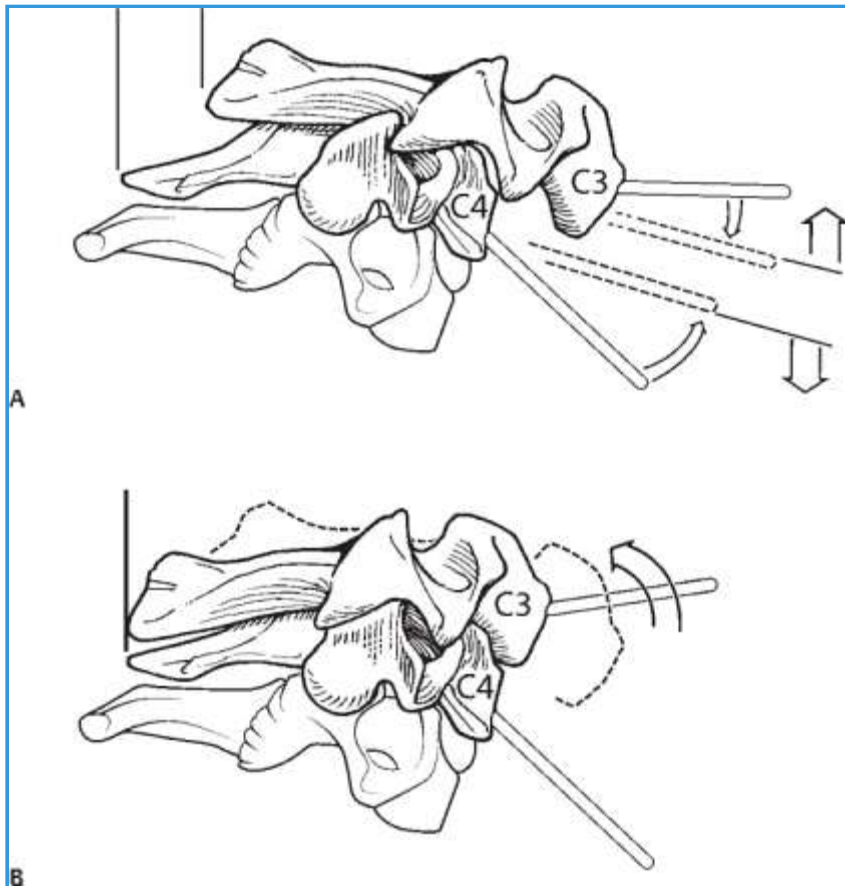
- once reduced, decrease traction weight by 10-15 lbs and apply an extension moment to the cervical spine
 - adjusting pulley system
 - placing pad underneath thorax
- perform serial neurologic exams and plain radiographs after addition of each weight addition
 - abort if there is over distraction of the spinal segment
 - >1.5 times that of the adjacent uninjured disc space
- can switch to carbonfiber Gardner-Wells tongs if need to obtain MRI in traction
 - traction limit ~80 lbs
- abort if neurologic exam worsens and obtain immediate MRI

○ **Anterior cervical discectomy and fusion +/- open reduction**

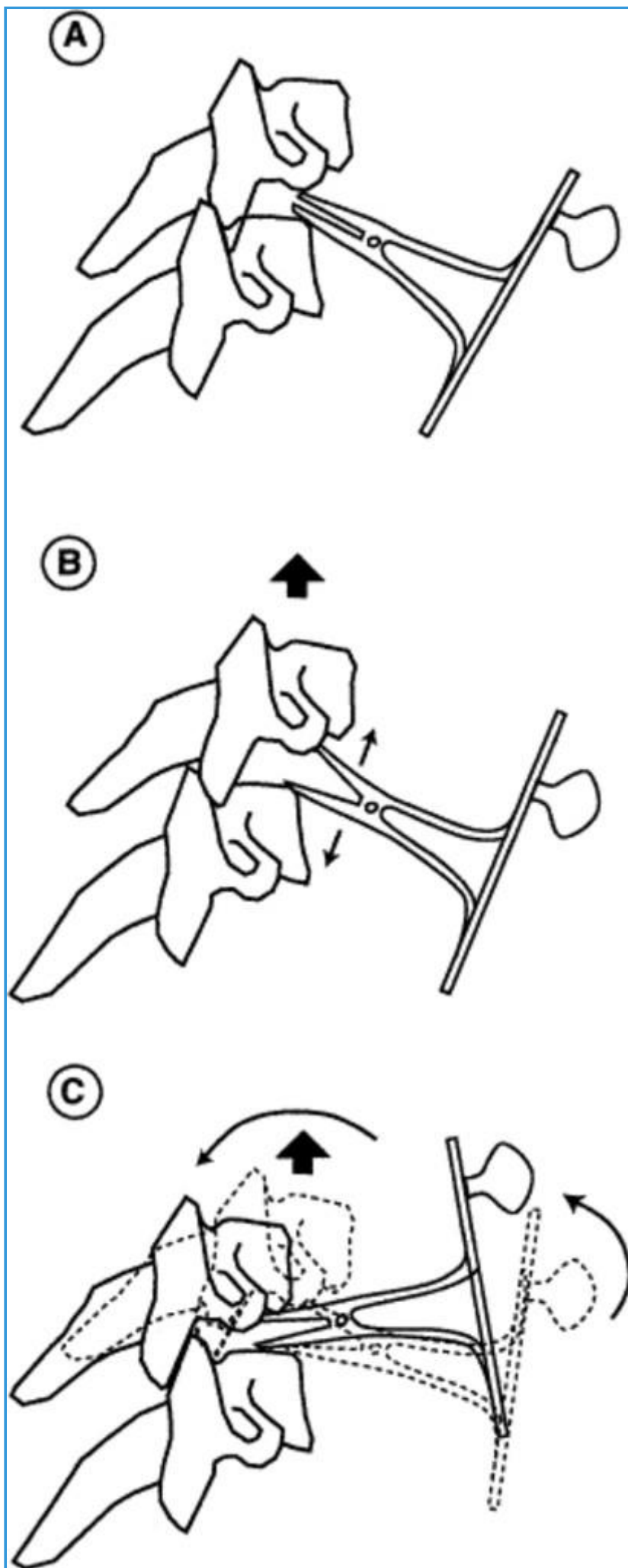
- indications
 - facet dislocations reduced through closed methods with a MRI showing cervical disc herniation with significant compression on the

spinal cord

- unilateral facet dislocations that fail closed reduction with a disc herniation with significant compression on the spinal cord
- anterior open reduction techniques
 - can be used to reduce a unilateral facet dislocation
 - standard Smith-Robinson approach
 - generous removal of the anterior-inferior aspect of the cephalad vertebra
 - allows disc space visualization
 - unilateral dislocations can be reduced by distracting vertebral bodies with caspar pins and then rotating the proximal pin towards the side of the dislocation
 - bilateral dislocations are reduced by placing converging Caspar pins (10-20° angle) and then compressing the ends together to unlock the facets



- posterior directed force applied to rostral vertebral body with currette
- alternatively, lamina spreaders applied to the endplates



- not effective for reducing bilateral facet dislocations
- pros and cons
 - overdistraction of the disc space
 - often the PLL and posterior ligaments are disrupted
 - excessively large graft may be used to obtain a press-fit interbody graft
 - will demonstrate the facet joints being gapped posteriorly
 - places hardware at risk for failure
 - over distraction also has risk of added spinal cord injury
- **Posterior instrumented stabilization +/- open reduction**
 - indications
 - when unable to reduce by closed or anterior approach

- no anterior compression of spinal cord(no disc herniation)
- technique
 - instrumentation performed with lateral mass screws
 - reduction
 - Penfield 4 inserted between facets and used to lever back into position
 - can remove the superior aspect of the superior facet of the caudad vertebrae to facilitate difficult reductions
 - distraction of the affected level between the affected spinous processes or lamina with use of lamina spreaders
 - usually have to fuse two levels due to inadequate lateral mass purchase at level of dislocation
- **Combined anterior decompression and posterior reduction / stabilization**
 - technique
 - go anterior first, perform discectomy, position plate but only fix plate to superior vertebral body
 - this way the plate will prevent graft kick-out but still allows rotation during the posterior reduction
 - this technique eliminates the need for a second anterior procedure

• Complications

- Surgical site infections
 - increased risk with posterior surgery
 - tissue trauma from injury increases risk of infection
- Recurrent dislocation
 - unilateral dislocations treated with immobilization
 - treated with anterior discectomy, reduction, and interbody fusion
- Respiratory complications
 - ARDS
 - higher risk in the multitraumatized patient
 - pneumonia
 - due to prolonged recumbency and need to tracheostomy
- Vertebral artery injury
 - occurs in up to 11% of patients with cervical spine injuries
 - increased risk when injury involves lateral mass and transverse process
 - often go unrecognized and untreated

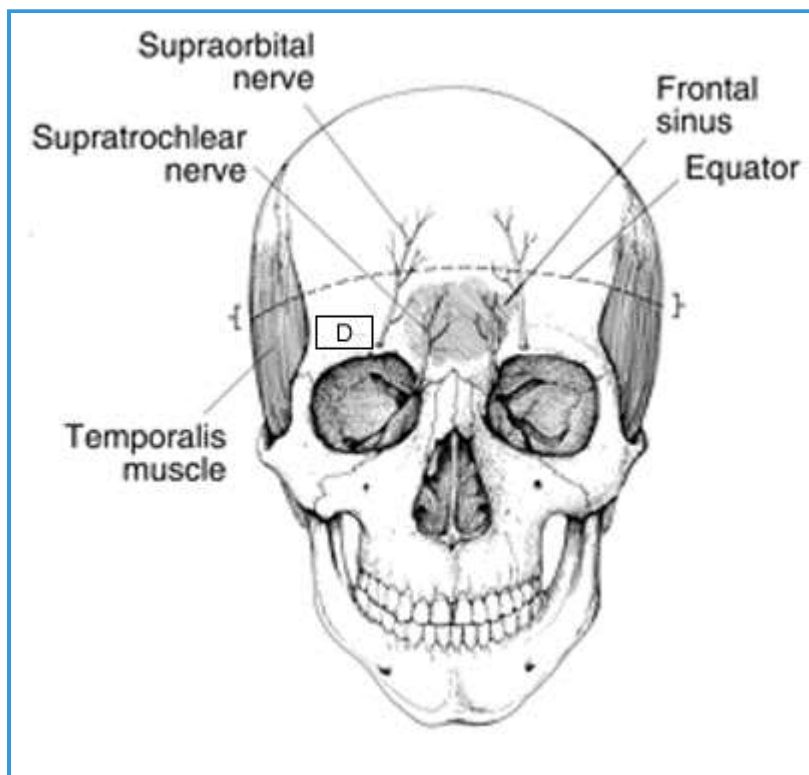
- Esophageal injury
 - related to anterior reduction and fixation
 - primary repair with thoracic surgeon upon identification
- Pin tract infections
 - associated with Halo vest immobilization
 - can result in decreased pin purchase
 - rarely result in meningitis if the inner table of the skull is violated
 - treat with local care and antibiotics

- Prognosis

- Neurologic recovery
 - lower probability of motor improvement with increasingly severe neurologic injury
 - increased age associated with decreased neurologic recovery
 - poor motor recovery potential with spinal cord hematoma

16- Halo Orthosis Immobilization

Images



• Introduction

- Fixes skull relative to torso
 - provides most rigid form of cervical spine external immobilization
 - ideal for upper C-spine injury
- Allows intercalated paradoxical motion in the subaxial cervical spine
 - therefore not ideal for lower cervical spine injuries (lateral bending least controlled)

		Bifid Spinous Process	Transverse Foramen / Vert?	Flexion/ Extension	Rotation	Lateral Bend
Occipitocervical	Occiput-C1			50	4	8
	C1 (Atlas)	None	Yes / Yes	10	50	0
Atlantoaxial	C2 (Axis)	Yes	Yes / Yes			
	C3	Yes	Yes / Yes			
Subaxial	C4	Yes	Yes / Yes			
	C5	Yes	Yes / Yes	50 (10/level)	50 (10/level)	60
	C6	Yes	Yes / Yes			
	C7 (VP)	No (95%)	Yes / No			
	Total Motion			110	100	68

- "snaking phenomenon"
 - recumbent lateral radiograph shows focal kyphosis in midcervical spine
 - yet, upright lateral radiograph shows maintained lordosis in midcervical spine

• Indications

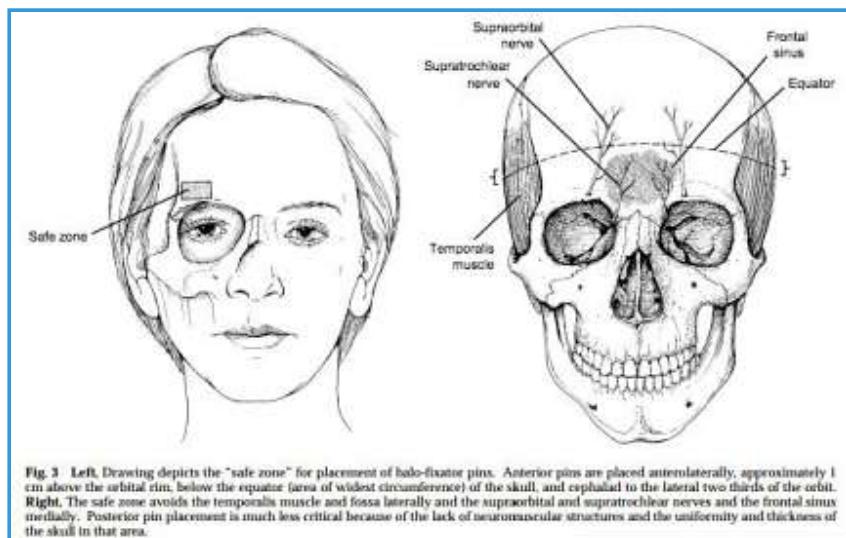
- Adult

- definitive treatment of cervical spine trauma including
 - occipital condyle fx
 - occipitocervical dislocation
 - stable Type II atlas fx (stable Jefferson fx)
 - type II odontoid fractures in young patients
 - type II and IIA hangman's fractures
- adjunctive postoperative stabilization following cervical spine surgery
- Pediatric
 - definitive treatment for
 - atlanto-occipital dissociation
 - Jefferson fractures (burst fracture of C1)
 - atlas fractures
 - unstable odontoid fractures
 - persistent atlanto-axial rotatory subluxation
 - C1-C2 dissociations
 - subaxial cervical spine trauma
 - preoperative reduction in the patients with spinal deformity
- Contraindications
 - Absolute
 - cranial fractures
 - infection
 - severe soft-tissue injury
 - especially near proposed pin sites
 - Relative
 - polytrauma
 - severe chest trauma
 - barrel-shaped chest
 - obesity
 - advanced age
 - recent evidence demonstrates an unacceptably high mortality rate in patients aged 79 years and older (21%)
- Imaging
 - CT scan prior to halo application
 - indications
 - clinical suspicion for cranial fracture
 - children younger than 10 to determine thickness of bone

• Adult Technique

○ Adults

- torque
 - tighten to 8 inch-pounds of torque
- location
 - total of 4 pins
 - 2 anterior pins
 - safe zone is a 1 cm region just above the lateral one third of the orbit (eyebrow) at or below the equator of the skull



- this is anterior and medial to temporalis fossa/temporalis muscle
- this is lateral to supraorbital nerve
- 2 posterior pins
 - placed on opposite side of ring from anterior pins
- followup care
 - can have patient return on day 2 to tighten again
 - proper pin and halo care can be done to minimize chance of infection

• Pediatric Technique

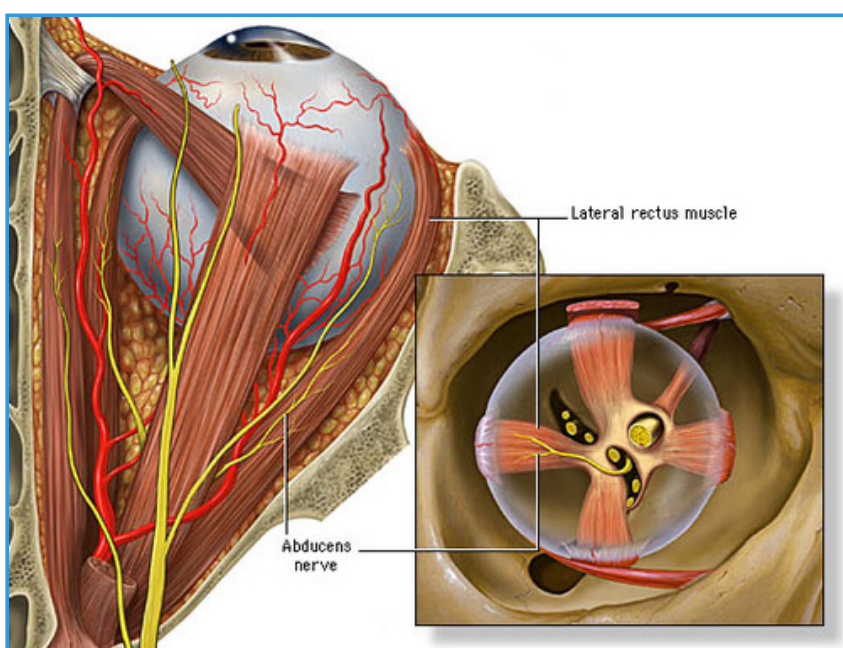
○ Pediatrics

- torque
 - best construct involves more pins with less torque
 - total of 6-8 pins
 - lower torque (2-4 in-lbs or "finger-tight")
- pin locations
 - place anterior pins lateral enough to avoid injury to the frontal sinus, supratrochlear and supraorbital nerves
 - place pins anterior enough to avoid the temporalis muscle
 - place pins posteriorly opposite from anterior pins
- brace/vest
 - custom fitted vest for children > 2 years

- children <2 yrs should use Minerva cast
- CT scans may help in pin placement
 - can help facilitate avoiding cranial sutures
 - can help facilitate avoiding thin regions of skull
 - help limit risk of complications

• Complications

- Higher complications in children (70%) than adults (35%)
- Loosening (36%)
 - can be treated with retightening
 - if continues to loosen, should be treated with pin exchange
- Infection (20%)
 - can especially occur with posterior pin in temporalis fossa because
 - pins hidden in hairline
 - bone is thin
 - temporalis muscle moves with chewing
 - can be treated with oral antibiotics if pin not loose
 - if pin infection and loose then pin should be removed
- Discomfort (18%)
 - treated by loosening skin around pin
- Dural puncture (1%)
- Abducens nerve (Cranial Nerve VI) palsy
 - epidemiology
 - is most commonly injured cranial nerve with halo
 - pathophysiology
 - thought to be a traction injury to cranial nerve 6, which affects abducens nerve (innervate lateral rectus muscles)



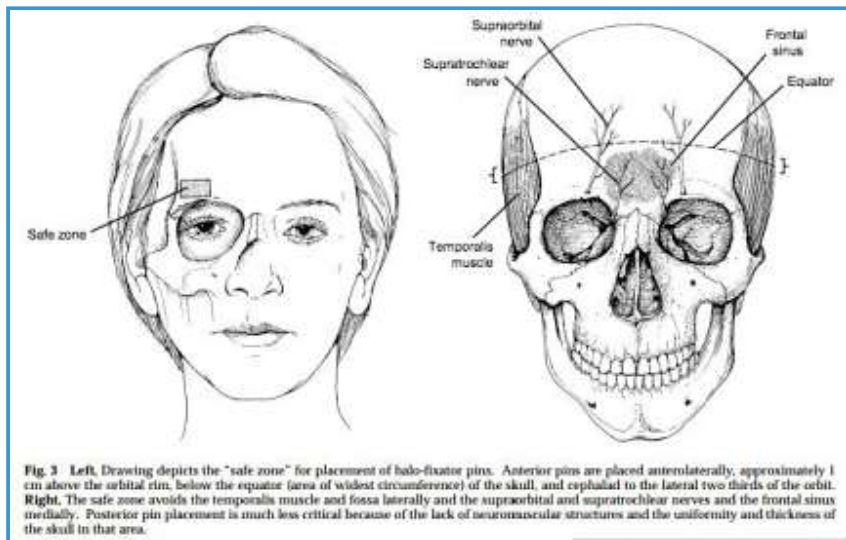
- symptoms
 - diplopia
- physical exam

- loss of lateral gaze on affected side



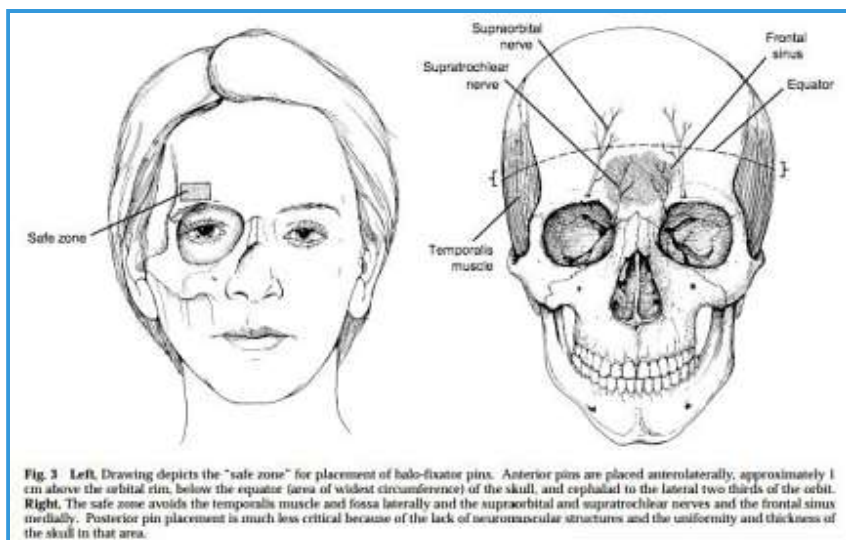
- treatment
 - observation as most resolve spontaneously

○ Supraorbital nerve palsy



- injured by medially placed anterior pins

○ Supratrochlear nerve palsy



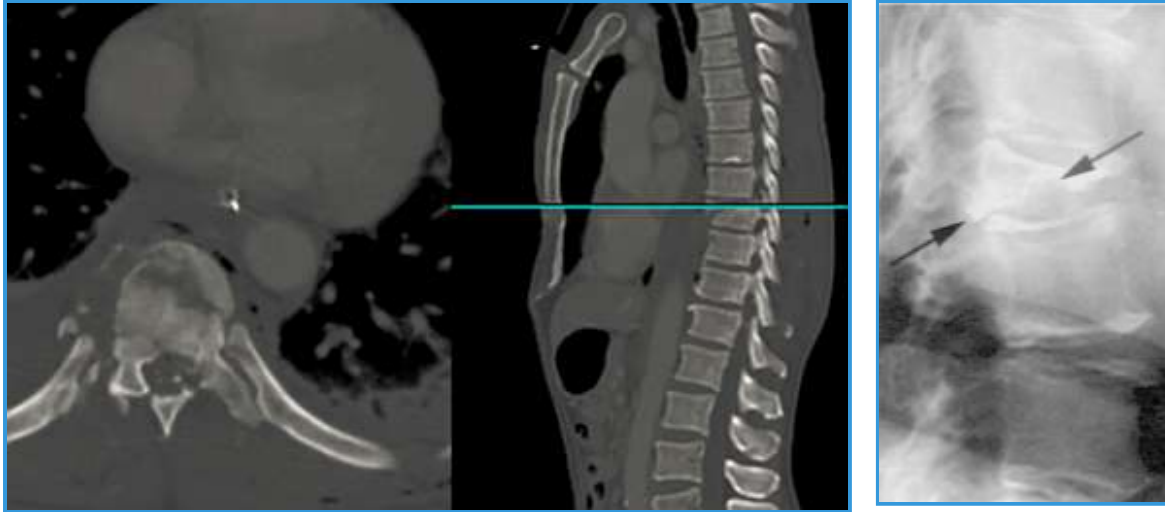
- injured by medially placed anterior pins

○ Medical complications

- pneumonia
- ARDS
- arrhythmia

17- Thoracolumbar Burst Fractures

Images



• SUMMARY

- Thoracolumbar Burst Fractures are a common high-energy traumatic vertebral fractures caused by flexion of the spine that leads to a compression force through the anterior and middle column of the vertebrae leading to retropulsion of bone into the spinal canal and compression of the neural elements.
- Diagnosis is made with radiographs of the thoracolumbar spine. CT scan is useful for fracture characterization and surgical planning.
- Treatment is bracing or surgical decompression and stabilization depending on whether the patient has neurologic deficits and whether the fracture is unstable with a risk of drifting into kyphosis.

• Epidemiology

- Demographics
 - often seen from falls from height or motor cycle accidents

• ETIOLOGY

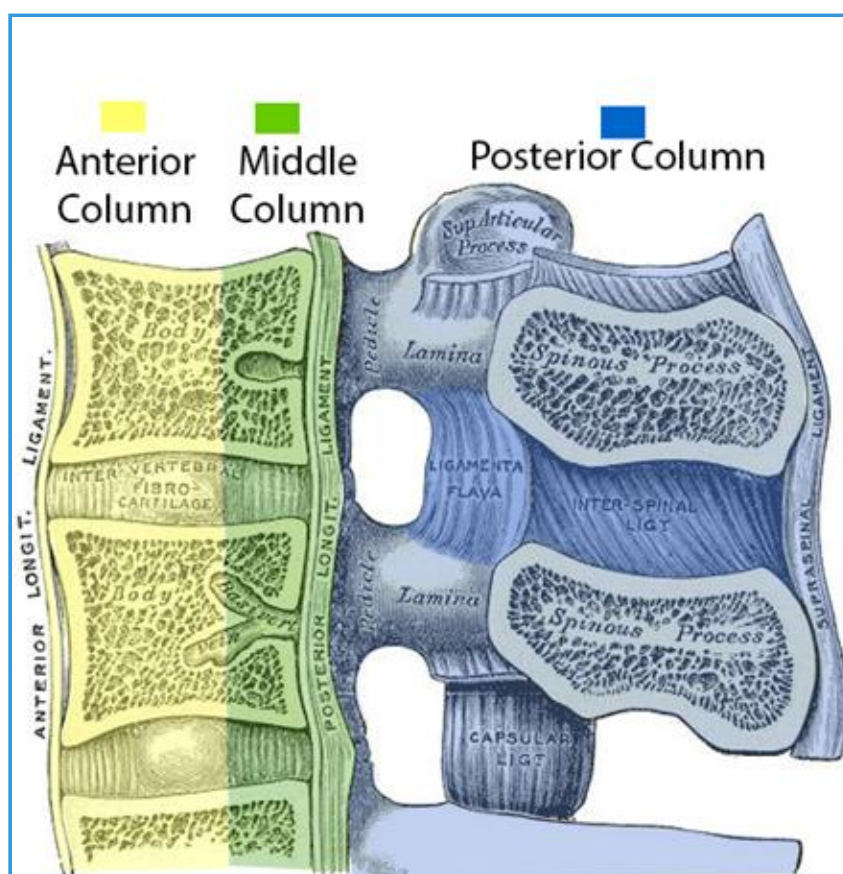
- Pathophysiology
 - mechanism
 - axial loading with flexion
 - pathoanatomy
 - at thoracolumbar junction there is fulcrum of increased motion that makes spine more vulnerable to traumatic injury

- burst fractures typically occur between T10-L2 (thoracolumbar junction)
 - neurologic deficits
 - canal compromise often caused by retropulsion of bone
 - maximum canal occlusion and neural compression at moment of impact
 - tissue recoiling post-injury can minimize the extent of displacement
 - retropulsed fragments resorb over time and usually do not cause progressive neurologic deterioration
 - deficit type
 - location of stenosis relative to conus determines
 - spinal cord injury
 - conus medullaris syndrome
 - neurogenic claudication due to stenosis distal to conus
- Associated injuries
 - concomitant spine fractures
 - occurs in 20%
 - traumatic durotomy
 - associated with
 - lamina fractures
 - split spinous process
 - chest and intra-abdominal injuries
 - common
 - thoracic spine fractures with neurologic deficit
 - 1/3 associated with hemopneumothorax, major vessel injury, and diaphragmatic rupture
 - flexion-distraction and fracture-dislocations
 - bowel rupture, major vessel injury, upper urinary tract injury, hepatic, splenic, and pancreatic lacerations
 - long bone fractures
 - can make rehabilitation difficult

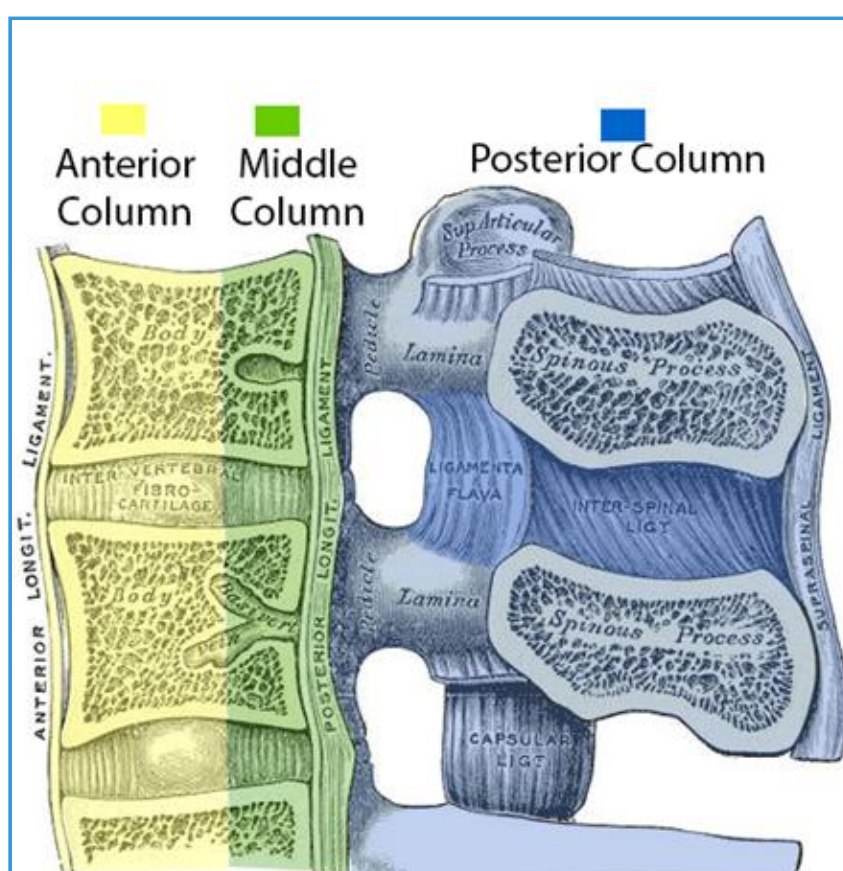
• ANATOMY

- Thoracic osteology
 - T1-10 are rigidly fixed to ribs that join each other anteriorly via the sternum
 - least mobile portion of the entire spine

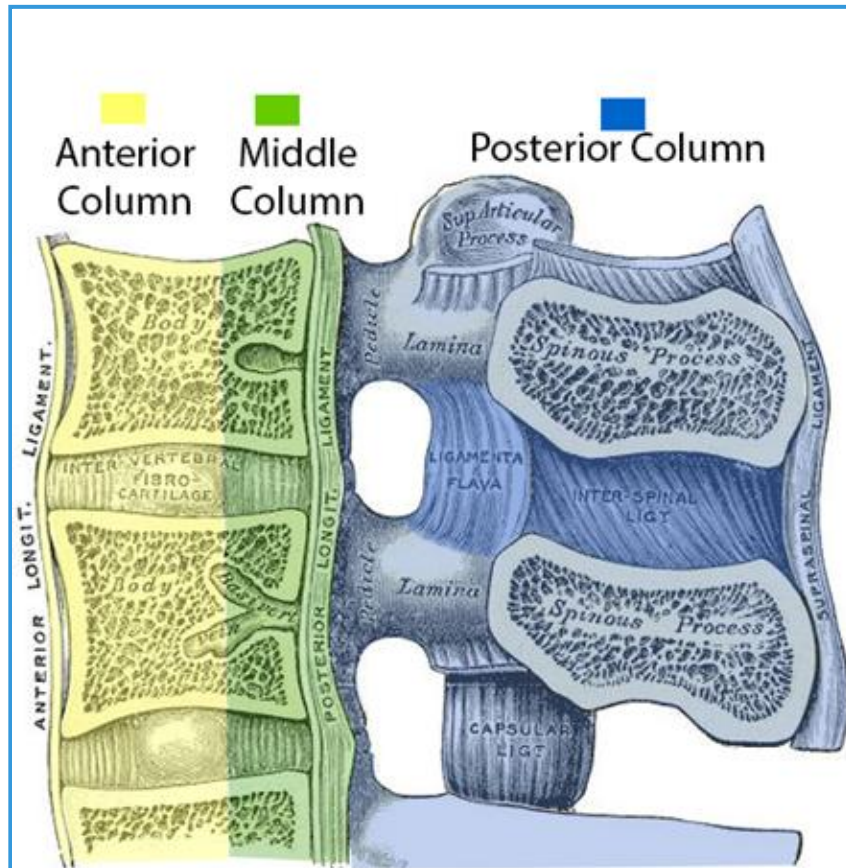
- T10-L2 is considered the thoracolumbar junction
 - T10-12 have free floating ribs and are more mobile than the upper thoracic spine
 - transition from rigid thoracic spine to mobile lumbar spine acts as a stress riser and predisposes to injury
- Lumbar osteology
 - increasingly more mobile as progresses caudal
 - increasingly prone to degenerative changes
- Denis three column system
 - clinical relevance
 - only moderately reliable in determining clinical degree of stability
 - definitions
 - anterior column



- anterior longitudinal ligament (ALL)
 - anterior 2/3 of vertebral body and annulus
- middle column

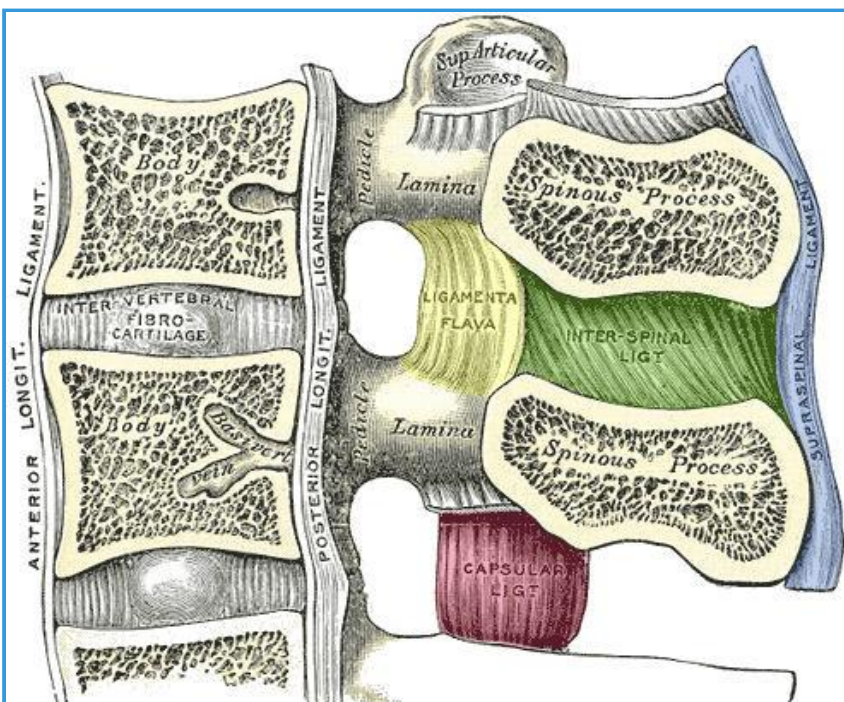


- posterior longitudinal ligament (PLL)
- posterior 1/3 of vertebral body and annulus
- posterior column



- pedicles
- lamina
- facets
- ligamentum flavum
- spinous process
- posterior ligament complex (PLC)
- instability defined by
 - injury to middle column
 - as evidenced by widening of interpedicular distance on AP radiograph
 - loss of height of posterior cortex of vertebral body
 - disruption of posterior ligament complex combined with anterior and middle column involvement

○ Posterior Ligamentous Complex



- considered to be a critical predictor of spinal fracture stability

- consists of
 - supraspinous ligament
 - interspinous ligament
 - ligamentum flavum
 - facet capsule
- evaluation
 - determining the integrity of the PLC can be challenging
 - conditions where PLC is clearly ruptured
 - bony chance fracture
 - widening of interspinous distance
 - progressive kyphosis with nonoperative treatment
 - facet diastasis
 - conditions where integrity of PLC is indeterminant
 - MRI shows signal intensity between spinous process
- Spinal cord
 - spinal cord ends at L1-2
 - conus medullaris
 - houses upper motor neurons on the sacral motor nerves
 - fractures involving L1 and result in conus medullaris syndrome
 - paralysis of the bowel and bladder with sparing of the motor nerve roots of the lower extremity

• CLASSIFICATION

- Dennis classification
 - Type A
 - fracture of both end-plates. The bone is retropulsed into the canal.
 - Type B
 - fracture of the superior end-plate. It is common and occurs due to a combination of axial load with flexion.
 - Type C
 - fracture of the inferior end-plate.
 - Type D
 - Burst rotation. This fracture could be misdiagnosed as a fracture-dislocation. The mechanism of this injury is a combination of axial load and rotation.
 - Type E
 - Burst lateral flexion. This type of fracture differs from the lateral compression fracture in that it presents an increase of the

interpediculate distance on anteroposterior roentgenogram

○ Thoracolumbar Injury Classification and Severity Score

The Thoracolumbar Injury Classification and Severity (TLICS) Score	
Injury Category	Point Value
Injury morphology	
Compression	1
Burst	2
Translation or rotation	3
Distraction	4
PLC status	
Intact	0
Injury suspected or indeterminate	2
Injured	3
Neurologic status	
Intact	0
Nerve root involvement	2
Spinal cord or conus medullaris injury	
Incomplete	3
Complete	2
Cauda equina syndrome	3

- injury characteristic qualifier points
 - injury morphology
 - compression (+1 point)
 - burst (+2 points)
 - rotation/translation (+3 points)
 - distraction (+4 points)
 - neurologic status
 - intact (0 point)
 - nerve root (+2 points)
 - incomplete Spinal cord or conus medullaris injury (+3 points)
 - complete Spinal cord or conus medullaris injury (+2 points)
 - cauda equina syndrome (+3 points)
 - posterior ligamentous complex integrity
 - intact (0 point)
 - no interspinous ligament widening seen with flexion views. MRI shows no edema in interspinous ligament region
 - suspected/indeterminate (+2 points)
 - MRI shows some signal in region of interspinous ligaments
 - disrupted (+3 points)
 - widening of interspinous distance seen
- TLICS treatment implications
 - score < 4 points
 - nonsurgical management

- score = 4 points
 - nonsurgical or surgical management
- score > 4 points
 - surgical management indicated

• PRESENTATION

- History
 - high-energy mechanism
 - axial-loading and flexion mechanisms
 - fall from height (e.g. fall from deer hunting stand, fall from ladder, etc.)
 - high-speed motor vehicle collision
- Symptoms
 - severe back pain
 - radicular pain
 - paresthesias
- Physical exam
 - vital signs
 - hypotension is common
 - neurogenic shock
 - hypotension with associated bradycardia
 - suggests spinal cord injury leading to loss of autonomic regulation
 - hypovolemic shock
 - hypotension with compensatory tachycardia
 - suggests massive hemorrhage from major vessel injury
 - inspection
 - log roll patient during initial assessment to avoid iatrogenic spinal cord injury in the setting of an unstable fracture pattern
 - skin abrasions and ecchymosis
 - open spinal fractures are uncommon
 - palpation of spinous processes
 - fluid collection
 - crepitus
 - increased interspinous distance
 - suggests injury to the posterior elements
 - localized tenderness
 - neurologic examination

- motor
- sensory
- reflexes

Reflex Testing in Thoracolumbar Injuries	
Reflex	Level Tested
Superficial abdominal (above umbilicus)	T7-T10
Superficial abdominal (below umbilicus)	T11-L1
Cremasteric reflex	T12-L1
Knee jerk	L3-L4
Ankle jerk	S1
Anal wink	S2-S4
Bulbocavernosus reflex	S3-S4
Plantar response	Brain/cord continuity

- absence of bulbocavernosus reflex is considered spinal shock
 - can persist for up to 72 hours
 - hyperactive bulbocavernosus reflex suggests disinhibition and a complete spinal cord injury

• IMAGING

○ Radiographs

- recommended views
 - AP/lateral cervical, thoracic, lumbar spine
 - often CT chest, abdomen, and pelvis done by trauma team and instead of radiographs
 - imaging of entire spine must be performed due to concomitant spine fractures in 20%
 - flexion and extension lateral radiographs
 - useful once patient is stabilized to get understanding of integrity of PLC
 - findings
 - AP shows
 - widening of pedicles
 - coronal deformity
 - lateral shows
 - retropulsion of bone into canal
 - extent of retropulsion can be underestimated with plain radiographs alone
 - kyphotic deformity
 - chance-like spinous process fx
 - flexion/extension
 - diastasis of spinous process with flexion indicates soft tissue injury to PLC

○ CT scan

- indications
 - fracture on plain film
 - neurologic deficit in lower extremity
 - inadequate plain films
 - higher sensitivity at detecting acute spine fractures than plain films
- most accurately assesses the extent of fragment retropulsion
 - best assess on the axial views



- better assessment vertebral body comminution
- CT myelography
 - indications
 - alternative for patients with pacemaker and other implants that are MRI incompatible
 - cannot assess the cord status
 - consider traumatic durotomy
- MRI
 - indications
 - whenever neurological deficits
 - assess the presence of a posterior ligamentous injury
 - should be performed in nearly every case, unless radiographs and CT clearly suggest injury
 - useful to evaluate for
 - level of conus relative to retropulsed bone
 - spinal cord or thecal sac compression by disk or osseous material
 - cord edema or hematoma
 - cord edema
 - fusiform cord enlargement
 - increased signal intensity on T2-weighted images
 - cord hematoma
 - decreased signal intensity on T2-weighted images
 - halo of T2 enhancement for surrounding edema

- presence of cord edema more than 2 vertebral levels and hematoma are poor prognostic signs for functional motor recovery
- injury posterior ligament complex
 - increased signal intensity on T2 weighted images in PLC is concerning for instability and may warrant surgical intervention
 - best visualized on the sagittal images

• TREATMENT

○ Nonoperative

■ **activity as tolerated +/- thoracolumbosacral orthosis**

- indications
 - patients that are neurologically intact and mechanically stable
 - posterior ligament complex preserved
 - no focal kyphosis on flexion and extension lateral radiographs
 - kyphosis < 30° (controversial)
 - vertebral body has lost < 50% of body height (controversial)
 - TLICS score = 3 or lower
- modality
 - thoracolumbar orthosis
 - recent evidence shows no clear advantage of TLSO on outcomes
 - if it provides symptomatic relief, may be beneficial for patient
 - bracing may not be suitable for those with associated abdominal or chest injuries
- outcomes
 - retropulsed fragments resorb over time and usually do not cause neurologic deterioration
 - decreased complication rates in neurologically intact patients treated nonsurgically
 - equivalent outcomes in neurologically intact patients
 - prolonged bedrest associated with increased deconditioning and recumbency complications (pneumonia, DVT, etc.)

○ Operative

■ **posterior instrumented fusion/stabilization without decompression**

- indications
 - unstable fracture pattern as defined by
 - injury to the Posterior Ligament Complex (PLC)
 - progressive kyphosis

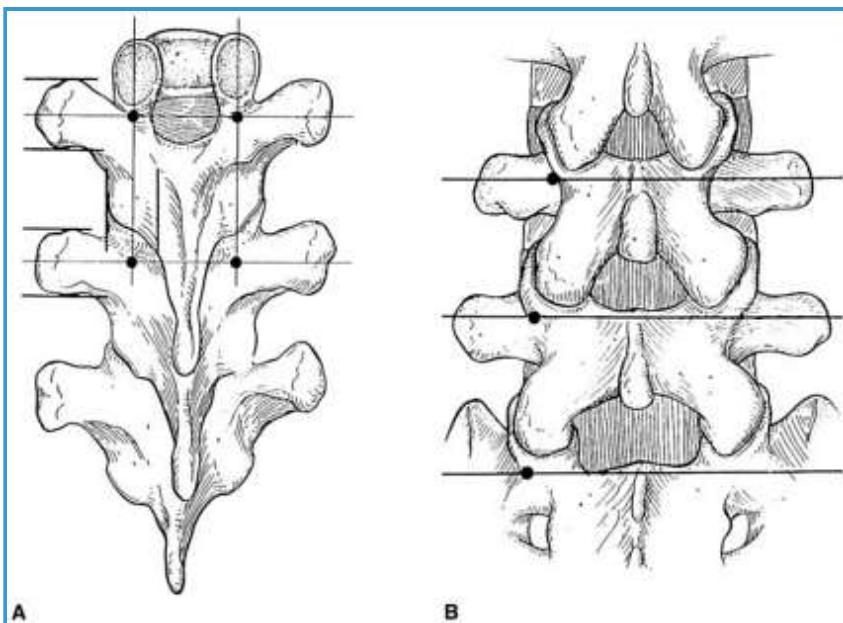
- lamina fractures (controversial)
 - polytrauma
 - surgical stabilization can assist with recovery and rehabilitation of other injuries
- technique
 - may be performed with percutaneous pedicle screws using fluoroscopy or navigation
 - may extend instrumentation further than level of arthrodesis (fuse short, instrument long)
- outcomes
 - unstable injuries are more likely to benefit from surgical stabilization compared to nonsurgical treatment
- **neurologic decompression & spinal stabilization**
 - indications
 - neurologic deficits with radiographic evidence of cord/thecal sac compression
 - both complete and incomplete spinal cord injuries require decompression and stabilization to facilitate rehabilitation
 - TLICS score = 5 or higher
 - techniques
 - while classic teaching was anterior approach is required to eliminate anterior pathology, with modern techniques decompression can be performed with
 - posterior approach
 - favored when
 - below conus so possible to medialize thecal sac to perform decompression of canal / posterior corpectomy and expandable cage
 - injury to posterior ligamentous complex so posterior tension-band stabilization required
 - fracture dislocations
 - anterior/direct lateral approach
 - favored when
 - neurologic deficits caused by anterior compression (bony retropulsion) , especially above the conus medullaris (above L2)
 - allow for thorough decompression of the thecal sac
 - substantial vertebral body comminution in order to reconstitute the anterior column

- kyphotic deformity $>30^\circ$
 - chronic injuries
 - greater than 4-5 days from the injury
 - cons
 - must consider level of diaphragm
- outcomes
 - studies have suggested posterior distraction instrumentation with ligamentotaxis have similar clinical and radiographic outcomes as anterior decompression and 360° stabilization
 - over distraction of the anterior column can lead to pseudoarthrosis, chronic pain, and recurrent deformity

• TECHNIQUES

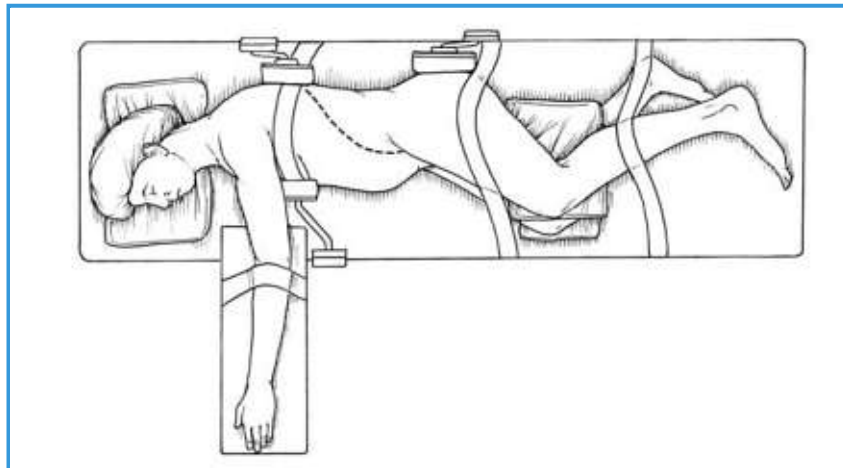
○ **Posterior instrumented fusion/stabilization without decompression**

- approach
 - posterior midline approach
 - subperiosteal elevation of paraspinal musculature
 - expose lateral to the transverse processes
- technique
 - transpedicular screw fixation above and below the level of injury



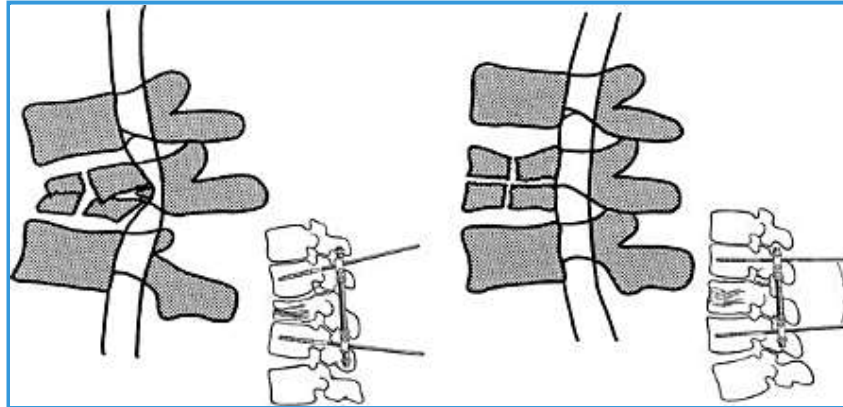
- historically involve three levels above and two levels below the level of injury
 - modern constructs typically involve one level above and one level below the injury
 - short segment fixation not suitable for injuries involving the thoracolumbar junction
 - complications
 - loss of sagittal plane correction
- **Neurologic decompression & spine stabilization**
 - approach

- posterior approach
 - typically posterior midline approach
 - subperiosteal elevation of paraspinal musculature
 - expose lateral to the transverse processes
- anterior approach
 - lumbar spine
 - anterior retroperitoneal or transperitoneal approach
 - left paramedian incision
 - suitable for levels below L1
 - thoracolumbar junction
 - lateral lumbotomy



- suitable for injuries at T11-L1
 - left-sided approach to avoid liver obstructing access
- thoracic spine
 - lateral thoracotomy
 - right-sided approach to avoid major vessels
 - appropriate for injuries above T11
- technique
 - neural decompression
 - direct decompression
 - posterior decompression
 - retropulsed bone can be removed via transpedicular approach
 - usually done below the level of the conus medullaris (L2)
 - significant dural retraction required, which may iatrogenically damage the cord
 - avoid laminectomy if possible as it will further destabilize the spine by compromising the posterior supporting structures
 - anterior decompression
 - corpectomy performed with direct removal of canal-occupying fragments

- ipsilateral pedicle and transverse process are removed
 - corpectomy performed until the medial wall of the contralateral pedicle is visualized
 - preferable for fractures at or above the level of the conus medullaris (L1-2)
- indirect decompression
 - distraction and lordosing rod construct leads to ligamentotaxis of the retropulsed fragments



- attachments of the annulus fibrosis and posterior longitudinal ligament to the fragments facilitates reduction
 - less effective if performed 4-5 days after the injury
- restored height and sagittal alignment with posterior instrumentation
- monoaxial screws provided greater distractive forces for deformity correction



- arthrodesis
 - posterior fusion
 - usually performed with locally harvested autograft and freeze-dried cancellous allograft +/- BMP
 - posterior instrumentation should be under distraction and lordosis to restore vertebral body height and achieve indirect decompression
 - anterior fusion
 - structural bone graft placed in corpectomy site to reconstitute the anterior column
 - tricortical iliac crest autograft
 - humeral or tibial allograft
 - expandable metal cages with locally harvested autograft

- can be stabilized with anterior instrumentation, posterior instrumentation, or both
- complications
 - posterior decompression
 - dural tear
 - iatrogenic cord injury
 - excessive thecal retraction above the conus medullaris
 - iatrogenic instability
 - laminectomy in the setting of disrupted posterior ligamentous complex
 - anterior decompression
 - ileus
 - transperitoneal approach to the lumbar spine
 - pleural effusion
 - related to approaches requiring thoractomy

• COMPLICATIONS

- Entrapped nerve roots and dural tear
 - from associated lamina fractures
 - can be iatrogenic from decompression
 - decreased risk of dural tears with anterior approach due to improved visualization of the thecal sac during decompression
 - requires closure primarily or reinforced with dural patch
 - prolonged recumbency postoperatively
- Pain
 - most common
 - over distraction with instrumentation
- Progressive kyphosis
 - common with unrecognized injury to PLL
 - increased comminution of the vertebral body
 - loss of anterior column support
- Flat back
 - leads to pain, a forward flexed posture, and easy fatigue
 - post-traumatic syringomyelia
- Surgical site infection
 - can occur in up to 10% of cases
 - trauma predisposes to infection
 - catabolic state

- increased soft tissue damage
 - inflammatory response
 - requires irrigation and debridement with culture specific antibiotics
- Pseudoarthrosis
 - can result from overdistracted instrumentation
- Iatrogenic neurologic injury
 - can occur in 1% of cases
 - causes include
 - over medialized pedicle screws
 - inadvertent manipulation of the spinal cord

18- Thoracolumbar Fracture Dislocation

- summary

- Thoracolumbar Fracture-Dislocations are rare fractures associated with a posterior facet dislocation occurring at the thoracolumbar junction.
- Diagnosis is made with radiographs of the thoracolumbar spine. CT scan is useful for fracture characterization and surgical planning.
- Treatment is usually posterior open reduction with instrumented fusion.

- Epidemiology

- Incidence
 - approx. 4% of spinal cord injuries admitted to Level 1 trauma centres
 - 50-60% of fracture-dislocations are associated with spinal cord injuries
- Demographics
 - 4:1 male-to-female ratio
- Anatomic location
 - most commonly occur at the thoracolumbar junction
- Risk factors
 - high energy injuries
 - motor vehicle accident (most common)
 - falls
 - sports
 - violence

- Etiology

- Pathophysiology
 - mechanism of injury
 - acceleration/deceleration injuries
 - resulting in hyperflexion, rotation and shearing of the spinal column
 - associated injury
 - neurologic deficits
 - head injury
 - concomitant injuries in thorax and abdomen
- Classification Systems

■ Thoracolumbar Injury Classification System (TLICS)

Component	Qualifiers	Score
Morphology type		
Compression		1
	Burst	1
Translational/Rotational		3
Distraction		4
Neurological involvement		
Intact		0
Nerve root		2
Cord, conus medullaris	Complete	2
	Incomplete	3
Cauda equina		3
PLC		
Intact		0
Injury suspected/Indeterminate		2
Injured		3

- categorizes injuries based on
 - morphology of injury
 - neurologic injury
 - posterior ligamentous complex integrity
- treatment recommendation based on total score
 - nonsurgical = 3 or lower
 - indeterminate = 4
 - surgical = 5 or higher

• Anatomy

- Lumbothoracic junction
 - Definition
 - T10 - L2
 - transition zone between thoracic spine (kyphosis) and lumbar spine (lordosis)
 - Pathoanatomy
 - greater mobility in the lumbar spine compared to thoracic spine
 - results in an area of the spine that is vulnerable to shearing forces
 - high risk of injury to the spinal cord, conus or cauda equina depending on the patients anatomy and degree of dislocation

• Presentation

- Pre-hospital
 - patients almost exclusively present as a major trauma with or without neurological deficit
 - transportation to a trauma center using spine immobilization precautions with a spinal board and cervical collar.

- Clinical Approach
 - ATLS
 - Airway, Breathing, Circulation
 - Neurological assessment
 - Inspection
 - open injury
 - deformity (e.g. kyphosis)
 - Palpation
 - point tenderness
 - step-off deformity
 - crepitus
 - Neurological Impairment
 - GCS
 - ASIA Impairment score
 - sensory, motor, or reflexes impairment
 - rectal examination
 - History
 - Physical examination

- Imaging

- Radiographs



- recommended views
 - AP and lateral view of thoraco-lumbar spine

- indications
 - suspected spinal column injury with bone tenderness
 - recognize stable versus unstable spine injuries
- findings
 - fracture type, pattern and dislocation
- CT scan



- indications
 - better visualization of fracture pattern and type compared to plain radiographs (e.g. unilateral facet dislocations, etc)
 - blunt trauma patients requiring a CT scan to screen for other injuries
- findings

- cannot adequately visualize and describe the spinal canal and other associated ligaments

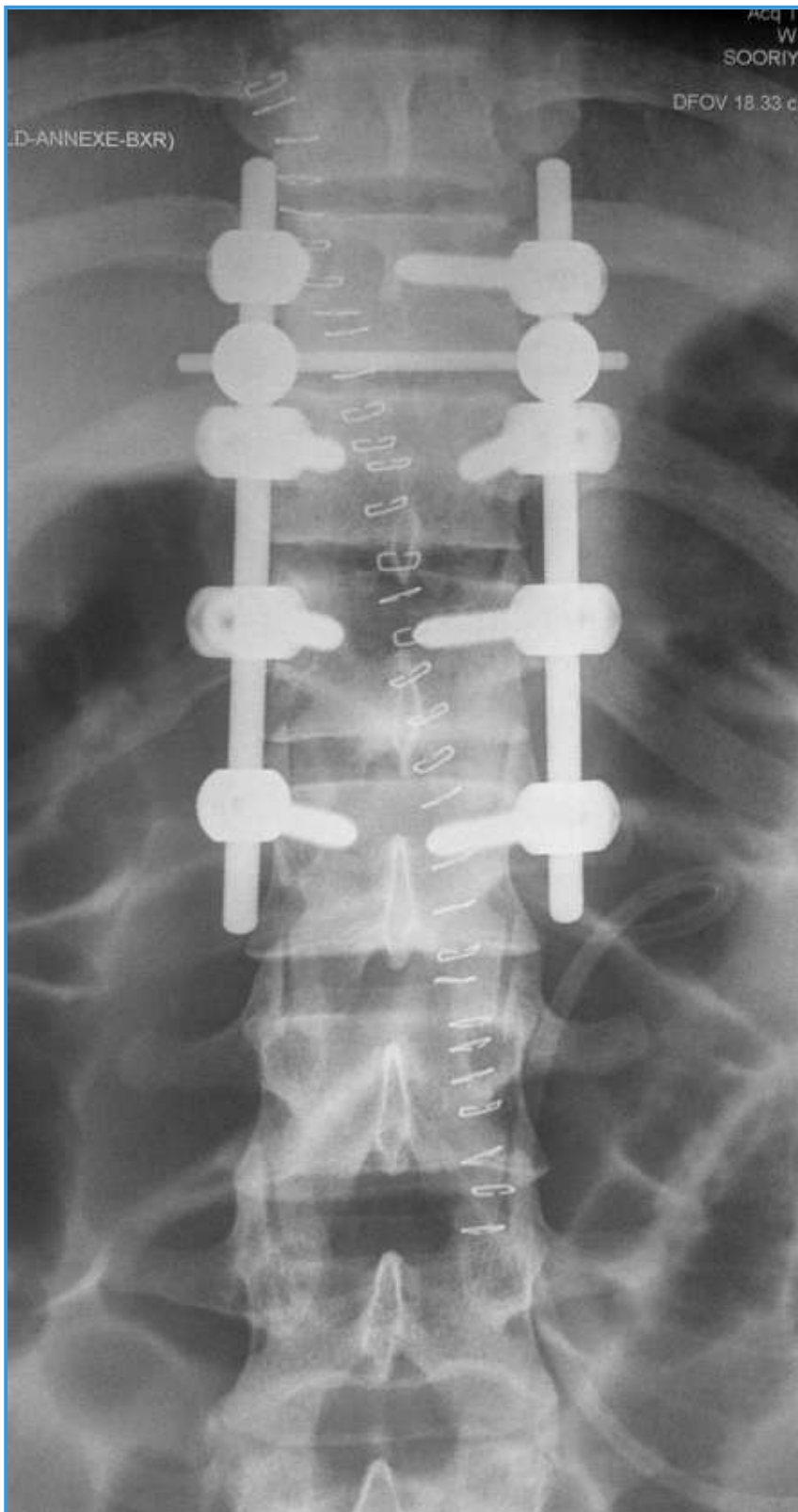
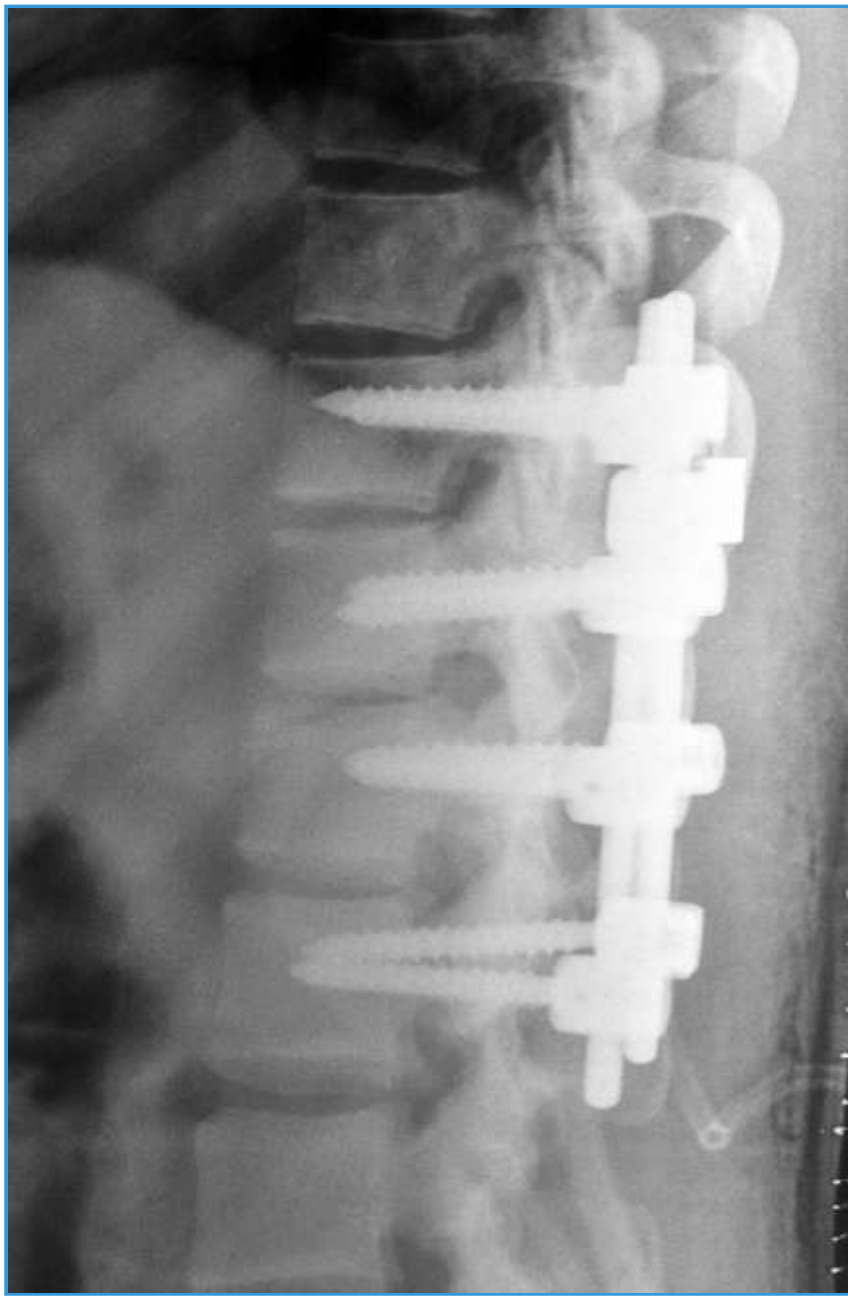
- MRI

- indications
 - better visualisation of the spinal cord and supporting ligamentous structures
 - level of neurological deficit does not align with apparent level of spinal injury
- findings
 - important to evaluate for injury to the posterior longitudinal ligament

- Treatment

- Operative

- **posterior open reduction with instrumented fusion**



- indications

- most patients with thoracolumbar fracture dislocation
- unstable fracture patterns
- disrupted supporting ligamentous structures
- technique
 - midline incision
 - identify fracture-dislocation site
 - use pedicle screws for distraction to obtain anatomical reduction
 - insert posterior instrumentation two levels above and two levels below the site of injury
- outcomes
 - early decompression and instrumentation has been shown to have better outcomes than delayed surgery or non-operative treatment
 - obtain postoperative CT/MRI to see if there is any residual anterior compression

• Complications

- Neurological injury
- Cauda equina syndrome
- DVT
- Non-union after spinal fusion
- Post-traumatic pain
 - most common complication
 - greater with increased kyphotic deformity
- Deformity
 - scoliosis
 - progressive kyphosis
 - common with unrecognized injury to PLL
 - flat back
 - leads to pain, a forward flexed posture, and easy fatigue
 - post-traumatic syringomyelia

19- Osteoporotic Vertebral Compression Fracture

- summary

- Osteoporotic Vertebral Compression Fractures are very common fragility fractures of the spine that affect up to 50% of people over 80 years old.
- Diagnosis can be made with lateral radiographs. Determining the acuity of a fracture requires an MRI or bones scan.
- Treatment is usually observation and pain management. Kyphoplasty is reserved for patients with recalcitrant symptoms after nonoperative treatment for 4-6 weeks fails. Assessment and management of osteoporosis is indicated in the presence of these injuries.

- Epidemiology

- Incidence
 - vertebral compression fractures (VCF) are the most common fragility fracture
 - 700,000 VCF per year in US
 - 70,000 hospitalizations annually
 - 15 billion in annual costs
- Demographics
 - affects up to
 - 25% people over 70 years
 - 50% people over 80 years
- Risk factors
 - history of 2 VCFs
 - is the strongest predictor of future vertebral fractures in postmenopausal women

- Etiology

- Pathoanatomy
 - osteoporosis
 - characteristics

- bone is normal quality but decreased in quantity
 - cortices are thinned
 - cancellous bone has decreased trabecular continuity
- bone mineral density in the lumbar spine (BMD)
 - peaks at
 - between 33 to 40 yrs in women
 - between 19 to 33 years in men
 - peak BMD is widely variable based on demographic factors and location in body
 - decreases with age following peak mass
 - correlate well with bone strength and is a good predictor of fragility fracture
- definition
 - WHO defines osteoporosis as T score below -2.5

○ Associated conditions

- compromised pulmonary function
 - increased kyphosis can affect pulmonary function
 - each VCF leads up to 9% reduction in FV
 - increased risk of mortality from pulmonary dysfunction

• Presentation

○ Symptoms

- pain
 - 25% of VCF are painful enough that patients seek medical attention
 - pain usually localized to area of fracture
 - but may wrap around rib cage if dermatomal distribution

○ Physical exam

- focal tenderness
 - pain with deep palpation of spinous process
- local kyphosis
 - multiple compression fractures can lead to local kyphosis
- spinal cord injury
 - signs of spinal cord compression are very rare
- nerve root deficits
 - may see nerve root deficits with compression fractures of lumbar spine that lead to severe foraminal stenosis

• Imaging

- Radiographs
 - obtain radiographs of the entire spine (concomitant spine fractures in 20%)
 - will see loss of anterior, middle, or posterior vertebral height by 20% or at least 4mm



- CT scan
 - usually not necessary for diagnosis
 - indications
 - fracture on plain film
 - neurologic deficit in lower extremity
 - inadequate plain films
- MRI
 - usually not necessary for diagnosis
 - useful to evaluate for
 - acute vs chronic nature of compression fracture
 - injury to anterior and posterior ligament complex
 - spinal cord compression by disk or osseous material
 - cord edema or hemorrhage

• Studies

- Laboratory
 - a full medical workup should be performed with CBC, BMP
 - ESR may help to rule out infection
 - Urine and serum protein electrophoresis may help rule out multiple myeloma

• Differential

- Metastatic cancer to the spine
 - must be considered and ruled out
 - the following variables should raise suspicion
 - fractures above T5
 - atypical radiographic findings
 - failure to thrive and constitutional symptoms
 - younger patient with no history of fall

- Treatment

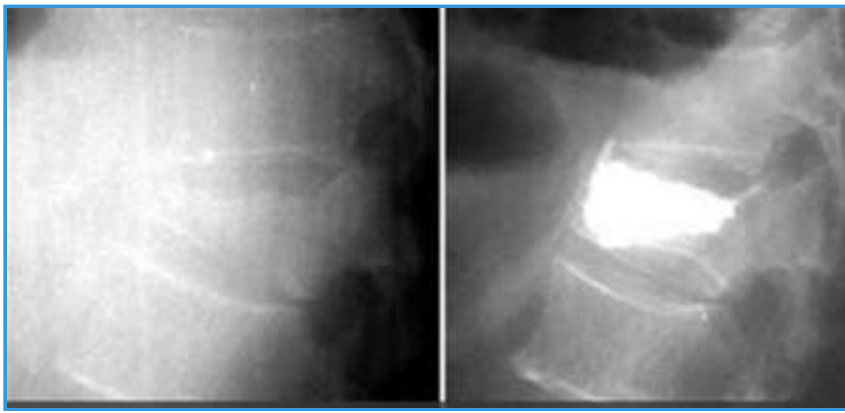
- Nonoperative
 - **observation, bracing, and medical management**
 - indications
 - majority of patients can be treated with observation and gradual return to activity
 - PLL intact (even if > 30 degrees kyphosis or > 50% loss of vertebral body height)
 - technique
 - if the fracture is less than five days old
 - calcitonin can be used for four weeks to decrease pain
 - medical management can consist of bisphosphonates
 - to prevent future risk of fragility fractures
 - some patients may benefit from an extension orthosis
 - although compliance can be an issue
- Operative
 - **vertebroplasty**
 - indications
 - controversial
 - AAOS recommends strongly against the use of vertebroplasty in 2011 but then changed their stance in 2014 based on recent studies
 - outcomes
 - randomized, double-blind, placebo-controlled trials have shown no beneficial effect of vertebroplasty
 - vertebroplasty has higher rates of cement extravasation and associated complications than kyphoplasty
 - **kyphoplasty**
 - indications

- patient continues to have severe pain symptoms after 6 weeks of nonoperative treatment
 - AAOS recommend may be used, but recommendation strength is limited
- technique
 - kyphoplasty is different than vertebroplasty in that a cavity is created by balloon expansion and therefore the cement can be injected with less pressure
 - pain relief thought to be from elimination of micromotion
- **surgical decompression and stabilization**
 - indications
 - very rare in standard VCF
 - progressive neurologic deficit
 - PLL injury and unstable spines
 - technique
 - to prevent possible failure due to osteoporotic bone
 - consider long constructs with multiple fixation points
 - consider combined anterior fixation

- Techniques

- **Kyphoplasty vs. vertebroplasty**

- performed under fluoroscopic guidance
 - percutaneous transpedicular approach used for cannula
 - vertebroplasty
 - PMMA injected directly into cancellous bone without cavity creation
 - performed when cement is more liquid
 - requires greater pressure because no cavity is created
 - increased risk of extravasation into spinal canal is greater
 - kyphoplasty
 - cavity created with expansion device (e.g., balloon) prior to PMMA injection
 - performed when cement is more viscous
 - may be possible to obtain partial reduction of fracture with balloon expansion



- Complications

- Neurological injury
 - can be caused by extravasation of PMMA into spinal canal
 - higher risk with vertebroplasty than kyphoplasty
 - important to consider defects in the posterior cortex of the vertebral body
- Vertebral body osteonecrosis (aka Kummell's disease)
 - Delayed post-traumatic osteonecrosis

- Prognosis

- Mortality
 - 1-year mortality ~ 15% (less than hip fx)
 - 2-year mortality ~20% (equivalent to hip fx)

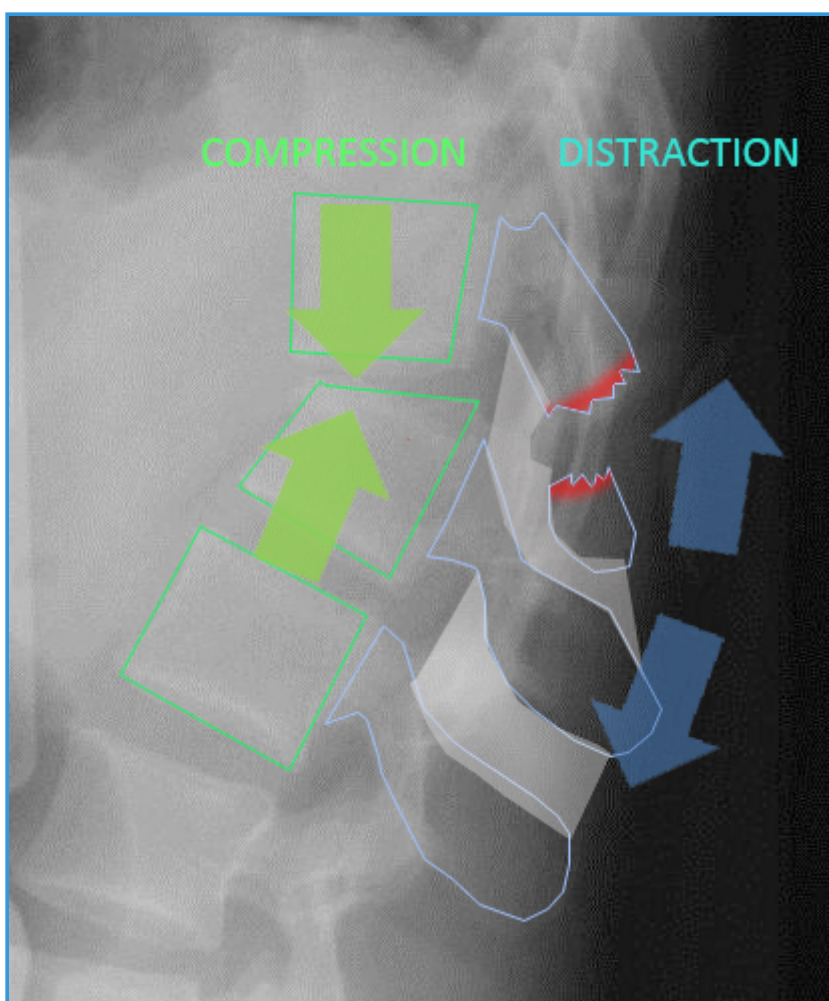
20- Chance Fracture Flexion Distraction Injury

- summary

- Chance Fractures are traumatic fractures of the thoracic and lumbar spine that occur by a flexion-distraction injury mechanism and are associated with high rates of mechanical instability and gastrointestinal injuries.
- Diagnosis of bony Chance fractures is made with radiographs or a CT scan. An MRI may be required to identify a ligamentous Chance injury with disruption of the PLC.
- Treatment can be nonoperative or surgical spinal stabilization depending on the presence of mechanical instability and/or neurological deficits.

- Etiology

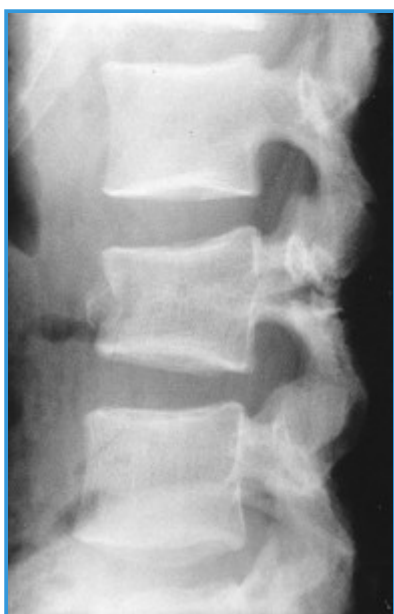
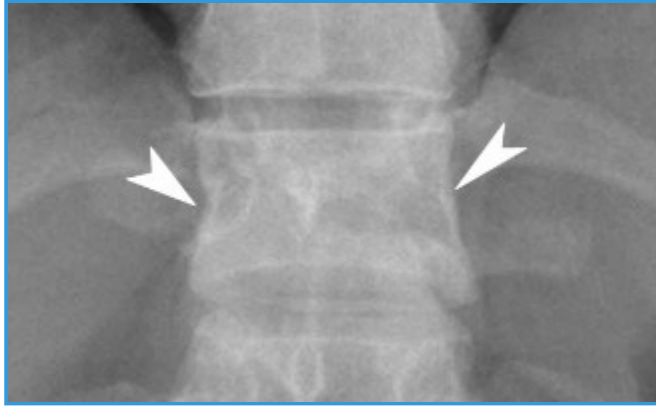
- Mechanism
 - a flexion-distraction injury (seatbelt injury)
 - may be a bony injury
 - may be ligamentous injury (flexion-distraction injury)
 - more difficult to heal
 - middle and posterior columns fail under tension
 - anterior column fails under compression



- Associated injuries
 - high rate of gastrointestinal injuries (50%)

- Imaging

- Radiographs
 - obtain AP and lateral



- flexion-extension radiographs
- MRI
 - important to evaluate for injury to the posterior elements
- CT
 - important to evaluate degree of bone injury and retropulsion of posterior wall into canal

- Treatment

- Nonoperative

- **immobilization in cast or TLSO**

- indications

- neurologically intact patients with

- stable injury patterns with intact posterior elements

- bony Chance fracture

- technique

- may cast or brace (TLSO) in extension

- must be followed for non-union and kyphotic deformity

- Operative

- **surgical decompression and stabilization**

- indications

- patients with neurologic deficits

- unstable spine with injury to the posterior ligaments (soft-tissue Chance fx)

- techniques

- anterior decompression and stabilization

- usually with vertebrectomy and strut grafting followed by instrumentation

- posterior indirect decompression and stabilization and compression fusion construct

- historically three levels above and two levels below

- modern pedicle screws have changed this to one level above and one level below

- distraction construct in burst fractures

- compression construct in Chance fractures

- Complications

- Pain

- most common

- Deformity

- scoliosis

- progressive kyphosis

- common with unrecognized injury to PLL

- flat back

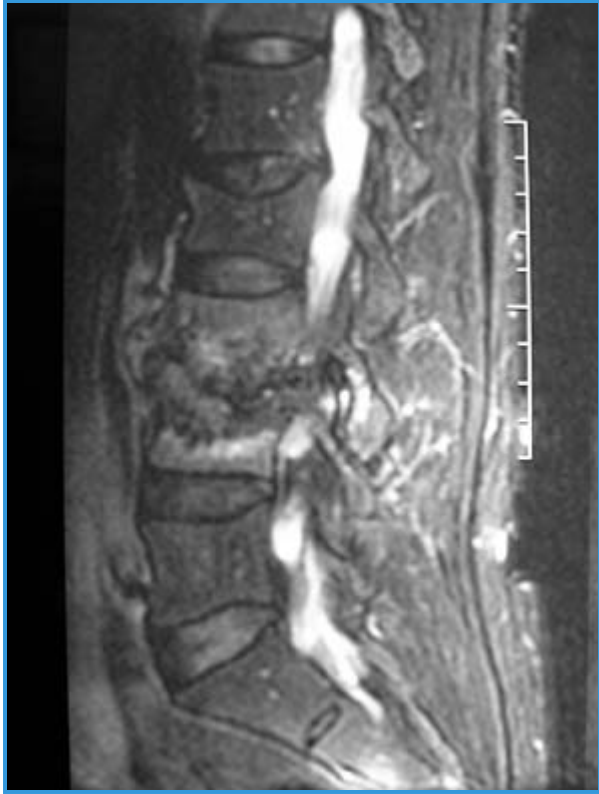
- leads to pain, a forward flexed posture, and easy fatigue

- post-traumatic syringomyelia

- Nonunion

21- Adult Pyogenic Vertebral Osteomyelitis

Images



- summary
 - Adult Pyogenic Vertebral Osteomyelitis, also known as spondylodiskitis, represents a spectrum of spinal infections including discitis, vertebral osteomyelitis, and epidural abscess.
 - Diagnosis is made with MRI studies with contrast.
 - Treatment may be long-term targeted antibiotics alone or surgical decompression and stabilization depending on the extent and chronicity of infection, location in the spine, and identification and susceptibility to antimicrobials of the pathogen.
- Epidemiology
 - Demographics
 - usually seen in adults (median age for pyogenic osteomyelitis is 50 to 60 years)
 - Anatomic location
 - 50-60% of cases occur in lumbar spine
 - 30-40% in thoracic spine
 - ~10% in cervical spine
 - Risk factors include
 - IV drug abuse
 - diabetes

- recent systemic infection (UTI, pneumonia)
- malignancy
- immunodeficiency or immunosuppressive medications
- obesity
- malnutrition (serum albumin < 3 g/dL indicative of malnutrition)
- trauma
- smoking

- Etiology

- Pathophysiology

- pathogens
 - bacterial
 - staph aureus
 - most common (50-65%)
 - staph epidermidis
 - is second most common cause
 - gram negative infections
 - increasing over last decade and often associated with gram negative infections of the GU and respiratory tract
 - pseudomonas
 - seen in patients with IV drug use
 - salmonella
 - seen in patients with sickle cell disease
 - fungal
 - tuberculosis
 - inoculation
 - hematogenous seeding
 - generally agreed that inoculation likely occurs through hematogenous seeding (arterial or venous) of the endplates and intervertebral discs
 - endplates contain area of low-flow vascular anastomosis that may provide an environment suited for inoculation
 - involvement of one endplate leads to direct extension into intervertebral discs, followed by direct extension into the second endplate
 - direct inoculation
 - can occur after penetrating trauma, open fractures, and following surgical procedure

- contiguous spread from local infection
 - most commonly associated with retropharyngeal and retroperitoneal abscesses
- neurologic involvement
 - neurologic deficits present in 10-20%
 - results from
 - direct infectious involvement of neural elements
 - compression from an epidural abscess
 - compression from instability of the spine
- Associated conditions
 - epidural abscess
 - defined as a collection of pus or inflammatory granulation tissue between dura mater and surrounding adipose tissue
 - epidemiology
 - usually associated with vertebral osteomyelitis
 - present in ~18% of patients with spondylodiskitis
 - 50% of patients with an epidural abscess will have neurologic symptoms
 - psoas abscess

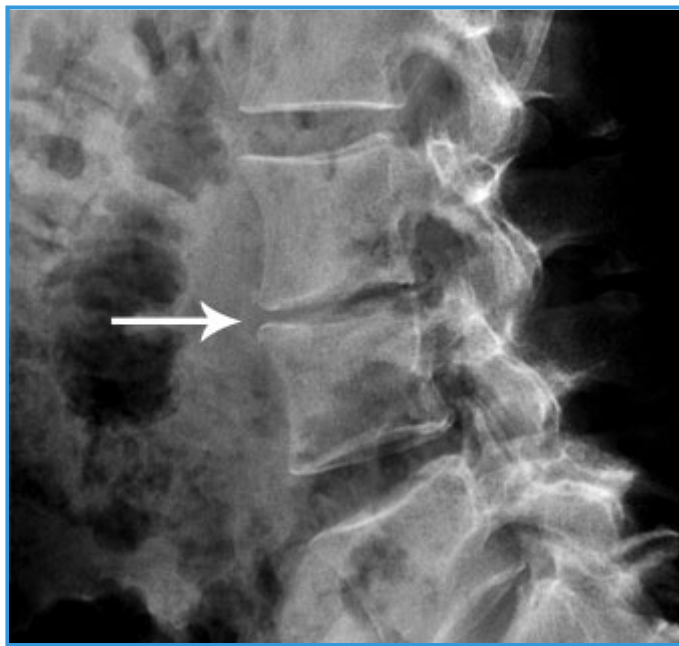
• Presentation

- History
 - history of UTI, pneumonia, skin infection, of organ transplant are common
- Symptoms
 - fever is only present in 1/3 of patients
 - pain
 - pain is often severe and insidious in onset
 - pain is usually worse with activity and unrelenting in nature
 - pain that awakens patients at night should raise concern for malignancy and infection
 - neurologic symptoms present in 10-20%
 - radiculopathy
 - myelopathy
- Physical exam
 - perform careful neurological exam

• Imaging

- Radiographs

- findings are usually delayed by weeks
- findings include
 - paraspinous soft tissue swelling (loss of psoas shadow)
 - seen if first few days
 - disc space narrowing and disc destruction
 - seen at 7-10 days



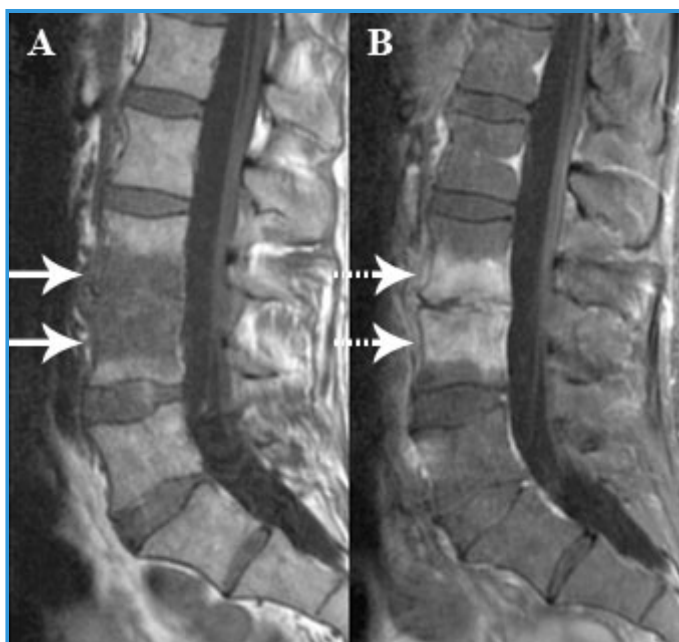
- remember disc destruction is atypical of neoplasm
- endplate erosion or sclerosis seen at 10-21 days
- local osteopenia

- CT

- useful to show bony abnormalities, abscess formation, and extent of bony involvement

- MRI

- MRI with gadolinium contrast
 - indications
 - gold standard for diagnosis and treatment
 - sensitivity and specificity
 - most sensitive (96%) and specific (93%) imaging modality for diagnosis of spinal osteomyelitis



- also most specific imaging modality to differentiate from tumor
- timing

- if performed early, finding may be interpreted as degenerative changes
 - repeat MRI to see progression may be required
- findings include
 - paraspinal and epidural inflammation
 - disc and endplate enhancement with gadolinium
 - T2-weighted hyperintensity of the disk and endplate
 - rim enhancing

○ Bone scan

- Technetium Tc99m bone scans
 - indications
 - patients who can not obtain an MRI
 - sensitivity and specificity
 - 90% sensitive but lack specificity
 - combined Technetium Tc99m and gallium 67 scan is both more specific and more sensitive than Technetium Tc99m alone
- indium 111 labeled scan
 - not recommended due to poor sensitivity (17%)

• Studies

○ Laboratory

- WBC
 - elevated only in ~ 50%
 - not a sensitive indicator for early infection
- ESR
 - elevated in 90% of cases
 - can be monitored serially to track success of treatment, however is considered less reliable than CRP
- CRP
 - elevated in 90% of cases
 - can be monitored serially to track success of treatment and is considered more reliable than ESR
- blood cultures
 - indications
 - all patients prior to antibiotic administration if organism unknown
 - identification of organism is mandatory for treatment
 - sensitivity & specificity
 - least invasive method to determine a diagnosis

- ~33% (reports show 25%-66%) of patients with spondylodiskitis have positive blood cultures
- when positive 85% are accurate for isolating the correct organism
- blood culture yield is improved by withholding antibiotic and obtaining cultures when patient is febrile
- CT guided biopsy
 - indications
 - in patients who do not have indications for immediate open surgery and blood cultures are negative
 - sensitivity & specificity
 - can provide diagnosis in 68-86% of patients
 - technique
 - can be guided by fluoroscopy or by CT scan



- cultures should be sent for
 - aerobic
 - anaerobic
 - fungal
 - acid-fast cultures
- Open biopsy
 - indications
 - when tissue/organism diagnosis can not be made with noninvasive techniques
 - technique
 - anterior, costotransversectomy, or transpedicular approach used

• Differential

- Spinal tumors
 - MRI is the most specific imaging modality to differentiate from tumor
 - features that weigh towards an infection include
 - disc space involvement
 - end-plate erosion

- significant inflammation

- Treatment

- Nonoperative

- **immediate broad spectrum antibiotics**

- indications

- critically ill patient who are septic

- obtain gram stains and cultures first then start abx

- consider immediate CT guided aspiration prior to administration of IV abx

- will not be able to wait for culture results before starting broad spectrum abx

- technique

- vancomycin +

- for penicillin-resistant and gram-positive bacteria

- third-generation cephalosporin

- for gram-negative coverage

- **organism-specific antibiotic for 6-12 weeks +/- bracing**

- indications

- lumbar vertebral osteomyelitis

- organism must be identified and sensitive to antibiotics

- controversial - some argue surgical debridement needed

- bracing

- helps improve pain and prevent deformity

- rigid cervicothoracic orthosis or halo required for cervical osteomyelitis

- antibiotics

- indications

- once organism has been identified via blood culture or biopsy

- technique

- usually treated with IV culture directed antibiotics until signs of improvement (~ 4-6 weeks) and then converted to PO antibiotics

- resistant strains

- new antibiotic-resistant strains of microorganisms are becoming more common and failure to diagnose can have negative consequences

- organisms include

- MRSA (methicillin-resistant Staph aureus)
 - VRSA (vancomycin resistant Staph aureus)
 - VRE (vancomycin resistant enterococcus)
 - treatment
 - newer generation antibiotics for antibiotic resistant organisms include linezolid and daptomycin
 - outcomes
 - successful in 80%
- Operative
 - **open biopsy alone**
 - indications
 - cultures and CT guided biopsy fail to provide pathogen
 - lumbar disease without abscess formation in canal
 - technique
 - can use transpedicular (kyphoplasty-like) approach
 - **neurologic decompression, surgical debridement, and spinal stabilization**
 - indications
 - cervical vertebral osteomyelitis
 - progressive neurologic deficits
 - progressive deformity & gross spinal instability
 - refractory cases
 - large abscess formation
 - technique
 - dictated by characteristics of pathology
 - anterior debridement and strut grafting, +/- posterior instrumentation
 - considered to be gold standard
 - posterior debridement and decompression alone
 - usually ineffective for debridement
 - may be indicated in some cases

• Techniques

- **Anterior debridement and strut grafting, +/- posterior instrumentation**
 - goals
 - identify organism
 - eliminate infection
 - prevent or improve neurologic deficits

- maintain spinal stability
- techniques
 - strut graft selection
 - autogenous tricortical iliac crest, rib, or fibula strut grafts have proven safe and effective in presence of acute infection
 - allograft being used with good results, but autogenous sources theoretically have better incorporation
 - a recent study showed improved deformity correction with titanium mesh cages filled with autograft (followed by posterior instrumentation)
 - instrumentation
 - spinal instrumentation in presence of active infection is controversial
 - some advocate I&D followed by staged instrumentation
 - some advocate a single procedure with bone graft and instrumentation in the presence of an active infection
 - titanium is preferred over stainless steel
 - posterior instrumentation
 - posterior instrumentation indicated when severe kyphotic deformity or a multilevel anterior construct required
 - posterior instrumentation can be performed at same time or as a staged procedure

22- Spinal Epidural Abscess

Images



- summary
 - Spinal Epidural Abscess is a spinal infection caused by a collection of pus or inflammatory granulation tissue between the dura mater and surrounding adipose tissue.
 - Early diagnosis is critical and is made with MRI studies with contrast.
 - Treatment is usually prompt surgical decompression and long-term IV antibiotics.
- Epidemiology
 - Demographics
 - usually seen in adults > 60 years of age
 - Anatomic location
 - usually dorsal in thoracolumbar spine
 - Risk factors
 - IV drug abuse
 - immunodeficiency
 - malignancy
 - HIV
 - immunosuppressive medications
 - recent spinal procedure
- Etiology

- Pathophysiology
 - origin
 - hematogenous spread ~50%
 - spread from diskitis ~ 33%
 - pathogens
 - staph aureus is most common (50-65%)
 - gram negative infections such as E coli (18%)
 - pseudomonas seen in patients with IV drug use
- Neurologic deficits
 - 33% of patients with an epidural abscess will have neurologic symptoms
 - 4-22% incidence of permanent paralysis
 - can be caused from direct compression or infarction of spinal cord blood flow.
- Associated conditions
 - often associated with vertebral osteomyelitis and discitis (spondylodiscitis)
 - present in ~18% of patients with spondylodiscitis

• Presentation

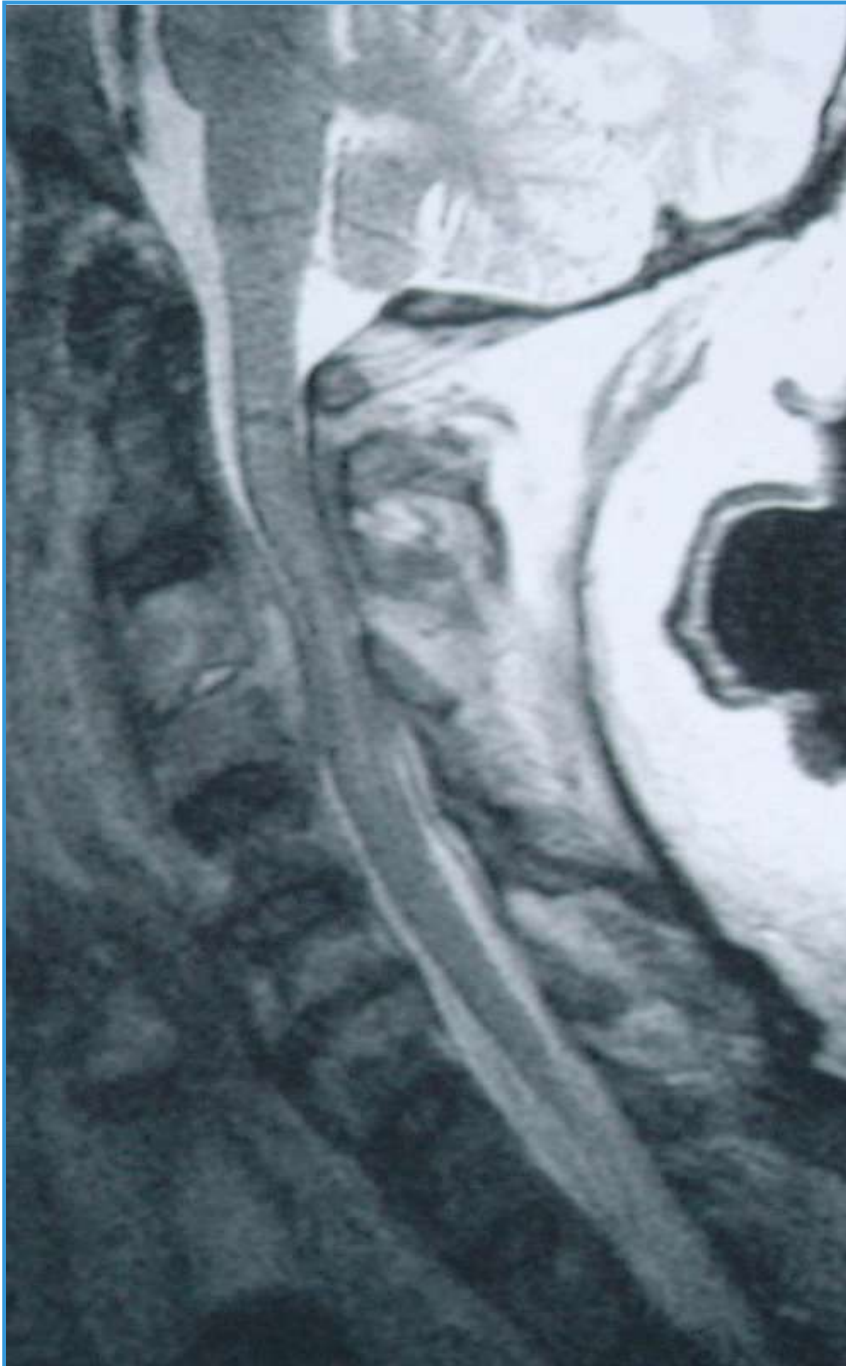
- Symptoms
 - systemic illness more profound than patients with vertebral osteomyelitis
 - fever present in ~50%
 - pain
 - pain is often severe and insidious in onset and occurs in 87%
- Physical exam
 - neurologic deficits present in ~33%
 - may present as a radiculopathy or a myelopathy

• Labs

- WBC
 - mean leukocytosis 22,000 cells/mm³
 - elevated in ~42%
- ESR
 - elevated in > 90% of cases (mean 86.3)
- CRP
 - elevated in 90% of cases

• Imaging

- Radiographs
 - usually normal
- CT
 - poor sensitivity for epidural abscess
- CT myelogram
 - 90% sensitivity but invasive
- MRI with gadolinium
 - the imaging modality of choice for diagnosis of spinal epidural abscess



- shows the extent of abscess, presence of vertebral osteomyelitis, and allows evaluation of neurologic compression



- gadolinium allows differentiation of pus from CSF



- a ring enhancing lesion is pathognomonic for abscess
- entire spine MRI should be performed to rule out skip epidural abscesses
 - concomitant infection outside of the spine
 - delayed presentation (>7 days of symptoms)
 - ESR > 95 mm/hr

• Treatment

○ Nonoperative

■ **bracing and IV antibiotics**

- indications
 - small abscess with minimal compression on neural elements and
 - no neurologic deficits and
 - a patient capable of close clinical followup
 - those who are not candidates for surgery due to medical comorbidities
- outcomes

- historically presence of epidural abscess has been considered a surgical emergency
- there has been a recent trend towards nonoperative management as new studies shows nonoperative treatment effective in patients without neurologic deficit
- medical treatment failure associated with:
 - neurologic deficits (strongest predictor of medical treatment failure)
 - diabetes
 - CRP >115 mg/L
 - WBC >12 k/mL
 - positive blood cultures
 - age >65 years
 - MRSA

○ Operative

■ **surgical decompression +/- spinal stabilization**

- indications
 - neurologic deficits present
 - risk factors for failure of nonoperative management: older (>65yrs), diabetics, new-onset neurologic deficits, and MRSA infections
 - evidence of spinal cord compression on imaging studies
 - persistent infection despite antibiotic therapy
 - progressive deformity or gross spinal instability
- postoperative antibiotics
 - indicated for 2-4 weeks if no bony involvement of infection
 - indicated for 6 weeks if bony involvement

• Techniques

○ **Decompressive laminectomy**

- most common form of operative treatment
- indications
 - indicated when abscess is posterior and there is no contiguous spondylodiscitis
- avoid wide decompression and facetectomy as it will result in spinal instability

○ **Anterior debridement and strut grafting**

- indications
 - abscess is located anteriorly

- anterior vertebral body and discs are involved (presence of spondylodiscitis)



- Prognosis

- Preoperative degree of neurologic deficits is most important indicator of clinical outcome
- Mortality ~ 5%
- Early diagnosis is most essential factor in preventing devastating outcomes

23- Spinal Tuberculosis

- summary

- Spinal Tuberculosis, also known as Pott's Disease, is a spinal infection caused by tuberculosis that can lead to osteomyelitis, kyphotic deformity, and spinal mechanical instability.
- Diagnosis is made with a CT-guided biopsy sent for acid-fast bacilli.
- Treatment is usually bracing and anti-tuberculosis antibiotics in the absence of neurological defects or mechanical instability. Surgical management is indicated in the presence of neurological deficits, progressive kyphosis, and/or mechanical instability.

- Epidemiology

- Incidence
 - increasing incidence of TB in United States due to increasing immunocompromised population
- Demographics
 - HIV positive population (often seen in patients with CD4+ count of 50 to 200)
- Anatomic location
 - 15% of patients with TB will have extrapulmonary involvement
 - the spine, and specifically, the thoracic spine is the most common extrapulmonary site
 - 5% of all TB patients have spine involvement

- Etiology

- Pathoanatomy
 - early infection
 - begins in the metaphysis of the vertebral body
 - spreads under the anterior longitudinal ligament and leads to
 - contiguous multilevel involvement
 - skip lesion or noncontiguous segments (15%)
 - paraspinal abscess formation (50%)

- usually anterior and can be quite large (much more common in TB than pyogenic infections)
- initially does not involve the disc space (distinguishes from pyogenic osteomyelitis, but can be misdiagnosed as a neoplastic lesion)



- chronic infection
 - severe kyphosis
 - mean deformity in nonoperative cases is 15°
 - in 5% of patients, deformity is $>60^\circ$
 - higher rate of progression of kyphosis when involvement of the vertebral body and posterior elements
 - infection is often diagnosed late, there is often much more severe kyphosis in granulomatous spinal infections compared to pyogenic infections
 - in adults
 - kyphosis stays static after healing of disease
 - in children
 - kyphosis progresses in 40% of cases because of growth spurt
 - classification of progression (Rajasekaran)
 - Type-I, increase in deformity until cessation of growth
 - should be treated with surgery
 - Type-II, decreasing progression with growth
 - Type-III, minimal change during either active / healed phases.

• Presentation

○ Symptoms

- onset of symptoms of tuberculous spondylitis is typically more insidious than pyogenic infection
 - constitutional symptoms
 - chronic illness
 - malaise
 - night sweats

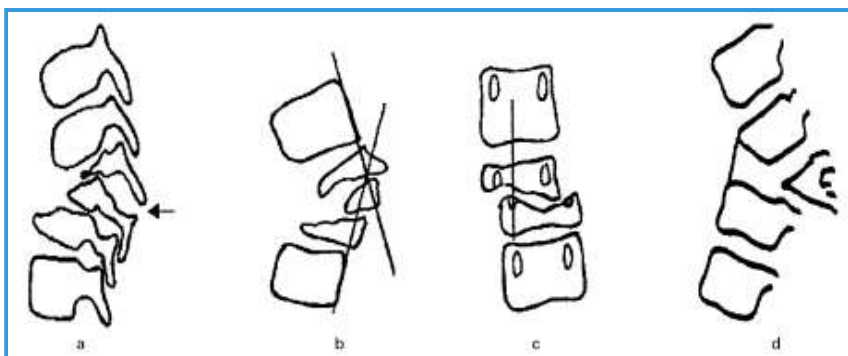
- weight loss
 - back pain
 - often a late symptom that only occurs after significant bony destruction and deformity.
- Physical exam
 - kyphotic deformity
 - neurologic deficits (present in 10-47% of patients with Pott's Disease)
 - mechanisms
 - mechanical pressure on cord by abscess, granulation tissue, tubercular debris, caseous tissue
 - mechanical instability from subluxation/dislocation
 - paraplegia from healed disease can occur with severe deformity
 - stenosis from ossification of ligamentum flavum adjacent to severe kyphosis

• Imaging

- CXR
 - 66% will have an abnormal CXR
 - should be ordered for any patients in which TB is a possibility
- Spine radiographs
 - early infection
 - shows involvement of anterior vertebral body with sparing of the disc space (this finding can differentiate from pyogenic infection)
 - late infection
 - shows disk space destruction, lucency and compression of adjacent vertebral bodies, and development of severe kyphosis



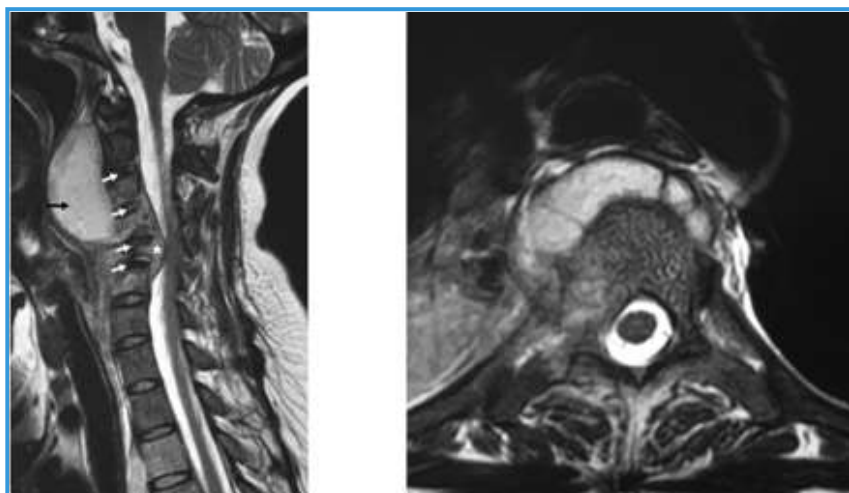
- risk factors for buckling collapse ("spine at risk signs")



- retropulsion
- subluxation
- lateral translation
- toppling
- MRI with gadolinium contrast
 - indications
 - remains preferred imaging study for diagnosis and treatment



- diagnose adjacent levels
 - multiple levels involved in 16-70%
- findings
 - low signal on T1-weighted images, bright signal on T2-weighted images
 - presence of a septate pre-/ paravertebral / intra-osseous smooth walled abscess with a subligamentous extension and breaching of the epidural space



- end-plate disruption
 - sensitivity 100%, specificity 81%
 - paravertebral soft tissue shadow
 - sensitivity 97%, specificity 85%
 - high signal intensity of the disc on the T2-weighted image
 - sensitivity 81%, specificity 82%
 - spinal cord
 - edema
 - myelomalacia
 - atrophy
 - syringomyelia
- CT
 - indications
 - demonstrates lesions <1.5cm better than radiographs
 - inaccurate for defining epidural extension
 - findings
 - types of destruction
 - fragmentary
 - osteolytic
 - subperiosteal
 - sclerotic
- Nuclear medicine studies
 - obtain with combination of technetium and gallium
 - shown to have highest sensitivity for detecting infection

• Studies

- CBC
 - relative lymphocytosis
 - low hemoglobin
- ESR
 - usually elevated but may be normal in up to 25%
- PPD (purified protein derivative of tuberculin)
 - positive in ~ 80%
- Diagnosis
 - CT guided biopsy with cultures and staining effective at obtaining a diagnosis
 - should be tested for acid-fast bacilli (AFB)

- mycobacteria (acid-fast bacilli) may take 10 weeks to grow in culture
- PCR allows for faster identification (95% sensitivity and 93% accuracy)
- smear positive in 52%
- culture positive in 83%

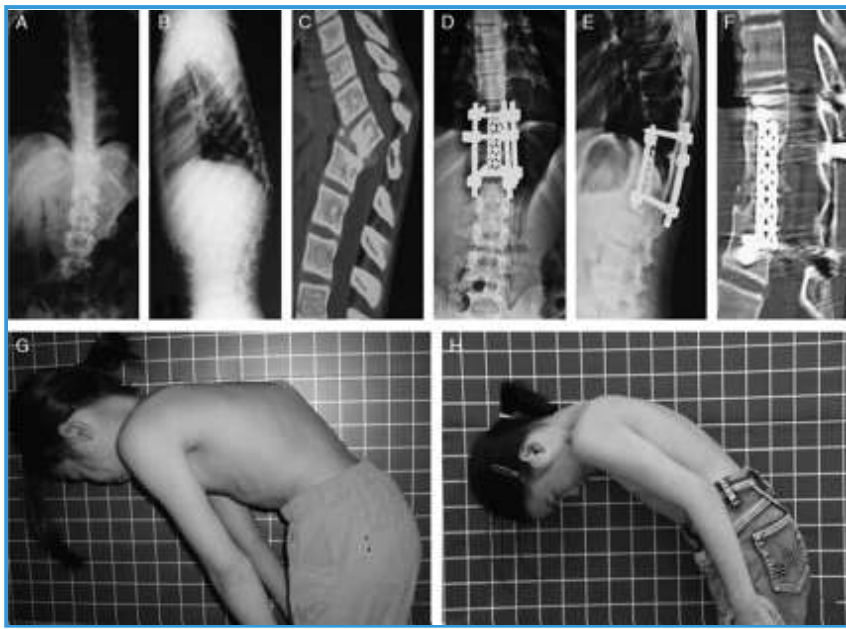
- Differential

- Other etiologies of granulomatous infection may have similar clinical picture as TB and include
 - atypical bacteria
 - Actinomyces israelii
 - Nocardia asteroides
 - Brucella
 - fungi
 - Coccidioides immitis
 - Blastomyces dermatitidis
 - Cryptococcus neoformans
 - Aspergillosis
 - spirochetes
 - Treponema pallidum

- Treatment

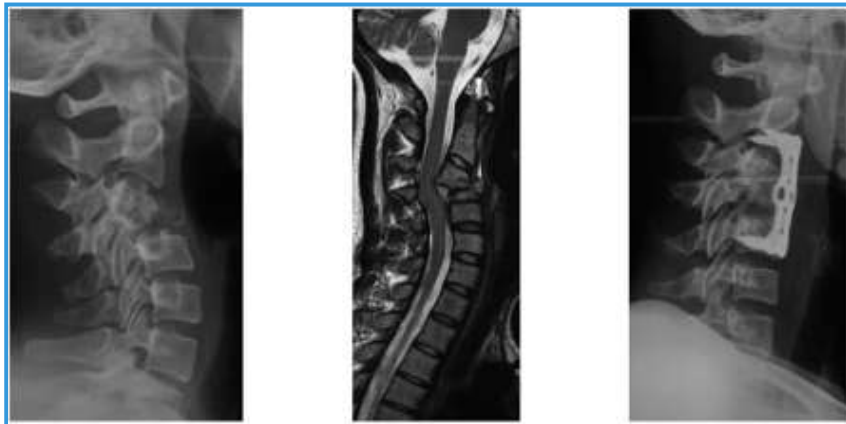
- Nonoperative
 - **pharmacologic treatment +/- spinal orthosis**
 - indications
 - no neurological deficit
 - drugs are the mainstay of treatment in most cases
 - pharmacologic
 - agents
 - isoniazid (H), rifampin (R), ethambutol (E) and pyrazinamide (Z) therapy
 - regimen
 - RHZE for 2 months, then RH for 9 to 18 months
 - spinal orthosis
 - indications
 - may be used for pain control and prevention of deformity
- Operative

- anterior decompression/corpectomy, strut grafting ± posterior instrumented stabilization ± posterior column shortening



- indications
 - neurologic deficit
 - worsening neurological deficit
 - acute severe paraplegia
 - with panvertebral involvement with/without subluxation/dislocation
 - spinal instability
 - kyphosis correction
 - > 60° in adult
 - progressive kyphosis in child
 - ≥3 vertebrae involved with loss of ≥1.5 vertebral bodies in thoracic spine
 - children ≤ 7 years with ≥3 vertebral bodies affected in T/TL spine and ≥ 2 at risk signs are likely to have progression and should undergo correction
 - late onset paraplegia (from kyphosis)
 - cosmetic correction of kyphosis controversial
 - advanced disease with caseation preventing access by antibiotics
 - failure of nonoperative treatment after 3 to 6 months
 - diagnosis uncertain
 - panvertebral lesion
- advantages of surgical treatment
 - less progressive kyphosis
 - earlier healing
 - decreased sinus formation
 - in patients with neurologic deficits, early debridement and decompression led to improved neurologic recovery
- technical aspects

- autogenous and allograft strut grafts are acceptable with good results
- continue medical management with isoniazid, rifampin, and pyrazinamide
- chronic implant colonization is less common in TB and other granulomatous infections compared to more common pyogenic infections
- **Halo traction, anterior decompression, bone grafting, anterior plating**



- indications
 - cervical kyphosis
- **Pedicle subtraction osteotomy**
 - indications
 - lumbar kyphosis
- **Direct decompression / internal kyphectomy**
 - indications
 - correction of healed thoracic/thoracolumbar kyphosis
 - allows spinal cord to transpose anteriorly

• Technique

- **Anterior decompression/corpectomy, strut grafting ± posterior instrumented stabilization ± posterior column shortening**
 - indications (see above)
 - kyphosis
 - active disease
 - techniques
 - single-stage transpedicular
 - 2-stage
 - anterior decompression with bone grafting
 - posterior kyphosis correction and instrumentation
 - single-stage extrapleural anterolateral

• Complications

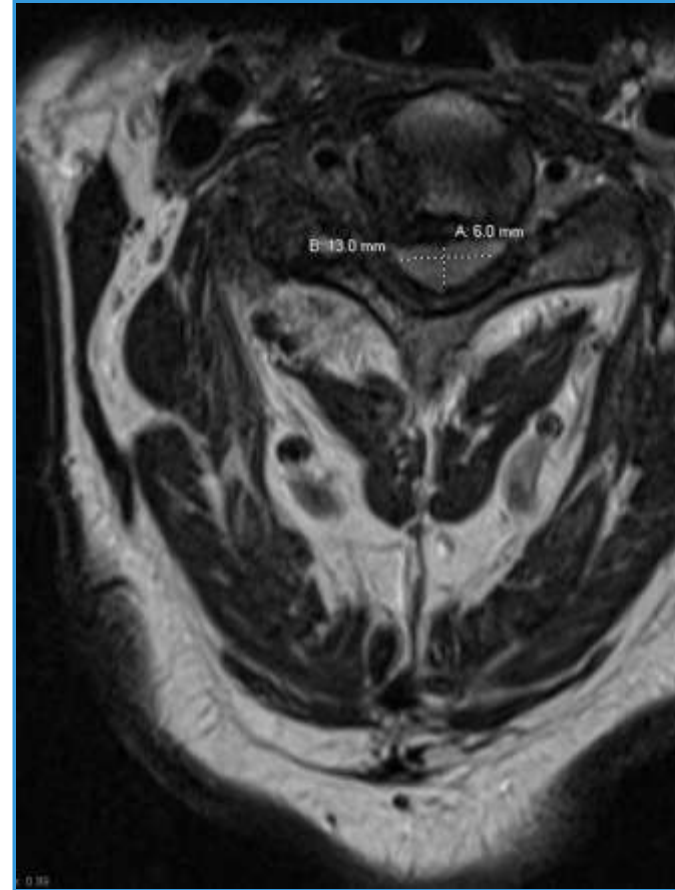
- Deformity (kyphosis/gibbus)
 - highest risk
 - after anterior decompression and grafting alone
 - slippage and breakage of graft (especially if ≥ 2 levels)
 - lowest risk
 - after both anterior and posterior fusion
- Retropharyngeal abscess affects swallowing/hoarseness
- TB arteritis and pseudoaneurysm
- Respiratory compromise if there is costopelvic impingement
- Sinus formation
- Pott's paraplegia
 - spinal cord injury can be caused by abscess/bony sequestra or meningomyelitis
 - abscess/bony sequestra has a better prognosis than meningomyelitis as the cause of spinal cord injury

- Atypical Spinal Tuberculosis

- definition
 - compressive myelopathy without visible spinal deformity, without typical radiological appearance
- etiology
 - intraspinal granuloma, neural arch involvement, concertina collapse of vertebra body , sclerotic vertebra with bridging of vertebral body
- treatment
 - **laminectomy**
 - indications
 - extradural extraosseous granuloma
 - subdural granuloma
 - **decompression and myelotomy**
 - indications
 - intramedullary granuloma

24- Cervical Myelopathy

Images



- summary

- Cervical Myelopathy is a common form of neurologic impairment caused by compression of the cervical spinal cord most commonly due to degenerative cervical spondylosis.
- The condition most commonly presents in older patients with symmetric numbness and tingling in the extremities, hand clumsiness, and gait imbalance.
- Treatment is usually surgical decompression and stabilization as the condition is associated with step-wise progression.

- Etiology

- Pathophysiology
 - etiology
 - degenerative cervical spondylosis (CSM)
 - most common cause of cervical myelopathy
 - compression usually caused by:
 - osteophytes
 - discosteophyte complex
 - degenerative spondylolisthesis
 - hypertrophy of ligamentum flavum

- congenital stenosis
 - symptoms usually begin when congenital narrowing combined with spondylotic degenerative changes in older patients
 - OPLL
 - tumor
 - epidural abscess
 - trauma
 - cervical kyphosis
- neurologic injury
 - mechanism of injury
 - direct cord compression
 - ischemic injury secondary to compression of anterior spinal artery
- Associated conditions
 - lumbar spinal stenosis
 - tandem stenosis occurs in lumbar and cervical spine in ~20% of patients

- Classification of Myelopathy

- Nurick Classification
 - based on gait and ambulatory function

○	■ Nurick Classification		
	■ Grade 0	■ Root symptoms only or normal	■
	■ Grade 1	■ Signs of cord compression; normal gait	■
	■ Grade 2	■ Gait difficulties but fully employed	■
	■ Grade 3	■ Gait difficulties prevent employment, walks unassisted	■
	■ Grade 4	■ Unable to walk without assistance	■
	■ Grade 5	■ Wheelchair or bedbound	■

- Ranawat Classification

○	■ Ranawat Classification		
	■ Class I	■ Pain, no neurologic deficit	■
	■ Class II	■ Subjective weakness, hyperreflexia, dysesthesias	■
	■ Class IIIA	■ Objective weakness, long tract signs, ambulatory	■
	■ Class IIIB	■ Objective weakness, long tract signs, non-ambulatory	■

- Japanese Orthopaedic Association Classification

TABLE I Japanese Orthopaedic Association Criteria* for the Evaluation of Operative Results in Patients with Cervical Myelopathy*	
I. Upper extremity function	
Impossible to eat with either chopsticks or spoon (0 points)	
Possible to eat with spoon, but not with chopsticks (1 point)	
Possible to eat with chopsticks but inadequate (2 points)	
Possible to eat with chopsticks but awkward (3 points)	
Normal (4 points)	
II. Lower extremity function	
Impossible to walk (0 points)	
Need cane or aid on flat ground (1 point)	
Need cane or aid only on stairs (2 points)	
Possible to walk without cane or aid, but slow (3 points)	
Normal (4 points)	
III. Sensory	
Upper extremity	
Apparent sensory loss (0 points)	
Minimal sensory loss (1 point)	
Normal (2 points)	
Lower extremity	
Apparent sensory loss (0 points)	
Minimal sensory loss (1 point)	
Normal (2 points)	
Trunk	
Apparent sensory loss (0 points)	
Minimal sensory loss (1 point)	
Normal (2 points)	
IV. Bladder function	
Complete retention (0 points)	
Severe disturbance (1 point)	
Inadequate evacuation of bladder	
Straining	
Dribbling of urine	
Mild disturbance (2 points)	
Urinary frequency	
Urinary hesitancy	
Normal (3 points)	
*Total normal score = 17 points.	

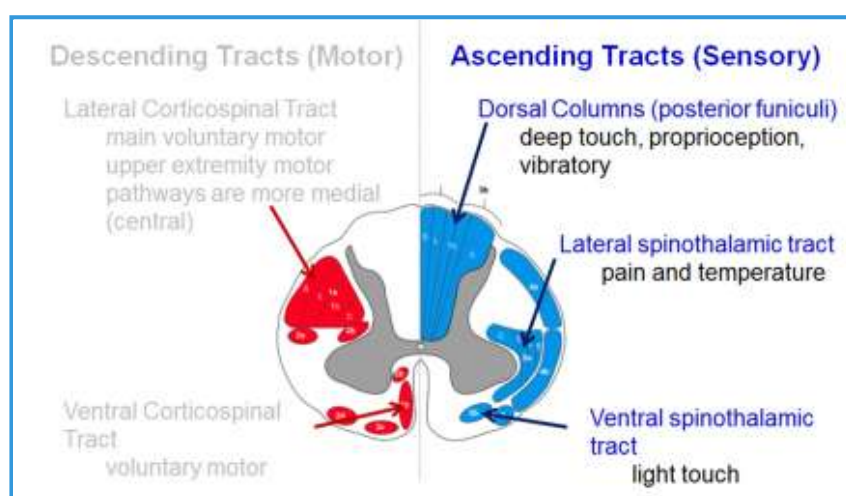
- A point scoring system (17 total) based on function in the following categories
 - upper extremity motor function
 - lower extremity motor function
 - sensory function bladder function
- Usually a significant improvement at 1-year postop, even in cases of severe myelopathy

• Presentation of Myelopathy

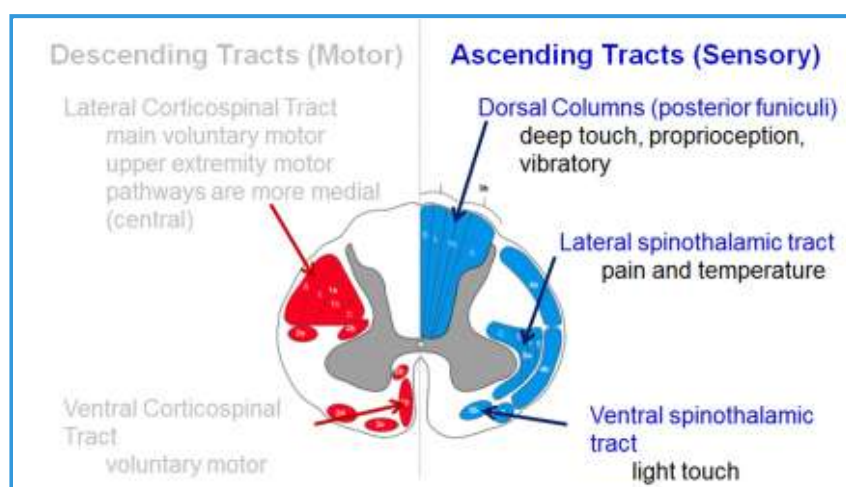
○ Symptoms

- neck pain and stiffness
 - axial neck pain (often absent)
 - occipital headache common
- extremity paresthesias
 - diffuse, bilateral, nondermatomal numbness and tingling
- weakness and clumsiness
 - bilateral weakness and decreased manual dexterity (dropping object, difficulty manipulating fine objects)
- gait instability
 - patient feels "unstable" on feet
 - weakness walking up and down stairs

- gait changes are most important clinical predictor
- urinary retention
 - rare and only appear late in disease progression
 - not very useful in diagnosis due to high prevalence of urinary conditions in this patient population
- Physical exam
 - motor
 - weakness
 - usually difficult to detect on physical exam
 - lower extremity weakness is a more concerning finding
 - finger escape sign
 - when patient holds fingers extended and adducted, the small finger spontaneously abducts due to weakness of intrinsic muscle
 - grip and release test
 - normally a patient can make a fist and release 20 times in 10 seconds. myelopathic patients may struggle to do this
 - sensory
 - proprioception dysfunction
 - due to dorsal column involvement



- occurs in advanced disease
- associated with a poor prognosis
- decreased pain sensation
 - pinprick testing should be done to look for global decrease in sensation or dermatomal changes
 - due to involvement of lateral spinothalamic tract

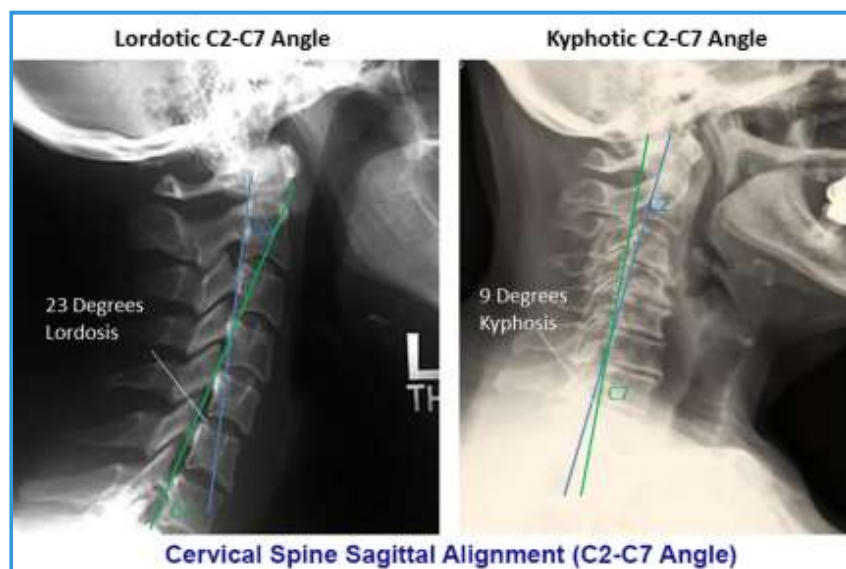


- vibratory changes are usually only found in severe case of long-standing myelopathy
- upper motor neuron signs (spasticity)
 - hyperreflexia
 - may be absent when there is concomitant peripheral nerve disease (cervical or lumbar nerve root compression, spinal stenosis, diabetes)
 - inverted radial reflex
 - tapping distal brachioradialis tendon produces ipsilateral finger flexion
 - Hoffmann's sign
 - snapping patients distal phalanx of middle finger leads to spontaneous flexion of other fingers
 - most common physical exam finding
 - sustained clonus
 - > three beats defined as sustained clonus
 - sustained clonus has poor sensitivity (~13%) but high specificity (~100%) for cervical myelopathy
 - Babinski test
 - considered positive with extension of great toe
- gait and balance
 - toe-to-heel walk
 - patient has difficulty performing
 - Romberg test
 - patient stands with arms held forward and eyes closed
 - loss of balance consistent with posterior column dysfunction
- provocative tests
 - Lhermitte Sign
 - test is positive when extreme cervical flexion leads to electric shock-like sensations that radiate down the spine and into the extremities

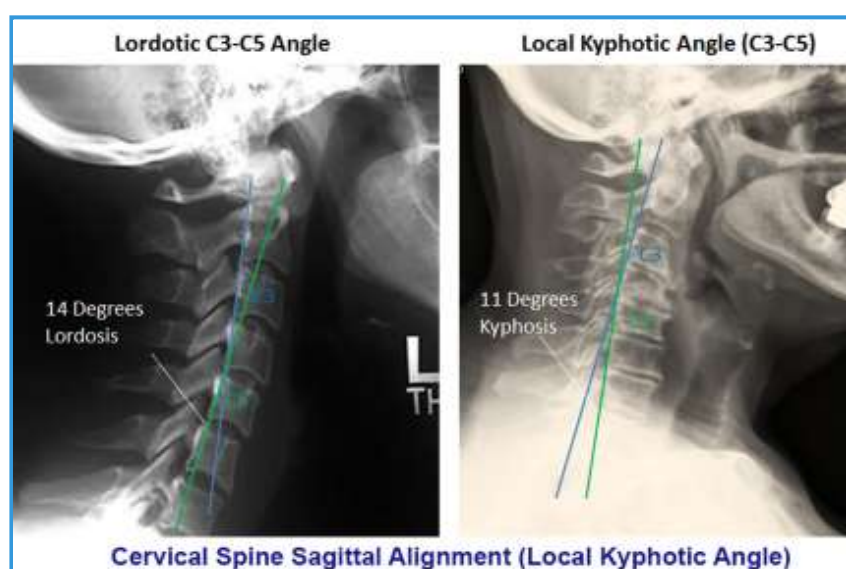
• Evaluation

- Radiographs
 - recommended views
 - cervical AP, lateral, oblique, flexion, and extension views
 - general findings
 - degenerative changes of uncovertebral and facet joints

- osteophyte formation
- disc space narrowing
- decreased sagittal diameter
 - cord compression occurs with canal diameter is $< 13\text{mm}$
- lateral radiograph
 - important to look for diameter of spinal canal
 - a Pavlov ratio of less than 0.8 suggest a congenitally narrow spinal canal predisposing to stenosis and cord compression
- sagittal alignment
 - C2 to C7 alignment



- determined by tangential lines on the posterior edge of the C2 and C7 body on lateral radiographs in neutral position
- local kyphosis angle

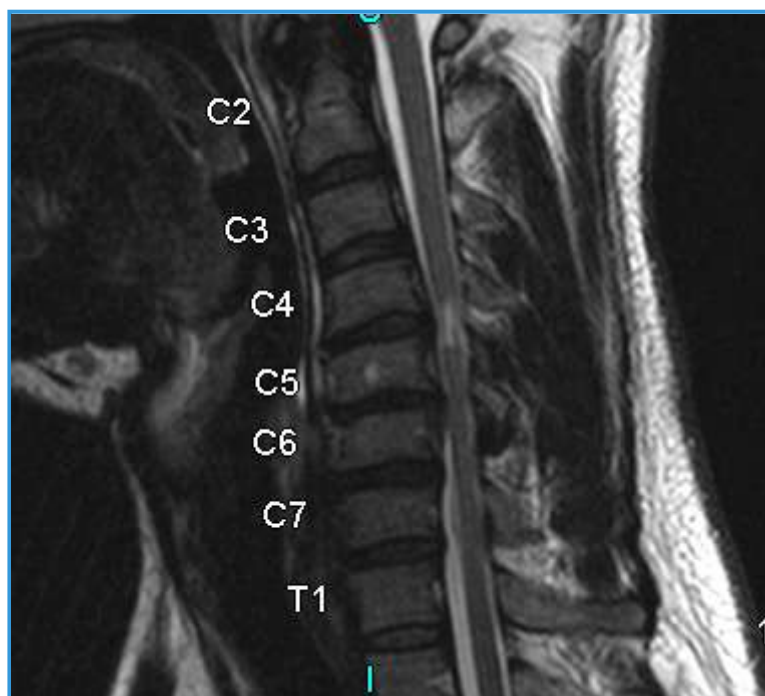


- the angle between the lines drawn at the posterior margin of most cranial and caudal vertebral bodies forming the maximum local kyphosis
- oblique radiograph
 - important to look for foraminal stenosis which often caused by uncovertebral joint arthrosis
- flexion and extension views
 - important to look for angular or translational instability
 - look for compensatory subluxation above or below the spondylotic/stiff segment
- sensitivity/specificity

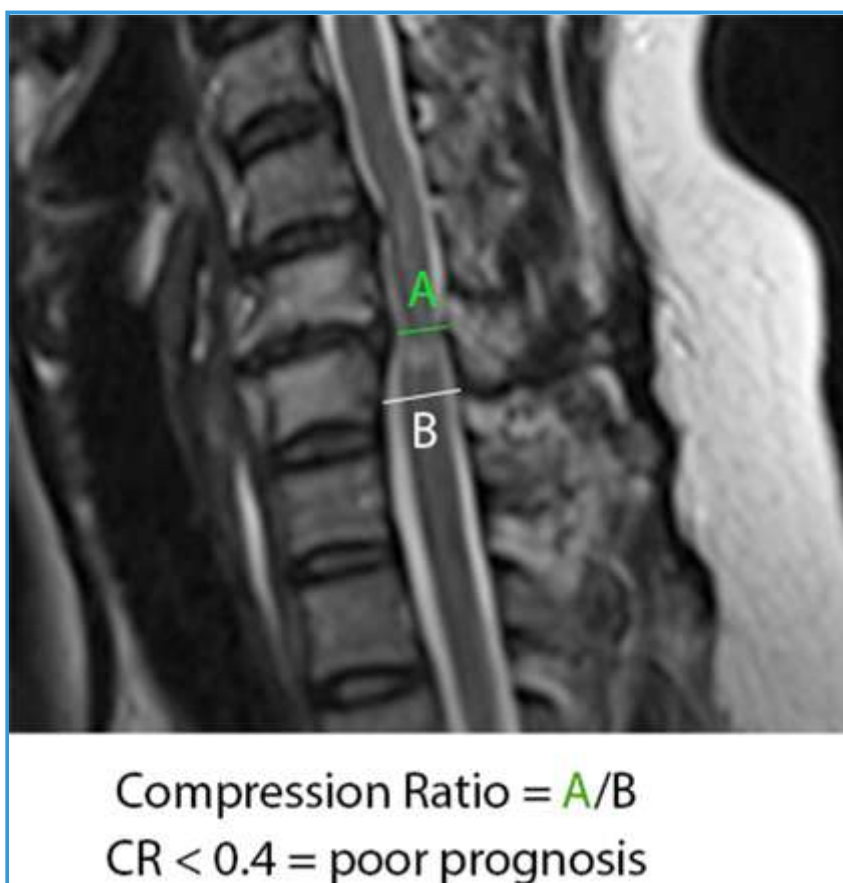
- changes often do not correlate with symptoms
 - 70% of patients by 70 yrs of age will have degenerative changes seen on plain xrays

○ MRI

- indications
 - MRI is study of choice to evaluate degree of spinal cord and nerve root compression
- findings
 - effacement of CSF indicates functional stenosis
 - spinal cord signal changes
 - seen as bright signal on T2 images (myelomalacia)



- signal changes on T1-weighted images correlate with a poorer prognosis following surgical decompression
- compression ratio of < 0.4 carries poor prognosis



- CR = smallest AP diameter of cord / largest transverse diameter of cord
- sensitivity/specificity

- has high rate of false positive (28% greater than 40 will have findings of HNP or foraminal stenosis)
- CT without contrast
 - can provide complementary information with an MRI, and is more useful to evaluate OPLL and osteophytes
- CT myelography
 - more invasive than an MRI but gives excellent information regarding degrees of spinal cord compression
 - useful in patients that cannot have an MRI (pacemaker), or have artifact (local hardware)
 - contrast given via C1-C2 puncture and allowed to diffuse caudally, or given via a lumbar puncture and allowed to diffuse proximally by putting patient in trendelenburg position.
- Nerve conduction studies
 - high false negative rate
 - may be useful to distinguish peripheral from central process (ALS)
- Differential
 - Normal aging
 - mild symptoms of myelopathy often confused with a "normal aging" process
 - Stroke
 - Movement disorders
 - Vitamin B12 deficiency
 - Amyotrophic lateral sclerosis (ALS)
 - Multiple sclerosis
- Treatment
 - Nonoperative
 - **observation, NSAIDs, therapy, and lifestyle modifications**
 - indications
 - mild disease with no functional impairment
 - function is a more important determinant for surgery than physical exam finding
 - patients who are poor candidates for surgery
 - modalities
 - medications (NSAIDS, gabapentin)
 - immobilization (hard collar in slight flexion)

- physical therapy for neck strengthening, balance, and gait training
- traction and chiropractic modalities are not likely to benefit and do have some risks
- be sure to watch patients carefully for progression
- outcomes
 - improved nonoperative outcomes associated with patients with larger transverse area of the spinal cord ($>70\text{mm}^2$)
 - some studies have shown improvement with immobilization in patients with very mild symptoms

○ Operative

■ **surgical decompression, restoration of lordosis, stabilization**

- indications
 - significant functional impairment AND
 - 1-2 level disease
 - lordotic, neutral or kyphotic alignment
- techniques
 - appropriate procedure depends on
 - cervical alignment
 - number of stenotic levels
 - location of compression
 - medical conditions (e.g., goiter)
 - treatment procedures include (see below)
 - anterior cervical discectomy/corpectomy and fusion
 - posterior laminectomy and fusion
 - posterior laminoplasty
 - combined anterior and posterior procedure
 - cervical disk arthroplasty
- outcomes
 - prospective studies show improvement in overall pain, function, and neurologic symptoms with operative treatment
 - early recognition and treatment prior to spinal cord damage is critical for good clinical outcomes
- goals
 - prevention of continued neurologic decline

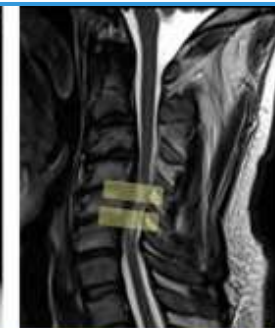
• Techniques

○ Goals

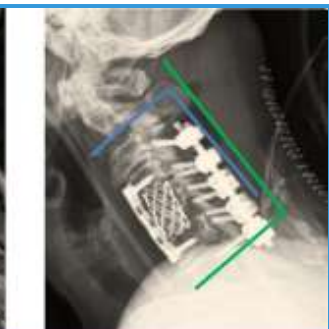
- optimal surgical treatment depends on the individual. Things to consider include
 - number of stenotic levels
 - sagittal alignment of the spine
 - degree of existing motion and desire to maintain
 - medical comorbidities (eg, dysphasia)
 - simplified treatment algorithm

Simplified Treatment Algorithm for CSM		
	1 or 2 levels of compression	3+ levels of compression
> 10 rigid Kyphosis	3 Anterior alone (ACDF/corpectomy /hybrid)	5 Combined AnteroPosterior •Anterior to correct kyphosis/decompress •Posterior to Decompress
< 10 rigid kyphosis		4 Posterior alone Laminoplasty vs Laminectomy + Fusion

			
	1 or 2 levels of compression	3+ levels of compression	
> 10 Kyphosis (Anterior Only)	Anterior alone ACDF/corpectomy/hybrid	Anterior & Posterior	
< 10 kyphosis/ Lordotic (Anterior or Posterior)		Laminoplasty Laminectomy & Fusion	

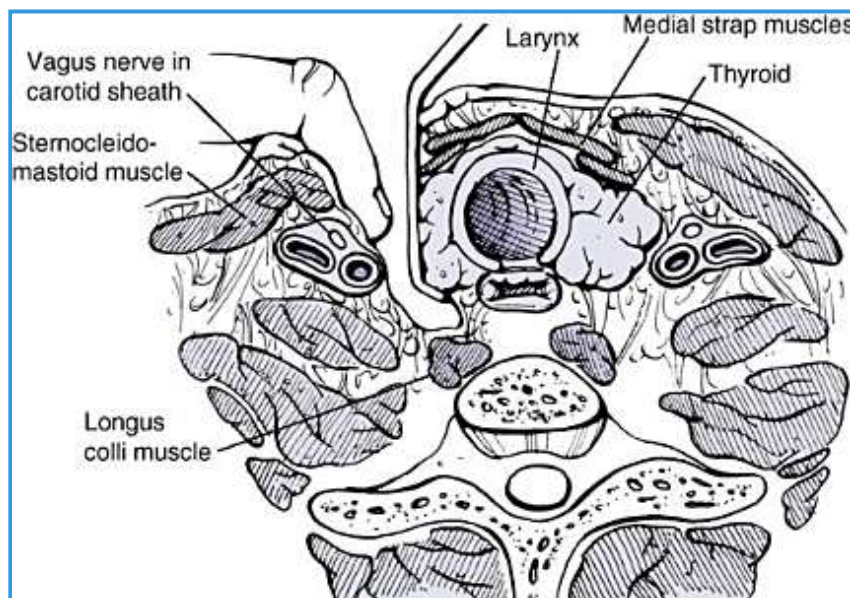
		
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- Anterior Decompression and Fusion (ACDF) alone

- indications
 - mainstay of treatment in most patients with single or two-level disease
 - fixed cervical kyphosis of > 10 degrees
 - anterior procedure can correct kyphosis
 - compression arising from 2 or fewer disc segments
 - pathology is anterior (OPLL, soft discs, disc osteophyte complexes)
- approach
 - uses Smith-Robinson anterior approach

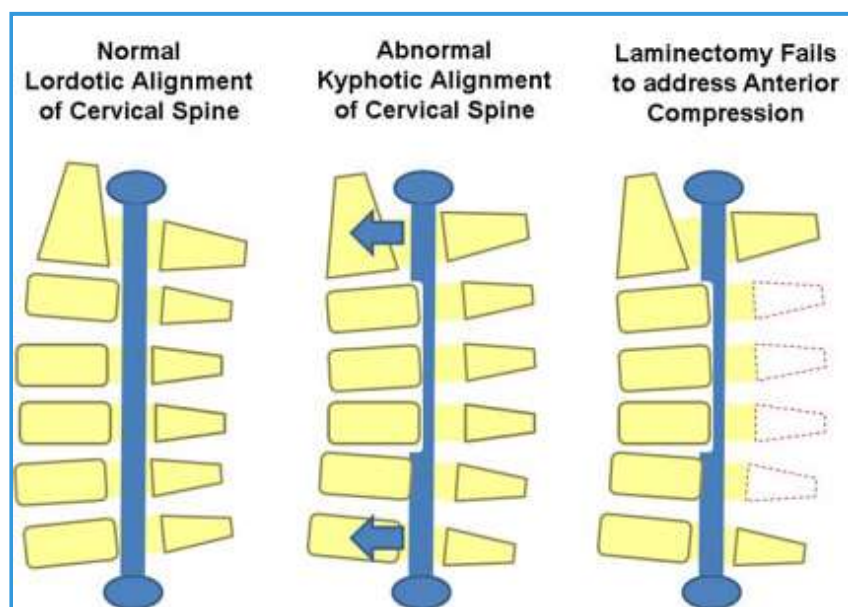


- decompression
 - corpectomy and strut graft may be required for multilevel spondylosis
 - two level corpectomies tend to be biomechanically vulnerable (preferable to combine single level corpectomy with adjacent level discectomy)
 - 7% to 20% rates of graft dislodgement with cervical corpectomy with associated severe complications, including death, reported.
- fixation
 - anterior plating functions to increase fusion rates and preserve position of interbody cage or strut graft
- pros & cons
 - advantages compared to posterior approach
 - lower infection rate
 - less blood loss
 - less postoperative pain
 - disadvantages
 - avoid in patients with poor swallowing function
- **Anterior corpectomy and fusion (ACF)**
 - indications
 - extensive retrovertebral disease
 - cervical kyphosis preventing from adequate decompression posteriorly
 - technique

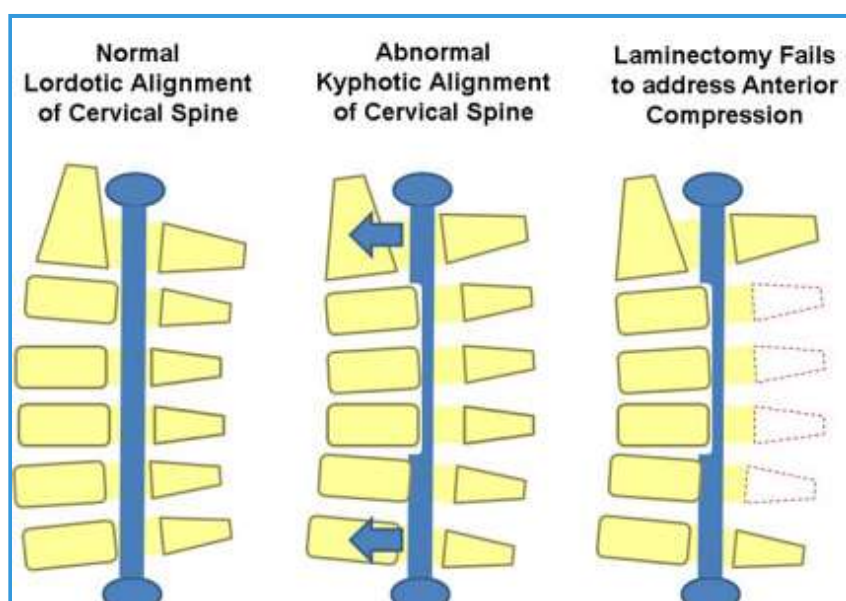
- anterior fixation alone
 - amenable in up to 2-level corpectomy
 - use of static anterior cervical plate with strut graft
- combined anterior and posterior fixation
 - indicated in 3-level corpectomy and above
 - use of anterior strut graft and plating combined with posterior lateral mass screw construct
 - anterior fixation alone in 3-level and above results in a high (>70%) catastrophic failure rate

○ Laminectomy with posterior fusion

- indications
 - multilevel compression with kyphosis of < 10 degrees
 - > 13 degrees of fixed kyphosis is a contraindication for a posterior procedure



- in flexible kyphotic spine, posterior decompression and fusion may be indicated if kyphotic deformity can be corrected prior to instrumentation
- contraindications
 - fixed kyphosis of > 10 degrees is a contraindication to posterior decompression
 - will not adequately decompress spinal cord as it is "bowstringing" anterior

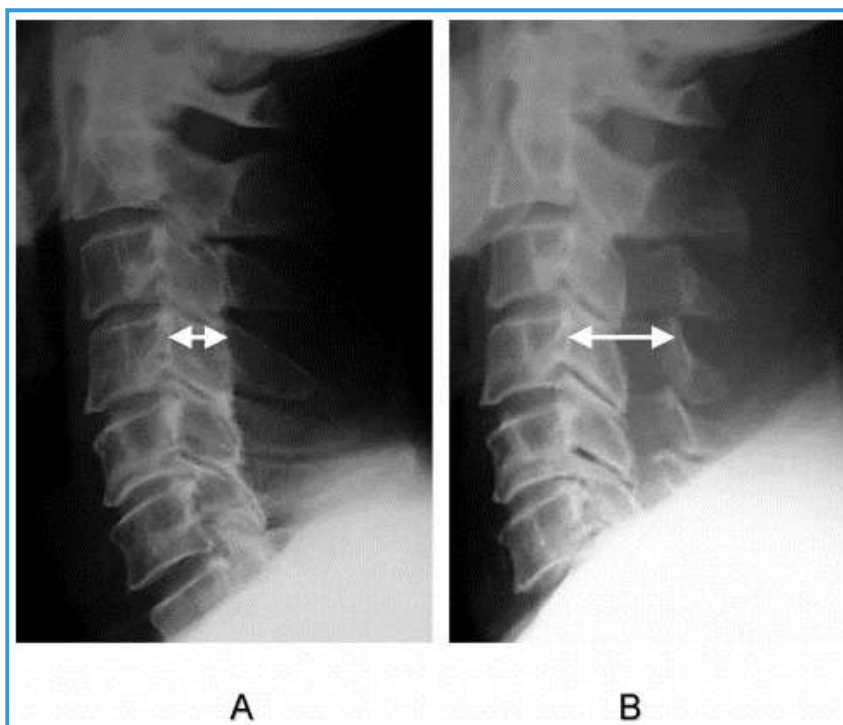


- pros & cons

- fusion may improve neck pain associated with degenerative facets
- not effective in patients with > 10 degrees fixed kyphosis

○ Laminoplasty

- indications
 - gaining in popularity
 - useful when maintaining motion is desired
 - avoids complications of fusion so may be indicated in patients at high risk of pseudoarthrosis
 - congenital cervical stenosis
- contraindications
 - cervical kyphosis
 - > 13 degrees is a contraindication to posterior decompression
 - will not adequately decompress spinal cord as it is "bowstringing" anterior
 - severe axial neck pain
 - is a relative contraindication and these patients should be fused
- technique
 - volume of canal is expanded by hinged-door laminoplasty followed by fusion



- usually performed from C3 to C7
- open door technique
 - hinge created unilateral at junction of lateral mass and lamina and opening on opposite side
 - opening held open by bone, suture anchors, or special plates
- French door technique
 - hinge created bilaterally and opening created midline
- pros & cons
 - advantages

- allows for decompression of multilevel stenotic myelopathy without compromising stability and motion (avoids postlaminectomy kyphosis)
 - lower complication rate than multilevel anterior decompression
 - especially in patients with OPLL
 - a motion-preserving technique
 - pseudoarthrosis not a concern in patients with poor healing potential (diabetes, chronic steroid users)
 - can be combined with a subsequent anterior procedure
 - combined laminoplasty with fusion has theoretical benefit of decreased muscular atrophy and preserved muscle attachments
 - disadvantages
 - higher average blood loss than anterior procedures
 - postoperative neck pain
 - still associated with loss of motion
 - outcomes
 - equivalent to multilevel anterior decompression and fusion
- **Combined anterior and posterior surgery**
 - indications
 - multilevel stenosis in the rigid kyphotic spine
 - multi-level anterior cervical corpectomies
 - postlaminectomy kyphosis
- **Occipitocervical fusion**
 - indications
 - periodontoid pannus
 - posterior-only occipitocervical fusion is safe and effective in promoting pannus resolution
 - transoral approaches are associated with increased morbidity, especially when surgical time exceeds 4 hours
- **Laminectomy alone**
 - indications
 - rarely indicated due to risk of post-laminectomy kyphosis
 - pros & cons
 - progressive kyphosis
 - 11 to 47% incidence if laminectomy performed alone without fusion

- **Complications**

- Surgical Infection
 - higher rate of surgical infection with posterior approach than anterior approach
- Pseudoarthrosis
 - incidence
 - 12% for single level fusions, 30% for multilevel fusions
 - treatment
 - treat with either posterior wiring or plating or repeat anterior decompression and plating if patient has symptoms of radiculopathy
- Postoperative C5 palsy
 - incidence
 - reported to occur in ~ 4.6% of patients after surgery for cervical compression myelopathy
 - higher incidence reported in males
 - no significant differences between patients undergoing anterior decompression and fusion and posterior laminoplasty
 - higher rates reported following posterior laminectomy and fusion
 - occurs immediately postop to weeks following surgery
 - mechanism
 - mechanism is controversial
 - in laminectomy patients, it is thought to be caused by tethering of nerve root with dorsal migration of spinal cord following removal of posterior elements
 - some studies suggest that prophylactic bilateral keyhole foraminotomies at the C4/5 level may help reduce the incidence of this complication
 - prognosis
 - patients with postoperative C5 palsy generally have a good prognosis for functional recovery, but recovery takes time
 - prolonged recovery associated with:
 - multilevel paresis
 - motor grade ≤ 2
 - sensory involvement with intractable pain
- Recurrent laryngeal nerve injury
 - approach
 - in the past it has been postulated that the RLN is more vulnerable to injury on the right due to a more aberrant pathway
 - recent studies have shown there is not an increased injury rate with a right sided approach

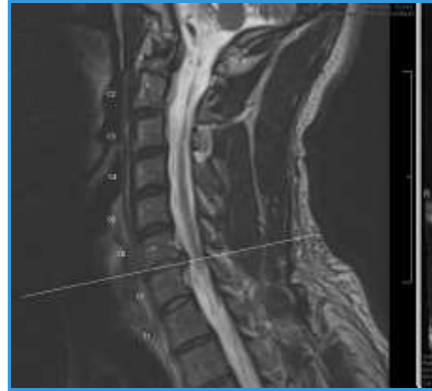
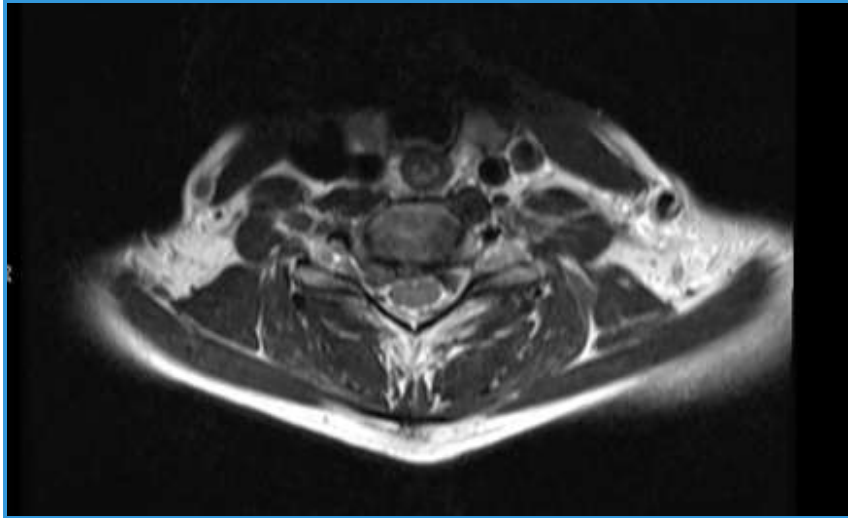
- prolonged retractor placement at the tracheoesophageal junction places RLN at risk for injury
- treatment
 - if you have a postoperative RLN palsy, watch over time
 - if not improved over 6 weeks, then ENT consult to scope patient and inject teflon
 - if you are performing revision anterior cervical surgery, and there is any suspicion of a RLN from the first operation, obtain ENT consult to establish prior injury
 - if patient has prior RLN nerve injury, perform revision surgery on the same as the prior injury/approach to prevent a bilateral RLN injury
- Hardware failure and migration
 - 7-20% with two level anterior corpectomies
 - two-level corpectomies should be stabilized from behind
- Postlaminectomy kyphosis
 - treat with anterior/posterior procedure
- Postoperative axial neck pain
- Airway compromise
 - prolonged surgery (>5 hours)
 - higher blood loss
 - anterior exposure involving C2, C3, and C4
- Vertebral artery injury
- Esophageal Injury
- Dysphagia & alteration in speech
 - Multiple studies have demonstrated the application of local steroid in retropharyngeal space prior to wound closure decreases rate of dysphagia
- Epidural hematoma
 - rare complication
 - 1:1000 incidence
 - associated with post-operative motor weakness and parasthesias
 - emergent MRI and hematoma evacuation
 - early evacuation results in better neurologic recovery
 - MRI appearance of hematoma depends on age
 - hyperacute (<24 hours):
 - hyperintense T2, hypointense T1

- Prognosis

- Natural history
 - tends to be slowly progressive and rarely improves with nonoperative modalities
 - progression characterized by steplike deterioration with periods of stable symptoms
- Prognostic variable
 - early recognition and treatment prior to spinal cord damage is critical for good clinical outcomes

25- Cervical Radiculopathy

Images



- Summary
 - Cervical Radiculopathy is a clinical condition characterized by unilateral arm pain, numbness and tingling in a dermatomal distribution in the hand, and weakness in specific muscle groups.
 - Evaluation consists of a thorough neurologic examination, cervical spine radiographs including flexion-extension views, and MRI of the cervical spine.
 - Nonoperative treatment is successful in 75% - 90% of patients, with surgical decompression reserved for refractory cases or patients with progressive neurologic deficits.
- Epidemiology
 - Incidence

- 107.3 per 100,000 men annually
- 63.5 per 100,000 women annually
- 50 to 54 years age peak range
- Risk factors
 - white race
 - cigarette smoking
 - prior lumbar radiculopathy

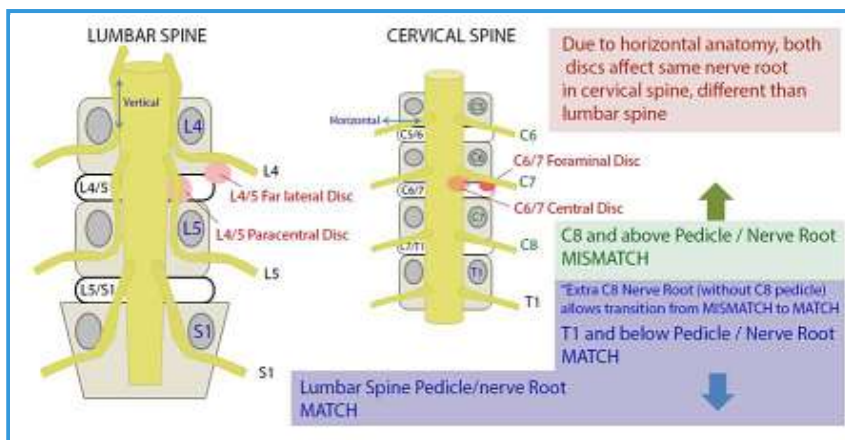
- Etiology

- Pathophysiology
 - causes
 - degenerative cervical spondylosis
 - discosteophyte complex and loss of disc height
 - chondrosesous spurs of facet and uncovertebral joints
 - disc herniation ("soft disc")
 - intraforaminal
 - radicular pain predominantly
 - posterolateral
 - most common
 - between posterior edge of uncinata and lateral edge of PLL
 - mostly motor symptoms
 - midline herniation
 - usually presents with myelopathic symptoms
 - double-crush phenomenon
 - combined cervical root compression and distal nerve compression
 - decreased axoplasmic flow from root compression predisposes downstream nerves to peripheral entrapment syndromes
 - rare causes
 - intraspinal/extraspinal tumors
 - trauma with nerve root avulsion
 - synovial cysts
 - meningeal cysts
 - dural arteriovenous fistulae
 - tortuous vertebral arteries
 - neural compression
 - nerve root irritation caused by
 - direct compression
 - irritation by chemical pain mediators

- including
 - IL-1
 - IL-6
 - substance P
 - neuropeptide Y
 - calcitonin gene-related peptide
 - bradykinin
 - TNF alpha
 - prostaglandins
- affects the nerve root below
 - C6/7 disease will affect the C7 nerve root

• Anatomy

- Articulations
 - facet joints
 - facet hypertrophy and osteophytes can impinge on nerve root posteriorly
 - disc space
 - loss of disc height can decrease volume of neuroforamen
 - uncovertebral joints
 - osteophytes from posterior joint can impinge on exiting nerve anteriorly
- Intervertebral disc
 - annulus fibrosus
 - thick fibrous outer layer of the intervertebral disc
 - contains type I collagen
 - thicker ventrally than dorsally
 - nucleus pulposus
 - "cushioning" between the vertebral bodies
 - contains type II collagen and glycosaminoglycans (GAGs)
 - GAGs contains a high negative charge and attracts large amounts of water molecules
 - GAGs breakdown with increasing age
 - 90% water content in patients under 30 years of age
 - decreases to 70% by eighth decade of life
- Nerve root anatomy
 - key differences between cervical and lumbar spine are



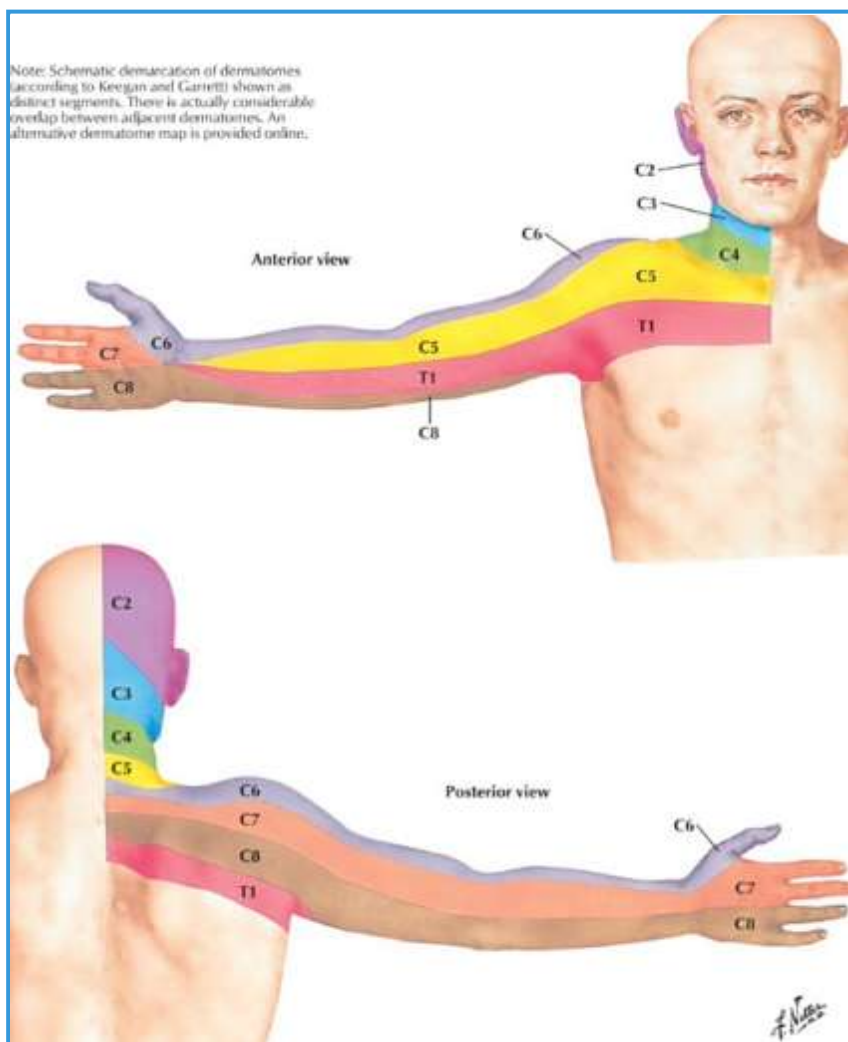
- pedicle/nerve root mismatch
 - cervical spine C6 nerve root travels above C6 pedicle (mismatch)
 - lumbar spine L5 nerve root travels under L5 pedicle (match)
 - extra C8 nerve root (no C8 pedicle) allows transition
- horizontal (cervical) vs. vertical (lumbar) anatomy of nerve root
 - because of vertical anatomy of lumbar nerve root, a paracentral and foraminal disc will affect different nerve roots
 - because of horizontal anatomy of cervical nerve root, a central and foraminal disc will affect the same nerve root
- ventrolateral course from spinal cord
 - predisposes to ventral compression

• Presentation

○ Symptoms

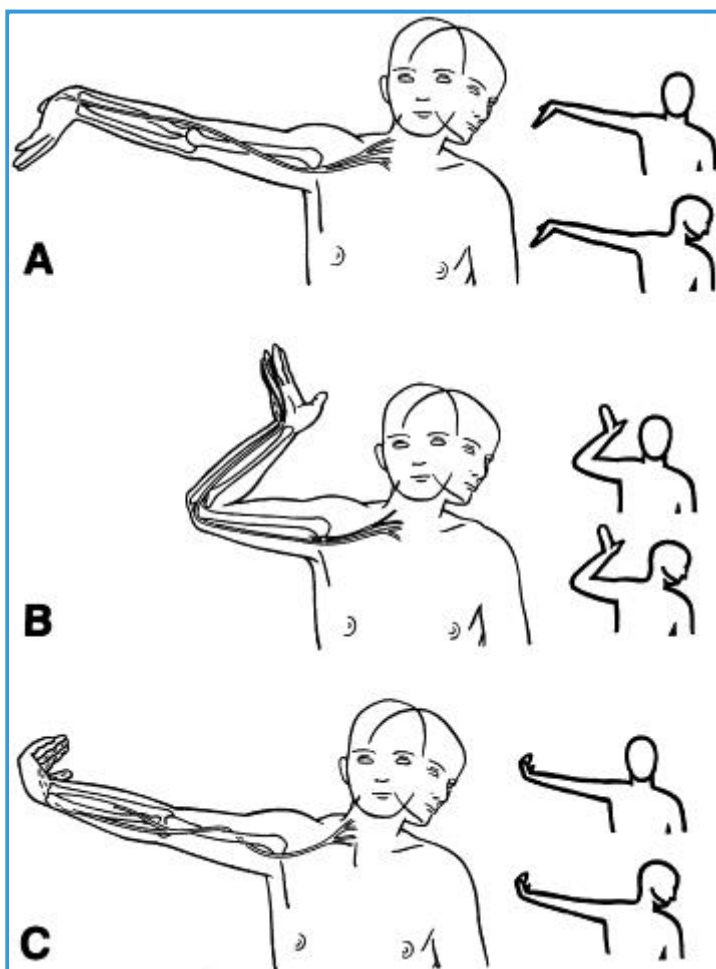
- occipital headache (common)
- trapezial or interscapular pain
- neck pain
 - may present with insidious onset of neck pain that is worse with vertebral motion
 - origin may be discogenic, or mechanical due to facet arthrosis
 - pain may radiate to shoulders
- unilateral arm pain
 - aching pain radiating down arm
 - often global and nondermatomal
- unilateral dermatomal numbness & tingling
 - numbness/tingling in thumb (C6)
 - numbness/tingling in middle finger (C7)
- unilateral weakness
 - difficulty with overhead activities (C7)
 - difficulty with grip strength (C7)

○ Physical exam



- common and testable exam findings
 - C4 radiculopathy
 - scapular winging
 - numbness and pain at the base of the neck
 - C5 radiculopathy
 - deltoid and biceps weakness
 - diminished biceps reflex
 - pain and numbness in the superior shoulder and lateral upper arm
 - C6 radiculopathy
 - brachioradialis and wrist extension weakness
 - diminished brachioradialis reflex
 - paresthesias in the thumb and radial arm
 - C7 radiculopathy
 - triceps and wrist flexion weakness
 - diminished triceps reflex
 - paresthesia in the middle finger
 - most commonly affected nerve root in cervical radiculopathy in several studies
 - C8 radiculopathy
 - weakness to distal phalanx flexion of middle and index finger (difficulty with fine motor function)
 - paresthesias in ring and little finger
 - C8 radiculopathy is extremely rare and often manifests similarly as ulnar neuropathy
 - T1 radiculopathy

- intrinsic hand muscle weakness
- axillary numbness
- ipsilateral Horner's syndrome
- provocative tests
 - Spurling's test
 - simultaneous extension, rotation to affected side, lateral bend, and vertical compression reproduces symptoms in ipsilateral arm
 - narrowing of the intervertebral foramina causes exacerbation of symptoms
 - specific, but not sensitive for radiculopathy
 - shoulder abduction test
 - shoulder abduction relieves symptoms
 - shoulder abduction (lifting arm above head) often relieves symptoms
 - decreases tension on affected nerves
 - valuable physical exam test to differentiate cervical pathology from other causes of shoulder/arm pain
 - upper limb tension tests



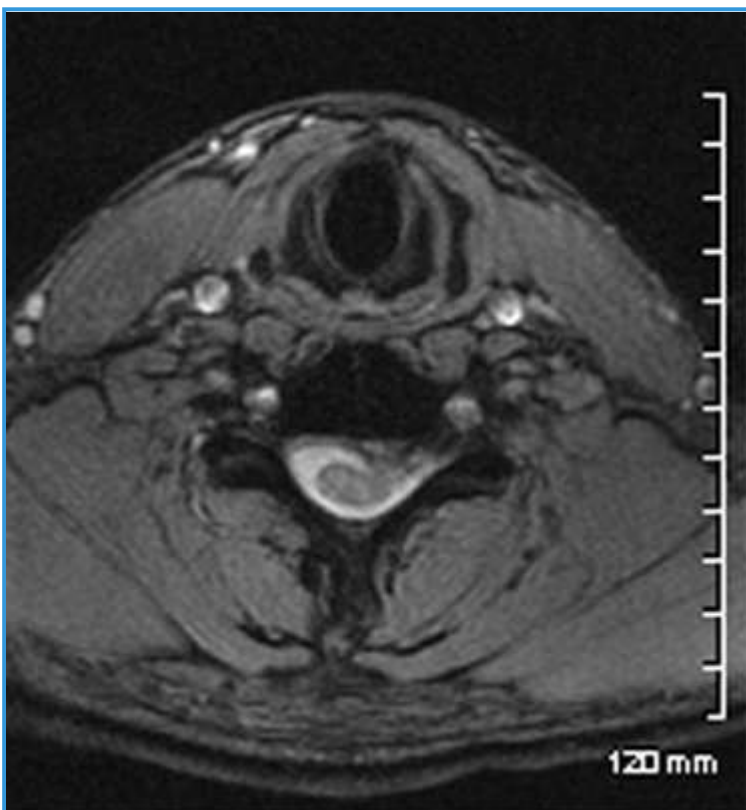
- valsalva maneuver
- neck distraction test
- myelopathy
 - check for findings of myelopathy in large central disc herniations

• Imaging

- Radiographs
 - recommended views

- AP, lateral, oblique views of cervical spine
- obtain flexion and extension views if suspicion for instability
- findings
 - general
 - degenerative changes of uncovertebral and facet joints
 - osteophyte formation
 - disc space narrowing & endplate sclerosis
 - lateral radiograph
 - important to look for sagittal alignment and spinal canal diameter
 - oblique radiograph
 - best view to identify foraminal stenosis caused by osteophytes
 - flexion and extension views
 - important to look for angular or translational instability
 - look for compensatory subluxation above or below the spondylotic/stiff segment
- sensitivity & specificity
 - changes often do not correlate with symptoms
 - 70% of patients by 70 yrs of age will have degenerative changes seen on plain xrays

○ MRI



- indications
 - red flags signs
 - fever
 - weight loss
 - pain that wakes patient at night
 - persistent symptoms despite 6 weeks of conservative treatment
 - motor weakness
- views

- T2 axial imaging is the modality of choice and gives needed information on the status of the soft tissues
 - CSF appears hyperintense
 - loss of CSF signal around the cord and nerve root
- findings
 - disc degeneration and herniation
 - foraminal stenosis with nerve root compression (loss of perineural fat)
 - central compression with CSF effacement
- sensitivity & specificity
 - has high rate of false positive (28% greater than age of 40 will have findings of HNP or foraminal stenosis)
 - >50% over the age of 40 years will have a degenerated disc
- CT
 - indications
 - pre-operative
 - gives useful information on bony anatomy including osteophyte formation that is compressing the neural elements
 - useful as a preoperative planning tool to plan instrumentation
 - detect ossification of the posterior longitudinal ligament
 - may not be as evident on MRI or radiography
 - post-operative
 - study of choice to evaluate for postoperative pseudoarthrosis
- CT myelography
 - indications
 - largely replaced by MRI
 - useful in patients who cannot have an MRI due to pacemaker, etc
 - useful in patients with prior surgery and hardware causing artifact on MRI
 - technique
 - intrathecal injection of water soluble contrast given via C1-C2 puncture and allowed to diffuse caudally
 - lumbar puncture and allowed to diffuse proximally by putting patient in Trendelenburg position
- Discography



- indications
 - controversial and rarely indicated in cervical spondylosis
- techniques
 - approach is similar to that used with ACDF
- risks include esophageal puncture and disc infection

• Studies

- Nerve conduction studies
 - high false negative rate
 - sensitivity 40% to 70%
 - not a good screening study
 - may be useful to distinguish peripheral from central process (ALS)
 - fibrillations and positive sharp waves in the affected distribution
 - may not manifest until 3 weeks after onset of symptoms
 - paraspinal muscles are affected before appendicular muscles
 - sensory nerve action potentials are typically normal
 - compression is usually proximal to the dorsal root ganglion
 - compound muscle action potential proportional decrease to muscle atrophy
- Selective nerve root corticosteroid injections
 - may help confirm level of radiculopathy in patients with multiple level disease, and when physical exam findings and EMG fail to localize level

• Differential

- Carpal tunnel syndrome
- Cubital tunnel syndrome
- Parsonage-Turner Syndrome
- Thoracic outlet syndrome
- Cervical myelopathy
- Brachial plexus injury

- Treatment

- Nonoperative

- **rest, medications, and rehabilitation**

- indications

- 75% of patients with radiculopathy improve with nonoperative management
 - improvement via resorption of soft discs and decreased inflammation around irritated nerve roots

- return to play

- indicated after resolution of symptoms and repeat MRI demonstrating no cord compression
 - studies have shown return to play expedited with brief course of oral methylprednisolone (medrol dose pack)
 - no increased risk of subsequent spinal cord injury

- **selective nerve root corticosteroid injections**

- indications

- may be considered as therapeutic or diagnostic option

- outcomes

- provides long-term relief in 40-70% of cases
 - increased risk when compared to lumbar selective nerve root injections with the following rare but possible complications, including
 - dural puncture
 - meningitis
 - epidural abscess
 - nerve root injury

- Operative

- **anterior cervical discectomy and fusion**

- indications

- persistent and disabling pain that has failed three months of conservative management
 - progressive and significant neurologic deficits
 - static neurologic deficit associated with significant radicular pain

- outcomes

- remains gold standard in surgical treatment of cervical radiculopathy
 - single level ACDF is not a contraindication for return to play for athletes

- very high success rate with single level disease
- higher rate of pseudoarthrosis with multilevel procedures
 - 20% for single level ACDF vs >50% for multilevel ACDF
 - pseudoarthrosis rate does not appear to correlate with clinical outcomes
- **anterior cervical foraminotomy**
 - indications
 - isolated unilateral nerve root compression
 - avoidance of fusion
 - high risk patients for pseudoarthrosis
 - smokers
 - diabetics
 - outcomes
 - limited studies
 - not widely accepted
 - 98% excellent outcomes reported in literature
- **posterior foraminotomy**
 - indications
 - foraminal soft disc herniation causing single level radiculopathy ideal
 - may be used in osteophytic foraminal narrowing
 - failed nonoperative treatment
 - high risk patients with anterior approach
 - previous anterior surgery
 - abnormal anatomy
 - contraindications
 - large central disc herniation
 - cervical myelopathy
 - instability
 - OPLL
 - kyphotic deformity
 - outcomes
 - >91% success rate
 - reduces the risk of iatrogenic injury with anterior approaches
 - low complication rate
 - ~3%
 - no difference in outcomes compared to ACDF
 - faster return to work and lower treatment cost than ACDF
- **cervical disc arthroplasty**

- indications (controversial)
 - single level disease with minimal arthrosis of the facets
- outcomes
 - studies show equivalence to ACDF
 - no difference in arm pain, NDI, SF-36 scores, and neurologic improvement
 - effect on adjacent level disease remains unclear
 - some studies show 3% per year for all approaches
 - systematic reviews have demonstrated no difference in ASD rate between CDA and ACDF
 - lower reoperation rates seen with CDA
 - lower neck pain intensity and frequency with CDA
 - high incidence of heterotopic bone formation
 - 60% of cases
 - no effect on motion profile

- Techniques

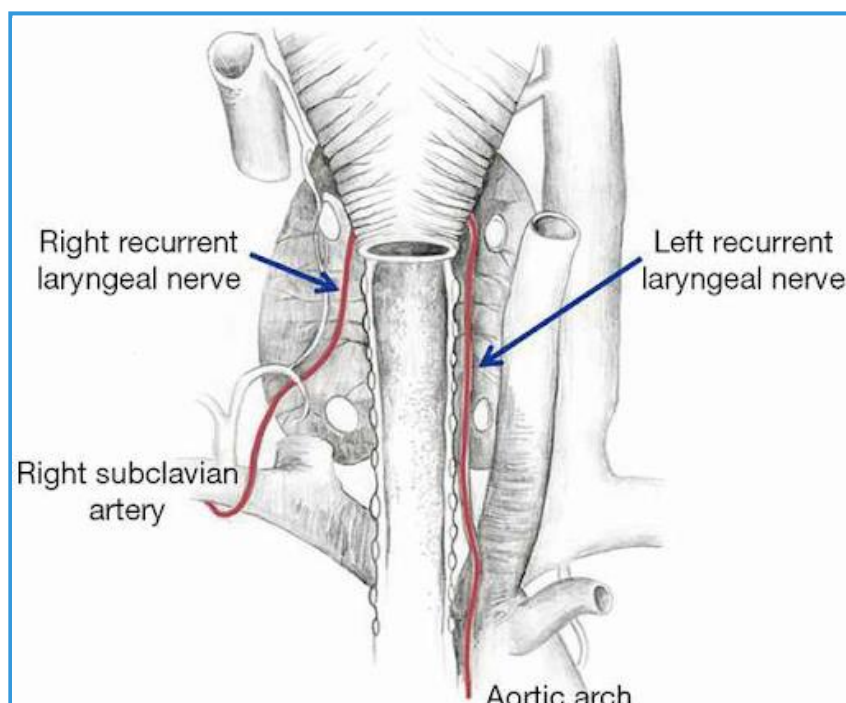
- **Rest, medications, and rehabilitation**

- techniques (very few substantiated by evidence)
 - immobilization
 - immobilization for short period of time (< 1-2 weeks) may help by decreasing inflammation and muscles spasm
 - prolonged immobilization should be avoided
 - cervical muscle atrophy
 - medications
 - NSAIDS / COX-2 inhibitors
 - oral corticosteroids
 - GABA inhibitors (neurontin)
 - narcotics
 - short term use in the acute phase
 - muscle relaxants
 - rehabilitation
 - moist heat
 - cervical isometric exercises
 - traction/manipulation
 - avoid in myelopathic patients

- **Selective nerve root corticosteroid injections**

- approach

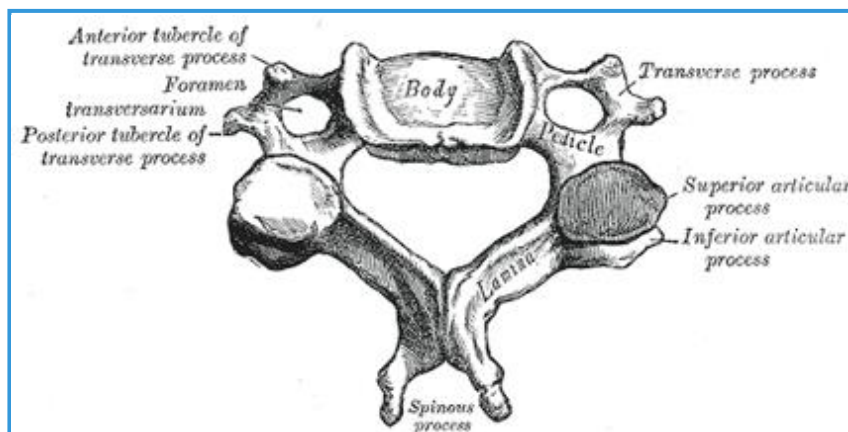
- fluoroscopic guidance
- injection consisting of steroid and local anesthetic
 - studies have shown no difference in long-term pain relief with local anesthetic alone and combined steroid
- **Anterior Cervical Discectomy and Fusion (ACDF)**
 - approach
 - uses Smith-Robinson anterior approach
 - transverse incision for 1- and 2-level disease
 - longitudinal incision for multilevel disease and corpectomies or patients with short and thick necks
 - C7-T1 exposure
 - increased risk of thoracic duct injury with left-sided approach
 - C7-T1 exposure
 - increased risk of thoracic duct injury with left-sided approach
 - lower risk of recurrent laryngeal nerve injury with left-sided approach



- recurrent laryngeal nerve passes between trachea and esophagus
- retractor displacement compresses nerve against inflated endotracheal tube
 - cuff deflation can theoretically decrease recurrent laryngeal nerve injury
- superficial landmarks for levels
 - C1-2: inferior margin of the mandible
 - C3-4: hyoid
 - C4-6: thyroid cartilage
 - C5-6: cricoid cartilage
- techniques
 - decompression
 - placement of bone graft increases disk height and decompresses the neural foramen through indirect decompression

- corpectomy and strut graft may be required for multilevel spondylosis
- fixation
 - anterior plating functions to increase fusion rates and preserve position of interbody cage or strut graft
 - increased cost and complication risk for increased exposure
 - decreases implant extrusion and graft collapse
 - historically, plating required bicortical fixation (Caspar plates)
 - high risk for neurologic injury
 - intraoperative fluoroscopy used to prevent over penetration of screws
 - modern plating contains constraining mechanism to allow sufficient fixation with unicortical screws
 - dynamic plates
 - allow controlled settling of the interbody construct and physiologic loading of the graft
 - theoretical benefit of increased fusion rates and decreased screw pull out
 - static plates
 - maintains screws at fixed angles through plate (similar to locking plate)
 - no difference in fusion rates with single-level disease with plating compared to no plating
 - increased fusion rate, decreased graft complications, lower reoperation rate, and earlier return to work with plating in multilevel disease
- graft
 - autograft
 - locally harvested
 - iliac crest bone graft
 - gold standard
 - donor site pain
 - minimized with limited surgical exposure
 - careful dissection of the inner and outer tables of the ilium
 - allograft
 - higher potential for disease transmission
 - higher pseudoarthrosis rates (41% vs 27%)
 - higher graft subsidence rates (28% vs 16%)
 - structural graft

- iliac crest
 - fibular strut
 - patella
- post-op care
 - ambulatory the day of surgery
 - soft collar immobilization for short period of time
 - prolonged immobilization in hard collar if anterior plating not used
 - range of motion and strengthening beginning at 6 weeks
 - return to full activity by 3 months
- pros and cons
 - complications of anterior surgery including persistent swallowing problems
 - adjacent segment disease
- **Anterior cervical foraminotomy**
 - approach
 - anterolateral approach to the cervical spine
 - longus colli split longitudinally
 - medial to the anterior tubercle of the transverse process



- technique
 - removal of uncovertebral joint
 - decompression of the exiting nerve root
 - pros and cons
 - avoids fusing the involved level
 - potential risk of sympathetic chain and vertebral artery injury
- **Posterior foraminotomy**
 - approach
 - positioning
 - sitting
 - comfortable position
 - limits epidural bleeding (less engorgement of veins compared to prone positioning)
 - risk of venous air embolism
 - prone

- familiar approach for most surgeons
- posterior approach
 - open
 - muscle stripping from lamina and spinous process
 - lateral exposure to the lateral border of the lateral mass
 - microendoscopic
 - minimally invasive approach
 - reduced intraoperative blood loss
 - faster OR time
 - shorter hospital stays
 - less postoperative narcotic consumption
 - no difference in effectiveness of decompression compared to open foraminotomy
- technique
 - if anterior disc herniation is to be removed, then superior portion of inferior pedicle should be removed
 - minimal nerve root retraction
 - nerve root decompressed posteriorly, superiorly, and inferiorly
- pros & cons
 - advantages
 - avoids need for fusion
 - avoids problems associated with anterior procedure
 - disadvantages
 - more difficult to remove discosteophyte complex
 - disc height can not be restored
 - significant muscle pain and spasm (muscle splitting approach)
 - significant bleeding (epidural vessels)
 - inability to correct sagittal alignment
- **Cervical disc arthroplasty**
 - approach
 - uses Smith-Robinson anterior approach
 - pros & cons
 - avoids nonunions

• Complications

- Pseudoarthrosis
 - incidence
 - 5 to 10% for single level fusions, 30% for multilevel fusions

- risk factors
 - **smoking**
 - diabetes
 - multi-level fusions
 - revision surgery
- treatment
 - if asymptomatic observe
 - if symptomatic, treat with either posterior cervical fusion or repeat anterior decompression and plating if patient has symptoms of radiculopathy
 - improved fusion rates seen with posterior fusion
- Recurrent laryngeal nerve injury (1%)
 - most common nerve injury from this operation
 - anatomic course of the nerve differs on the right and left side
 - although theoretically the nerve is at greater risk of injury with a right sided approach, there is no evidence to support a greater incidence of nerve injury with a right sided approach.
 - treatment
 - initial treatment is observation
 - if not improved over 6 weeks, than ENT consult to scope patient and inject teflon
- Hypoglossal nerve injury
 - a recognized complication after surgery in the upper cervical spine with an anterior approach
 - tongue will deviate to side of injury
- Vascular injury
 - vertebral artery injury (can be fatal)
 - very rare injury
 - aberrant vertebral artery path poses greater risk for injury
- Dysphagia
 - higher risk at higher levels (C3-4)
 - risk can be minimized with the use of zero-profile anchored cages



- less prominence of anterior hardware reduces irritation and impingement of prevertebral structures, such as esophagus
- Esophageal injury
 - rare but devastating injuries
 - early perforation (at the time of the procedure)
 - usually caused by sharp instruments
 - can be minimized by using dull retractors and avoiding excessive retraction
 - should be repaired as soon as the injury is noticed
 - late perforation
 - usually from plate loosening or pullout
 - technically difficult to repair
 - require nasogastric tube and parenteral hyperalimentation for a prolonged period of time
- Horner's syndrome
 - characterized by ptosis, anhydrosis, miosis, enophthalmos and loss of ciliospinal reflex on the affected side of the face
 - caused by injury to sympathetic chain, which sits on the lateral border of the longus coli muscle at C6
- Adjacent segment disease
- Airway complications
 - risk factors
 - prolonged surgical duration (>5 hours)
 - exposure above C4
 - greater than 4 levels involved in fusion construct

26- Rheumatoid Cervical Spondylitis

Images

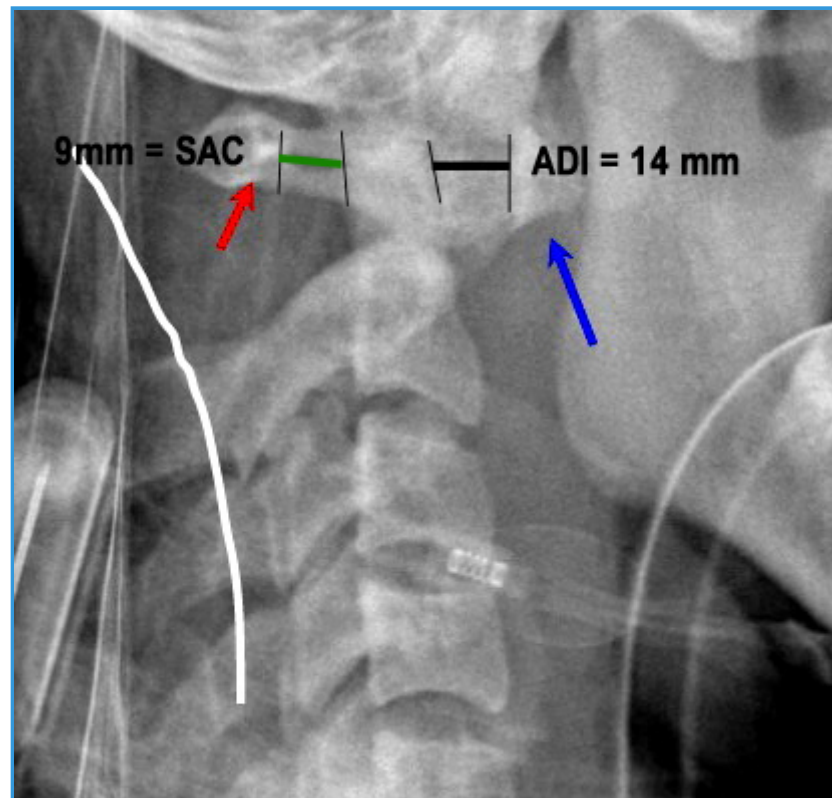
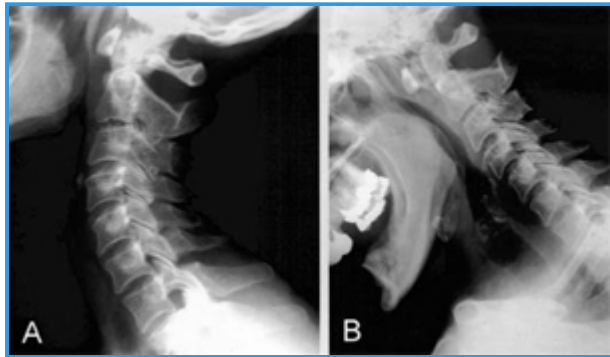


Figure 4 - Lateral cervical spine radiograph showing upward odontoid migration

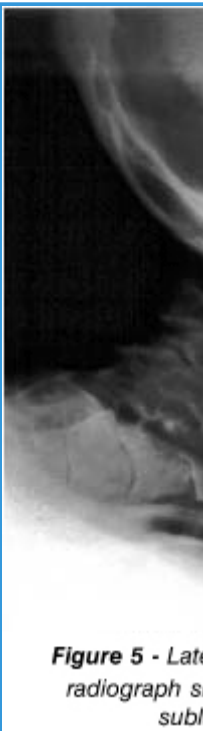


Figure 5 - Lateral cervical spine radiograph showing subaxial subluxation

- Summary
 - Rheumatoid Cervical Spondylitis comprises of 3 specific patterns of cervical spine instability seen in rheumatoid arthritis that consist of atlantoaxial subluxation, basilar invagination, and subaxial subluxation.
 - Diagnosis is made radiographically with cervical spine flexion-extension radiographs and supplemented with MRI studies to measure the degree of spinal cord compression.
 - Treatment may be observation versus decompression with instrumentation depending on patient's neurological status, degree of mechanical instability, and severity of spinal cord compression.
- EPIDEMIOLOGY
 - Present in 90% of patients with RA
 - diagnosis often missed
- ETIOLOGY
 - Cervical rheumatoid spondylitis includes three main patterns of instability
 - atlantoaxial subluxation
 - most common form of instability
 - basilar invagination
 - subaxial subluxation

• Classification

■ Ranawat Classification		
■ Class I	■ Pain, no neurologic deficit	■
■ Class II	■ Subjective weakness, hyperreflexia, dysesthesias	■
■ Class IIIA	■ Objective weakness, long tract UMN signs, ambulatory	■
■ Class IIIB	■ Objective weakness, long tractUMNsigns, non-ambulatory. Do NOT operate	■

• Presentation

- Symptoms
 - symptoms and physical exam findings similar to cervical myelopathy
 - neck pain
 - neck stiffness
 - occipital headaches
 - due to lesser occipital nerve, which is branch of the C2 nerve root
 - gradual onset of weakness and loss of sensation
- Physical exam
 - hyperreflexia
 - upper and lower extremity weakness
 - ataxia (gait instability and loss of hand dexterity)

• Imaging

- Radiographs
 - flexion-extension xrays
 - always obtain before elective surgery
 - see subtopic for radiographic lines and measurements
- CT scan
 - useful to better delineate bony anatomy and for surgical planning
- MRI
 - study of choice to evaluate degree of spinal cord compression and identify myelomalacia

• General Treatment

- Nonoperative
 - **pharmacologic therapy**
 - pharmacologic treatment for RA has seen significant recent advances
 - has led to a decrease in surgical intervention
- Operative

- **spinal decompression and stabilization**

- indications

- goal is to prevent further neurologic progression and surgery may not reverse existing deficits

- **Atlantoaxial Subluxation**

- Introduction

- present in 50-80% of patients with RA
 - most common to have anterior subluxation of C1 on C2 (can have lateral and posterior)

- Mechanism

- caused by pannus formation between dens and ring of C1 that leads to the destruction of transverse ligament and dens

- Radiographs

- controlled flexion-extension views to determine AADI and SAC/PADI
 - AADI (anterior atlanto-dens interval)
 - instability defined as > 3.5 mm of motion between flexion and extension views
 - instability alone is not an indication for surgery
 - > 7 mm of motion may indicate disruption of alar ligament
 - > 10 mm motion is indication for surgery
 - because of increased risk of neurologic injury
 - PADI / SAC (posterior atlanto-dens interval and space available for cord describe same thing)
 - < 14 mm is an indication for surgery
 - because of increased risk of neurologic injury
 - > 13 mm is the most important radiographic finding that may predict complete neural recovery after decompressive surgery

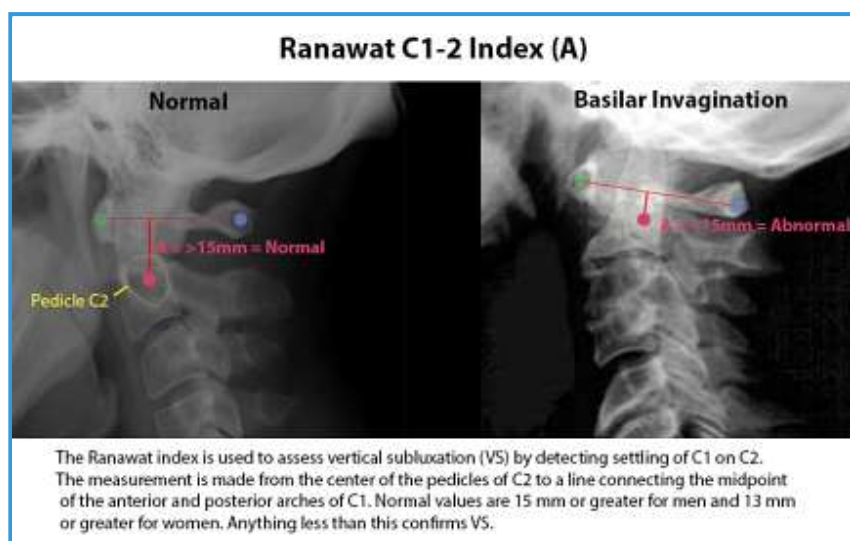
- Treatment

- nonoperative
 - indicated in stable atlantoaxial subluxation
 - operative
 - **posterior C1-C2 fusion**
 - general indications for surgery
 - AADI > 10 mm (even if no neuro deficits)
 - SAC / PADI < 14 mm (even if no neuro deficits)
 - progressive myelopathy
 - indications for posterior C1-2 fusion

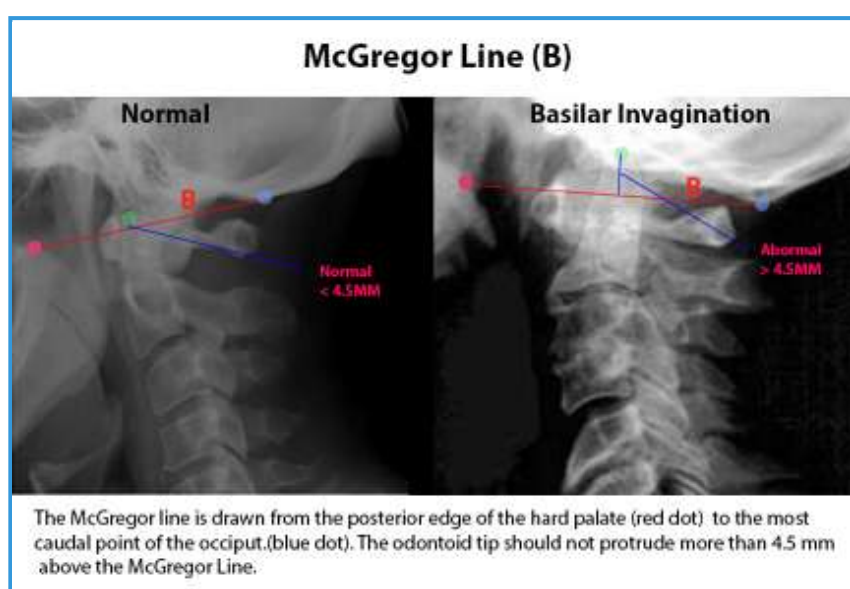
- able to reduce C1 to C2 so no need to remove posterior arch of C1
 - technique
 - adding transarticular screws eliminated need for halo immobilization (obtain preoperative CT to identify location of vertebral arteries)
 - **occiput-C2 fusion ± resection of posterior C1 arch**
 - indications
 - when atlantoaxial subluxation is combined with basilar invagination
 - resection of C1 posterior arch for complete decompression
 - leads to indirect decompression of anterior cord compression by pannus
 - may be required if atlantoaxial subluxation is not reducible
 - **odontoidectomy**
 - indications
 - rarely indicated
 - used as a secondary procedure when there is residual anterior cord compression due to pannus formation that fails to resolve with time following a posterior spinal fusion
 - pannus often resolves following posterior fusion alone due to decrease in instability

• Basilar Invagination

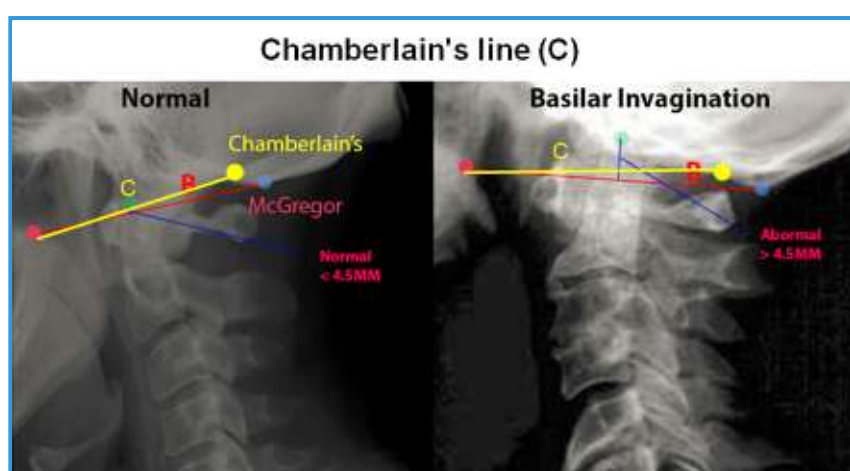
- Introduction
 - also known as superior migration of odontoid (SMO)
 - tip of dens migrates above foramen magnum
 - present in 40% of RA patients
 - often seen in combination with fixed atlantoaxial subluxation
- Mechanism
 - cranial migration of dens from erosion and bone loss between occiput and C1&C2
- Imaging
 - radiographic lines
 - Ranawat C1-C2 index



- center of C2 pedicle to a line connecting the anterior and posterior C1 arches
- normal measurement in men is 17 mm, whereas in women it is 15 mm
- distance of < 13 mm is consistent with impaction
- most reproducible measurement
- McGregor's line



- line drawn from the posterior edge of the hard palate to the caudal posterior occiput curve
- cranial settling is present when the tip of dens is more than 4.5 mm above this line
- can be difficult when there is dens erosion
- Chamberlain's line



- line from dorsal margin of hard palate → posterior edge of the foramen magnum
- abnormal if tip of dens > 5 mm proximal Chamberlain's line
- normal distance from tip of dens to basion of occiput is 4-5 mm
- this line is often hard to visualize on standard radiographs

- McRae's line
 - defines the opening of the foramen magnum
 - the tip of the dens may protrude slightly above this line, but if the dens is below this line then impaction is not present
- MRI
 - cervicomedullary angle $< 135^\circ$ suggest impending neurologic impairment
- Treatment
 - operative
 - **C2 to occiput fusion**
 - indications
 - progressive cranial migration (> 5 mm)
 - neurologic compromise
 - cervicomedullary angle $< 135^\circ$ on MRI
 - **transoral or anterior retropharyngeal odontoid resection**
 - indications
 - brain stem compromise

• Subaxial Subluxation

- Introduction
 - present in 20% with RA
 - often occurs at multiple levels
 - often combined with upper c-spine instability
 - lower spine involvement more common with
 - steroid use
 - males
 - seropositive RA
 - nodules present
 - severe RA
- Pathophysiology
 - pannus formation and soft tissue instability of facet joints and Luschka joints
- Radiographs
 - subaxial subluxation (of vertebral body) of > 4 mm or $> 20\%$ indicates cord compression
 - cervical height index (body height/width) < 2.0 is almost 100% sensitive and specific for predicting neurologic compromise
- Treatment

- operative
 - **posterior fusion and wiring**
 - indications
 - > 4mm / >20% subaxial subluxation + intractable pain and neurologic symptoms

- Operative Complications

- Failure to improve symptoms
 - outcome less reliable in Ranawat Grade IIIB (objectively weak with UMN signs and nonambulatory)
- Pseudoarthrosis
 - 10-20% pseudoarthrosis rate
 - decreased by extension to occiput
- Adjacent level degeneration

27- Cervical Disc Arthroplasty

Images



- SUMMARY

- Cervical Disc Arthroplasty is a motion preserving technique that has shown to be equivalent, and superior in two level disease, to cervical fusion.
- There is mounting evidence that by avoiding a fusion, adjacent level disease and subsequent reoperation rates, are decreased.
- Primary contraindication is advanced degenerative disease of the facets with associated neck pain.

- History

- 1966: Fernström first implanted a stainless steel ball bearing in the cervical spine but reported unacceptable rates of device-related complications.
 - at that time, ACDF was gaining popularity with reports of great clinical success and therefore interest in motion preserving procedures decreased.

- 1980-90s: a renewed interest in cervical ADR resurfaced when lumbar disk arthroplasty gained in popularity use in Europe.
- 2002: first report on modern cervical ADR appeared with the premise that it would decrease or prevent adjacent segment disease by maintaining motion
- 2010 to present
 - several RCT showing superiority to cervical fusion with regard to
 - reoperation rate
 - quicker return to work

• OUTCOMES

- Pros and cons
 - benefit
 - potential to preserve motion
 - pseudoarthrosis not a concern
 - quicker return to routine activities
 - risks
 - hardware failure with potential paralysis
 - persistent neck pain from pain originating from facets
- Evidence
 - single-level disease
 - CDA equivalent to fusion in
 - neurologic improvement
 - patient reported outcomes
 - CDA superior to fusion in
 - reoperation rate
 - two-level disease
 - CDA equivalent to fusion in
 - neurologic improvement
 - patient reported outcomes
 - CDA superior to
 - reoperation rates

• Indications

- Indications
 - primary CDA
 - single and double level cervical radiculopathy
 - single and double level cervical myelopathy

- revision CDA
 - if performed within 2 weeks results are equivalent to revision
- Contraindications
 - significant facet degeneration
- Preoperative Imaging
 - Radiographs
 - AP and lateral of cervical spine
 - CT scan
 - useful to determine positioning and sizing of THA
 - MRI
 - required to evaluate central and foraminal stenosis.
- Technique
 - Approach
 - anterior approach to cervical spine
 - Biomechanics
 - critical to align center of rotation in both coronal and sagittal plane
 - especially important in two level CDA
- Complications
 - Hardware failure
 - may have catastrophic consequence in retropulsion into spinal canal

28- Synovial Facet Cyst

- summary

- Synovial Facet Cysts are degenerative lesions of the lumbar spine that can lead to lumbar spinal stenosis and cause low back pain and radicular symptoms.
- Diagnosis is made with MRI studies of the lumbar spine.
- Treatment is a trial of nonoperative management with NSAIDs and physical therapy.Â Surgical management is indicated for progressive disabling pain that has failed nonoperative management, and/or progressive neurological deficits.

- Epidemiology

- Incidence
 - rare
- Anatomic location
 - usually in lumbar spine
 - 60% to 89% occur at the L4-L5 level (most mobile segment)
 - ~14% occurrence at L3-4
 - ~12% occurrence at L5-S1

- Etiology

- Pathophysiology
 - possible etiologies
 - trauma (controversial)
 - microinstability of the facet leading to
 - extruded synovium through joint capsules
 - myxoid degeneration of collagen tissue
 - proliferation of fibroblasts with increased hyaluronic acid production
 - cyst composition
 - ganglion cysts
 - flavum cysts
 - serous contents

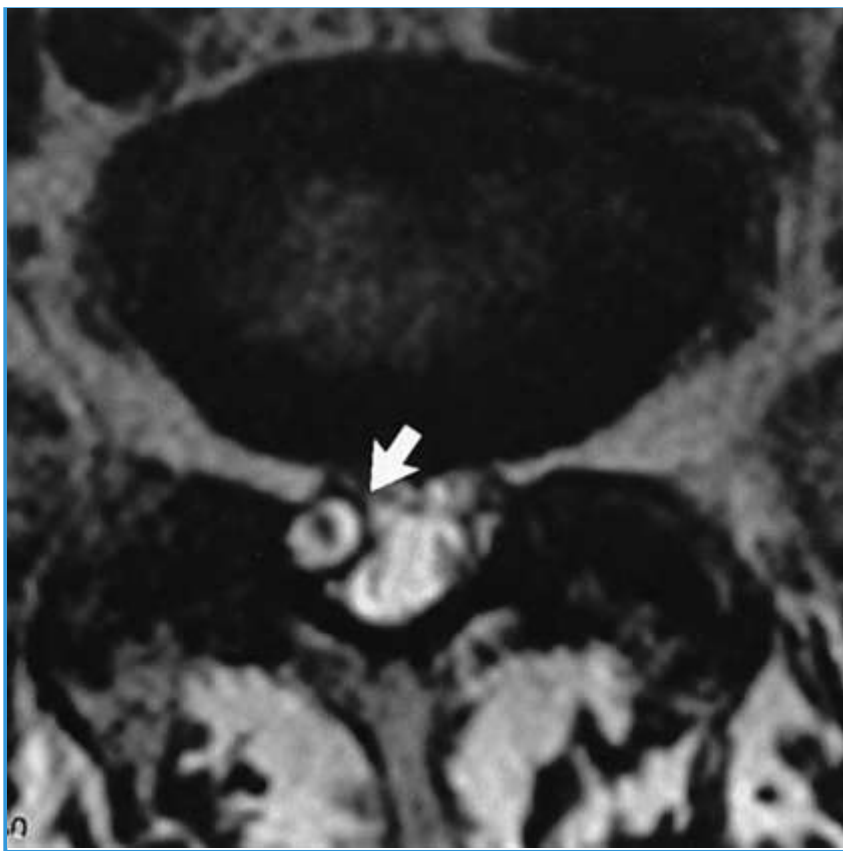
- mucoid contents
- hemorrhagic contents
- Associated conditions
 - degenerative spondylolisthesis

- Presentation

- Symptoms
 - mechanical back pain
 - radicular symptoms (leg pain)
 - rapid onset or sudden deterioration suggests a facet cyst hematoma
 - neurogenic claudication (buttock/leg pain with walking)
- Physical exam
 - neurovascular
 - may see nerve root deficits at associated spinal levels

- Imaging

- Radiographs
 - recommended views
 - required
 - AP lateral, lateral, flexion and extension views of spine
 - findings
 - usually normal
 - look for segmental instability
- MRI
 - indications
 - significant leg pain
 - views
 - best seen on T2 axial and sagittal images



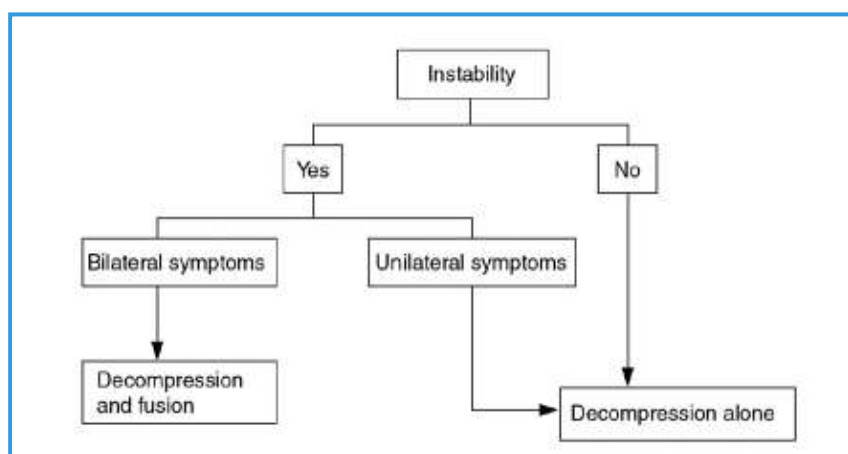
- traditionally hyperintense centers with hypointense rims on T2 and hypointense inner cores on T1 sequences
 - peripheral rim enhancement with gadolinium contrast
- improved detection rate with positional MRI
 - 89% sensitivity when supine
 - 97% sensitivity when standing
 - cysts increase in size while standing
- high-signal intensity on T2 weighted images
 - synovial content
 - higher success rate with CT guided cyst rupture
- low-signal intensity on T2 weighted images
 - gelatinous or calcified contents
 - lower success rate with CT guided cyst rupture

• Treatment

- Nonoperative
 - **NSAIDS, rest, immobilization, physical therapy, epidural steroid injections**
 - indications

- mild symptoms
- first-line treatment
- radicular pain without motor weakness
- outcomes
 - no natural history studies have been conducted to date
- **CT-guided cyst rupture, facet steroid injection, cyst injection**
 - indications
 - second-line management after failing conservative measures
 - radicular symptoms correlate with facet cyst location
 - outcomes
 - 50-75% pain relief at 1-year
 - approximately 39% of patients will require surgical intervention at 7 months

○ Operative

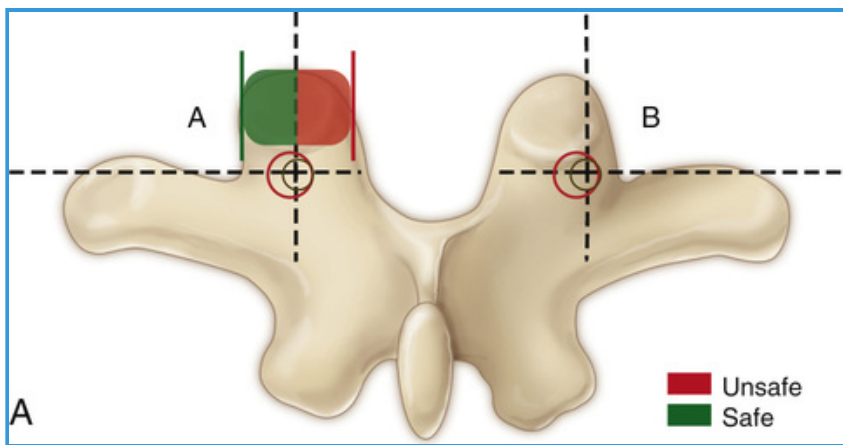


- **laminectomy with decompression and cyst excision**
 - indications
 - persistent symptoms despite non-operative management
 - unilateral symptoms
 - can be performed in patients with spondylolisthesis with unilateral symptoms as long as they are aware of the higher risk of slip progression
 - outcomes
 - high incidence of recurrent back pain and cyst formation within two years
 - 80-90% success rate in back and leg pain
 - risk of iatrogenic spondylolisthesis
- **facetectomy and instrumented fusion**
 - indications
 - some consider first line of surgical treatment due to high recurrence rates
 - symptomatic recurrence following laminectomy with decompression
 - bilateral symptoms

- central canal stenosis
 - wider decompression will likely lead to iatrogenic instability
 - presence of instability (e.g. degenerative spondylolisthesis)
- outcomes
 - demonstrated to have the lowest risk of persistent back pain and recurrence of cyst formation in recent studies
 - complete resolution of symptoms in 80-90% of patients

• Techniques

- **NSAIDS, rest, immobilization, physical therapy, epidural steroid injections**
 - technique
 - recommended for 6-8 weeks prior to proceeding with surgical treatment or CT-guided rupture
- **CT-guided cyst rupture, facet steroid injection, cyst injection**
 - technique
 - fluoroscopic guidance
 - commonly used
 - secondary surgery rate roughly 50%
 - CT guidance
 - improved visualization of spinal anatomy
 - slightly improved patient outcomes compared to fluoroscopic guidance
- **laminectomy with decompression and cyst excision**
 - approach
 - posterior approach to the spine
 - technique
 - unilateral laminotomy and medial facetectomy with a high-speed burr
 - create plane between dura and cyst
 - grab cyst with allis clamp or forceps and apply gentle traction
 - separate cyst from underlying dura with Epstein curet or Woodson elevator
- **facetectomy and instrumented fusion**
 - approach
 - posterior approach to the spine
 - technique
 - place pedicle screws at the intersection of the superior border of the transverse process and midline of the superior process



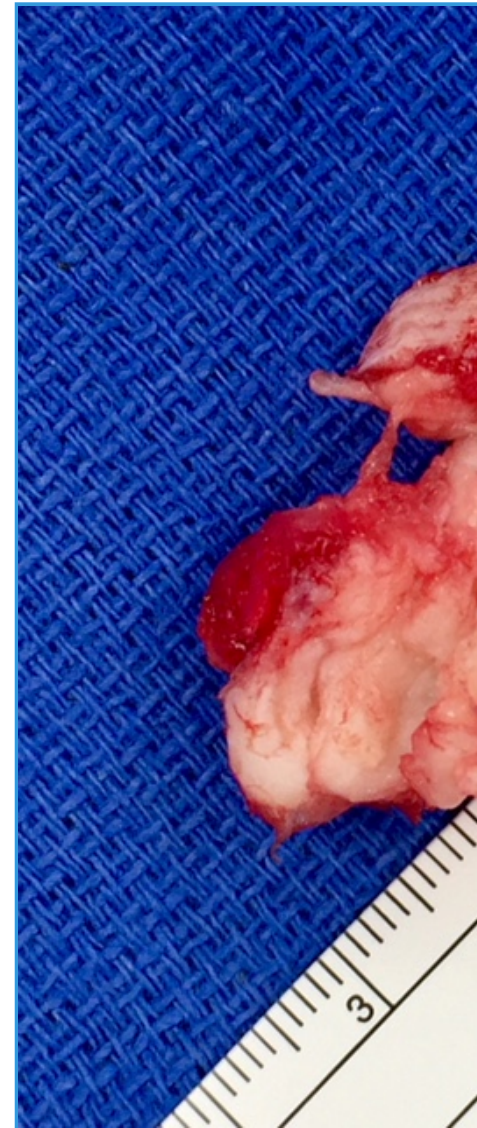
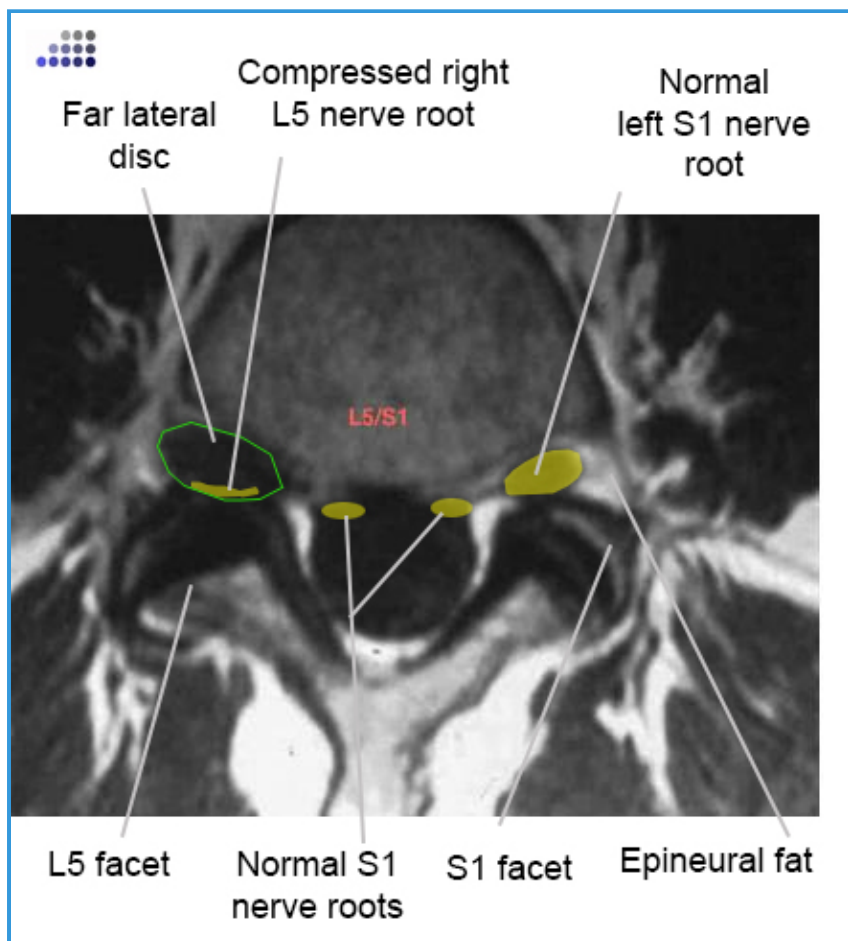
- perform decompressive laminectomy and facetectomy
- excise cyst after developing interval between cyst and dura
 - partial excision in cases of cysts adherent to the dura

• Complications

- Cyst recurrence
 - incidence
 - high incidence of recurrence with resection alone
 - treatment
 - new studies favor facetectomy and fusion as first line of operative treatment
- Iatrogenic spondylolisthesis
 - risk factors
 - decompressive laminectomy without fusion
 - treatment
 - posterior instrumented fusion +/- spondylolisthesis reduction
- Dural tear
 - incidence
 - risk factors
 - revision surgery
 - cyst adherent to dura
 - 50-55% of cases the facet cyst is adherent to the dura
 - limited cyst resection in these cases minimizes dural tear risk
 - partial cyst excision results in 88% success rate for lumbar spinal stenosis while minimizing risk of dural tear

29- Lumbar Disc Herniation

Images



- summary

- Lumbar Disc Herniation is a very common cause of low back pain and unilateral leg pain, known as radiculopathy. In rare cases a large disc herniation can lead to Cauda Equina Syndrome which requires emergent diagnosis and treatment.
- Diagnosis is made clinically and confirmed with an MRI studies of the lumbar spine.
- Treatment for radicular leg pain is initially nonoperative with oral medications and physical therapy. Surgical microdiscectomy is only indicated for severe pain and/or motor deficit that have failed to respond to nonoperative management. Treatment for Cauda Equina Syndrome in contrast is emergent microdiscectomy within 48 hours.

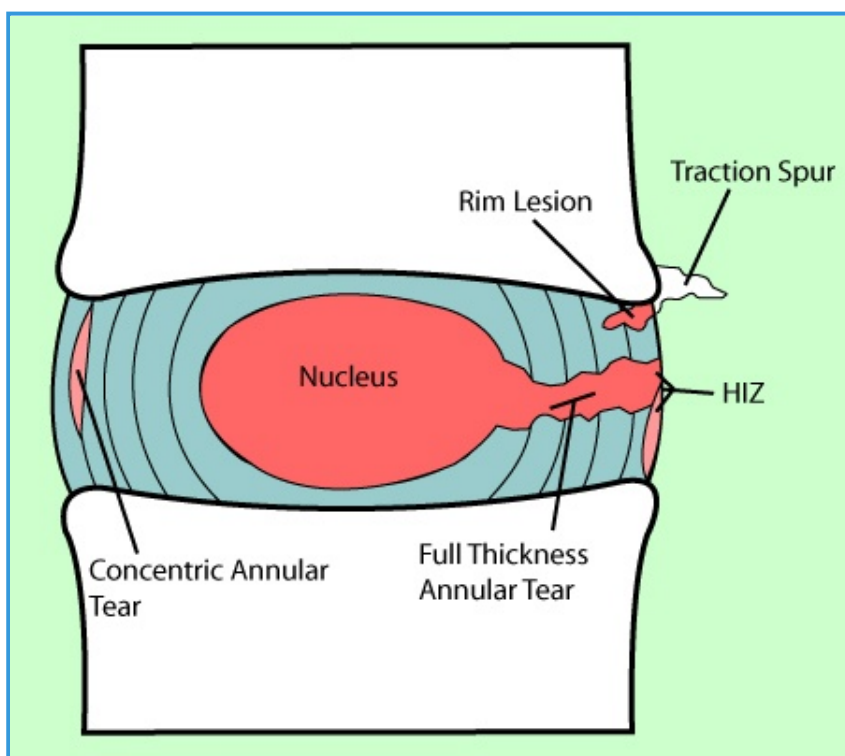
- Epidemiology

- Incidence
 - peak incidence is 4th and 5th decades
 - lifetime prevalence of 10%

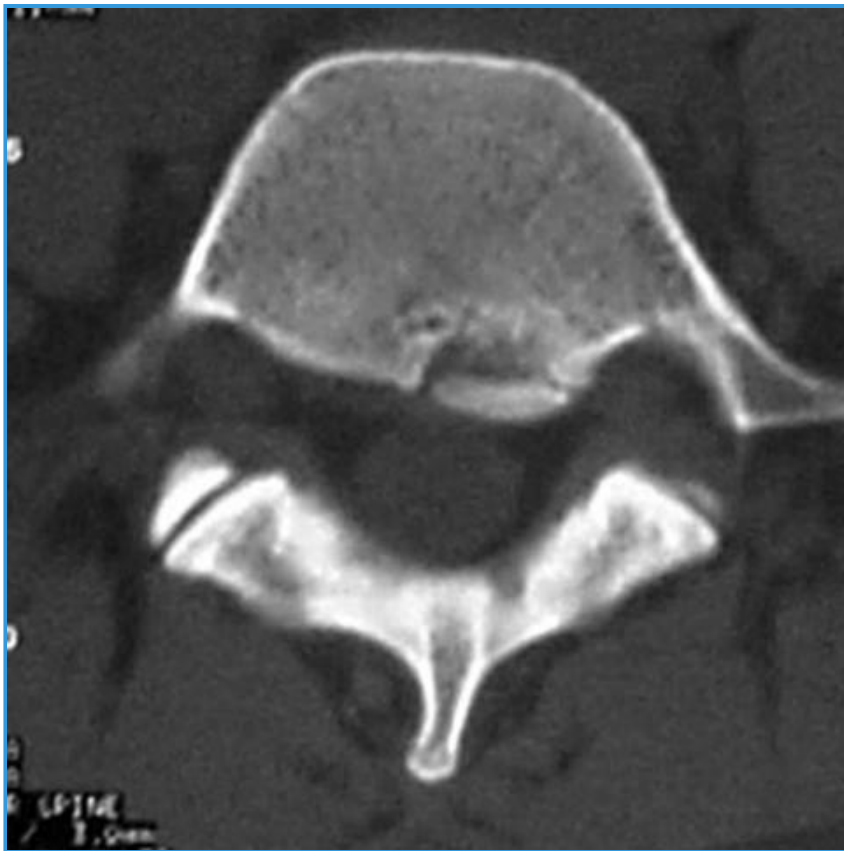
- only ~5% become symptomatic
- Demographics
 - 3:1 male:female ratio
- Location
 - L5/S1 most common level
 - 95% involve L4/5 or L5/S1 levels

• Etiology

- Pathoanatomy
 - recurrent torsional strain leads to tears of the outer annulus which leads to herniation of nucleus pulposus
 - lateral edge of posterior longitudinal ligament weakest region
 - common site for posterolateral/paracentral disc herniations
 - sinuvertebral nerves provide pain innervation to the posterior annulus
 - mediate vertebrogenic back pain that precedes or accompanies disc herniation
- Pathophysiology
 - cellular senescence of fibrochondrocytes leads to loss of proteoglycan production leading to disc height loss
 - loss of height causes increased strain on the annulus fibrosus
 - increased strain leads to fissures of the annulus fibrils
 - annular tears compromise hoop stresses that act against the deforming forces of the nucleus pulposus



- nucleus pulposus herniates through tear
 - younger, well-hydrated discs more likely to herniate
 - pediatric patients may have Salter-Harris II fracture of the ring apophysis

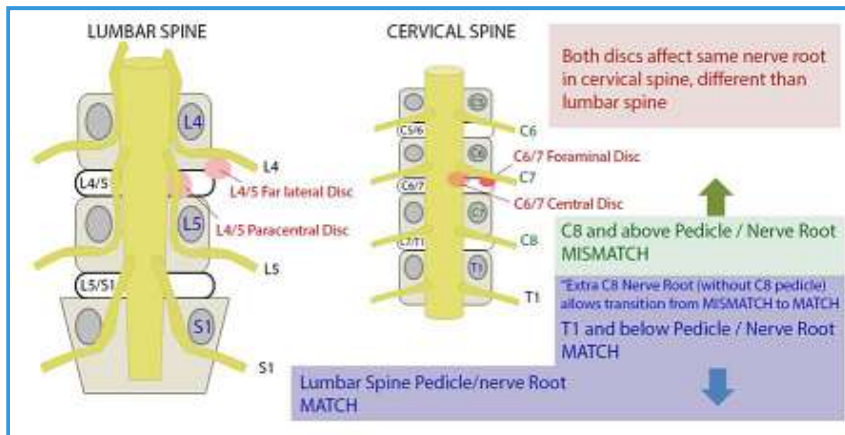


- older, desiccated discs less likely to herniate
- sciatica symptoms result from combined mechanical compression and associated inflammation
 - not all patients with mechanical compression develop symptoms
 - TNF- α , MMP, NO, PGE₂, and IL-6 are implicated in nerve irritation leading to radiculopathy
 - weak evidence to support DMARDs for treatment

• Anatomy

- Complete intervertebral disc anatomy and biomechanics
- Disc composition
 - annulus fibrosis
 - composed of type I collagen, water, and proteoglycans
 - 15-25 sheets of lamellae
 - characterized by extensibility and tensile strength
 - high collagen / low proteoglycan ratio (low % dry weight of proteoglycans)
 - nucleus pulposus
 - composed of type II collagen, water, and proteoglycans
 - characterized by compressibility
 - low collagen / high proteoglycan ratio (high % dry weight of proteoglycans)
 - proteoglycans interact with water and resist compression
 - a hydrated gel due to high polysaccharide content and high water content (88%)
 - disc height dependent on the degree of hydration
 - avascular structure

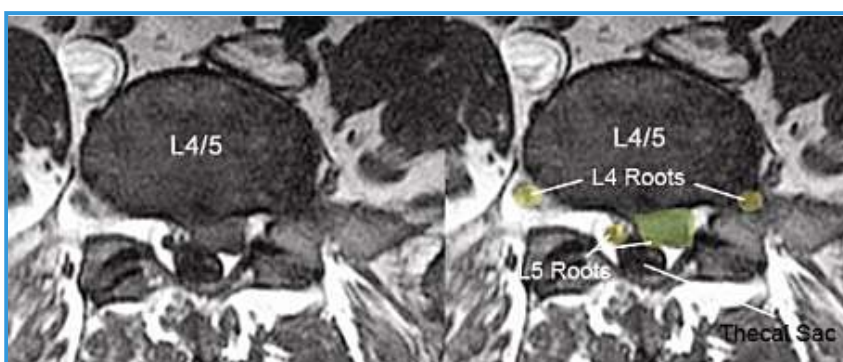
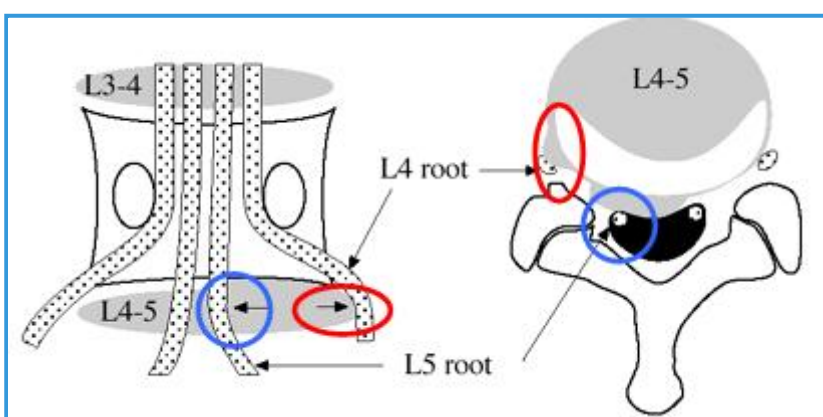
- nutrients supplied by diffusion from the end plates
- Nerve root anatomy
 - key difference between cervical and lumbar spine is



- pedicle/nerve root mismatch
 - cervical spine C6 nerve root travels under C5 pedicle (mismatch)
 - lumbar spine L5 nerve root travels under L5 pedicle (match)
 - extra C8 nerve root (no C8 pedicle) allows transition
- horizontal (cervical) vs. vertical (lumbar) anatomy of nerve root
 - because of vertical anatomy of lumbar nerve root a paracentral and foraminal disc will affect different nerve roots
 - because of horizontal anatomy of cervical nerve root a central and foraminal disc will affect the same nerve root

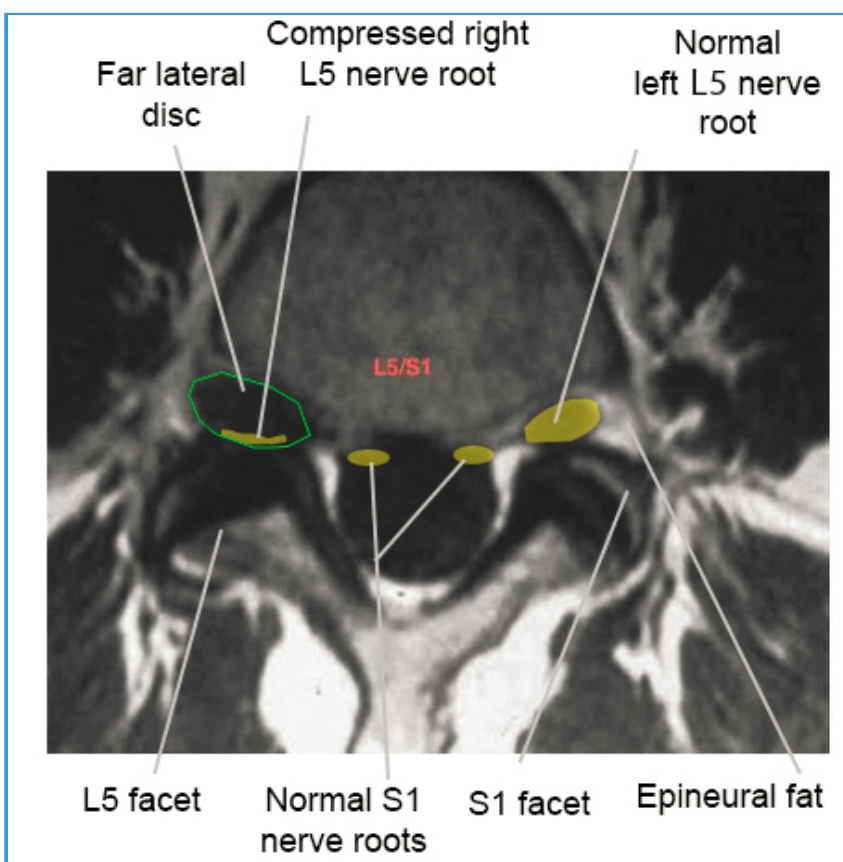
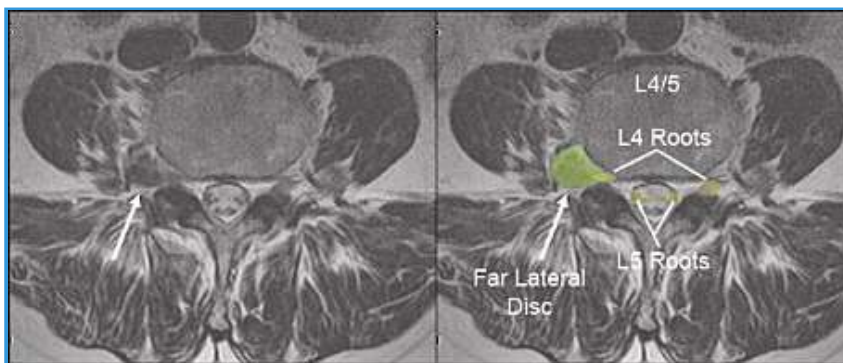
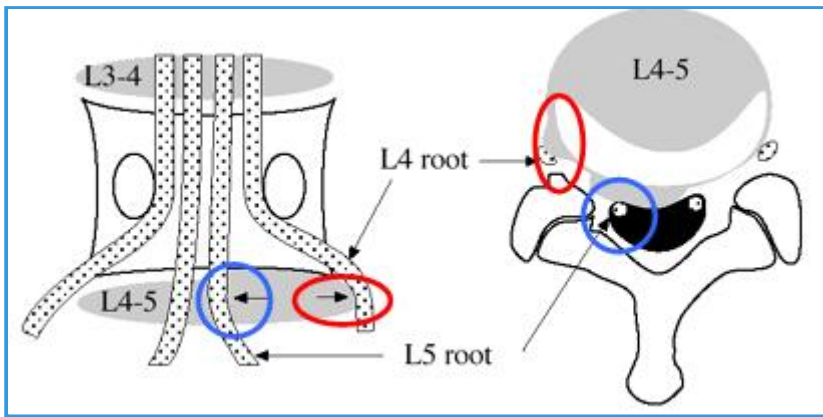
• Classification

- Location Classification
 - central prolapse
 - often associated with back pain only
 - may present with cauda equina syndrome which is a surgical emergency
 - posterolateral (paracentral)



- most common (90-95%)
- PLL is weakest here

- affects the traversing/descending/lower nerve root
 - at L4/5 affects L5 nerve root
- foraminal (far lateral, extraforaminal)



- less common (5-10%)
- affects exiting/upper nerve root
 - at L4/5 affects L4 nerve root
- herniated disc material directly compresses dorsal root ganglion
 - can manifest with more severe pain than traditional posterolateral disc herniation
- axillary
 - can affect both exiting and descending nerve roots
- Morphology classification
 - protrusion
 - eccentric bulging with an intact annulus
 - extrusion
 - disc material herniates through annulus but remains continuous with disc space

- sequestered fragment (free)
 - disc material herniates through annulus and is no longer continuous with disc space
 - prone to proximal or distal migration
 - Containment classification
 - contained
 - disc material is contained beneath the posterior longitudinal ligament
 - uncontained
 - disc material passes dorsal to the posterior longitudinal ligament
 - Timing classification
 - acute
 - herniations present < 3-6 months
 - important consideration given surgical outcomes are associated with chronicity
 - chronic
 - herniations present >6 months
- Presentation
 - History
 - sudden onset of pain after lifting a heavy object
 - occupational exposure
 - prolonged sitting with lateral bending and rotation in the presence of vibrational energy
 - symptomatic improvement lying supine with knees and hips flexed
 - especially with lower lumbar disc herniations
 - Symptoms
 - can present with symptoms of
 - axial back pain (low back pain)
 - this may be discogenic or mechanical in nature
 - can precede herniation
 - radicular pain (buttock and leg pain)
 - often worse with sitting , improves with standing
 - symptoms worsened by coughing, valsalva, sneezing
 - pain not worsened with ambulation
 - cauda equina syndrome (present in 1-10%)
 - bilateral leg pain
 - LE weakness
 - saddle anesthesia

- bowel/bladder symptoms
- Physical exam
 - inspection
 - limited lumbar range of motion
 - often the pain is the limiting factor
 - patient leaning away from side of radiculopathy
 - effort to increase the size of the neuroforamen
 - palpation
 - spasms of the paraspinal musculature
 - nonspecific
 - associated tenderness in the paraspinal musculature
 - nonspecific
 - motor exam & reflexes
 - see lower extremity neuro exam
 - L3 radiculopathy
 - hip adduction weakness
 - knee extension weakness
 - dermatomal pain in the anteromedial thigh
 - L4 radiculopathy
 - ankle dorsiflexion weakness (L4 > L5)
 - decreased patellar reflex
 - dermatomal pain in the lateral thigh, crossing the knee, to medial foot
 - L5 radiculopathy
 - EHL weakness (L5)
 - manual testing
 - ankle dorsiflexion weakness (L4 > L5 contribution)
 - test by having patient walk on heels
 - ankle inversion weakness
 - hip abduction weakness (L5)
 - have patient lie on side on exam table and abduct leg against resistance
 - dermatomal pain in anterolateral leg and dorsum of foot
 - S1 radiculopathy
 - ankle plantar flexion weakness (S1)
 - have patient do 10 single leg toes stands
 - decreased Achilles tendon reflex
 - dermatomal pain in posterior calf and lateral foot
 - provocative tests

- straight leg raise (Lasegue's sign)
 - a tension sign for L4, L5 and S1 nerve root
 - technique
 - can be done sitting or supine
 - reproduces pain and paresthesia in leg at 30-70 degrees hip flexion
 - sensitivity/specificity
 - most important and predictive physical finding for identifying who is a good candidate for surgery
- contralateral SLR
 - crossed straight leg raise is less sensitive but more specific
- femoral nerve stretch test (Wasserman sign)
 - tension sign for L2 and L3
 - performed in prone position
 - knee flexed and hip extended
 - reproduction of pain in anterior thigh is considered positive
- Braggard's sign
 - perform SLR to the point of exacerbation
 - lower leg just to the point where pain recedes
 - ankle dorsiflexion causes exacerbated pain
- Bowstring sign
 - SLR aggravated by compression on popliteal fossa
- Kernig test
 - pain reproduced with neck flexion, hip flexion, and leg extension
- Naffziger test
 - pain reproduced by coughing, which is instigated by lying patient supine and applying pressure on the neck veins
- Milgram test
 - pain reproduced with straight leg elevation for 30 seconds in the supine position
- gait analysis
 - Trendelenburg gait
 - due to gluteus medius weakness which is innervated by L5

• Imaging

- Radiographs
 - recommended views
 - AP and lateral radiographs

- helpful for surgical localization
 - identify anomalous vertebrae (sacralized L5 or lumbarized S1)
- optional views
 - flexion-extension
 - identifies instability
 - if present can changes surgical plan to involve fusion
- findings
 - most often normal
 - abnormal findings
 - loss of lordosis (spasm)



- loss of disc height



- especially at the involved level
 - lumbar spondylosis (degenerative changes)
 - facet hypertrophy
 - disc space collapse
 - peridiscal osteophytes
 - sciatic scoliosis
 - convex or concave list to the ipsilateral side of herniation
- sensitivity
 - poor sensitivity for identifying disc herniation
 - more often used as a screening tool for other pathology prior to proceeding with MRI
- CT myelogram



- indications
 - patients unable to obtain MRI
 - pacemaker
- views
 - sagittal and coronal reconstructions demonstrate compression of the thecal sac
- findings
 - myelography filling defect at the level of herniation
 - a calcified disc may be visible
- sensitivity
 - 93% accurate at detecting associated surgical pathology
 - unable to detect foraminal or extraforaminal herniations
- MRI without gadolinium
 - indications for obtaining an MRI
 - pain lasting > one month and not responding to nonoperative management **or**
 - red flags are present
 - infection (IV drug user, h/o of fever and chills)
 - tumor (h/o or cancer)
 - trauma (h/o car accident or fall)
 - cauda equina syndrome (bowel/bladder changes)
 - modality of choice for diagnosis of lumbar disc herniations
 - highly sensitive and specific
 - helpful for preoperative planning
 - useful to differentiate from synovial facet cysts
 - however high rate of abnormal findings on MRI in normal people
 - need to correlate MRI findings with symptoms and physical exam findings
 - views
 - sagittal and coronal T2 reconstructions
 - localize the level and side of the herniation
 - location anatomic location (central vs paracentral vs foraminal vs extraforaminal)
- MRI with gadolinium
 - indications
 - useful for revision surgery
 - findings
 - allows to distinguish between post-surgical fibrosis (enhances with gadolinium) vs. recurrent herniated disc (does not enhance with

gadolinium)

- Treatment

- Nonoperative

- **rest and physical therapy, anti-inflammatory medications, and limited narcotics**

- indications

- first line of treatment for most patients with disc herniation

- new-onset radicular pain

- no significant motor weakness

- absence of cauda equina syndrome

- no bowel/bladder incontinence

- outcomes

- 90% improve without surgery

- positive predictors of good outcomes with nonoperative treatment

- higher level of education

- **selective nerve root corticosteroid injections**

- indications

- second line of treatment if therapy and medications fail

- usually after 6 weeks

- outcomes

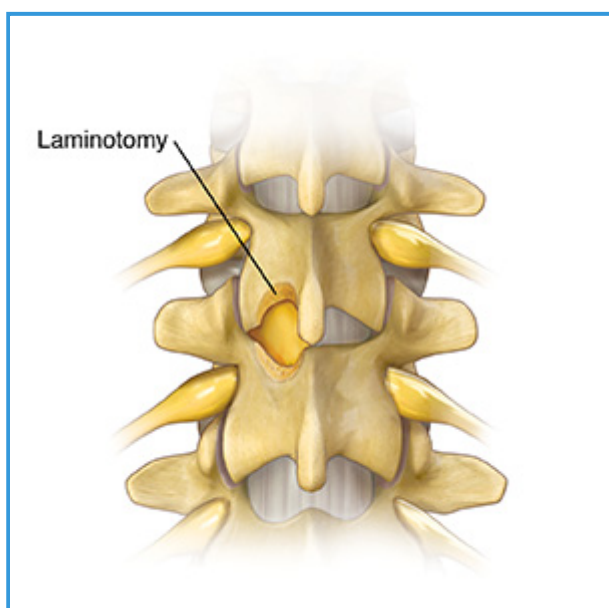
- leads to long lasting improvement in ~ 50% (compared to ~90% with surgery)

- results best in patients with extruded discs as opposed to contained discs

- no difference in pain relief using lidocaine with and without steroids

- Operative

- **laminotomy and discectomy (microdiscectomy)**



- indications

- persistent disabling pain lasting more than 6 weeks that have failed nonoperative options (and epidural injections)
 - timing of appropriate nonoperative treatment varies
 - better surgical outcomes if addressed within 2 months
- progressive and significant weakness
- cauda equina syndrome
- rehabilitation
 - patients may return to medium to high-intensity activity at 4 to 6 weeks
- outcomes
 - outcomes with surgery compared to nonoperative
 - improvement in pain and function greater with surgery
 - early and sustained pain relief out to 2 years
 - equal likelihood of receiving disability at 5 years
 - positive predictors for good outcome with surgery
 - leg pain is chief complaint
 - positive straight leg raise
 - weakness that correlates with nerve root impingement seen on MRI
 - married status
 - progressively worsening symptoms prior to surgery
 - professional athletes
 - younger age, greater number of games played prior to injury
 - paracentral and foraminal herniations
 - central and extraforaminal associated with worse outcomes
 - herniation at caudal levels
 - L5-S1 results in better outcomes than L2-3
 - negative predictors for good outcome with surgery
 - worker's compensation
 - WC patients have less relief from symptoms and less improvement in quality of life with surgical treatment
 - smokers
 - chronic headaches
 - depression
- **far lateral microdiscectomy**
 - indications
 - for far-lateral disc herniations

- Techniques

- **Rest and physical therapy, anti-inflammatory medications, and limited narcotics**
 - bedrest followed by progressive activity as tolerated
 - historical treatment
 - most modern protocols involve immediate activity with modification to avoid pain exacerbation
 - medications
 - NSAIDS
 - muscle relaxants (more effective than placebo but have side effects)
 - oral steroid taper
 - modest but significant improvement in function, no significant improvement in pain
 - narcotic medications
 - typically avoided due to complication profile
 - dependence
 - difficult post-op pain control
 - worse outcomes following surgical treatment
 - if used, usually for a short period (2-3 days) in the acute setting
 - physical therapy
 - typically initiated three weeks after symptom onset
 - extension exercises are extremely beneficial
 - traction
 - chiropractic manipulation
 - should be performed with care
- **Selective nerve root corticosteroid injections**
 - epidural
 - selective nerve block
 - can be therapeutic and diagnostic
 - useful in case of diagnostic dilemmas
- **Laminotomy and discectomyÂ (microdiscectomy)**
 - various techniques available
 - most techniques can be performed in a "minimally invasive" fashion
 - can be done with small incision or through "tube" access
 - open technique using a crank (McCulloh) retractor
 - discectomy performed through microscope or loupe magnification
 - no difference in outcomes between the two
 - endoscopic techniques available
 - provide smaller incisions
 - similar outcomes between all techniques surgical techniques

- fragment excision vs extended disc space curettage (subtotal discectomy)
 - lower long term back pain with fragment excision
 - higher reherniation rates with fragment excision at 2-years follow-up
- **Far lateral microdiscectomy**
 - utilizes a paraspinal approach of Wiltse
 - can also be done with tubular or crank retractors

- **Complications**

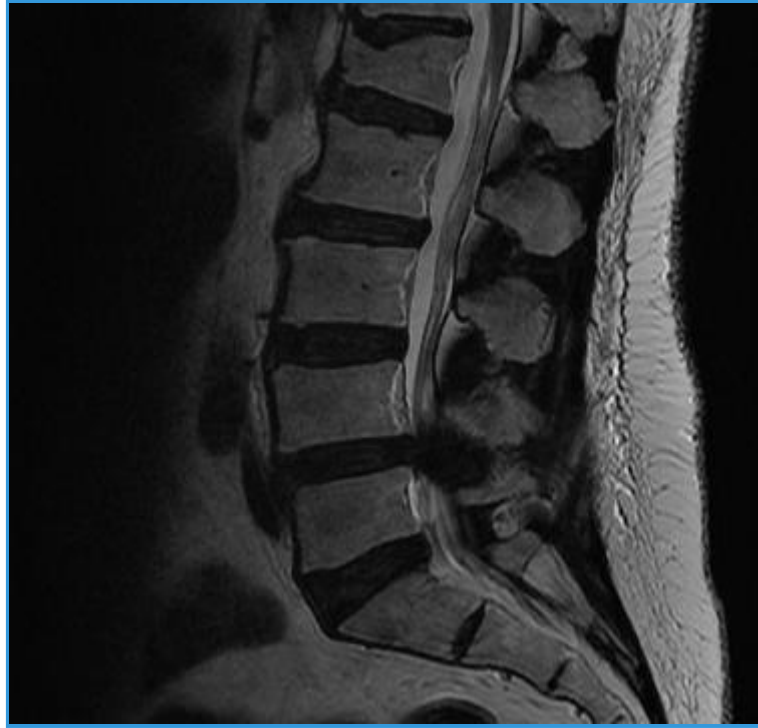
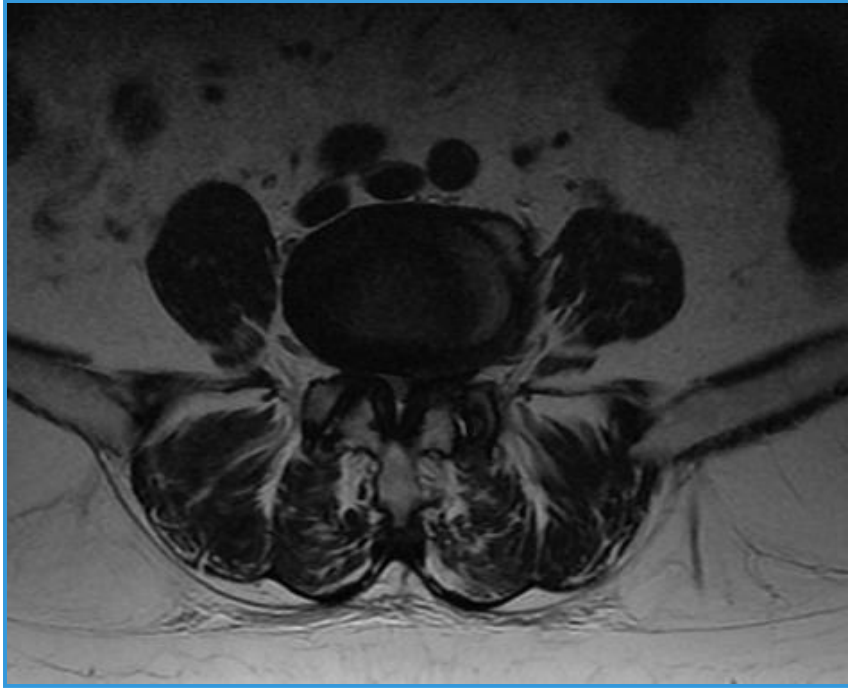
- Dural tear
 - occurs in 0-4% of cases
 - treatment
 - if have tear at time of surgery then perform water-tight repair
 - has not been shown to adversely affect long term outcomes
- Recurrent HNP
 - defined as recurrent sciatica at the same operated level
 - pain-free interval of 6 months prior to recurrence of symptoms
 - pathology can be ipsilateral to contralateral to the index presentation
 - recurrence rate 5-15%
 - revision rate at 8-year follow-up is 15% according to the SPORT trial
 - risk factors protective against recurrent herniation
 - discrete herniations
 - small annular defects (<6 mm)
 - treatment
 - can treat nonoperatively initially
 - revision microdiscectomy in patients with persistent symptoms
 - outcomes for revision discectomy have been shown to be as good as for primary discectomy
- Wound infections
 - occurs in up to 3% of cases
 - epidural abscess in 0.3% of cases
 - risk factors
 - microscope usage proposed as a source of infection
 - some data refutes this claim
 - treatment
 - superficial infections
 - treat with local wound care and antibiotics

- deep infections
 - surgical I&D
- Epidural fibrosis
 - scarring the compresses the dura leading to radicular symptoms
 - associated with poor outcomes following revision surgery
 - persistent back pain
 - patients 3.2 times more likely to suffer from recurrent radiculopathy
 - MRI may demonstrate retraction of the dura on the side of the lesion
- Pyogenic discitis
 - occurs in 2.3% of cases
 - treatment
 - IV antibiotics +/- surgical I&D
- Chronic low back pain
 - not completely understood but central sensitization may be a factor
 - amplification of neural signaling within the central nervous system (CNS) that elicits pain hypersensitivity.
 - Modic changes on MRI imaging are associated with post-operative back pain
 - Pain diagrams may be useful in identifying patients with an increased likelihood of pain sensitization, psychosocial load, and utilizing pain management resources
- Vascular catastrophe
 - exceedingly rare
 - caused by breaking through anterior annulus and injuring vena cava/aorta
 - treatment
 - immediate recognition of complication followed by coordinated repair by vascular service
- Instability
 - due to over resection of lamina and pars interarticularis
 - not all patients are symptomatic
 - treatment
 - instrumentation and fusion of the affected segment
- Prognosis
 - Natural history
 - 90% of patients will have improvement of symptoms within 3 months without substantial medical treatment

- patients less likely to improve if still symptomatic after 6 weeks
- factors associated with good outcomes with nonoperative treatment
 - lack of radiculopathy
- factors associated with worse outcomes with nonoperative treatment
 - obese patients (BMI >30)
 - symptoms present >6 months prior to starting treatment
- Size of herniation decreases over time (reabsorbed)
 - sequestered disc herniations show the greatest degree of spontaneous reabsorption
 - macrophage phagocytosis and enzymatic degradation is the mechanism of reabsorption
- Factors associated with favorable surgical outcomes
 - severe preoperative leg pain
 - shorter symptom duration
 - younger age
 - increased preoperative physical activity
- Surgical treatment is equivalent to nonsurgical treatment in the long term
 - surgery provides faster pain relief

30- Lumbar Spinal Stenosis

Images



- summary
 - Lumbar Spinal Stenosis is a degenerative spinal condition characterized by the narrowing of the lumbar spinal canal due to a variety of bony or soft tissues structures.
 - Diagnosis is made with MRI studies of the lumbar spine.
 - Treatment is a trial of nonoperative management with NSAIDs and physical therapy.Â Surgical laminotomy and discectomy is indicated for progressive disabling pain that has failed nonoperative management, and/or progressive neurological deficits.
- Epidemiology
 - Incidence
 - most common reason for lumbar spine surgery in patients > 65 years old
 - seen in 20-25%
 - Demographics
 - slightly more common in males (1.5:1)
 - average age at presentation is 65 years old
 - Anatomic location
 - most commonly occurs at L4-5 (91%)
 - Risk factors
 - Caucasian race
 - increased BMI

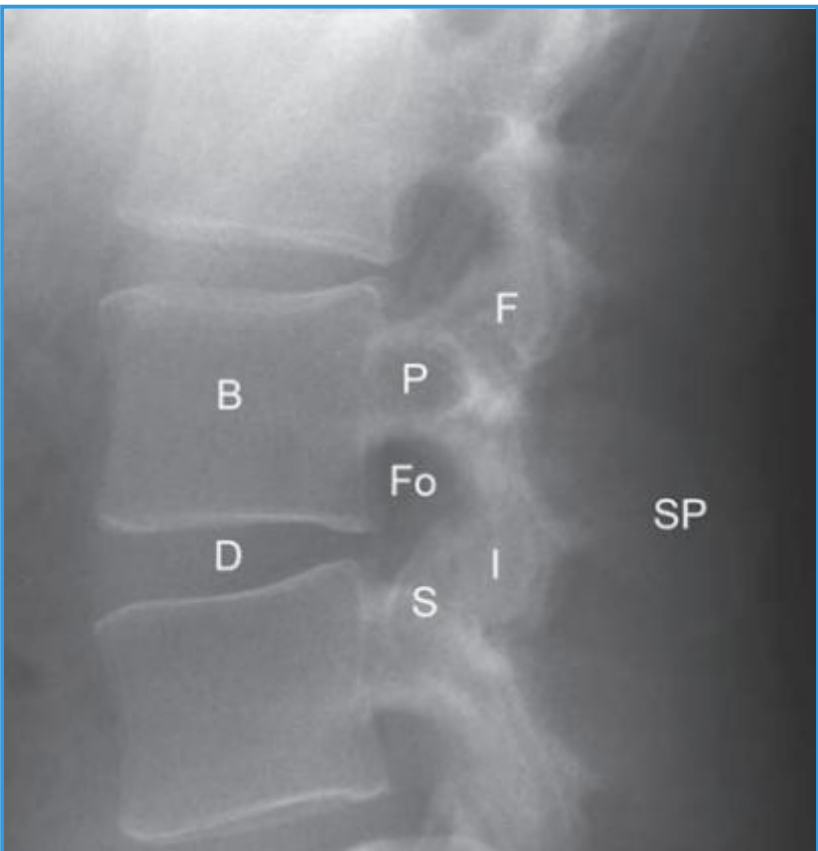
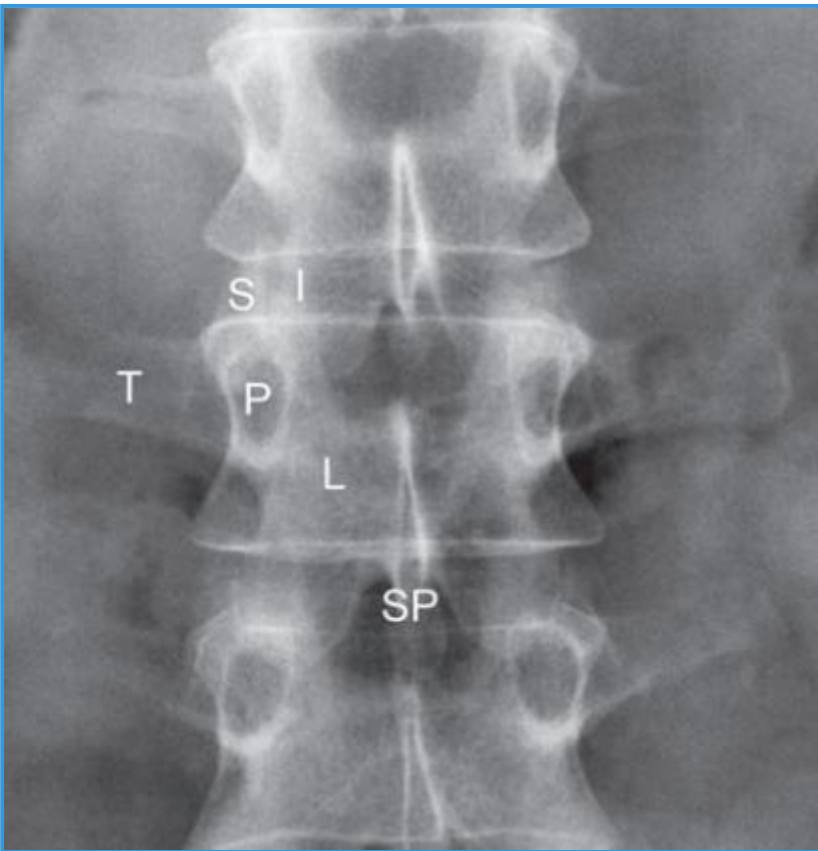
- congenital spine anomalies (20%)
 - failure of posterior elements to develop, leading to short pedicles and laminae

- Etiology

- Mechanism
 - Narrowing of the lumbar spinal canal can be due to
 - bony structures
 - facet osteophytes
 - uncinata spur (posterior vertebral body osteophyte)
 - spondylolisthesis
 - soft tissue structures
 - herniated or bulging discs
 - hypertrophy or buckling of the ligamentum flavum
 - synovial facet cysts
- Pathophysiology
 - cell, water, and proteoglycan content in the nucleus pulposus decreases with age
 - degeneration of the intervertebral disk leads to diminished disk height and buckling/bulging of the annulus fibrosus
 - anterior spinal column begins to have decreased ability to absorb stress, leading to an abnormal transfer of force to the posterior elements
 - increased stress through the facets leads to facet joint hypertrophy, osteophyte formation, and ligamentum flavum buckling and hypertrophy
 - combined changes lead to a narrowing of the spinal canal and compression of the neural elements
- Associated conditions
 - degenerative spondylolisthesis
 - degenerative scoliosis
 - cauda equina syndrome
 - rare

- Anatomy

- Osteology

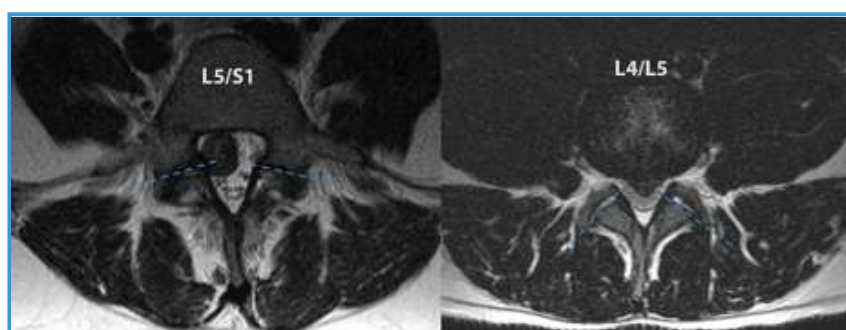
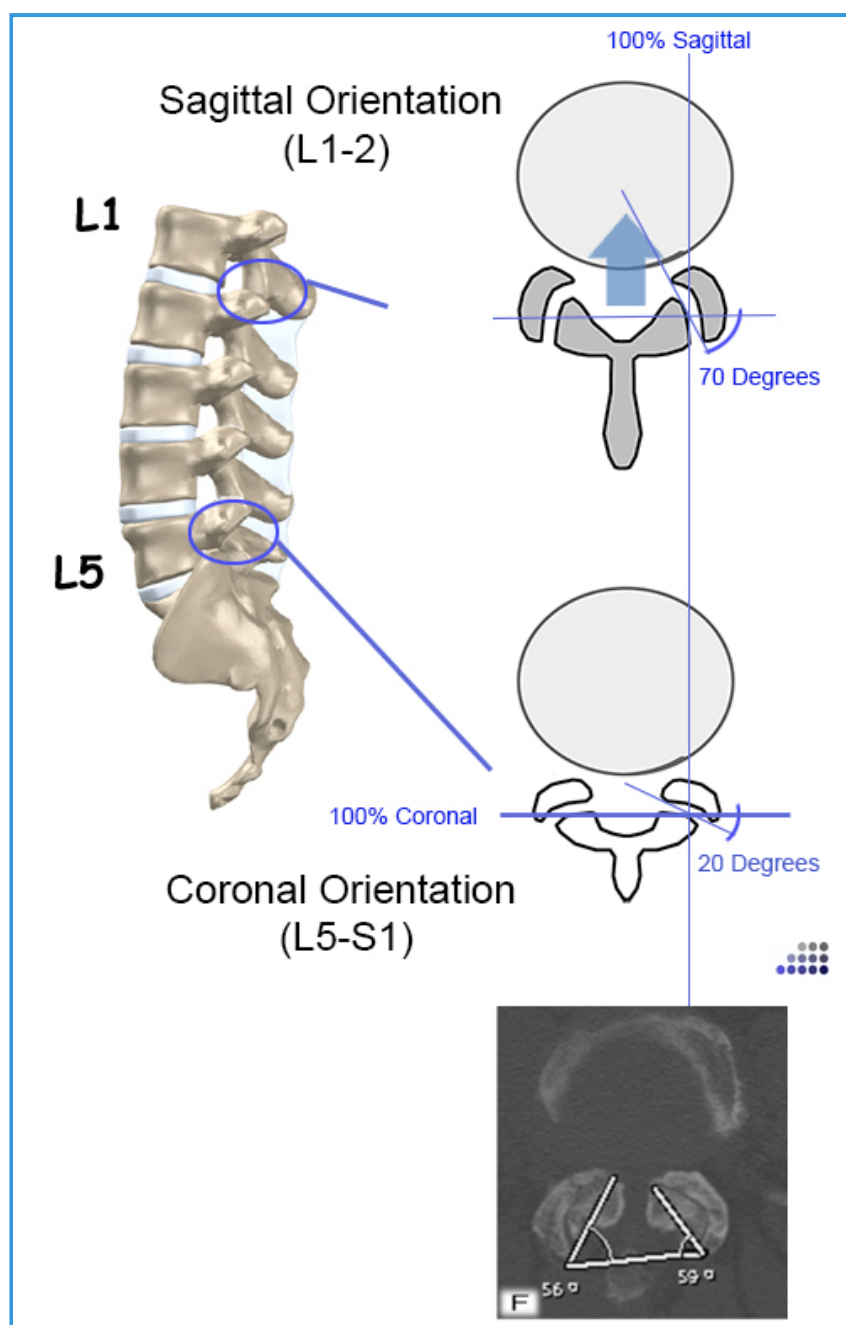


- anterior vertebral body
- posterior arch
 - formed by
 - pedicles
 - pedicles project posteriorly from posterolateral corners of vertebral bodies
 - lamina
 - lamina project posteromedially from pedicles, join in the midline
- spinous process
- transverse process
- mammillary processes
 - separate ossification centers
 - project posteriorly from superior articular facet
- pars interarticularis
 - mass of bone between superior and inferior articular facets
 - site of spondylolysis



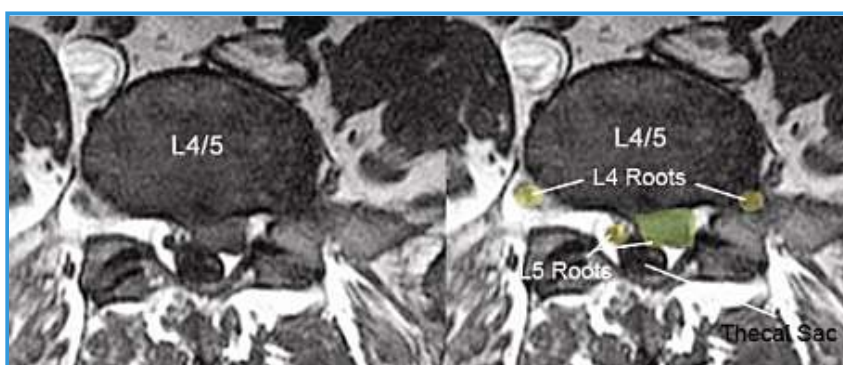
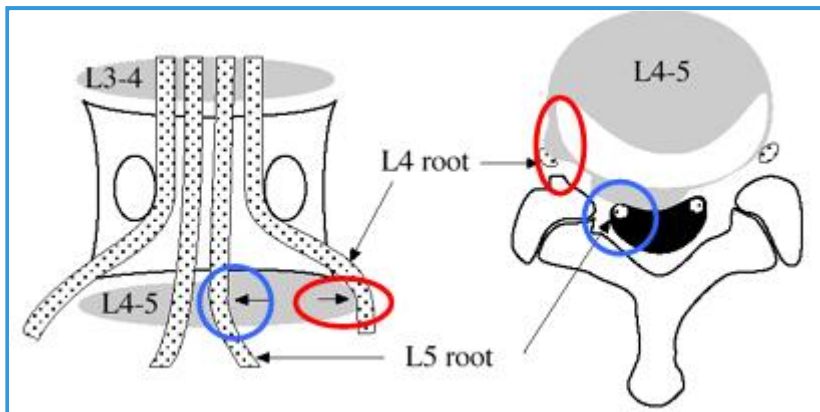
○ Articulations

- intervertebral disc
 - act as an articulation above and below
- facet joint (zygapophyseal joint)
 - formed by superior and inferior articular processes that project from junction of pedicle and lamina
 - facet orientation
 - facets become more coronal as you move inferior

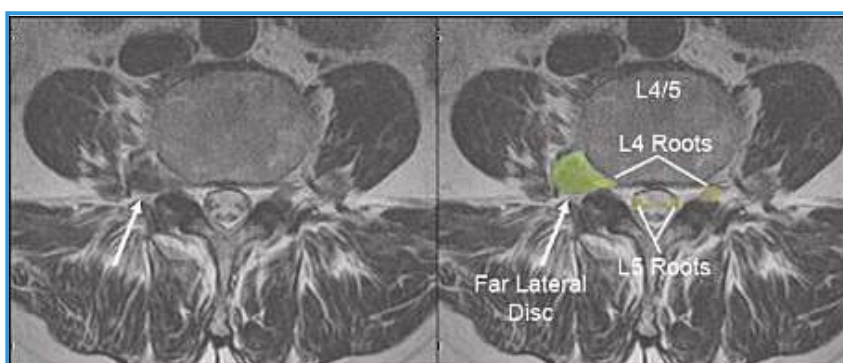
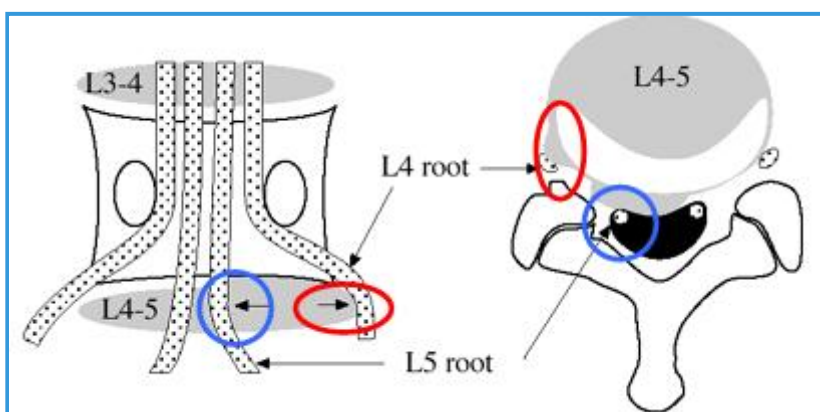


- Nerve roots

- nerve root exits foramen under same numbered pedicle
- central herniations affect traversing nerve root



- far lateral herniations affect exiting nerve root



- Blood Supply

- segmental arteries
- dorsal branches supply blood to the dura & posterior elements

- Classification

- Etiologic classification

- acquired
 - degenerative/spondylotic changes (most common)
 - post-surgical
 - post-traumatic (vertebral fractures)
 - inflammatory (ankylosing spondylitis)
 - secondary to systemic diseases (Paget disease, acromegaly, fluorosis)

- congenital
 - short pedicles with medially placed facets
 - can be subdivided into
 - idiopathic
 - developmental (achondroplasia)
- Anatomic classification
 - central stenosis
 - cross sectional area $<100\text{mm}^2$ or $<10\text{mm}$ A-P diameter on axial CT
 - caused by ligamentum hypertrophy directly under the lamina posteriorly and the bulging disc anteriorly
 - results in thecal sac compression
 - presents with nonspecific root compression or symptoms of lower nerve root (at the L4/5 level, the root of L5 is affected)
 - lateral recess stenosis (subarticular recess)
 - caused by facet joint arthropathy and osteophyte formation
 - overgrowth of the superior articular facet is usually the primary culprit
 - results in nerve root compression
 - presents with symptoms of descending nerve root (at the L4/5 level, the root of L5 is affected)
 - foraminal stenosis
 - occurs between the medial and lateral border of the pedicle
 - caused by a substantial loss of disk height, foraminal disk protrusions or osteophytes, or angulation in the setting of degenerative scoliosis
 - results in nerve root compression by the ventral cephalad overhang of the superior facet and the bulging disc
 - presents with symptoms of exiting nerve root (at the L4/5 level, the root of L4 is affected)
 - extraforaminal stenosis
 - located lateral to the lateral edge of the pedicle
 - caused by far lateral disc herniations
 - presents with symptoms of exiting nerve root (at the L4/5 level, the root of L4 is affected)
- Presentation
 - Symptoms
 - back pain
 - referred buttock pain

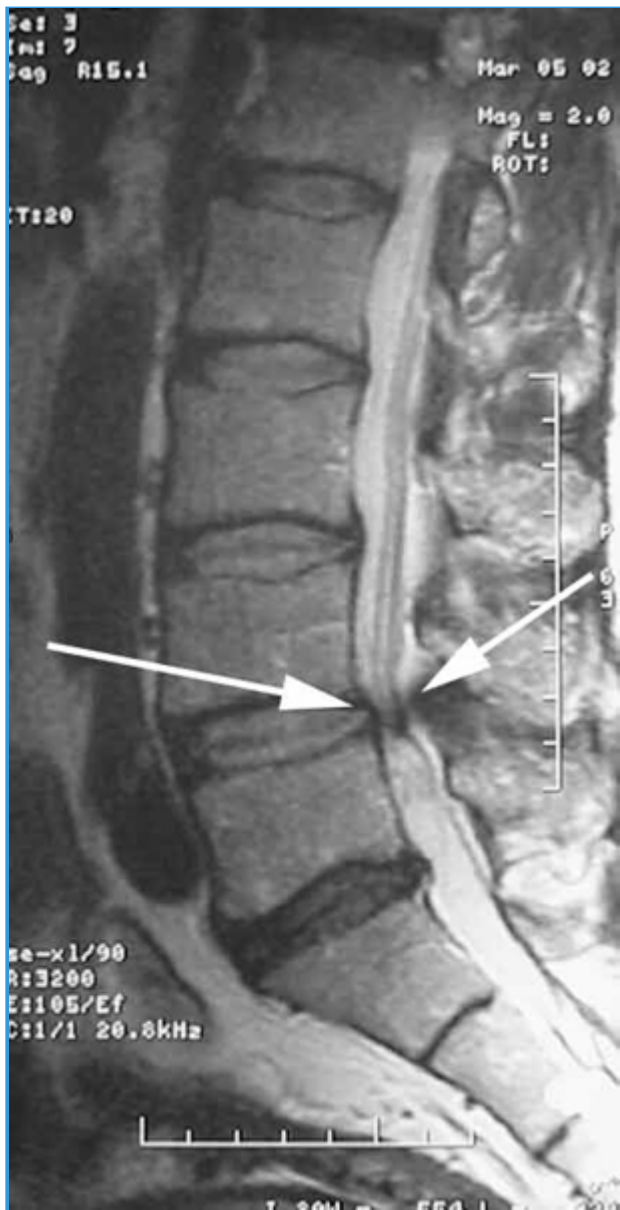
- leg pain
 - often unilateral
- neurogenic claudication
 - pain worse with extension (walking, standing upright)
 - pain relieved with flexion (sitting, leaning over shopping cart, sleeping in fetal position)
- weakness
- bladder disturbances
 - recurrent UTI present in up to 10% due to autonomic sphincter dysfunction
- cauda equina syndrome (rare)
- Physical exam
 - Kemp sign
 - unilateral radicular pain from foraminal stenosis made worse by back extension
 - straight leg raise (tension sign)
 - usually negative
 - Valsalva test
 - radicular pain not worsened by Valsalva as is the case with a herniated disc
 - normal neurologic exam
 - patients may have no focal deficits, as exam often takes place with patient seated and symptoms may be reproducible or exacerbated only with lumbar extension or ambulation

- Imaging

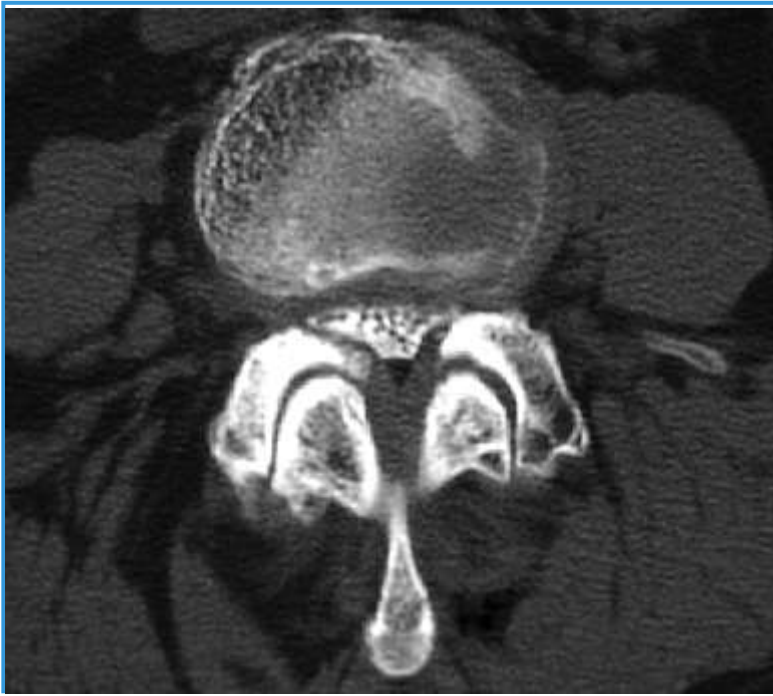
- Radiographs
 - findings do not always correlate with clinical symptomatology
 - standing AP and lateral may show
 - nonspecific degenerative findings (disk space narrowing, osteophyte formation)
 - degenerative scoliosis
 - degenerative spondylolisthesis



- flexion/extension radiographs may show
 - segmental instability and subtle degenerative spondylolisthesis
- myelogram
 - plain film myelography provides dynamic information such as degree of cut off when a patient goes into extension
 - an invasive procedure
- MRI
 - imaging modality of choice
 - findings
 - central stenosis with a thecal sac $<10\text{mm}$



- obliteration of perineural fat and compression of lateral recess or foramen
- facet and ligamentum hypertrophy
- MRI findings of spinal stenosis may found in asymptomatic patients
- CT myelogram
 - more invasive than MRI
 - findings
 - central and lateral neural element compression



- bony anomalies
- bony facet hypertrophy

• Differential

- Important to differentiate symptoms of neurogenic claudication from vascular claudication
 - flexion improves symptoms in neurogenic claudication because this posture increases the limited area available for the neural elements in the spinal canal and foramen

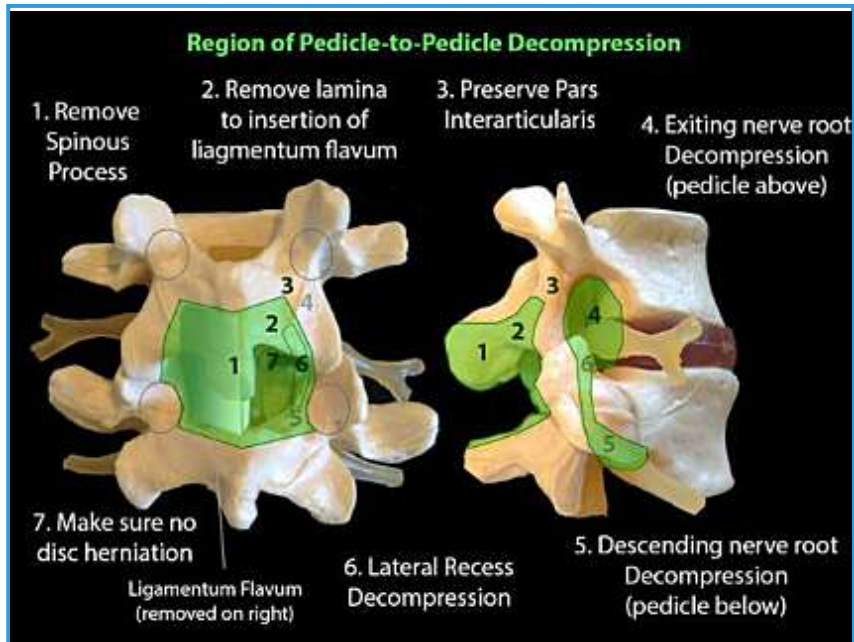
○	■ Neurogenic Claudication vs. Vascular Claudication		
	■	■ Neurogenic Claudication	■ <i>Vascular Claudication</i>
	■ Postural changes	■ Yes	■ No
	■ Walking upright	■ Causes symptoms	■ Causes symptoms
	■ Standing stationary	■ Causes symptoms	■ Relieves symptoms
	■ Sitting	■ Relieves symptoms	■ Relieves symptoms
	■ Stair climbing	■ Up easier (back flexed)	■ Down easier
	■ Stationary bicycle (back flexed)	■ Relieves symptoms	■ Causes symptoms
	■ Pulses	■ Normal	■ Abnormal

- Hip-spine syndrome
 - presence of coexisting hip and spine pathology
 - must determine primary pain generatory prior to surgical treatment
 - may require diagnostic injections to aid in diagnosis

• Treatment

- Nonoperative
 - **oral medications, physical therapy, and corticosteroid injections**
 - indications
 - first line of treatment

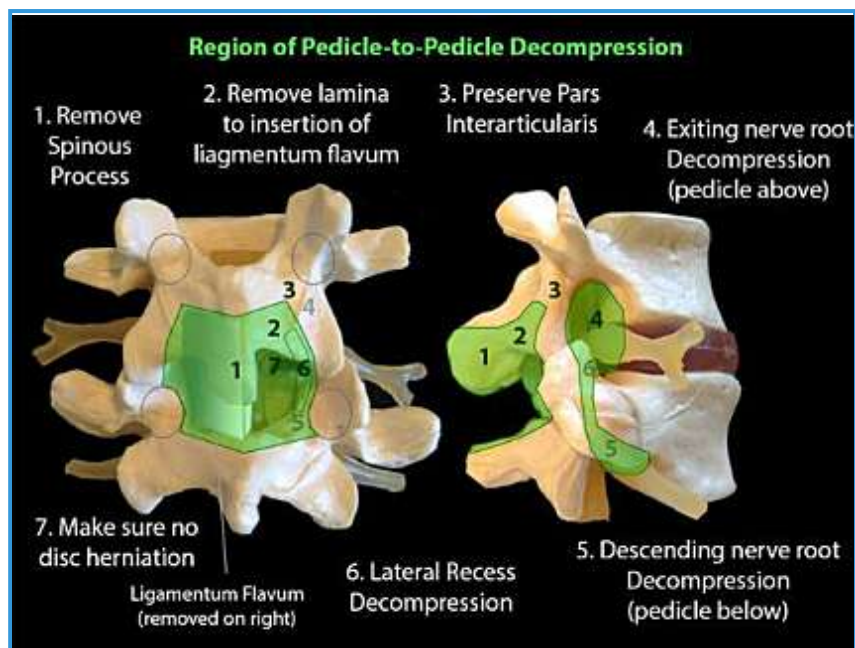
- modalities include
 - NSAIDS, physical therapy, weight loss and bracing
 - preoperative opioid use associated with prolonged hospital stays and increased postoperative pain
 - steroid injections (epidural and transforaminal)
 - found to be effective and may obviate the need for surgery
- Operative
 - **wide pedicle-to-pedicle decompression**



- indications
 - persistent pain for 3-6 months that has failed to improve with nonoperative management
 - progressive neurologic deficits (weakness or bowel/bladder)
- outcomes
 - results in better improvement in pain and function than nonsurgical treatment
- **wide pedicle-to-pedicle decompression with instrumented fusion**
 - indications
 - segmental instability (isthmic spondylolisthesis, degenerative spondylolisthesis, degenerative scoliosis)
 - surgical instability
 - created by complete laminectomy and/or removal of > 50% of facets
 - risk of adjacent segment degeneration >30% at 10 years

• Techniques

- **Wide pedicle-to-pedicle decompression**



- technique
 - a single level decompression at L4/5 would include
 - resection of the inferior half of spinous process of L4
 - resection of the L4 lamina to the level of the insertion of the ligamentum flavum
 - resection of the ligamentum flavum
 - medial facetectomy and lateral recess decompression
 - undercutting of facets and removal of ligamentum flavum from lateral recess
 - exploration and decompression of the L4/5 and L5/S1 foramina
 - palpate L4 and L5 pedicle (pedicle-to-pedicle) and be sure the nerve root is patent below it
- complications specific to this treatment
 - infection
 - dural tear
 - epidural hematoma
 - instability
- outcomes
 - improved pain, function, and satisfaction with surgical treatment
 - most common cause of failed surgery is recurrence of disease above or below decompressed level
 - comorbid conditions are strongest predictor of clinical outcomes after decompression for lumbar spinal stenosis
- **Wide decompression with posterolateral fusion**
 - instrumentation is controversial
 - circumferential fusion (with PLIF or TLIF) is accepted but no studies showing its superiority

• Complications

- Complications increase with age, blood loss, and levels fused

- Major complications
 - wound infection (10%)
 - deep surgical infections are to be treated with surgical debridement and irrigation
 - pneumonia (5%)
 - renal failure (5%)
 - neurologic deficits (2%)
- Minor complications
 - UTI (34%)
 - anemia requiring transfusion (27%)
 - confusion (27%)
 - dural tear
 - failure for symptoms to improve

31- Low Back Pain Introduction

Images



- Epidemiology

- Low back pain affects 50-80% of population in lifetime
 - \$100 billion in annual cost
 - second only to respiratory infection as cause to visit doctors office

- Etiology

- Mechanism
 - muscle strain
 - most common cause of low back pain
 - most common degenerative disorders
 - lumbar spinal stenosis
 - lumbar disc herniation
 - discogenic back pain
- Risk factors
 - obesity, smoking, gender
 - lifting, vibration, prolonged sitting
 - job dissatisfaction
- Red flags
 - infection (IV drug user, h/o of fever and chills)
 - tumor (h/o or cancer)

- trauma (h/o car accident or fall)
- cauda equina syndrome (bowel/bladder changes)
- Outcomes
 - 90% of low back pain resolves within one year

- Presentation

- Symptoms
 - axial pain
 - musculogenic
 - most common cause of back pain
 - associated with activity
 - characterized by stiffness and difficulty bending
 - discogenic pain
 - controversial
 - confirmed by discogram
 - mechanical pain
 - caused by
 - facet degeneration
 - micro and macro instability
 - worse with activity such as lifting objects and prolonged standing
 - sacroiliac symptoms
 - pain originating from sacroiliac joint
 - peripheral / neurogenic
 - radicular pain
 - unilateral leg pain
 - usually dermatomal
 - referred pain
 - buttocks
 - posterior thighs
 - inguinal region (think L5-S1)
 - neurogenic claudication
 - pain in buttock and legs that is worse with prolonged standing
 - fairly specific for spinal stenosis
 - myelopathy
 - clumsiness in hands
 - gait instability
 - due to injury of spinal cord (~ L1 or above)
 - conus medullaris syndrome

- cauda equina syndrome
 - bilateral leg pain
 - LE weakness
 - saddle anesthesia
 - bowel/bladder symptoms
- spinal cord injury
 - incomplete
 - complete
- Wadell Signs
 - system to evaluate non-organic back pain symptoms,
 - clinically significant if three positive signs are present
 - superficial and non-anatomic tenderness
 - pain with axial compression or simulated rotation of the spine
 - negative straight-leg raise with patient distraction
 - regional disturbances which do not follow dermatomal pattern
 - overreaction to physical examination

• Imaging

- Radiographs
 - indications for radiographs
 - pain lasting > one month and not responding to nonoperative management
 - red flags are present
- MRI
 - highly sensitive and specific
 - high rate of abnormal findings on MRI in normal people

■ Positive MRI Findings in Asymptomatic Patients			
■ <i>Age</i>	■ % HNP	■ % <i>Disc Bulge</i>	■ % <i>Degeneration</i>
■ 20-39	■ 21	■ 56	■ 34
■ 40-59	■ 22	■ 50	■ 59
■ 60-79	■ 36	■ 79	■ 93

• Differential

- Neck and arm pain
 - trauma
 - cervical spondylosis
 - metastatic disease / infection
 - cervical radiculopathy

- cervical myelopathy
- ankylosing spondylitis
- Thoracic back and rib pain
 - trauma
 - metastatic disease / infection
 - thoracic disc herniation
 - osteoporotic compression fracture
 - trauma
- Low back pain
 - muscles strain
 - disc herniation / discogenic pain
 - degenerative spondylolithesis
 - spinal stenosis
 - lumbar radiculopathy
 - abdominal aortic aneurism
- Sacroiliac pain
 - SI infection
 - ankylosing spondylitis
- Sacral pain
 - coccydynia
 - sacral insufficiency fracture

- Treatment

- Treatment dictated by cause of pain.

32- Discogenic Back Pain

Images

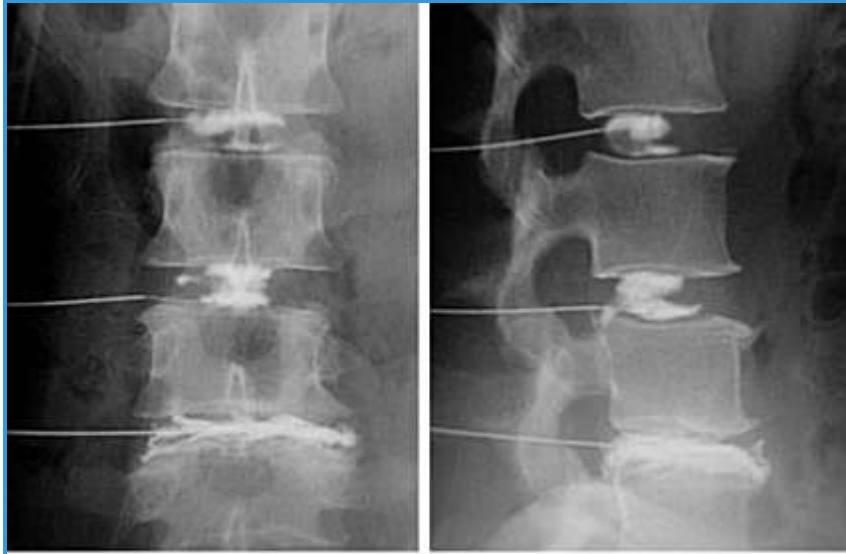
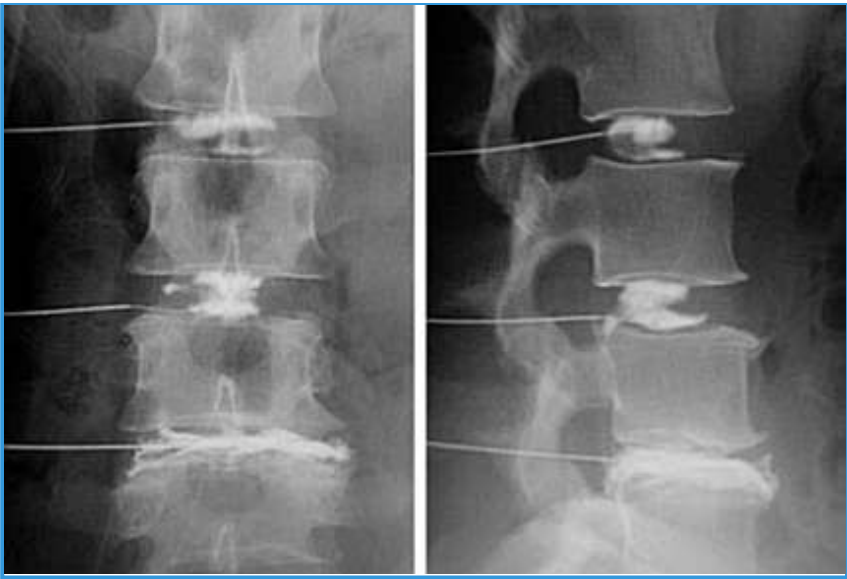


Figure 4 Discographic patterns in a 43-year-old woman who had low back pain with radiation to the left calf. (A) Anteroposterior and (b) lateral radiographic projections show a normal bilaminar L2/3 disc. There is small posteroinferior tear of the L3/4 disc that was asymptomatic. The L4/5 disc is decreased in height, and had extensive annular disruption and posterior protrusion. The L4/5 disc was also symptomatic.

- summary
 - Discogenic Back pain is a common cause of axial low back pain without radicular symptoms caused by intervertebral disc degeneration.
 - Diagnosis is made by a combination of history, physical examination, and MRI studies.
 - Treatment is usually NSAIDS, physical therapy, cognitive therapy and lifestyle modifications.
- Etiology
 - Mechanism
 - disc characteristics modified by bone morphogenic proteins
- Presentation
 - Symptoms
 - axial low back pain without radicular symptoms
 - pain exacerbated by
 - bending
 - sitting
 - axial loading
 - Physical exam
 - nerve tension (straight leg raise) signs are negative
- Imaging

- Radiographs
 - plain radiographs are the first diagnostic study to evaluate for disc degeneration
- MRI
 - shows degenerative discs without significant stenosis or herniation
- Provocative Diskography



- criteria for a positive test
 - must have concordant pain response
 - must have abnormal disc morphology on fluoroscopy and postdiskography CT
 - must have negative control levels in lumbar spine
- outcomes
 - studies have show provocative diskography leads to accelerated disc degeneration including
 - increased incidence of lumbar disc herniations
 - loss of disk height
 - endplate changes

• Treatment

- Nonoperative
 - **NSAIDS, physical therapy, cognitive therapy, lifestyle modifications**
 - indications
 - treatment of choice of majority of patients with low back pain in the absence of leg pain
 - outcomes
 - no statistically significant difference in ODI at short (1 year) or long term (10 years) for patients treated with cognitive and exercise therapy compared to lumbar discectomy with fusion
- Operative
 - **lumbar discectomy with fusion**
 - indications

- controversial
- outcomes
 - poor results when lumbar fusion is performed for discogenic back pain diagnosed with a positive provocative discography
- **lumbar total disc replacement**
 - indications
 - controversial
 - most argue single level disc disease with disease-free facet joints is the only true indication
 - outcomes
 - shown to have better 2-year patient outcomes than fusion
 - lower rates of adjacent segment disease with total disc replacement compared to fusion
 - complications
 - persistent back pain
 - thought to be facet joint in origin or subtle instability of prosthesis
 - if implant in good position, treat with posterior stabilization alone
 - dislocation of polyethylene inlay
 - treat with either revision arthroplasty or revision to arthrodesis

33- Thoracic Disc Herniation

Images



- summary
 - Thoracic Disc Herniations are rare, causes of midline back pain and sensory changes around the rib cage.
 - Diagnosis is made with MRI studies of the thoracic spine.
 - Treatment is usually activity modification, physical therapy, and pain management. Surgical management is indicated in patients with persistent pain or progressive neurological symptoms.
- Epidemiology
 - Incidence
 - relatively uncommon and makes up only 1% of all HNP
 - rare due to decrease motion of the thoracic spine and decreased disc height
 - Demographics
 - most commonly seen between 4th and 6th decades of life
 - as the disc desiccates it is less likely to actually herniate
 - Anatomic location
 - usually involves middle to lower levels
 - T11-T12 most common level
 - 75% of all thoracic disc herniations occur between T8 and T12
 - Risk factors

- underlying Scheuermann's disease may predispose to thoracic HNP

- Classification

- Herniation type
 - bulging nucleus
 - annulus remain intact
 - extruded disc
 - through annulus but confined by PLL
 - sequestered
 - disc material free in canal
- Location classification
 - central
 - posterolateral
 - lateral

- Presentation

- Symptoms
 - pain
 - axial back or chest pain is most common symptom
 - thoracic radicular pain
 - band-like chest or abdominal pain along course of intercostal nerve
 - arm pain (see with HNP at T2 to T5)
 - neurologic
 - numbness, paresthesias, sensory changes
 - myelopathy
 - paraparesis
 - bowel or bladder changes (15% - 20% of patients)
 - sexual dysfunction
- Physical exam
 - localized tenderness
 - root symptoms
 - dermatomal sensory changes (paresthesias and dysesthesia)
 - cord compression and findings of myelopathy
 - weakness
 - weakness or mild paraparesis
 - abnormal rectal tone
 - upper motor neuron findings

- hyperreflexia
- sustained clonus
- positive Babinski sign
- gait changes
 - wide based spastic gait
- Horner's syndrome
 - seen with HNP at T2 to T5

• Imaging

- Radiographs
 - lateral radiographs
 - may show disc narrowing
 - may show calcification (osteophytes)
- MRI



- most useful and important imaging method to demonstrate thoracic disc herniation
 - allows for identification of neoplastic pathology
 - can see intradural pathology
 - will show myelomalacia
 - may not fully demonstrate calcified component of herniated disc
- disadvantage is high false positive rate
 - in a study looking at asymptomatic individuals
 - 73% had thoracic disk abnormalities
 - 37% had frank herniations
 - 29% of these had cord compression.

• Treatment

- Nonoperative

- **activity modification, physical therapy, non-narcotic medication, steroid injections**
 - indications
 - the majority of cases
 - modalities include
 - activity modification
 - immobilization and short term rest
 - progressive activity restoration
 - physical therapy
 - range of motion and strengthening
 - medications
 - NSAIS, tylenol, gabapentin
 - injections
 - injections may be useful for symptoms of radiculopathy
 - outcomes
 - majority improve with nonoperative treatment
- Operative
 - **discectomy with possible hemicorpectomy or fusion**
 - indications
 - acute disc herniation with myelopathic findings attributable to the lesion, especially if there is progressive neurologic deterioration
 - persistent and intolerable pain
 - surgery rarely indicated
 - technique
 - debate between discectomy with or without fusion is controversial.
 - most studies do indicate that anterior or lateral (via costotransversectomy) is the best approach
 - see below for different approaches

• Techniques

- **Transthoracic discectomy**
 - indications
 - best approach from central disc herniations
 - complications
 - intercostal neuralgia
 - techniques
 - can be done with video assisted thoracic surgery (VATS)
- **Costotransversectomy**

- indications
 - lateral disc herniation
 - extruded or sequestered disc

- Complications

- Intercostal neuralgia
 - associated with transthoracic discectomy

34- Cauda Equina Syndrome

- Summary

- Cauda Equina Syndrome is caused by severe compression of the nerve roots in the thecal sac of the lumbar spine, most commonly due to an acute lumbar disc herniation.
- Early diagnosis is critical and is made clinically by characteristic symptoms of saddle-like paresthesias combined with acute back and leg pain. Urgent MRI is performed to confirm the cause.
- Treatment is prompt surgical decompression that should preferably be performed within 24 hours, absolutely within 48 hours.

- ETIOLOGY

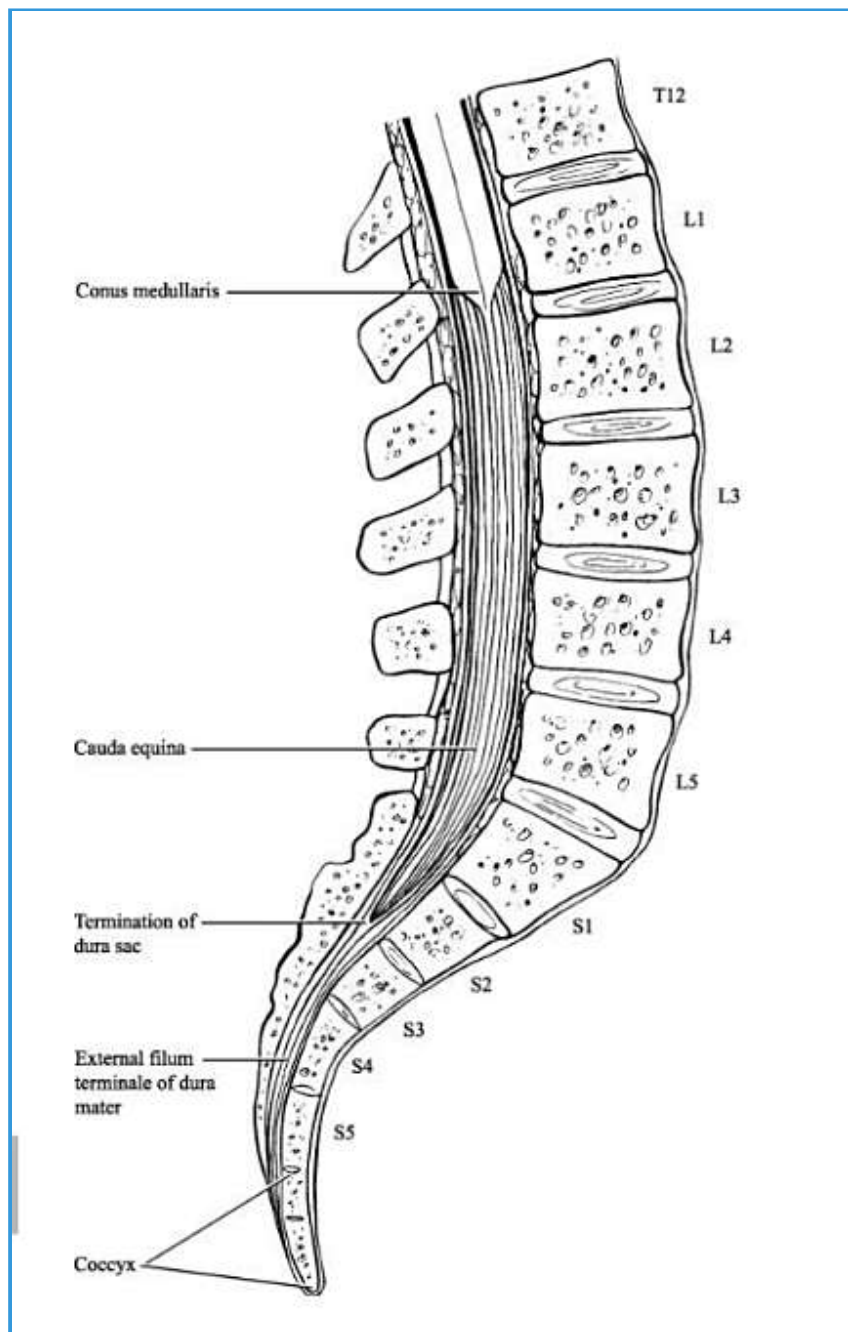
- Epidemiology
 - incidence
 - rare (annual incidence between 1.5 to 3.4 cases per million)
 - estimated prevalence of ~ 1 in 65,000
 - about 1000 new cases per year in US
 - occurs with ~3% of all lumbar disc herniations
 - demographics
 - more common in males
 - 4th decade (30s) of life is most common age group
 - location
 - most commonly occurs at the L4-5 level
- Pathophysiology
 - pathoanatomy
 - massive space-occupying lesion within lumbosacral canal
 - disc herniation (most common)
 - spinal epidural hematoma
 - may be spontaneous with aggressive DVT prophylaxis
 - can occur after neuraxial anesthesia (epidural)
 - can occur in postoperative period with early DVT prophylaxis
 - spinal cord tumors
 - myxopapillary ependymoma

- schwannoma
 - spinal meningioma
 - synovial facet cyst
 - spinal epidural abscess
 - trauma (retropulsion of fracture fragment, dislocation or collapse)
 - lumbar burst fractures
 - developmental spondylolisthesis
- pathobiology
 - mechanical compression decreases nutrient delivery to the nerve root
 - decreased blood flow
 - decreased CSF diffusion
 - intraneural compartment syndrome
 - venous congestion and intraneural edema from hypoperfusion
 - injury further decreases arterial perfusion pressures
 - nerve root ischemia follows
- Associated conditions
 - orthopedic conditions
 - conus medullaris syndrome
 - lumbar disc herniation
 - spinal cord tumors
 - spondylolisthesis
 - lumbar burst fractures
 - sacral fractures
 - epidural hematoma
 - medical conditions
 - deep vein thrombosis (DVT)
 - is a well known complication after spinal trauma or spine surgery
 - often DVT prophylaxis is held out of concern for epidural hematoma
 - antiplatelet medications can be safely resumed
 - approximately 48-72 hours post-op from spinal procedures
- Prognosis
 - natural history
 - delays in diagnosis and management can lead to devastating life-long impairment.
 - progressive weakness of the lower extremities without surgery
 - progressive loss of bowel and bladder function without surgery
 - even with early surgery neurologic recovery is variable
 - long term urinary dysfunction is common

- prognostic variables
 - presence of saddle anesthesia or bladder dysfunction is associated with worse outcomes
 - surgical decompression after 48 hours is associated with worse outcomes

• Anatomy

○ Spinal cord



- conus medullaris
 - tapered, terminal end of the spinal cord
 - terminates at T12 or L1 vertebral body
- filum terminale
 - non-neural, fibrous extension of the conus medullaris that attaches to the coccyx
- cauda equina (horse's tail)
 - collection of L1-S5 peripheral nerves within the lumbar canal
 - compression considered to cause lower motor neuron lesions
 - roots only covered with endoneurium and therefore are sensitive to compression
- Bladder
 - receives innervation from

- parasympathetic nervous system (pelvic splanchnic nerves and the inferior hypogastric plexus)
 - promotes urination
 - contraction of the detrusor urinae muscles
 - relaxation of the internal sphincter
- sympathetic plexus (hypogastric plexus)
 - promotes urinary retention
 - relaxation of the detrusor urinae muscles
 - contraction of the internal sphincter
- external sphincter of the bladder is controlled by the pudendal nerve
 - voluntary control
- lower motor neuron lesions of cauda equina will interrupt the nerves forming the bladder reflex arcs
 - unable to sense bladder filling
 - unable to initiate appropriate muscle contraction and relaxation

• Classification

○ Bladder Function Classification

- incomplete
 - loss of urgency or decreased urinary sensation but no incontinence or retention
- complete
 - clear urinary and/or bowel retention or incontinence

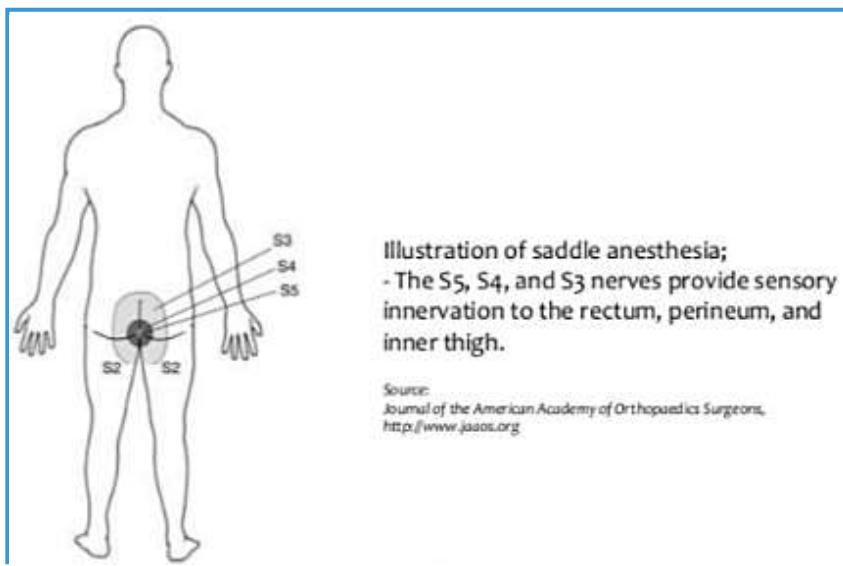
• Presentation

○ History

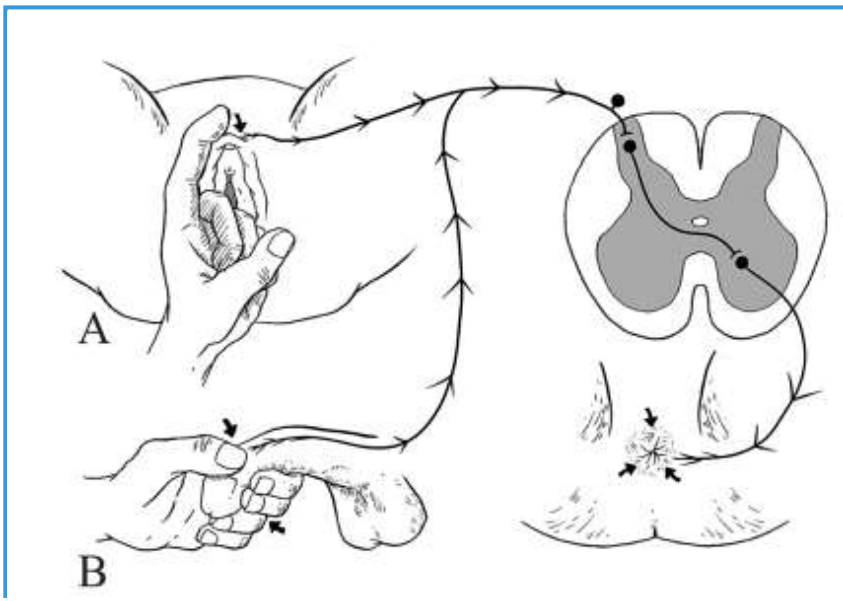
- might have history of lifting heavy object with lumbar spine in flexed position
- ask about use of anticoagulation (hematoma) and invasive procedure and IV drug use (infection)

○ Symptoms

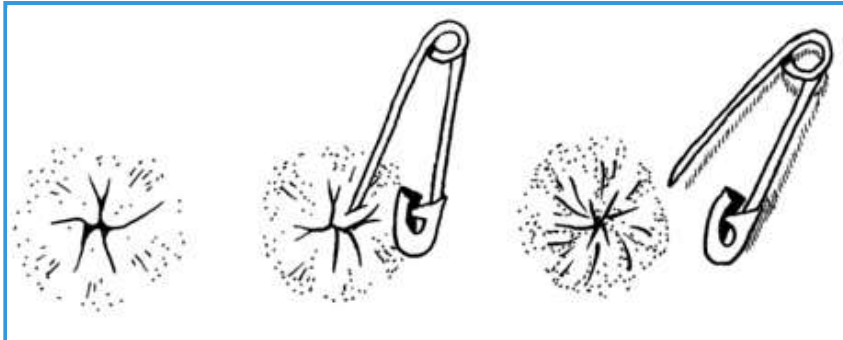
- common
 - back pain (most common)
 - may be initial presenting symptom alone
 - unilateral or bilateral leg pain (2nd most common)
 - saddle anesthesia



- while less common, more specific for CES, and if present should initiate surgery emergency protocol.
- bladder dysfunction
 - disruption of bladder contraction and sensation leads to urinary retention and eventually to overflow incontinence
 - important to document presence of bladder dysfunction prior to surgery
- unilateral or bilateral sensory changes in legs
- unilateral or bilateral motor weakness in legs
- rare
 - sexual dysfunction (impotence in men)
 - bowel dysfunction
- Physical exam
 - inspection
 - patient in distress due to low back pain, leg pain, and weakness
 - palpation
 - lower back pain/tenderness is not a distinguishing feature
 - palpation of the bladder for urinary retention
 - neurologic
 - motor
 - bilateral or unilateral lower extremity weakness
 - decreased rectal tone on voluntary contracture
 - sensory
 - reduced or absent sensation to pinprick in the perianal region (S2-S4 dermatomes), perineum, and posterior thigh
 - must distinguish between pinprick and light touch sensation
 - bilateral or unilateral lower extremity sensory disturbances
 - reflex
 - decreased or absent lower extremity reflexes
 - provocative tests
 - diminished or absent bulbocavernosus reflex



- diminished or absent anal wink test

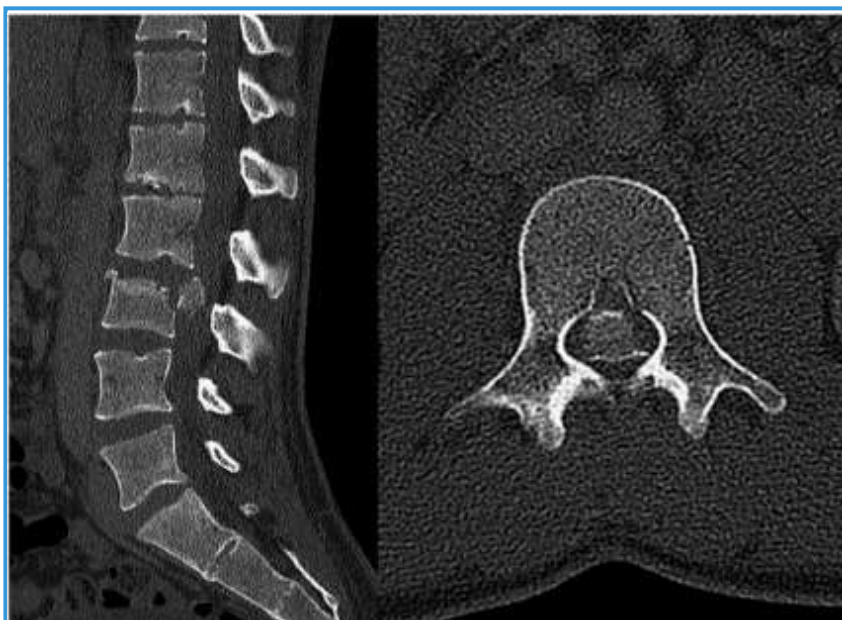


- reflex contraction of the external anal sphincter upon pinprick stimulation of skin around the anus

• Imaging

○ Radiographs

- indications
 - if high suspicion of CES study of choice is MRI
 - can obtain radiographs but initiate process of obtaining MRI immediately
- recommended views
 - AP, lateral
- findings
 - usually normal with most common cause of lumbar disc herniation
 - may see other cause of spinal canal stenosis
 - burst fractures



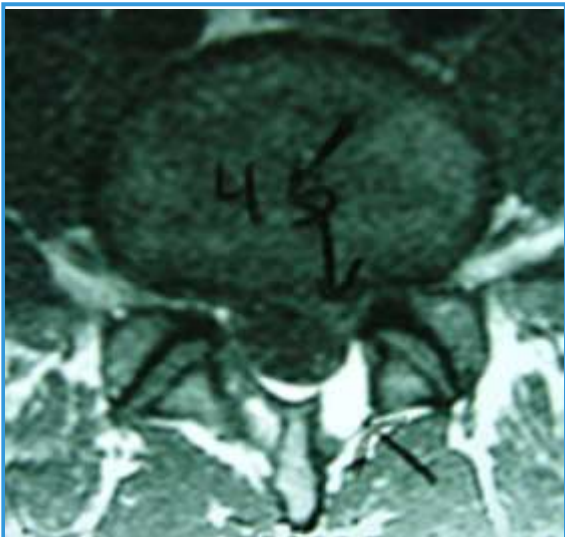
- high-grade developmental spondylolisthesis (intact-lamina)



- MRI

- indications

- study of choice to evaluate neurologic compression



- must be performed emergently if cauda equina syndrome is suspected
 - ideally obtained within 1-2 hours of presentation to ER
 - findings
 - often reveals large central disc herniation with complete spinal canal obliteration



- presence of spinal stenosis
- epidural hematoma
- epidural abscess
- CT myelography
 - indications
 - study of choice if patient unable to undergo MRI
 - e.g. pacemaker, MRI-incompatible implants
 - findings
 - sagittal and axial reconstructions can reveal space-occupying lesion
 - partial or complete blockage of contrast
- Studies
 - Laboratory
 - CBC, ESR, CRP
 - concern for infectious etiology (i.e. epidural abscess)
 - Urodynamic studies
 - preoperative postvoid residual volumes (PVR)
 - recommended to be obtained prior to decompression but not at delay of decompression
 - normal post-void residual volume is less than 50 to 100 mL
 - PVR values < 200 ml with a 97% negative predictive value for cauda equina syndrome
 - postoperative postvoid residual volume
 - assessment for return of bladder function
- DIAGNOSIS

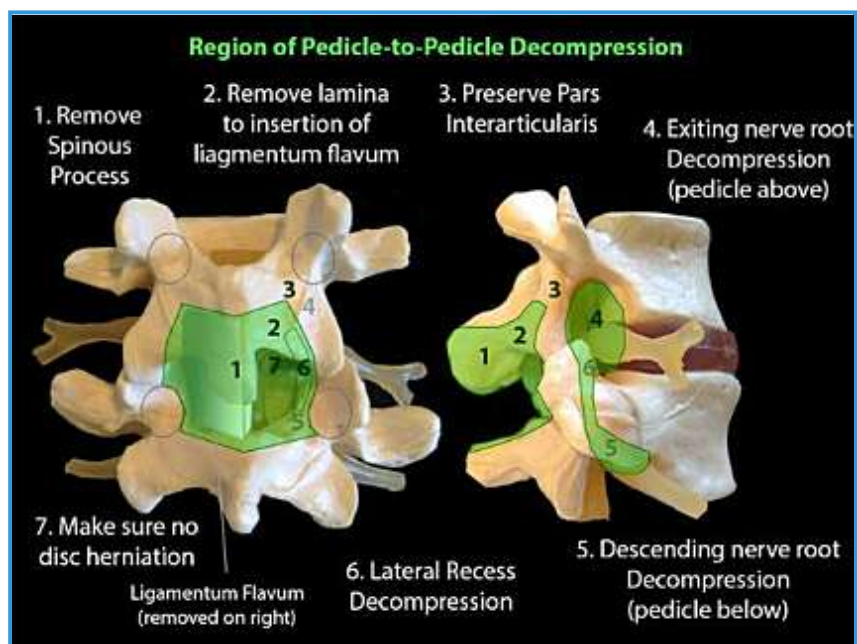
- Key differential
 - conus medullaris syndrome
 - spinal cord infarct
 - myelopathy
- Diagnosis
 - diagnosis of cauda equina syndrome is made by history, symptoms, and physical exam
 - MRI imaging confirms the cause of the CES and is critical for surgical planning

- Treatment

- Operative
 - **emergent surgical decompression**
 - indications
 - clinical symptoms of CES with imaging to support diagnosis
 - timing
 - as soon as safety possible
 - within 24 hours preferable.
 - within 48 hours considered acceptable standard of care.
 - techniques
 - microdisectomy (unilateral laminotomy, medial facetectomy, disectomy)
 - laminectomy (bilateral laminectomy and medial facetectomy)
 - laminectomy with fusion (rarely indicated)
 - outcomes
 - studies have shown improved outcomes in bowel and bladder function and resolution of motor and sensory deficits when decompression performed within 48 hours of the onset of symptoms
 - residual bladder deficits may persist despite successful decompression
 - motor recovery may continue up to 1 year post-op
 - bladder function may continue to improve up to 16 months post-op
 - no comparison studies between microdisectomy alone and wide decompression combined with microdisectomy

- Techniques

- **Microdiscectomy (unilateral laminotomy, medial facetectomy, discectomy)**
 - indications
 - massive soft disc herniation in younger patient with minimal degenerative changes
 - approach
 - 2 cm midline (or slightly paramedian) incision made on one side of pathology
 - expose lamina from spinous process to facet joint
 - laminotomy
 - 5-10mm laminotomy made over area of disc herniation
 - medial facetectomy
 - minimal facetectomy made with Kerrison
 - ligamentum flavum window
 - cleft in ligamentum flavum made and lateral section removed
 - anulotomy
 - dural retraction
 - removal of offending disc material
 - micropituitary rongeur
 - irrigation through a metal cannula
 - ensure disc material is thoroughly removed
- **Laminectomy (bilateral laminectomy and medial facetectomy)**



- indications

- older patient with degenerative changes included hypertrophic ligamentum flavum, lateral recess stenosis
- approach
 - preservation of spinous process and PLC
 - can be performed with PLC preserving undercutting approach or spinous process resection
 - comes with risk of incomplete decompression
 - spinous process (and PLC) resection
 - traditional method of resection of spinous process with complete laminectomy may be preferred to ensure complete decompression
 - technique
 - bilateral laminectomy
 - bilateral ligamentum flavum resection
 - bilateral medial facetectomy, unilateral discectomy
 - advantages
 - wide laminectomy performed
 - decreases the amount of dural retraction
 - greater degree of decompression
 - better visualization of the dura
 - removal of offending disc fragment

○ **Laminectomy and Fusion**

- indications
 - high-grade spondylolisthesis
 - insidious-type cauda equina syndrome in the context of degenerative spondylolisthesis

● **Complications**

○ Nonoperative

- sexual dysfunction
 - risk factors
 - delay in surgical decompression
 - prognosis
 - recovery may be prolonged over several years
 - worse prognosis for recovery in older patients
- urinary dysfunction
 - risk factors
 - delay in surgical decompression
 - treatment

- may require permanent catheterization
- chronic pain
- persistent leg weakness
- Operative
 - dural tear

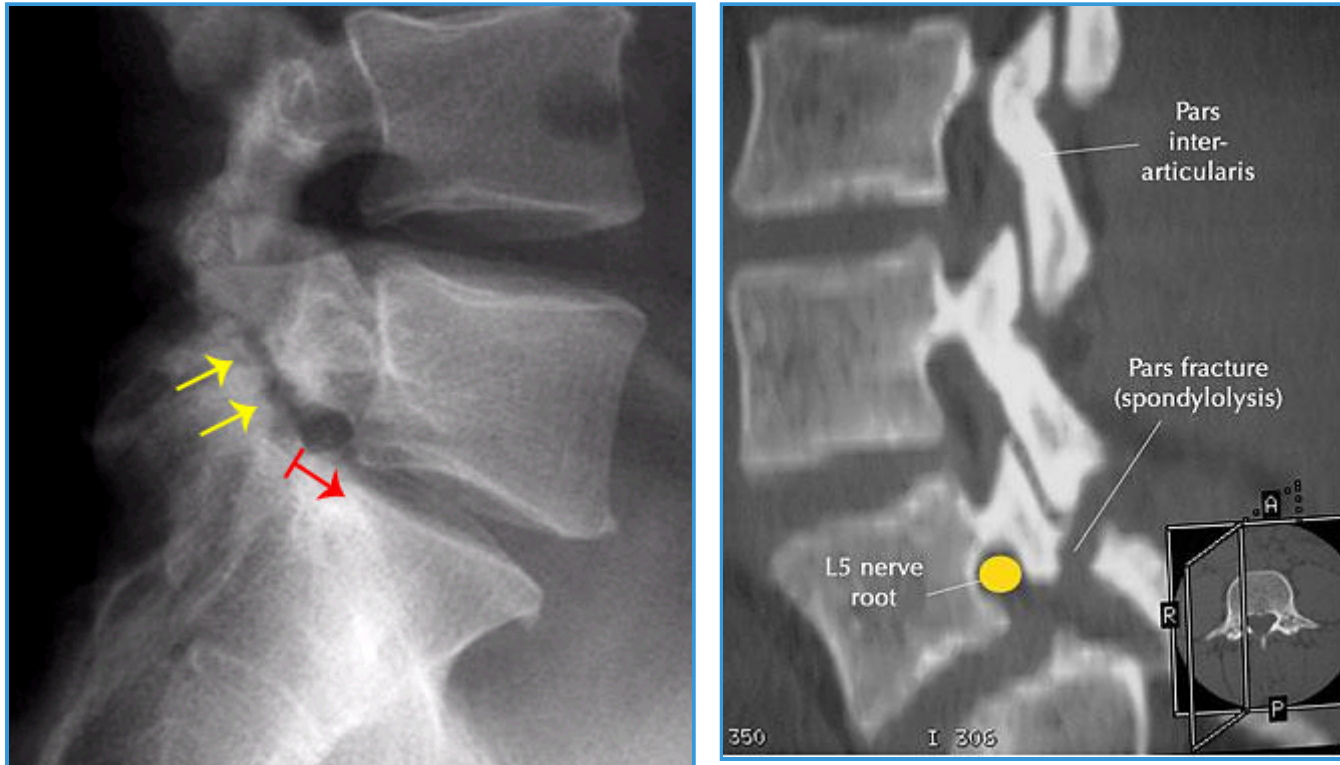


- incidence
 - occurs in 1-4% of cases
 - treatment
 - treatment involves primary repair of the dura with or without dural graft or fat grafting
 - prevents pseudomeningocele and durocutaneous fistula sequelae
 - postoperative bed rest for 4-7 days
 - may require a lumbar drain
 - no difference in outcomes if adequately treated
- iatrogenic segmental instability
 - occurs with overly aggressive medial facetectomy
- epidural fibrosis (scarring)
 - cause of postoperative back and leg pain
 - presents about 3 months post-op
 - treatment
 - responds poorly to re-exploration
 - evaluates with gadolinium-enhanced MRI
 - differentiates from recurrent HNP
- wound infection
 - incidence
 - approximately 1% of cases
 - risk factors
 - increased risk with diabetics
- vascular injury
 - incidence
 - rare complication

- risk factors
 - perforation of the ALL with curettes during disc removal
- treatment
 - requires immediate resuscitation and intraoperative vascular consultation
 - mortality up to 50%

35- Adult Isthmic Spondylolisthesis

Images



- summary

- Adult Isthmic Spondylolisthesis is a common adult spinal condition characterized by subluxation of one vertebral body anterior to the adjacent inferior vertebral body, caused by a defect in the pars interarticularis.
- Diagnosis is made with lateral radiographs. Flexion and extension lateral lumbar radiographs can identify the degree of instability. MRI studies can be helpful for central or foraminal stenosis.
- Treatment is a trial of nonoperative management with NSAIDs and physical therapy. Surgical management is indicated for progressive disabling pain that has failed nonoperative management, and/or progressive neurological deficits.

- Epidemiology

- Incidence
 - spondylolysis is seen in 4-6% of population
 - increased prevalence in sports that involve repetitive hyperextension (gymnasts, weightlifters, football linemen)
- Anatomic location
 - 82% occur at L5/S1
 - 11% occurs L4/5 (11%)

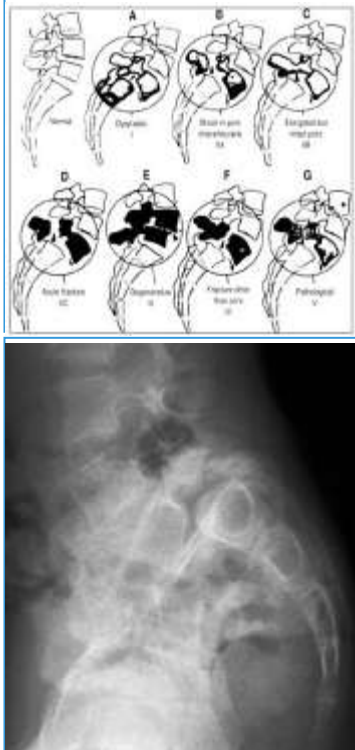
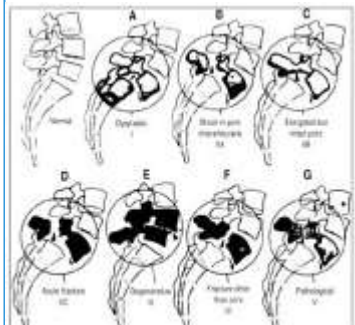
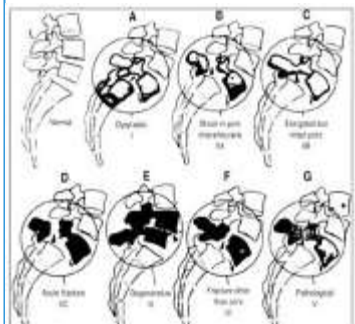
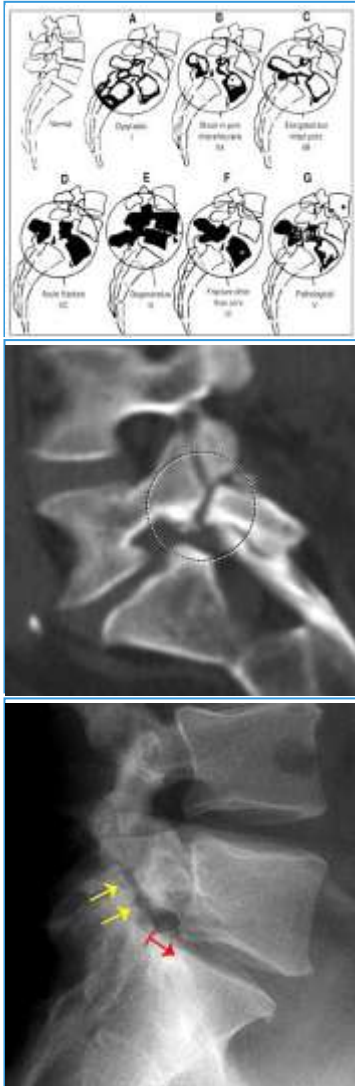
- due to forces in the lumbar spine being greatest at these levels and the facet being more coronal

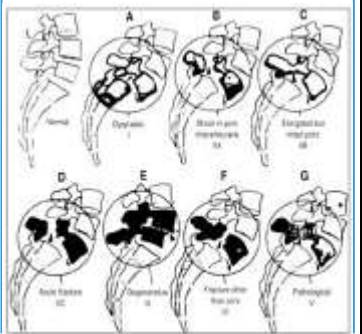
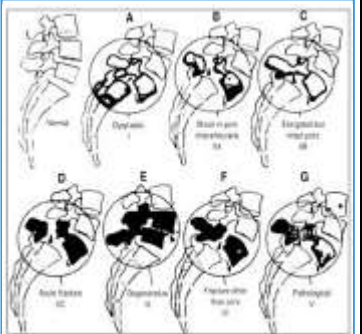
- Etiology

- Pathophysiology

- foraminal stenosis
 - adult isthmic spondylolisthesis at L5/S1 often leads to radicular symptoms caused by compression of the exiting L5 nerve root in the L5-S1 foramen
 - compression can be caused by
 - hypertrophic fibrous repair tissue of the pars defect
 - uncinata spur formation of the posterior L5 body
 - bulging of the L5/S1 disc
 - lateral recess stenosis
 - caused by facet arthrosis and hypertrophic ligamentum flavum
 - central stenosis
 - rare due to fact that these slips are usually only Grade I or II

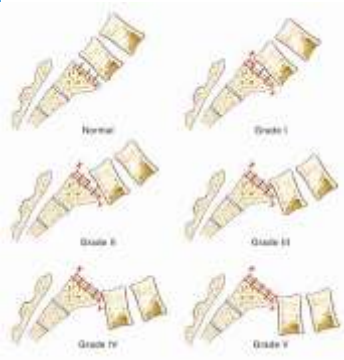
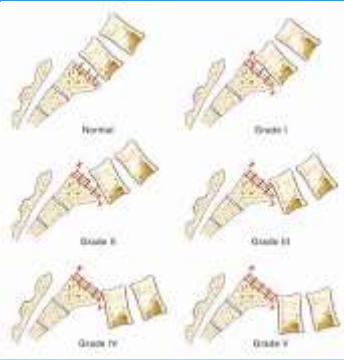
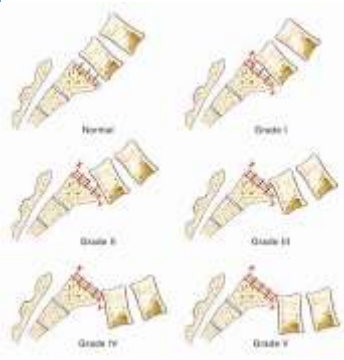
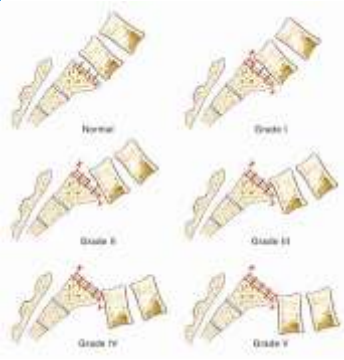
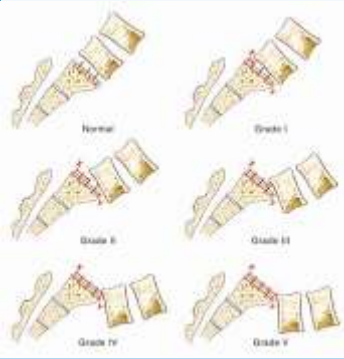
- Classification

Wiltse-Newman Classification		
Type I	Dysplastic: a congenital defect in pars	
Type II-A	Isthmic - pars fatigue fx	
Type II-B	Isthmic - pars elongation due to multiple healed stress fx	
Type II-C	Isthmic - pars acute fx	
Type III	Degenerative: facet instability without a pars fx	

		
■ Type IV	■ Traumatic: acute posterior arch fx other than pars	■ 
■ Type V	■ Neoplastic: pathologic destruction of pars	■ 

○

■ Myerding Classification

■ Grade I	■ < 25%	■ 
■ Grade II	■ 25-50%	■ 
■ Grade III	■ 50-75%	■ 
■ Grade IV	■ 75-100%	■ 
■ Grade V	■ Spondyloptosis	■ 

● Physical Exam

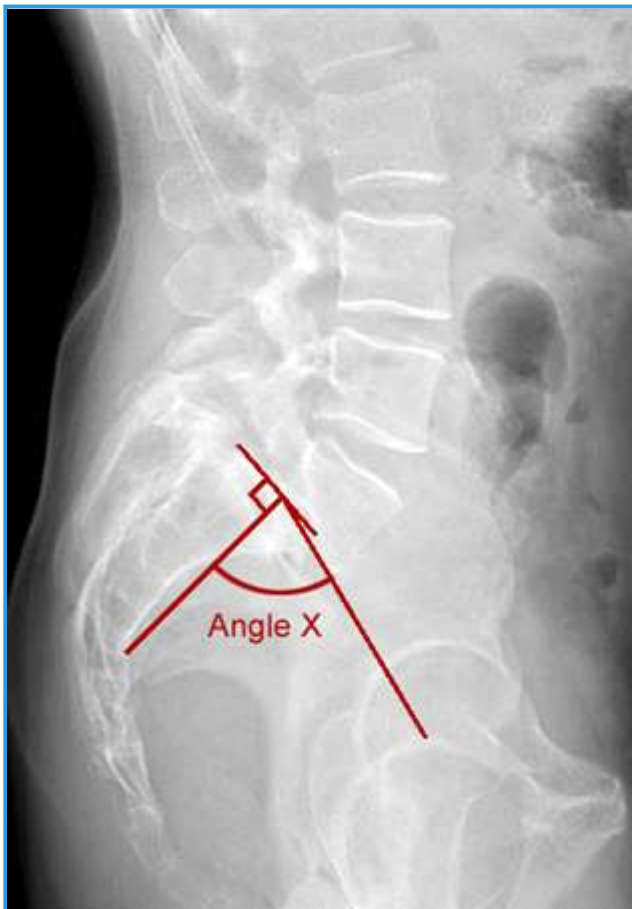
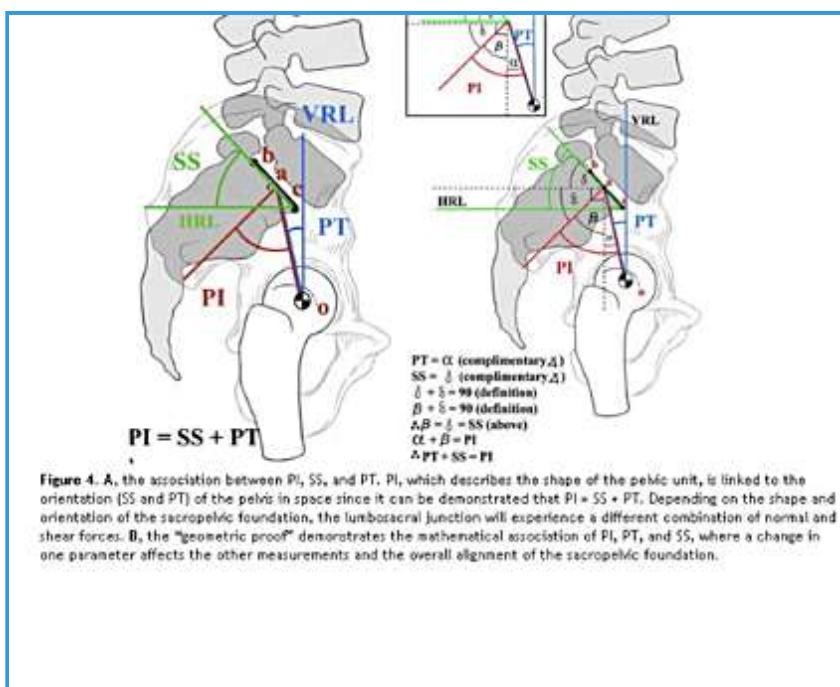
○ Symptoms

- axial back pain
 - most common presentation
 - pain usually has a long history with periodic episodes that vary in intensity and duration
- leg pain
 - usually a L5 radiculopathy usually caused by foraminal stenosis at the L5-S1 level
- neurogenic claudication
 - caused by spinal stenosis
 - characterized by buttock and leg pain worse with walking

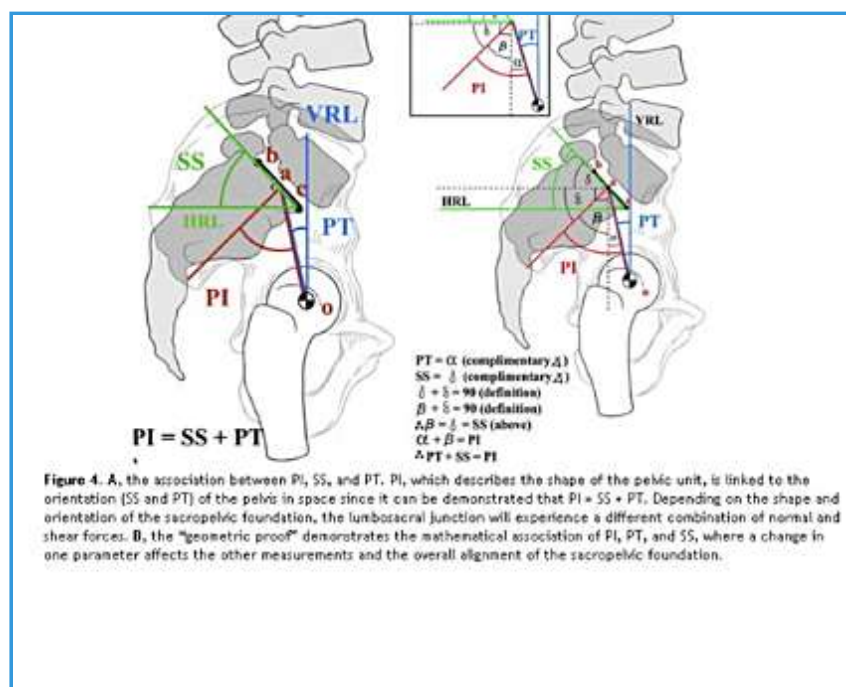
- symptoms of neurogenic claudication rare because these slips rarely progress beyond Grade II
 - cauda equina syndrome
 - rare because these slips rarely progress beyond Grade II
- Physical exam
 - L5 radiculopathy
 - ankle dorsiflexion and EHL weakness

- Imaging

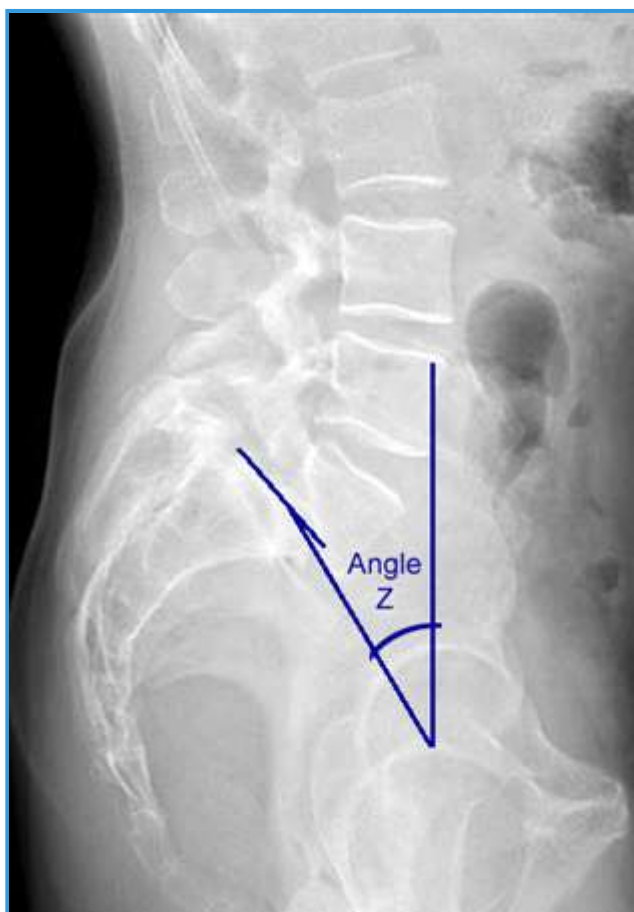
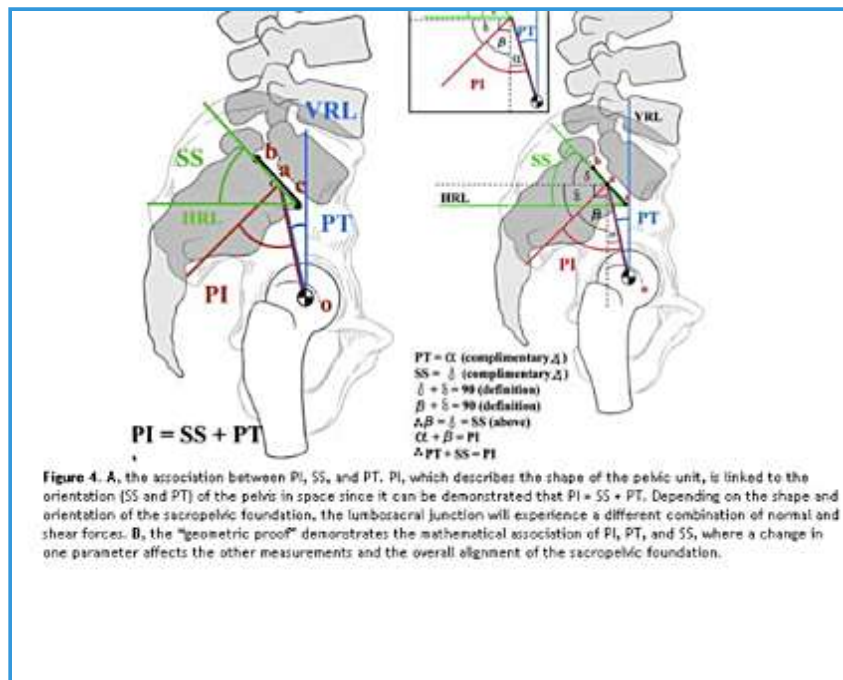
- Radiographs
 - recommended views
 - obtain AP, lateral, obliques, and flexion-extension views
 - findings
 - AP
 - deformity in coronal plane
 - lateral
 - will see spondylolisthesis and pars defect
 - flexion-extension
 - instability defined as 4 mm of translation or 10° of angulation of motion compared to adjacent motion segment
 - measurements
 - pelvic incidence



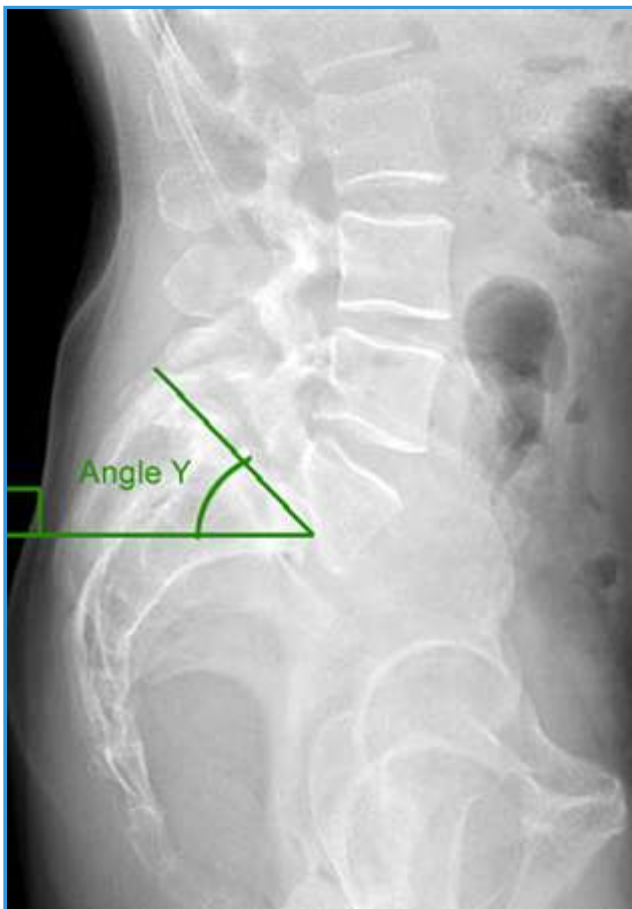
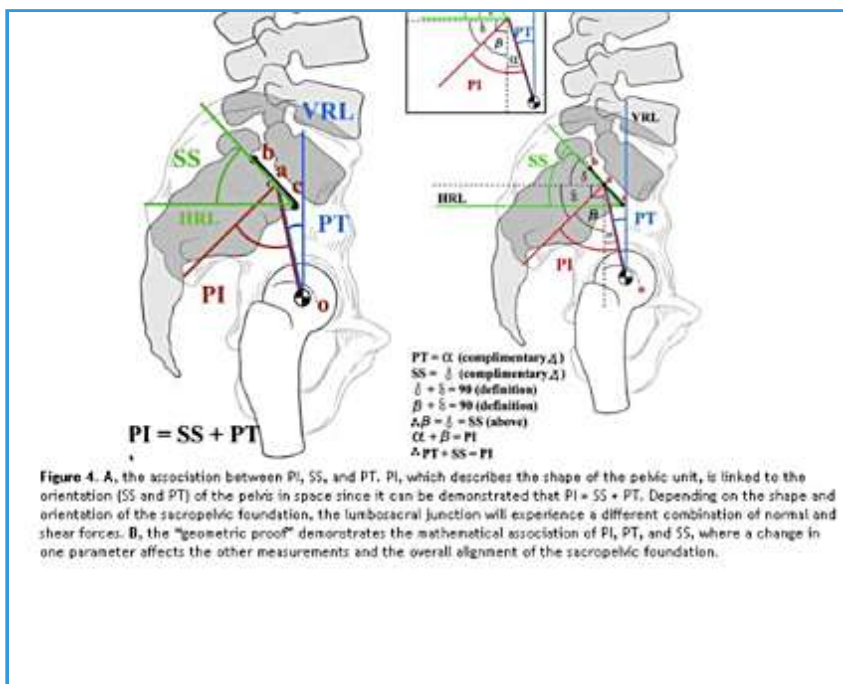
- pelvic incidence = pelvic tilt + sacral slope
- a line is drawn from the center of the S1 endplate to the center of the femoral head
- a second line is drawn perpendicular to a line drawn along the S1 endplate, intersecting the point in the center of the S1 endplate
- the angle between these two lines is the pelvic incidence (see angle X in figure above)
- correlates with severity of disease
- pelvic incidence has direct correlation with the Meyerding-Newman grade



■ pelvic tilt



- sacral slope = pelvic incidence - pelvic tilt
- a line is drawn from the center of the S1 endplate to the center of the femoral head
- a second vertical line (parallel with side margin of radiograph) line is drawn intersecting the center of the femoral head
- the angle between these two lines is the pelvic tilt (see angle Z in figure above)
- sacral slope



- pelvic tilt = pelvic incidence - sacral slope
- a line is drawn parallel to the S1 endplate
- a second horizontal line (parallel to the inferior margin of the radiograph) is drawn
- the angle between these two lines is the sacral slope (see angle Y in the figure above)

○ MRI

■ views

- T2 parasagittal images are best study to evaluate for foraminal stenosis and compression of neural elements

• Treatment

○ Nonoperative

- **oral medications, lifestyle modifications, therapy**
- indications
 - most patients can be treated nonoperatively
- techniques

- activity restriction
- NSAID
- role of injections unclear
- bracing may be beneficial especially in the acute phase

○ Operative

■ **L5-S1 decompression and instrumented fusion +/- reduction**

- indications
 - L5-S1 low-grade spondylolisthesis with persistent and incapacitating pain that has failed 6 months of nonoperative management (most common)
 - progressive neurologic deficit
 - slip progression
 - cauda equina syndrome
- reduction
 - improved sagittal balance with reduction
 - risk of stretch injury to L5 nerve root with reduction

■ **L4-S1 decompression and instrumented fusion +/- reduction**

- indications
 - L5-S1 high-grade spondylolisthesis with persistent and incapacitating pain that has failed 6 months of nonoperative management

■ **ALIF**

- indications
 - can be used successfully to treat low-grade isthmic spondylolisthesis even when radicular symptoms are present
 - cannot be used to treat high grade isthmic spondylolisthesis due to translational and angular deformity
- outcomes
 - studies have shown good to excellent results in 87-94% at 2 years

• Techniques

○ **L5/S1 wide decompression and instrumented fusion**

- approach
 - posterior midline
- decompression
 - indicated in adult with leg pain below knee
 - usually involves Gill laminectomy and foraminal decompression

- removal of loose lamina and scared pars defect allows decompression of nerve root
 - a Gill decompression is destabilizing and should be combined with fusion
- fusion
 - posterolateral fusion is standard
 - interbody fusion (PLIF/TLIF) commonly performed
 - posterior lumbar interbody fusion (PLIF) involves insertion of device medial to facets
 - transforaminal lumbar interbody fusion (TLIF) requires facetectomy and more lateralized and transforaminal approach to the disc space
- cons
 - interbody fusion has increased operative time with greater blood loss and longer hospitalizations
- **Anterior Lumbar Interbody Fusion (ALIF)**
 - approach
 - usually done through trans-retroperitoneal approach
 - decompression
 - decompression of nerve root done indirectly by foraminal distraction via restoration of disc height
 - fusion
 - grafts used include autologous iliac crest, structural allograft, and cages of various materials
 - pros
 - may increase chance of union by more complete discectomy and endplate preparation
 - allows improved restoration of disc height
 - cons
 - retrograde ejaculation and sexual dysfunction
 - persistent radiculopathy due to inadequate indirect foraminal decompression
 - persistent low back pain may be caused by nociceptive pain fibers in pars defect that are not removed in an anterior procedure alone
- preferred treatment is surgeon dependent with each technique having similar outcomes

- **Complications**

- Psuedoarthrosis
- Dural Tear

- Prognosis

- Relatively few patients (5%) with spondylolysis with develop spondylolisthesis
- Slip progression more common in females
- Slip progression usually occurs in adolescence and rare after skeletal maturity

36- Adult Spinal Deformity

- summary

- Adult Spinal Deformity is an idiopathic or degenerative condition of the adult spine leading to a deformity in the coronal or sagittal plane.
- Diagnosis is made with full-length spine radiographs.
- Treatment is a trial of nonoperative management with NSAIDs and physical therapy.Â Surgical deformity corrected is indicated for progressive disabling pain that has failed nonoperative management, and/or progressive neurological deficits.

- Epidemiology

- Demographics
 - mean age is 60 years
 - males and females equally affected
- Anatomic location
 - idiopathic scoliosis is more common in the thoracic spine
 - degenerative scoliosis occurs more commonly in the lumbar spine.

- Etiology

- Types
 - coronal plane imbalance
 - defined as lateral deviation of the normal vertical line of the spine > 10 degrees
 - sagittal plane imbalance
 - defined as radiographic sagittal imbalance of >5cm
- Pathoanatomy
 - degenerative scoliosis results from the asymmetric degeneration of disc space and/or facet joints in the spine.
 - may occur in the coronal plane (scoliosis) or the sagittal plane (kyphosis/lordosis)
 - factors contributing to loss of sagittal plane balance
 - osteoporosis
 - preexisting scoliosis

- iatrogenic instability
- degenerative disc disease

• Classification

- Coronal deformity can be broken down into
 - idiopathic (residual) ASD
 - the result of untreated adolescent idiopathic scoliosis in the adult
 - degenerative (de novo) ASD
 - defined as a progressive deformity in the adult caused by
 - degenerative changes
 - iatrogenic
 - paralytic

○	■ Difference between Idiopathic (residual) and Degenerative (de novo) ASD			
		■ Idiopathic (residual)	■ <i>Degenerative (de novo)</i>	
	■ Curve pattern	■ Follows classic curve patterns	■ Lack classic curve patterns	■
	■ Vertebral segments	■ Involves more vertebral segments	■ I nvolves fewer vertebral segments	■
	■ Curve location	■ Thoracic spine	■ Lumbar spine	■
	■ Curve magnitude	■ Larger curves	■ Smaller curve magnitude	■

• Presentation

- Symptoms
 - low back pain (40-90%)
 - commonest symptom is low back pain
 - caused by spondylosis, micro/macro instability, and discogenic pain
 - more severe and recurrent than general population
 - neurogenic claudication
 - pain in lower extremities and buttocks
 - unlike classic claudication, patients with scoliosis + stenosis do not obtain relief with sitting / forward flexion
 - caused by spinal stenosis
 - stenosis is located on the concave side of the curve
 - radicular leg pain and weakness
 - caused by foraminal and lateral recess stenosis
 - worse in concavity of the deformity where there is vertebral body rotation and translation
- Physical exam
 - deformity with thoracic prominence seen with forward bending

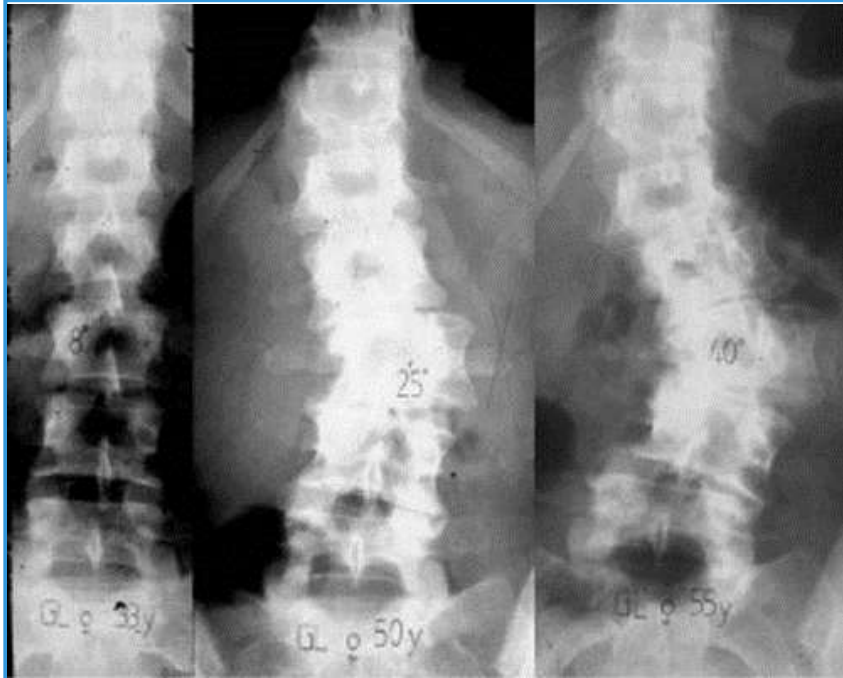
- muscle weakness

• Imaging

○ Radiographs

■ recommended views

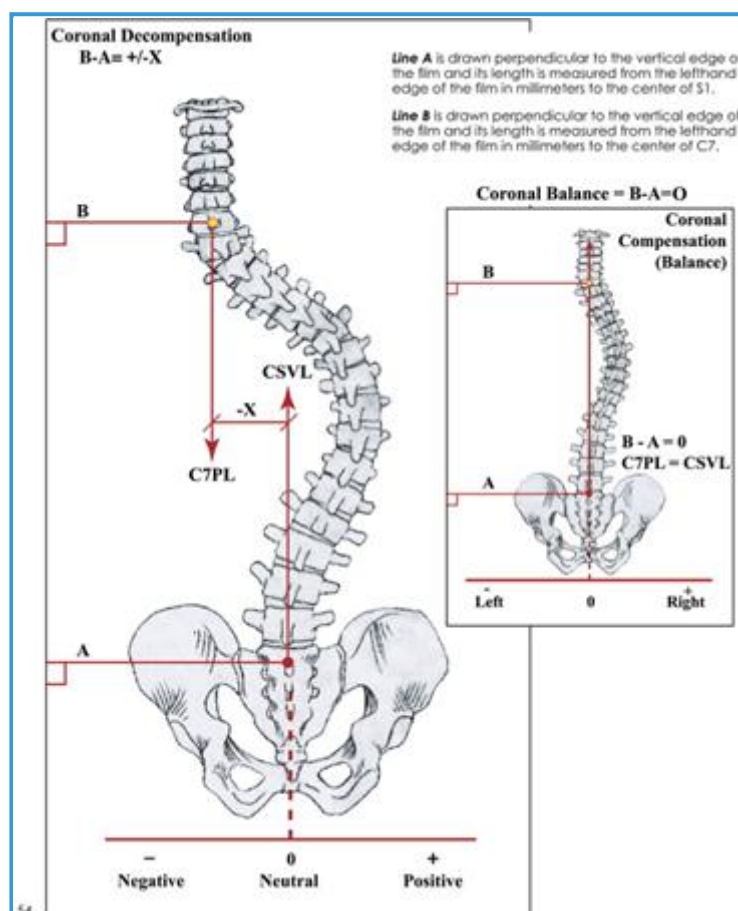
- full length long 36-inch cassette standing scoliosis xrays in coronal (AP radiograph) and sagittal plane (lateral radiograph), with right and left bending films



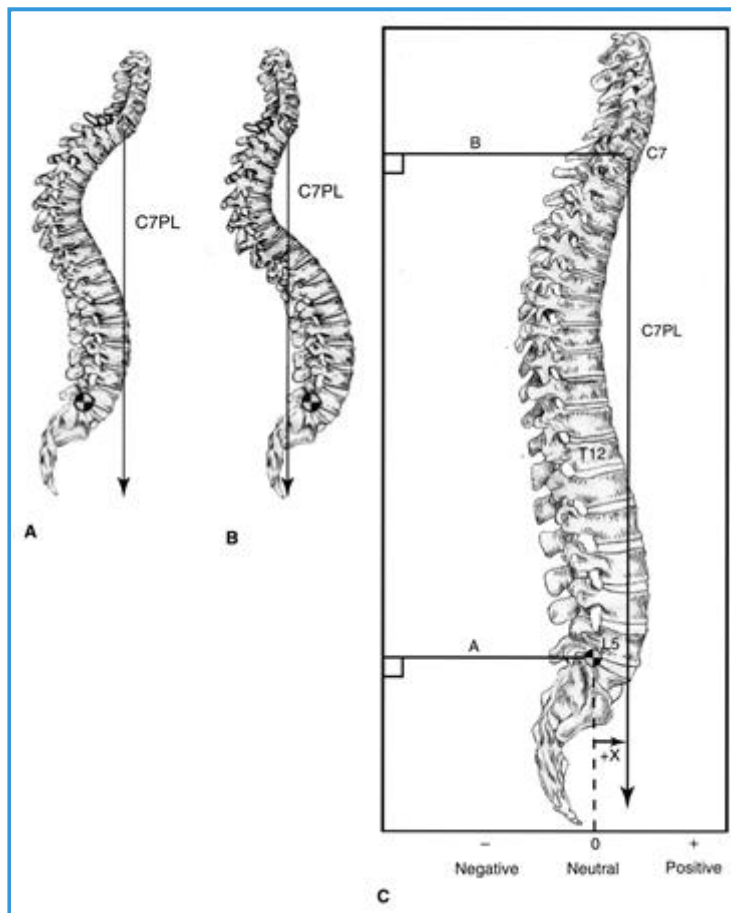
- bending films help assess curve flexibility and possibility of correction with surgical intervention

■ measurements

- AP radiograph
 - Cobb angle
 - coronal balance



- using C7 plumb line (C7PL) and center sacral vertical line (CSVL)
- lateral radiograph
 - sagittal balance



- using C7 plumb line (C7PL)
- pelvic incidence



- pelvic incidence (PI) = sacral slope (SS) + pelvic tilt (PT)
- CT scan
 - will help identify bony deformity such as facet arthrosis
- CT myelogram
 - most useful for assessing stenosis and bony anatomy as rotation makes interpretation of MRI difficult
 - better appreciation of bony anatomy and rotational deformity than MRI
- MRI
 - indicated when lower extremity pain is present
 - can identify
 - central canal stenosis

- facet hypertrophy
- pedicular enlargement
- foraminal encroachment
- disc degeneration
- DEXA scan
 - important to determine bone density for surgical planning

- Treatment

- Nonoperative
 - **observation with nonoperative modalities**
 - indications
 - coronal curves < 30 degrees rarely progress
 - modalities
 - oral medications
 - NSAIDS
 - tricyclic antidepressants help with sleep disturbance
 - physical therapy
 - includes core strengthening (walking, cycling, swimming, selected weight lifting)
 - corticosteroid injections and nerve root blocks
 - diagnostic and therapeutic
 - bracing
 - may slow progression and increase comfort
 - Operative
 - **surgical curve correction with instrumented fusion**
 - general indications
 - curve > 50 degrees of the following type
 - sagittal imbalance
 - curve progression
 - intractable back pain or radicular pain that has failed nonsurgical efforts
 - cosmesis (controversial)
 - cardiopulmonary decline
 - thoracic curves >60deg affect pulmonary function tests
 - thoracic curves >90deg affect mortality
 - technique
 - posterior only curve correction and instrumented fusion
 - indications

- thoracic curves > 50 degrees
 - most double structural curves > 50 degrees
 - selecting technique is patient and surgeon specific
- combined anterior/posterior curve correction with instrumented fusion
 - indications
 - isolated thoracolumbar
 - isolated lumbar curves
 - extremely rigid curves requiring anterior release

• Techniques

○ General

- goals of surgery
 - restore spinal balance
 - sagittal plane balance is the most reliable predictor of clinical symptoms postoperatively
 - can be measured by C7 plumb line (C7 sagittal vertical axis)
 - correction of sagittal plane deformity requires intense preoperative planning
 - correct lumbar lordosis to normal anatomic range:
 - $PI = LL \pm 9^\circ$
 - $LL \leq 45^\circ - TK - PI$
 - most predictive of sagittal plane correction maintenance
 - relieve pain
 - obtain solid fusion
- Worse outcomes associated with:
 - Baseline depression
 - Obesity

○ **Selecting Proximal and Distal fusion level**

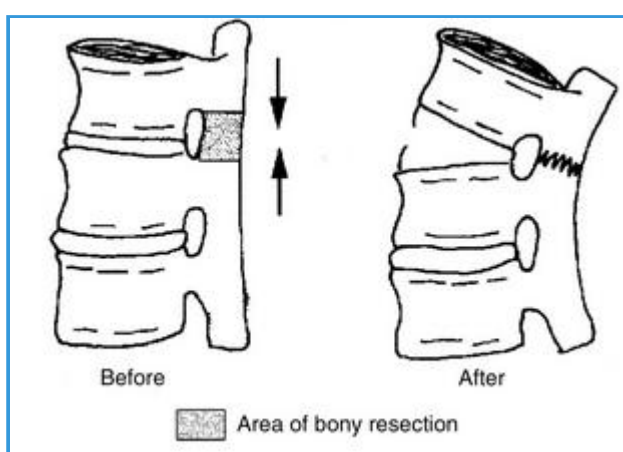
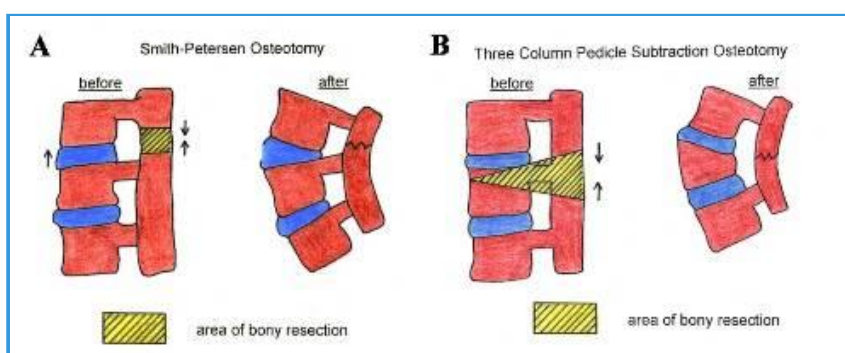
- proximal extension
 - extend to a neutral and horizontal vertebra above the main curve
- extend fusion to L5
 - indications
 - only indicated if no pathology at L5/S1
 - patients with normal C7 plumb line and normal sacral inclination have lowest risk of future L5-S1 disc degeneration
 - outcomes

- high failure rate if instrumentation does not extend to the sacrum if pathology at L5/S1
- extend fusion to sacrum (S1)
 - indications
 - extend to sacrum if any pathology at L5-S1 including
 - L5-S1 spondylolisthesis
 - L5-S1 spondylolysis
 - L5-S1 facet arthrosis
 - prior laminectomy
 - technique
 - may require concomitant anterior release and anterior column support (through anterior approach) for better deformity correction
 - outcomes
 - advantages
 - increased stability of long fusion construct
 - constructs less likely to fail if instrumentation extends to sacrum
 - disadvantages
 - increased risk of pseudoarthrosis
 - increased surgical time
 - increased reoperation rate
 - increased risk of sacral insufficiency fractures
 - altered gait postoperatively
- extend fusion to ilium (sacropelvic fusion)
 - indications
 - consider this if sacrum is included in fusion involving >3 levels
 - technique
 - using iliac screws or bolts
 - outcomes
 - advantage
 - increased stability of long fusion construct
 - increases success of lumbosacral fusion
 - disadvantage
 - prominent hardware
- cement augmentation
 - indications
 - osteoporotic patients
 - technique

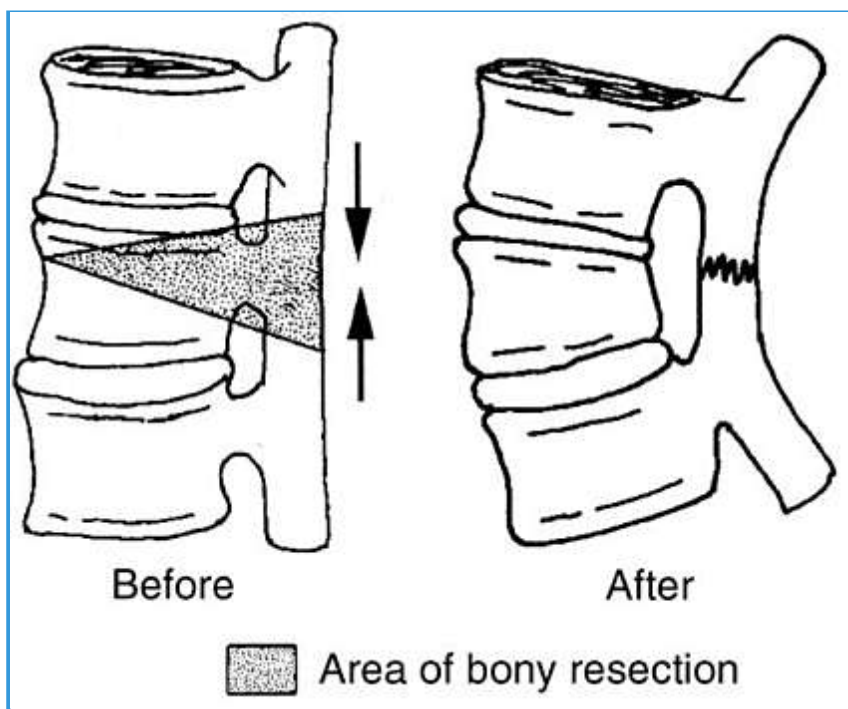
- cement injection through fenestrated tap at the end vertebra followed by pedicle screw insertion
- outcomes
 - increased fusion rates
 - decreased deformity correction loss
 - increased screw pull-out strength
 - no added complications

○ Osteotomies

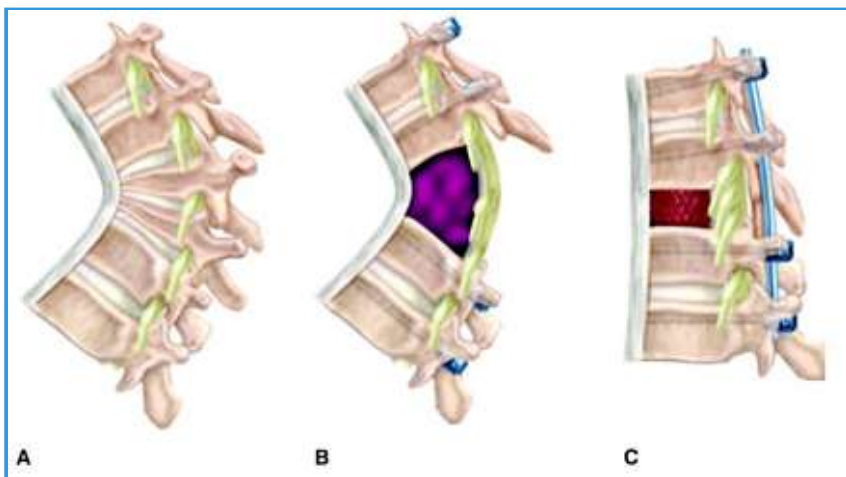
- overview
 - useful to regain sagittal balance in severe angulation deformities
 - 30deg or more correction can be obtained through Smith-Petersen or pedicle subtraction osteotomies
 - intraoperative neuromonitoring preferred
- Smith-Petersen osteotomy (SPO)



- indications
 - mild-moderate sagittal imbalance
 - requiring correction of up to 10deg (per level of osteotomy)
- prerequisites
 - no anterior fusion at the level of osteotomy
 - adequate correction requires adequate disc height and mobility (correction is at the level of the disc)
 - more correction in the lumbar spine (greater disc height and mobility)
 - less correction in the thoracic spine (lesser disc height and mobility)
- pedicle subtraction osteotomy (PSO)



- indications
 - severe sagittal imbalance >12cm
 - requiring correction of 30-35deg in the lumbar spine, and 25deg in the thoracic spine
 - where anterior fusion is present (correction is at the level of the vertebral body and not at the disc)
- vertebral column resection



- indications
 - severe sagittal imbalance (provides more correction than PSO)
 - requiring correction of up to 45deg
 - rigid angular thoracic spine kyphosis, such as associated with tumor, fracture or infection
 - severe rigid scoliosis
 - congenital kyphosis
 - hemivertebrae resection in thoracic/lumbar spines

○ Anterior Procedures

- indications
 - large curves >70deg
 - rigid curves (no flexibility on side bending films)
 - isolated lumbar or thoracolumbar curves
 - anterior interbody fusion at L5/S1 when fusing to sacrum
- technique

- anterior release and fusion usually combined with posterior instrumentation and fusion
 - staged or same day
- outcomes
 - disadvantages
 - longer surgeries (if performed on the same day)
 - higher complication rates
 - more medically stressful
 - advantage
 - increases stability of L5-S1 long fusion constructs
 - helps restore and maintain sagittal and coronal balance

- Complications (surgical)

- Overall
 - overall complication rate ~13.5%
 - 10% major complications which often irreversibly affect long term health of patient
 - complication rate is significantly higher when osteotomies, revision procedures, and combined anterior/posterior approaches
 - venous thromboembolism is most likely to result in poor clinical outcome following adult spinal deformity surgery
- Pseudoarthrosis
 - incidence (~5-25%)
 - most common surgical technique resulting in pseudoarthrosis is posterior only fusion (15%)
 - commonest locations
 - L5-S1
 - thoracolumbar junction
 - risks
 - age > 55
 - kyphosis > 20 degrees
 - positive sagittal balance > 5cm
 - hip arthritis
 - smoking
 - thoracoabdominal approach
 - incomplete lumbopelvic fixation
 - osteoporosis
- Dural tear (~2.9%)

- Infection
 - deep wound infection (~1.5%)
 - superficial wound infection (~0.9%)
 - increased risk with diabetes, smoking, increasing age, and revision surgery
- Implant complication
 - instrumentation failure more likely in bone with lowest ratio of cortical to cancellous bone (sacrum)
 - most common cause of reoperation, related to pseudoarthrosis
 - lower rates of mechanical complications with GAP scores <3
- Neurologic deficits
 - acute neurological deficits (~1.0%)
 - can occur intraoperatively after deformity correction maneuver
 - if identified on neurophysiologic monitoring, should remove instrumentation and consider wake-up test
 - delayed neurological deficits (~0.5%)
 - acute neurological deficits following PSO (18%)
 - nerve root injury
 - screw malposition
 - corrective maneuver
- Epidural hematoma (~0.2%)
- Pulmonary embolus (~0.2%)
- Deep venous thrombosis (~0.2%).
- Deaths (~0.3%)

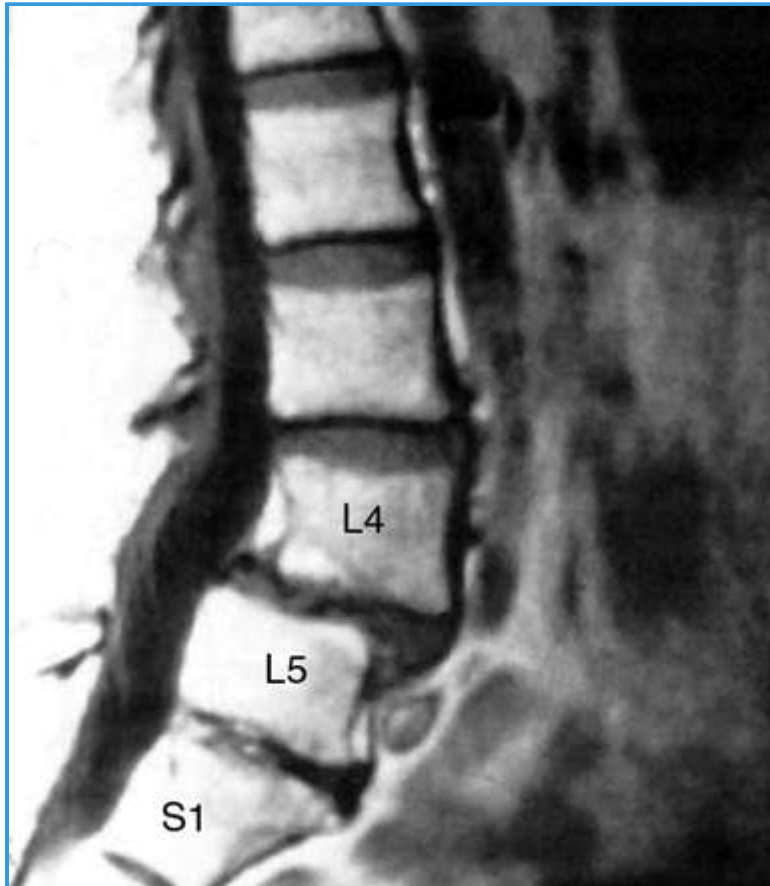
• Prognosis

- Worse prognosis with
 - if symptoms progress to the side of curve convexity
 - sagittal plane imbalance
 - sagittal plane balance is the most reliable predictor of clinical symptoms in adults with spinal deformity
- Progression
 - depends on curve type
 - thoracic > lumbar > thoracolumbar > double major
 - right thoracic curves (1 degree per year)
 - right lumbar curves (0.5 degree per year)
 - thoracolumbar curves (0.25 degree per year)
 - depends on curve magnitude

- curves <30 deg rarely progress
- curves >50 deg commonly progress
- additional risk factors for progression
 - increased risk when intercrestal line is below L4-5
 - preexisting rotational changes exist

37- Degenerative Spondylolisthesis

Images



- summary

- Degenerative Spondylolisthesis is a common degenerative condition characterized by subluxation of one vertebral body anterior to the adjacent inferior vertebral body with intact pars.
- The condition is most common in females over 40 years of age, at the L4-5 level.
- Diagnosis is made with lateral radiographs. Flexion and extension lateral lumbar radiographs can identify the degree of instability. MRI studies can be helpful for central or foraminal stenosis.
- Treatment is a trial of nonoperative management with NSAIDs and physical therapy. Surgical management is indicated for progressive disabling pain that has failed nonoperative management, and/or progressive neurological deficits.

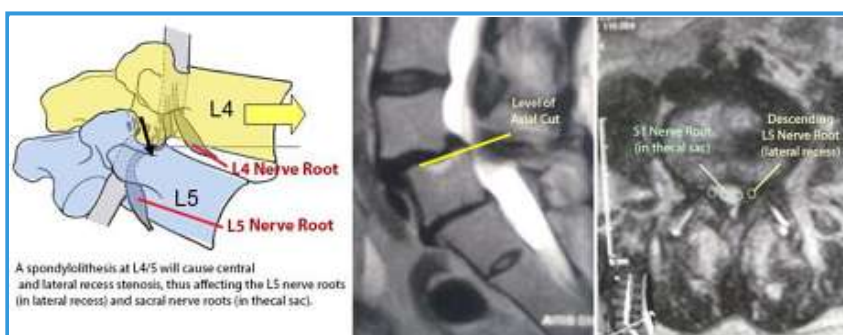
- Epidemiology

- Prevalence
 - ~5% in men
 - ~9% in woman

- Demographics
 - more common in African Americans, diabetics, and woman over 40 years of age
 - ~8 times more common in woman than men
 - increase in prevalence in women postulated to be due to increased ligamentous laxity related to hormonal changes
- Anatomic location
 - degenerative spondylolisthesis is 5-fold more common at L4/5 than other levels
 - this is different that isthmic spondylolisthesis which is most commonly seen at L5/S1
- Risk factors
 - sacralization of L5 (transitional L5 vertebrae)
 - sagittally oriented facet joints

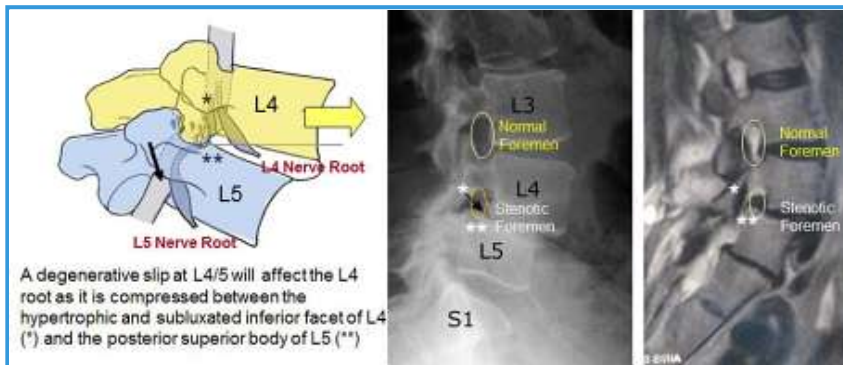
• Etiology

- Pathoanatomy
 - forward subluxation (intersegmental instability) of vertebral body is allowed by
 - facet joint degeneration
 - facet joint sagittal orientation
 - intervertebral disc degeneration
 - ligamentous laxity (possibly from hormonal changes)
 - degenerative cascade involves
 - disc degeneration leads to facet capsule degeneration and instability
 - microinstability which leads to further degeneration and eventual macroinstability and anterolisthesis
 - instability is worsening with sagittally oriented facets (congenital) that allow forward subluxation
 - neurologic symptoms caused by
 - central and lateral recess stenosis



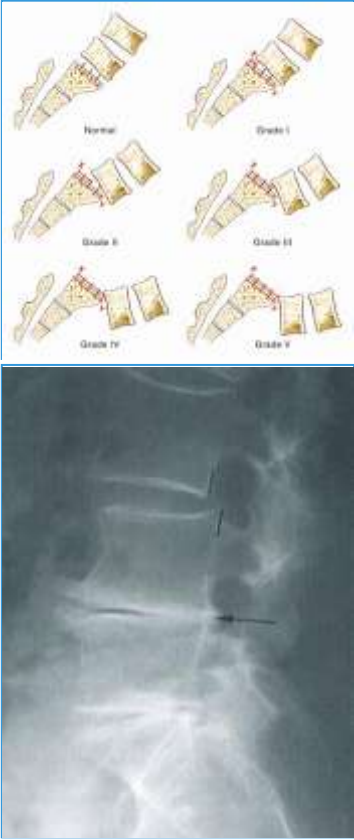
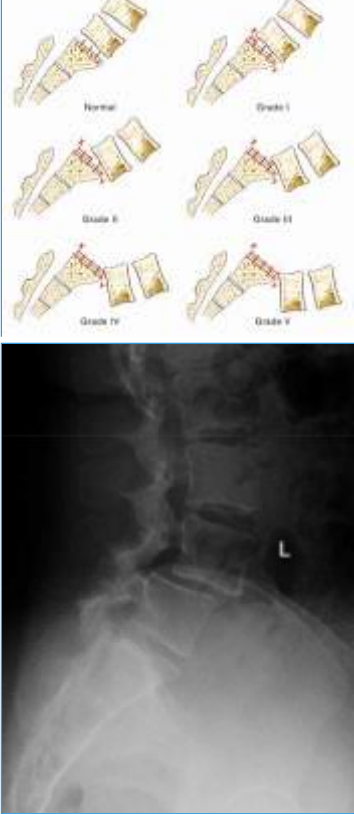
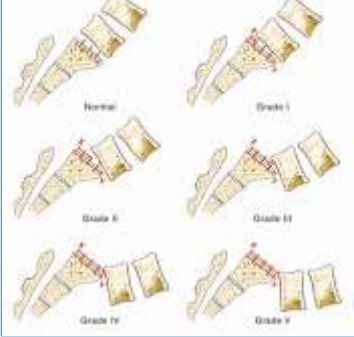
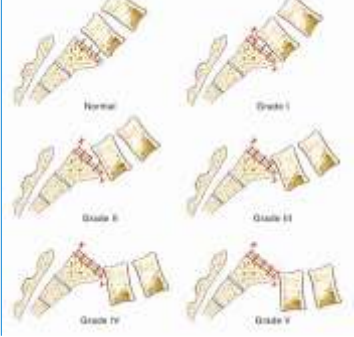
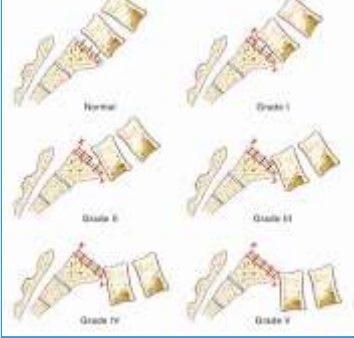
- a degenerative slip at L4/5 will affect the descending L5 nerve root in the lateral recess

- caused by slippage, hypertrophy of ligamentum flavum, and encroachment into the spinal canal of osteophytes from facet arthrosis
- foraminal stenosis



- a degenerative slip at L4/5 will affect the L4 nerve root as it is compressed in the foramen
- vertical foraminal stenosis (loss of height of foramen) caused by
 - loss of disk height
 - osteophytes from posterolateral corner of vertebral body pushing the nerve root up against the inferior surface of the pedicle
- anteroposterior foraminal stenosis (loss of anterior to posterior area) caused by
 - degenerative changes of the superior articular facet and posterior vertebral body

• Classification

Myerding Classification		
Grade I	< 25%	
Grade II	25 to 50%	
Grade III	50 to 75% (Grade III and greater are rare in degenerative spondylolisthesis)	
Grade IV	75 to 100%	
	Grade V	Spondyloptosis (all the way off)

- Presentation

- Symptoms

- mechanical/ back pain
 - most common presenting symptom
 - usually relieved with rest and sitting
 - neurogenic claudication & leg pain
 - second most common symptoms
 - defined as buttock and leg pain/discomfort caused by upright walking
 - relieved by sitting
 - not relieved by standing in one place (as is vascular claudication)
 - may be unilateral or bilateral
 - same symptoms found with spinal stenosis
 - cauda equina syndrome (very rare)

- Physical exam

- L4 nerve root involvement (compressed in foramen with L4/5 DS)
 - weakness to quadriceps
 - best seen with sit to stand exam maneuver
 - weakness to ankle dorsiflexion (cross over with L5)
 - best seen with heel-walk exam maneuver
 - decreased patellar reflex
 - L5 nerve root involvement
 - weakness to ankle dorsiflexion (cross over with L4)
 - best seen with heel-walk exam maneuver
 - weakness to EHL (great toe extension)
 - weakness to gluteus medius (hip abduction)
 - provocative walking test
 - have patient walk prolonged distance until onset of buttock and leg pain
 - have patient stop but remain standing upright
 - if pain resolves this is consistent with vascular claudication
 - have patient sit
 - if pain resolves this is consistent with neurogenic claudication (DS)
 - hamstring tightness
 - commonly found in this patients, and must differentiate this from neurogenic leg pain

- Imaging

- Radiographs

- recommended views

- weight bearing lumbar AP, lateral neutral, lateral flexion, lateral extension

- findings

- slip is evident on lateral x-ray



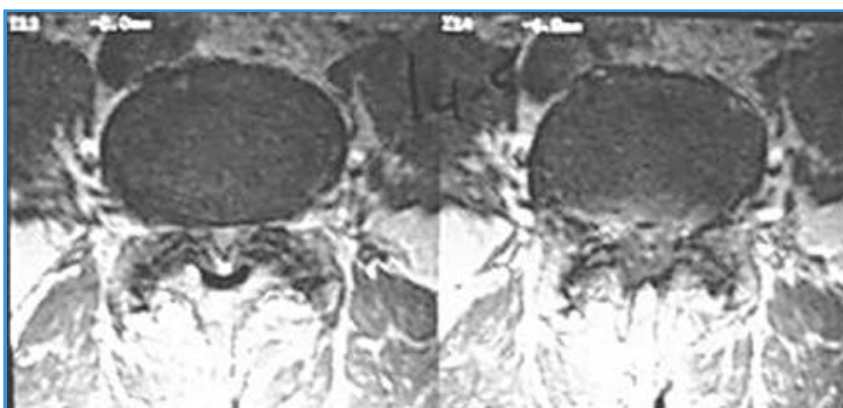
- flexion-extension studies

- instability defined as 4 mm of translation or 10° of angulation of motion compared to adjacent motion segment

- MRI

- indications

- persistent leg pain that has failed nonoperative modalities
 - best study to evaluate impingement of neural elements



- views

- T2 weighted sagittal and axial images best to look for compression of neurologic elements



- CT
 - useful to identify bony pathology
- CT myelogram
 - helpful in patients in which a MRI is contraindicated (pacemaker)

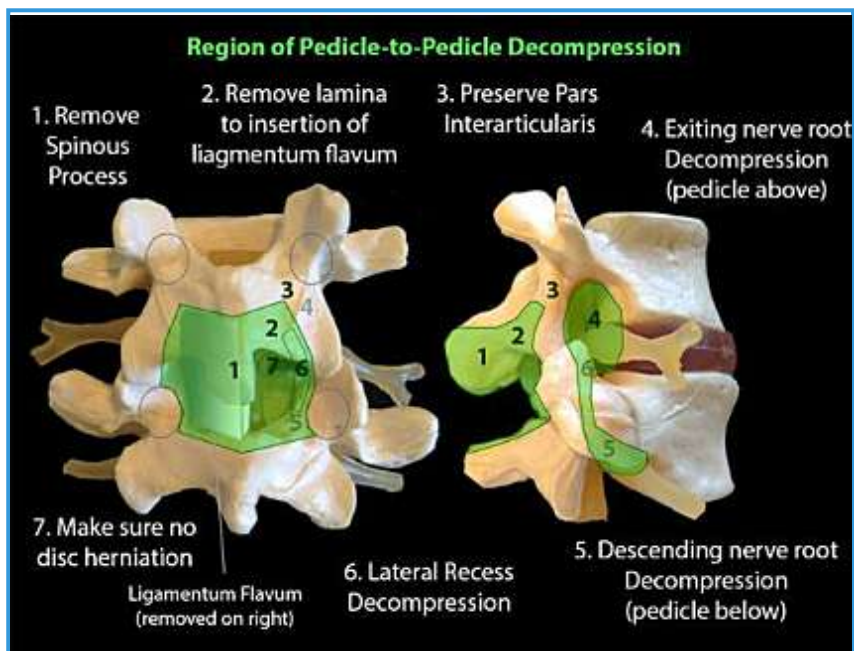
- Treatment

- Nonoperative
 - **physical therapy and NSAIDS**
 - indications
 - most patients can be treated nonoperatively
 - modalities include
 - activity restriction
 - NSAIDS
 - PT
 - **epidural steroid injections**
 - indications
 - second line of treatment if non-invasive methods fail
- Operative
 - **lumbar decompression with instrumented fusion, +/- interbody fusion**
 - indications
 - most common is persistent and incapacitating pain that has failed 6 mos. of nonoperative management and epidural steroid injections
 - progressive motor deficit
 - cauda equina syndrome

- technique
 - often combined with a posterior lumbar interbody fusion or transforaminal interbody fusion
 - new data shows equivalent outcomes using cortical screw fixation verses pedicle screw fixation
 - decompression often performed with a PLC preserving unilateral (undercutting) approach
 - navigation and MIS techniques are widely used
- outcomes
 - ~79% have satisfactory outcomes
 - improved fusion rates shown with pedicle screws
 - improved outcomes with successful arthrodesis
 - worse outcomes found in smokers
 - smokers should undergo smoking cessation prior to surgery
- **posterior lumbar decompression alone**
 - indications
 - usually not indicated due to instability associated with spondylolithesis
 - only indicated in medically frail patients who cannot tolerate the increased surgical time of performing a fusion
 - outcomes
 - ~69% treated with decompression alone are satisfied
 - ~ 31% have progressive instability
- **anterior lumbar interbody fusion (ALIF)**
 - indications
 - reserved for revision cases with pseudoarthrosis
 - outcomes
 - injury to superior hypogastric plexus can cause retrograde ejaculation

- Techniques

- **Posterior decompression and posterolateral fusion (+/- instrumentation)**
 - approach
 - posterior midline approach
 - multiple parasagittal incisions for minimally invasive approaches
 - decompression

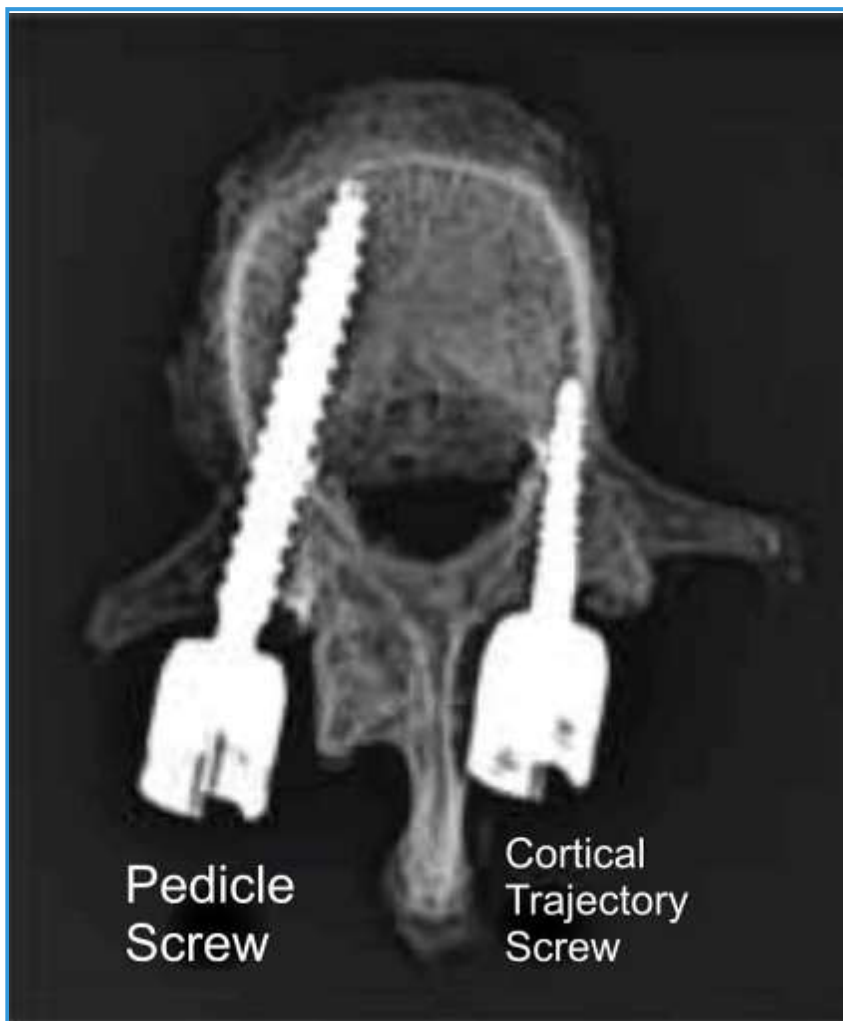


- usually done with laminectomy, wide decompression, and foraminotomy
- fusion
 - posterolateral fusion with instrumentation most common
 - TLIF/PLIF growing in popularity and may increase fusion rates and decrease risk of postoperative slip progression
- reduction of listhesis
 - limited role in adults
- cost
 - in degenerative spondylolisthesis adding an interbody cage increases hospital costs without increasing fusion rates
- **Cortical bone trajectory screw**
 - designed to decrease the amount of lateral exposure for obtaining screw starting points
 - lower intraoperative blood loss, smaller skin incision, and decreased pain scores at 1-week post-op
 - fusion rates and functional outcomes similar to conventional pedicle screw fixation
 - some studies suggest conventional pedicle screw fixation may be more stable
 - other studies have demonstrated greater screw pullout strength given cortical contact of screw
 - mostly described in combination with interbody fusion (PLIF or TLIF)
 - starting point is more medial and caudal than traditional pedicle screws



- trajectory is more cephalad and lateral than traditional screw

- cortical trajectory screws are generally smaller than traditional pedicle screws



- Complications

- Pseudoarthrosis (5-30%)
 - CT scan is more reliable than MRI for identifying failed arthrodesis
- Adjacent segment disease (2-3%)
 - risk of adjacent segment degeneration requiring surgery is about 20-29% at 10 years
- Surgical site infection (0.1-2%)
 - treat with irrigation and debridement (usually hardware can be retained)
- Dural tear
- Positioning neuropathy
 - LFCN
 - seen with prone positioning due to iliac bolster
 - ulnar nerve or brachial plexopathy
 - from prone positioning with inappropriate position
- Complication rates increase with
 - older age
 - increased intraoperative blood loss
 - longer operative time
 - number of levels fused

38- Ankylosing Spondylitis

- summary

- Ankylosing Spondylitis is a chronic seronegative autoimmune spondyloarthropathy characterized by bridging spinal osteophyte formation, enthesitis, sacroiliitis, and uveitis.
- Diagnosis is made with the presence of HLA-B27 antigens, the presence of bilateral sacroiliitis, and ocular examination to assess for uveitis.
- Treatment is observation, NSAIDs, and physical therapy for mild symptoms. Surgical management is indicated for unstable spinal fractures, progressive deformity, and the presence of neurological deficits.

- Epidemiology

- Incidence
 - affects ~0.2% of Caucasian population
- Demographics
 - 4:1 male:female
 - usually presents in 3rd decade of life
 - juvenile form <16-years-old includes enthesitis
 - fewer than 10% of HLA-B27 positive patients have symptoms of AS

- Etiology

- Pathoanatomy
 - exact mechanism is unknown, but most likely due to an autoimmune reaction to an environmental pathogen in a genetically susceptible individual.
 - theories of relation to HLA-B27 include
 - HLA-B27 aggregates with peptides in the joint and leads to a degenerative cascade
 - cytotoxic T-cell autoimmune reaction against HLA-B27
 - enthesitis
 - entheses inflammation leads to bony erosion, surrounding soft-tissue ossification, and eventually joint ankylosis

- preferentially targets sacroiliac joints, spinal apophyseal joints, symphysis pubis
 - this differentiates from RA, which is a synovial process
- disc space involvement
 - inflammation of the annulus lead to bridging osteophyte formation (syndesmophytes)
- Genetics
 - there is a genetic predisposition, but mode of inheritance is unknown
 - HLA-B27 is located on sixth chromosome, B locus
- Diagnostic criteria
 - bilateral sacroiliitis
 - +/- uveitis
 - HLA-B27 positive (90% positive)
- Systemic manifestations
 - acute anterior uveitis & iritis
 - heart disease (cardiac conduction abnormalities)
 - pulmonary fibrosis
 - renal amyloidosis
 - ascending aortic conditions (aortitis, stenosis, regurgitation)
 - Klebsiella pneumoniae synovitis
 - HLA-B27 individuals are more susceptible to Klebsiella pneumoniae synovitis
- Orthopaedic manifestations
 - bilateral sacroiliitis
 - progressive spinal kyphotic deformity
 - cervical spine fractures
 - large-joint arthritis (hip and shoulder)

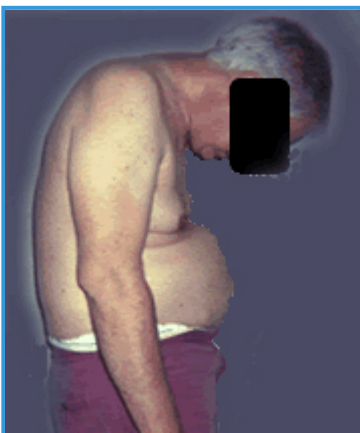
• Anatomy

- Enthesis
 - defined as the insertion of tendon, ligaments, or muscle into bone

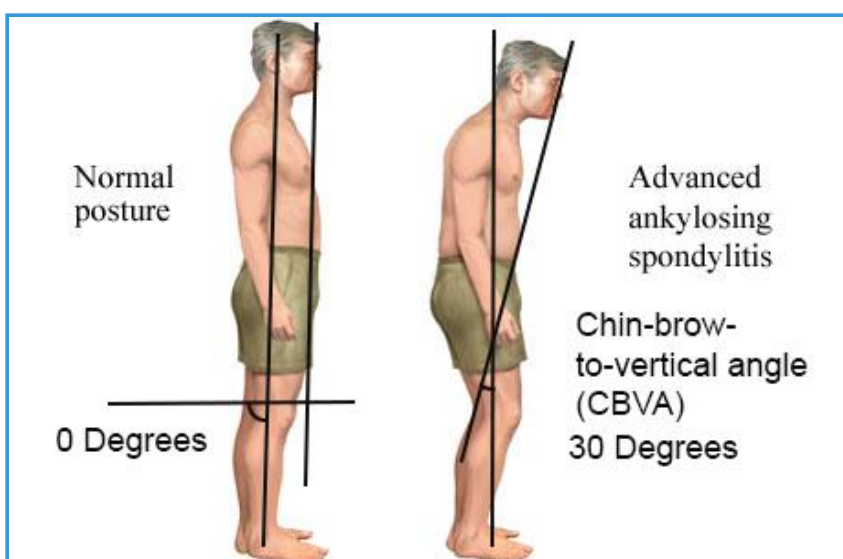
• Presentation

- Symptoms
 - lumbosacral pain and stiffness
 - present in most patients
 - worse in morning
 - insidious onset in 3rd decade of life

- neck and upper thoracic pain
 - occurs later in life
 - acute neck pain should raise suspicion for fracture
- sciatic
 - likely originates from sciatic nerve involvement in the pelvic (piriformis spasm)
- loss of horizontal gaze
- shortness of breath
 - caused by costovertebral joint involvement, leading to reduced chest expansion
- Physical exam
 - limitation of chest wall expansion
 - < 2cm of expansion is more specific than HLA-B27 for making diagnosis
 - decreased spine motion
 - Schober test
 - used to evaluate lumbar stiffness
 - kyphotic spine deformity
 - chin-on-chest (flexion) deformity of the spine



- caused by multiple microfractures that occur over time
- chin-brow-to-vertical angle (CBVA)



- measured from standing exam of standing lateral radiograph
 - useful for preoperative planning
 - correction of this angle correlates with improved surgical outcomes
- hip flexion contracture

- examining patient in supine and sitting position helps differentiate sagittal plane imbalance due to hip flexion contractures or kyphotic spinal deformity
- sacroiliac provocative tests
 - Faber test
 - flexion abduction external rotation of the ipsilateral hip causes pain

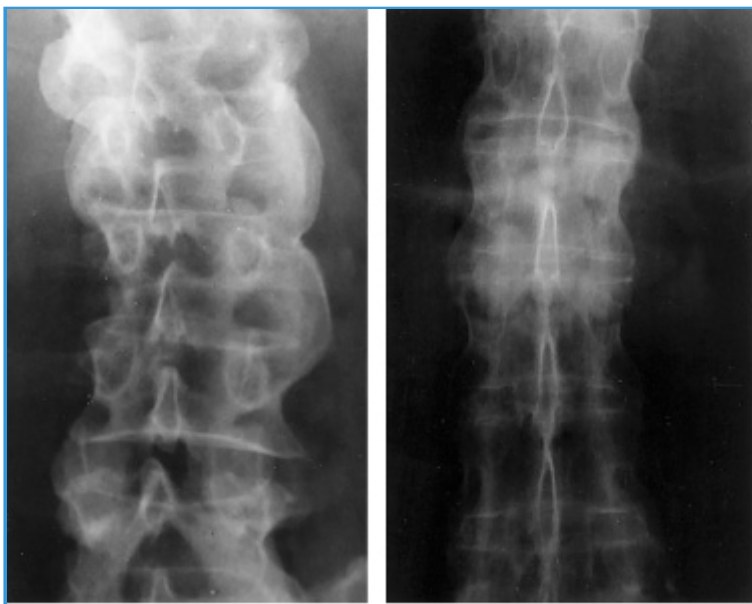
- Imaging

- Radiographs

- spine
 - recommended views
 - standing full-length AP and lateral of axial spine
 - findings
 - negative in 50% of cases with spine fractures
 - squaring of vertebrae with vertical or marginal syndesmophytes



- late vertebral scalloping (bamboo spine)



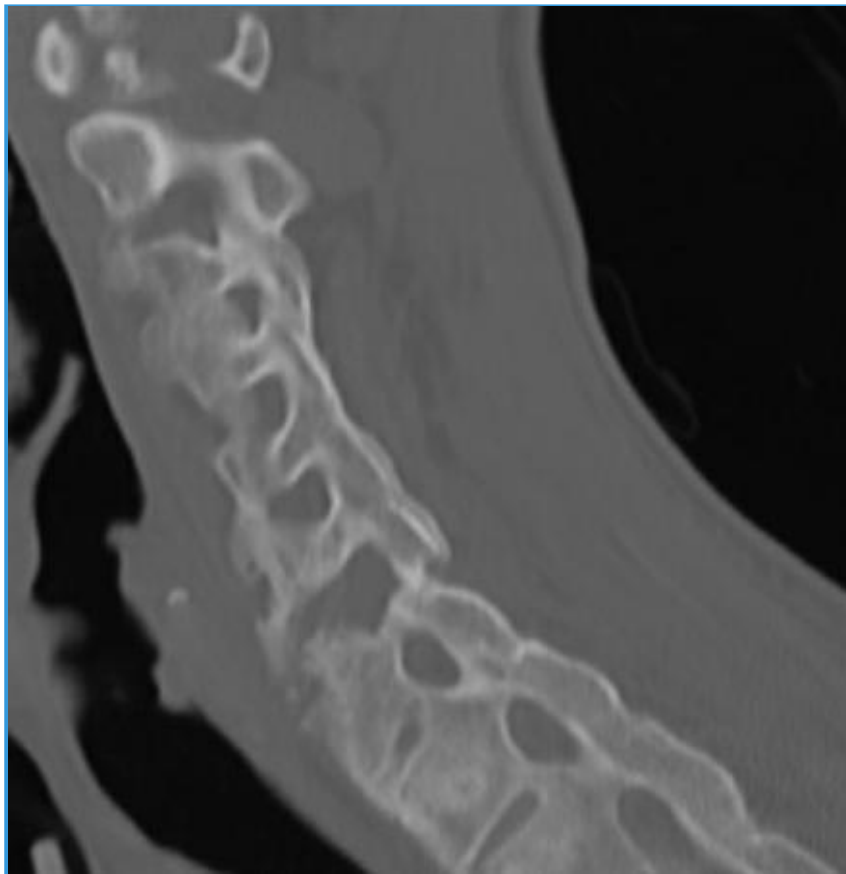
- measurements
 - chin-brow to vertical angle
 - used to measure chin-on-chest deformity
 - useful for preoperative planning for osteotomy
- pelvis & lower extremity
 - recommended views
 - Ferguson pelvic tilt view
 - allows for improved visualization of anterior SI joint
 - xray beam directed 10 to 15 degrees cephalad
- findings
 - bilateral symmetric sacroiliac erosion



- earliest radiographic sign is erosion of iliac side of sacroiliac joint
- joint space narrowing
- ankylosis

○ CT

- will show bony changes but not active inflammation



- CT is most sensitive test to diagnose cervical fractures in patients with AS
 - entire spinal axis should be imaged in patients presenting with trivial trauma

○ MRI

- will detect inflammation, making it the best modality for early detection of AS in young patients
- obtain with cervical fractures to look for epidural hemorrhage

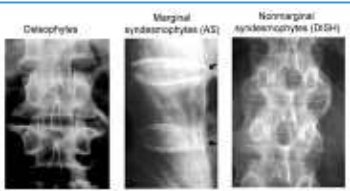
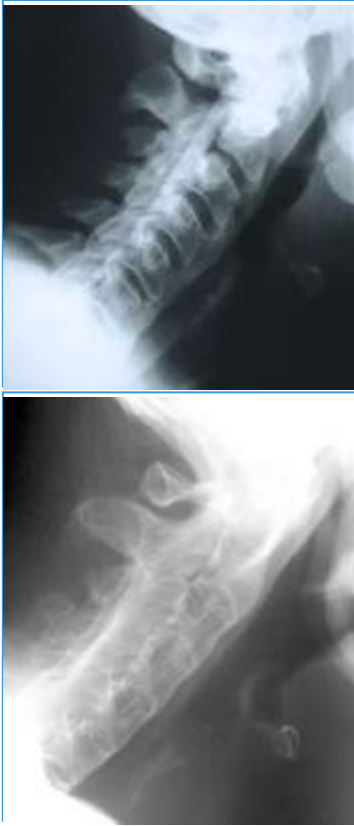


- Bone scan
 - will show inflammation in the sacroiliac joints, but lacks specificity

- Studies

- Labs
 - little diagnostic value
 - often see nonspecific elevations in ESR and CRP
 - RF negative (seronegative)
- Diagnostic Injections
 - SI joint injection
 - local anesthetic injected into SI joint under fluoroscopic guidance
 - often most sensitive diagnostic test

- Differentials

DISH vs. Ankylosing Spondylitis			
	<i>DISH</i>	Ankylosing spondylitis	
Syndesmophytes	Nonmarginal	Marginal	
Radiographs	"Flowing candle wax"	"Bamboo spine", squaring of vertebral bodies, "shiny corners" at the attachment of annulus fibrosus (Romanus lesions)	
Disc space	Preservation of disc space	AS in cervical spine will show ossification of disc space	
Osteopenia	No osteopenia (rather, there may be increased radiodensity)	Osteopenia present	
HLA	- No evidence of association with HLA-B27 - Associated with HLA-B8 (common in patients with DISH and diabetes)	Strong association with HLA-B27	
Age group	Older patients (middle-aged)	Younger patients	
SI joint involvement	No involvement (SI joint abnormality generally excludes the diagnosis of DISH)	Bilateral sacroiliitis	
Diabetes	Yes	No	

- Treatment General
 - Nonoperative
 - NSAIDS, COX-2 inhibitors, and therapy
 - indications
 - first line of treatment for pain and stiffness

- oral steroids not recommended
 - techniques
 - physical therapy should focus on maintaining flexibility
 - **TNF-alpha-blocking agents**
 - indications
 - second line of medical management
 - techniques
 - includes infliximab, etanercept, adalimumab
 - outcomes
 - clinical studies show significant improvement in severity of symptoms
- Operative
 - see below

• Spine Trauma

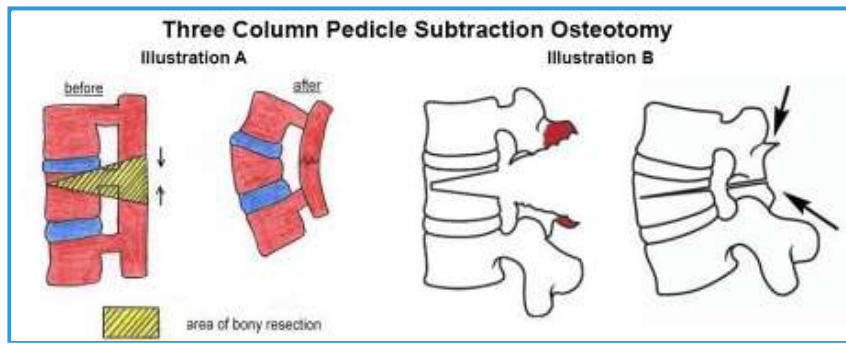
- Introduction
 - epidemiology
 - most occur in midcervical and cervicothoracic junction (some occur at thoracolumbar junction)
 - pathanatomy
 - often extension-type fracture that involved all three columns
 - prognosis
 - high mortality rate secondary to epidural hemorrhage
 - 75% neurologic involvement
- Presentation
 - symptoms
 - usually present with pain after low energy fall
 - physical exam
 - neurologic deficits often present late and therefore patients should be admitted and observed
- Imaging
 - radiographs
 - may be occult
 - CT
 - if suspicious consider CT scan (best modality to make diagnosis)
 - MRI
 - high mortality rate secondary to epidural hemorrhage
- Treatment

- nonoperative
 - **immobilize in existing kyphotic position, admit for observation and advanced imaging**
 - indications
 - stable spine fractures with no neurologic deficits
 - technique
 - low-weight traction may facilitate reduction
- operative
 - **spinal decompression with instrumented fusion**
 - indications
 - progressive neurologic deficit
 - epidural hematoma with neurologic compromise
 - unstable fracture patterns
 - technique
 - decompression
 - decision to go anterior or posterior depends on fracture level, presence and location of hematoma, and osteoporosis
 - instrumentation
 - need to obtain long fusion construct
 - multiple points of fixation above and below the fracture are necessary because of
 - osteoporosis
 - long lever arms of the ankylosed spine
 - do not make an effort to correct deformity
 - outcomes & complications
 - high rate of complications including
 - progressive deformity
 - nonunion
 - hardware failure
 - infection

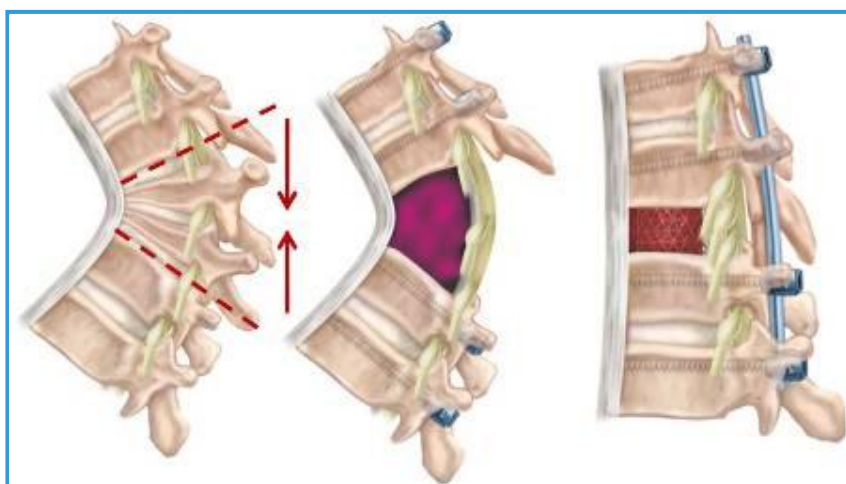
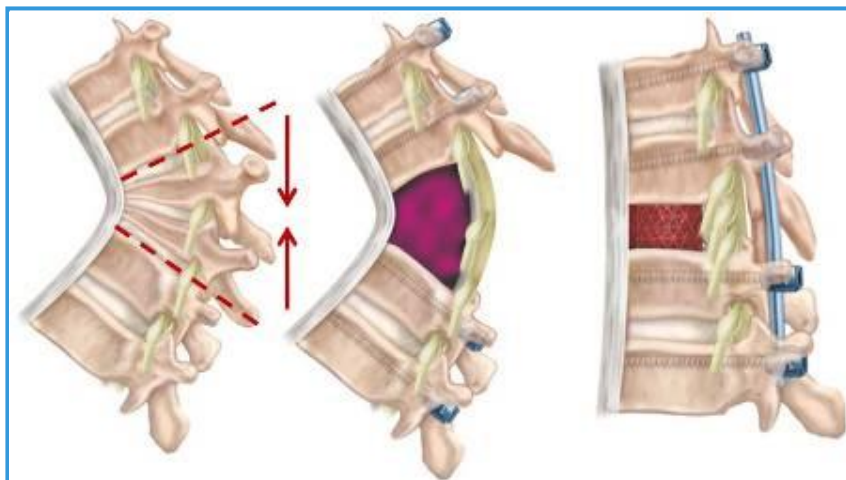
• Spinal Deformity

- Introduction
 - usually a kyphotic deformity of upper spine
 - be sure to eliminate hip contractures as reason for deformity
- Treatment
 - **lumbar osteotomy**
 - indications

- thoracolumbar kyphotic deformity
- goals
 - goal is to restore sagittal balance and horizontal gaze
- techniques
 - closing wedge (pedicle subtracting) osteotomy



- transpedicular decancellation procedure with removal of posterior elements
- location of osteotomy determined by type of spine flexion deformity
- hinge located on anterior vertebral body
- considered procedure of choice due to
 - greater deformity correction (30 to 40 degrees per level)
 - better fusion and stability due to direct bony apposition
- vertebral body resection



- entire vertebral body is removed and replaced with a cage
- single-level opening wedge osteotomy
 - hinges on posterior edge of vertebral body
 - requires rupture of ALL
- multi-segment opening osteotomy
 - advantage of less bone loss and preservation of ALL by distributing correction over multiple levels

- outcomes & complications
 - lumbar approach avoids complications of thoracic cage, spinal cord injury, and has potential for greater correction due to long lever arm
- **C7-T1 cervicalthoracic osteotomy**
 - indications
 - cervicothoracic kyphotic (chin-on-chest) deformity
 - goals
 - slight under-correction with final brow-to-chin angle of 10 degrees
 - technique
 - osteotomy
 - advantage of C7-T1 osteotomy include
 - vertebral artery is external to transverse foramen
 - larger canal diameter
 - requires wide decompression with removal of C7 lateral mass and portions of C7-T1 pedicles to prevent iatrogenic SCI
 - instrumentation
 - usually a combination of lateral mass screws, pedicle screws, and sublaminar hooks
 - postoperative
 - postoperative halo immobilization often required in patients with poor bone quality
 - outcomes & complications
 - increased risk of venous air embolus (VAE) in the sitting operative position

• Large-Joint Arthritis

- Introduction
 - asymmetric involvement of large joints
 - shoulder and hip most commonly involved
- Treatment
 - **total hip replacement**
 - indications
 - in patients with severe arthritis of this hips secondary to AS
 - technique
 - patients have more vertical and anteverted acetabulum (may lead to anterior dislocations after total hip arthroplasty)
 - **bilateral total hip arthroplasty**

- indications
 - kyphotic deformity due to hip flexion contracture deformity
- outcomes & complications
 - at risk for dislocation

39- Dish Diffuse Idiopathic Skeletal Hyperostosis

Images



- SUMMARY

- DISH, also known as Forestier disease, is a common disorder of unknown etiology characterized by enthesopathy of the spine and extremities, that usually presents with back pain and spinal stiffness.
- Diagnosis can be confirmed with radiographs of the cervical and thoracic spine. A CT scan should be performed whenever there is concern for a fracture following low energy trauma.
- Treatment is usually activity modification, physical therapy, and bisphosphonate therapy. Associated spine fractures are treated with long spinal fusion.

- Epidemiology

- Demographics
 - overall incidence 6-12%

- uncommon before 50 years old
- prevalence
 - > 50 y.o. (25% males; 15% females)
 - > 80 y.o. (28% males; 26% females)
- less common in Black, Native-American and Asian populations
- Location
 - occurs anywhere in spine
 - most common in the thoracic spine (right side) > cervical > lumbar
 - postulated to be due to the protective effect of the pulsatile aorta on the left of the thoracic spine



- symmetrical in the cervical and lumbar spine (syndesmophytes both on left and right of the spine)

- Risk factors
 - gout
 - hyperlipidemia
 - diabetes

• ETIOLOGY

- Associated conditions
 - lumbar spine
 - lumbar spinal stenosis
 - cervical spine
 - dysphagia and stridor



- hoarseness
- sleep apnoea
- difficulty with intubation
- cervical myelopathy
- spine fracture and instability
 - because ankylosis of vertebral segments proximal and distal to the fracture creates long lever arms that cause displacement even in low-energy injuries
 - hyperextension injuries are common
 - seemingly minor, low energy injury mechanisms may result in unstable fracture patterns. One must have increase vigilance in patients with pain and an ankylosed spine

- Presentation

- Symptoms
 - often asymptomatic and discovered incidentally
 - thoracic and lumbar involvement
 - mild chronic back pain
 - usually pain is minimal because of stabilization of spinal segments through ankylosis
 - stiffness
 - worse in the morning
 - aggravated by cold weather
 - cervical involvement (with large anterior osteophytes)

- pain and stiffness
- dysphagia



- stridor
- hoarseness
- sleep apnea

- Physical exam

- decreased ROM of the spine
 - neurologic symptoms of myelopathy or spinal stenosis

- Imaging

- Radiographs

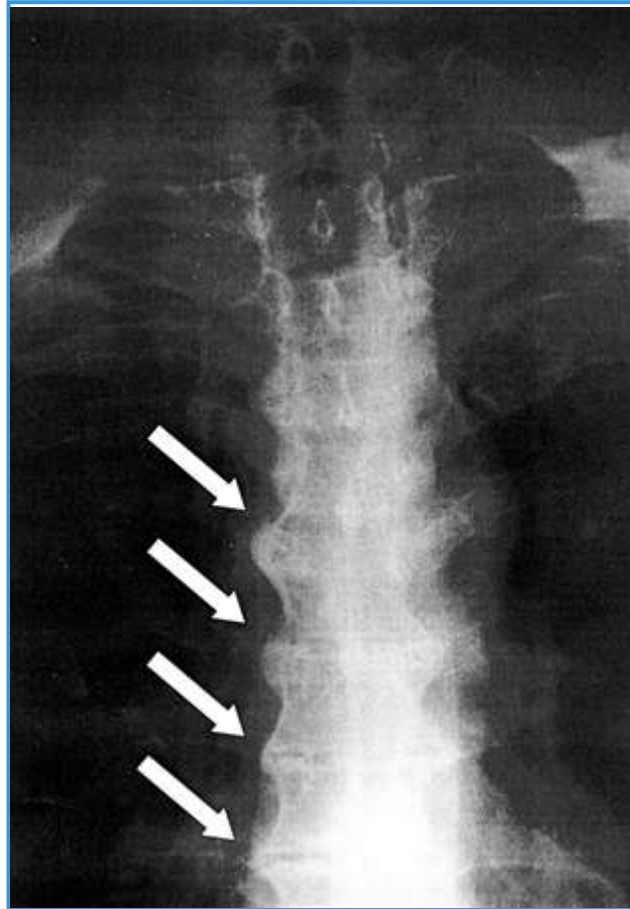
- recommended views
 - AP and lateral spine radiographs of involved region
 - findings
 - non-marginal syndesmophytes at three successive levels (4 contiguous vertebrae)



- thoracic spine
 - radiographic findings on the right side



- thoracic spine is often involved in isolation
- particularly T7-T11
- radiographic examination of this area is helpful when attempting to establish a diagnosis of DISH



- cervical spine
 - anterior bone formation with preservation of disc space (best seen on lateral cervical view)
 - lateral cervical radiographs useful to differentiate from AS
 - AS will demonstrate disc space ossification (fusion between vertebral bodies)
- lumbar spine

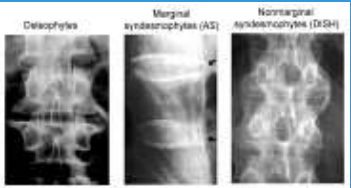


- symmetrical syndesmophytes (on left and right side of lumbar spine)
- other joint involvement e.g. elbow



- Technetium bone scan
 - increased uptake in areas of involvement
 - may be confused with metastases
- CT or MRI
 - patients with DISH, neck pain and history of trauma must be evaluated for occult fracture with CT

- Differential

○	■ DISH vs AS Table		
		■ <i>DISH</i>	■ <i>Ankylosing spondylitis</i>
■ Syndesmophytes	■ Nonmarginal 		■ Marginal
■ Radiographs	■ "Flowing candle wax" 		■ "Bamboo spine", squaring of vertebral bodies, "shiny corners" at attachment of annulus fibrosus (Romanus lesions) 
■ Disc space	■ Preservation of disc space		■ AS in cervical spine will show ossification of disc space 
■ Osteopenia	■ No osteopenia (rather, there may be increased radiodensity)		■ Osteopenia present
■ HLA	■ No evidence of association with HLA-B27 ■ Associated with HLA-B8 (common in patients with DISH and diabetes)		■ Strong association with HLA-B27
■ Age group	■ Older patients (middle aged)		■ Younger patients
■ SI joint involvement	■ No involvement (SI joint abnormality generally excludes diagnosis of DISH)		■ Bilateral sacroiliitis
■ Diabetes	■ Yes		■ No

- Diagnosis

- Diagnostic criteria

- flowing ossification along the anterolateral aspect of at least 4 contiguous vertebrae
 - preservation of disk height in the involved vertebral segment; relative absence of significant degenerative changes (e.g. marginal sclerosis in vertebral bodies or vacuum phenomenon)
 - absence of facet-joint ankylosis; absence of SI joint erosion, sclerosis or intraarticular osseous fusion

- Treatment

- Nonoperative

- **activity modification, physical therapy, brace wear, NSAIDS and bisphosphonate therapy**
 - indications
 - most cases
 - **cervical traction**
 - indications
 - cervical spine fracture
 - use with caution because traction may result in excessive distraction due to lack of ligamentous structures

- Operative

- **spinal decompression and stabilization**
 - indications
 - reserved for specific sequelae (e.g., lumbar stenosis, cervical myelopathy, adult spinal deformity)

- Complications

- Mortality

- for cervical spine trauma in DISH
 - 15% for those treated operatively
 - 67% for those treated nonoperatively
 - higher mortality rates than cervical spine trauma with ankylosing spondylitis
 - similar mortality rates to patients with ankylosing spondylitis overall

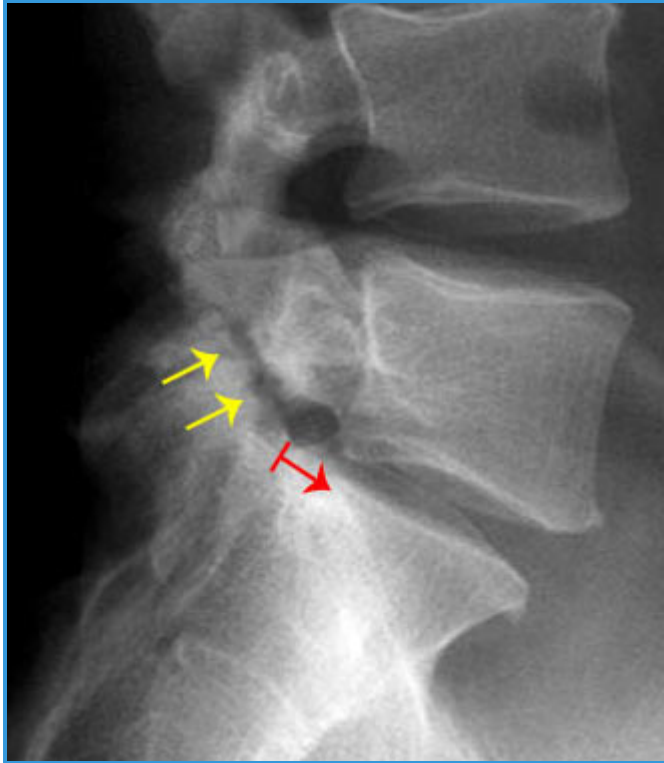
- Heterotopic ossification

- increased risk of HO after THA
 - 30-50% for THA in patients with DISH

- <20% for THA in patients without DISH

40- Pediatric Spondylolysis And Spondylolisthesis

Images



• Summary

- Pediatric Spondylolysis & Spondylolisthesis represent a continuum of disease where there is a fracture of the pars interarticularis (spondylolysis) which may progress to anterior subluxation of one vertebral body anterior to the adjacent inferior vertebral body (spondylolisthesis).
- Diagnosis of spondylolysis alone can be challenging on imaging and the ideal study is controversial. Radiographs, CT scan, and MRI may all play a role. Spondylolisthesis is diagnosed on a lateral radiograph.
- Treatment may be nonoperative or surgical depending on the degree of back pain, malalignment of vertebral bodies, and neurological symptoms.

• Epidemiology

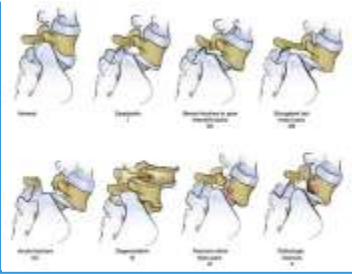
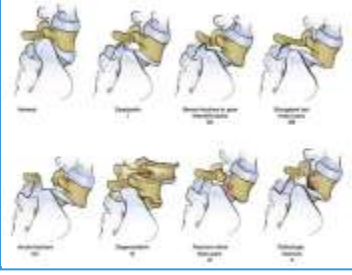
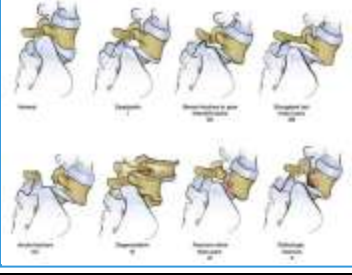
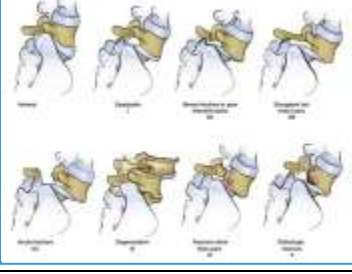
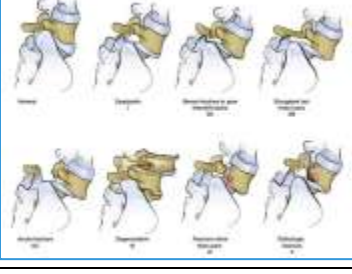
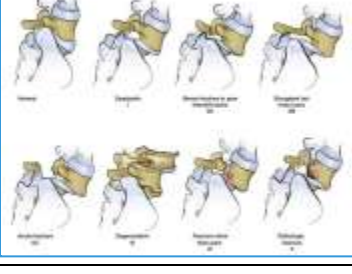
- Incidence
 - common
 - up to 6-7% of adolescent athletes
 - implicated in up to 47% of low back pain complaints in this population
- Demographics
 - higher incidence in Native Americans
- Anatomic location
 - typically involves pars of L5 and anterolisthesis of L5 relative to S1

- Risk factors
 - prevalence of spondylolysis may be as high as 47% in certain athletes (gymnasts, weightlifters, football linemen)
 - contact sports and those involving repetitive hyperextension (ex. linebacker)
 - higher sacral table index, pelvic incidence, sacral slope, and lower sacral table angle

- Etiology

- Pathophysiology
 - conditions represent a continuum of disease including
 - pars stress reaction
 - defined as sclerosis of pars without complete bone disruption
 - spondylolysis
 - defined as a complete fracture of the pars interarticularis
 - mechanism
 - defects are not present at birth and develop over time (seen in 4-6% of population)
 - usually activity related and occurs from repetitive hyperextension
 - isthmic spondylolisthesis (spondylolytic spondylolisthesis)
 - defined as forward translation of one vertebral segment over the one beneath it due to a pars defect
 - risks of progression
 - approximately 15% of individuals with a pars interarticularis lesion have progression to spondylolisthesis
 - the larger the slip the more likely it is to progress
 - > Myerding 2 (>50% slip)
 - dysplastic slips (Wiltse Type I) are more likely to progress
 - severity of current slip
 - correlates most strongly with pelvic incidence
 - spondyloptosis
 - 100% translation of one vertebra over the next caudal vertebra
- Genetics
 - possible autosomal dominant inheritance pattern

- Classification

■ Wiltse-Newman Classification		
■ Type I	■ Dysplastic ■ Secondary to congenital abnormalities of lumbosacral articulation including mal-oriented or hypoplastic facets, sacral deficiency, poorly developed pars ■ Posterior elements are intact (no spondylolysis) ■ More significant neurologic symptoms	■ 
■ Type II-A	■ Isthmic - Pars Fatigue Fx	■ 
■ Type II-B	■ Isthmic - Pars Elongation due to healed stress fx	■ 
■ Type II-C	■ Isthmic - Pars Acute Fx	■ 
■ Type III	■ Degenerative	■ 
■ Type IV	■ Traumatic	■ 
■ Type V	■ Neoplastic	■ 

■ Marchetti-Bartolozzi Classification		
■ Developmental	■ Includes Wiltse I and II	■
■ Acquired	■ Traumatic, postsurgical, pathologic, degenerative	■

■ Meyerding Classification		
■ Grade I	■ < 25%	■ 
■ Grade II	■ 25-50%	■ 
■ Grade III	■ 50-75%	■ 
■ Grade IV	■ 75-100%	■ 
■ Grade V	■ Spondyloptosis	■ 

- Presentation

- History

- classic history is healthy active adolescent who presents with acute onset of low back pain with athletic activity

- Symptoms

- asymptomatic
 - many cases of spondylolysis are asymptomatic
 - low back pain
 - no association between radiologic grade and clinical presentation
 - symptoms include insidious onset of activity related low back pain
 - leg symptoms
 - buttock pain
 - hamstring tightness (most common) and knee contracture
 - radicular pain (L5 nerve root)
 - listhetic crisis
 - severe back pain aggravated by extension and relieved by rest
 - neurologic deficit
 - hamstring spasm
 - bowel and bladder symptoms
 - rare
 - cauda equina syndrome (rare)

- Physical exam

- inspection

- high grade/dysplastic patients may develop "heart shaped buttocks" due to sacral prominence
- flattened lumbar lordosis



- palpation
 - palpable step off of spinous process
- motion
 - limitation of lumbar flexion and extension
 - measure popliteal angle to evaluate for hamstring tightness



- neurovascular
 - straight leg raise may be positive
 - rectal exam if bowel and bladder symptoms present
- provocative tests
 - pain with single-limb standing lumbar extension
- gait
 - may walk with a crouched gait when symptoms severe

- Imaging

- **Pars stress reaction & spondylolysis**

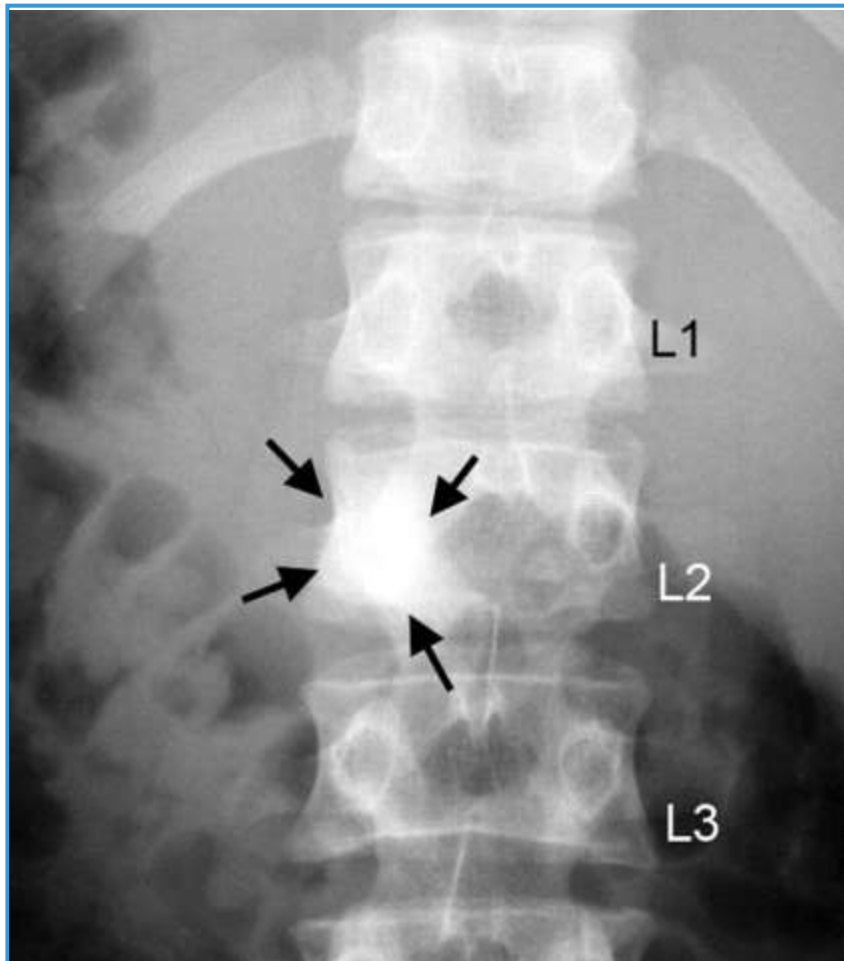
- radiographs

- indications

- AP and lateral indicated in all patients with concern for spondylolysis and spondylolithesis

- AP view

- may see sclerosis of the stress reaction



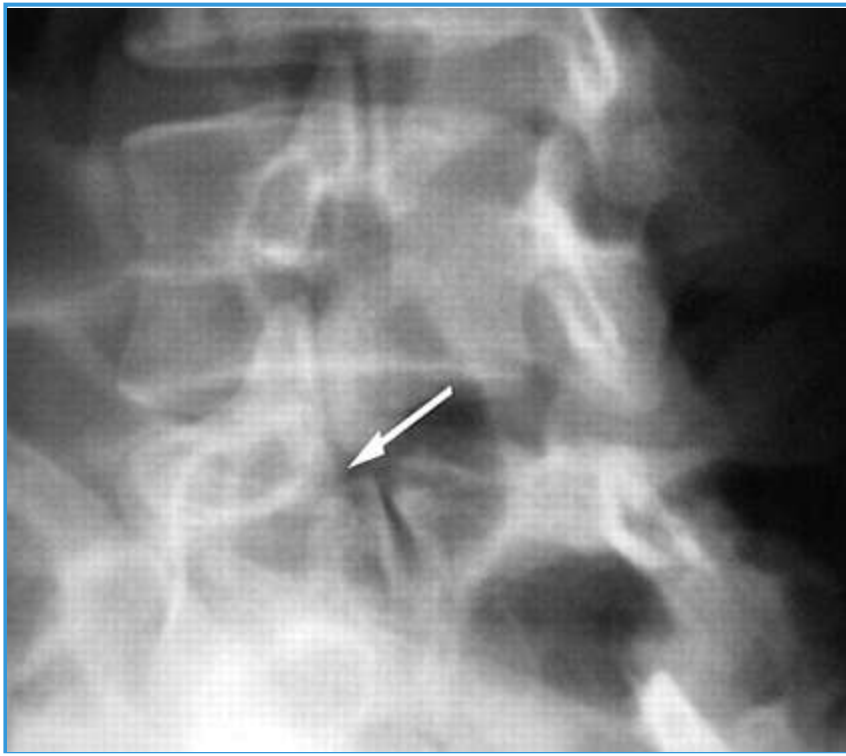
- lateral view

- may show defect in pars in 80%



- oblique view

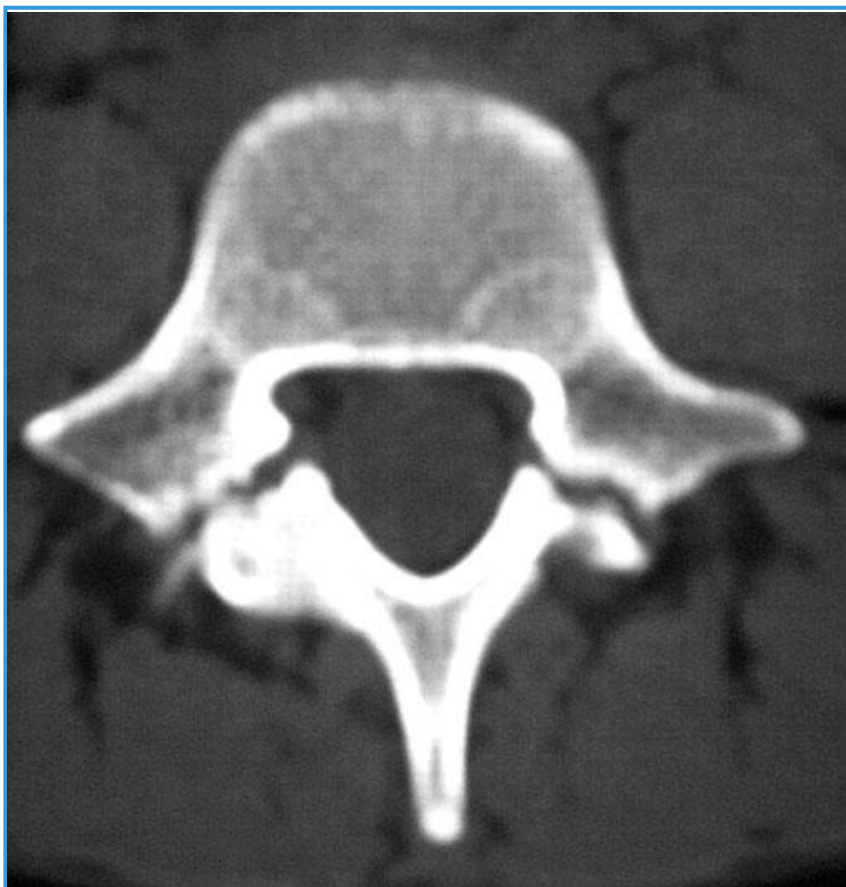
- views may show sclerosis and elongation in pars interarticularis (scotty dog sign)



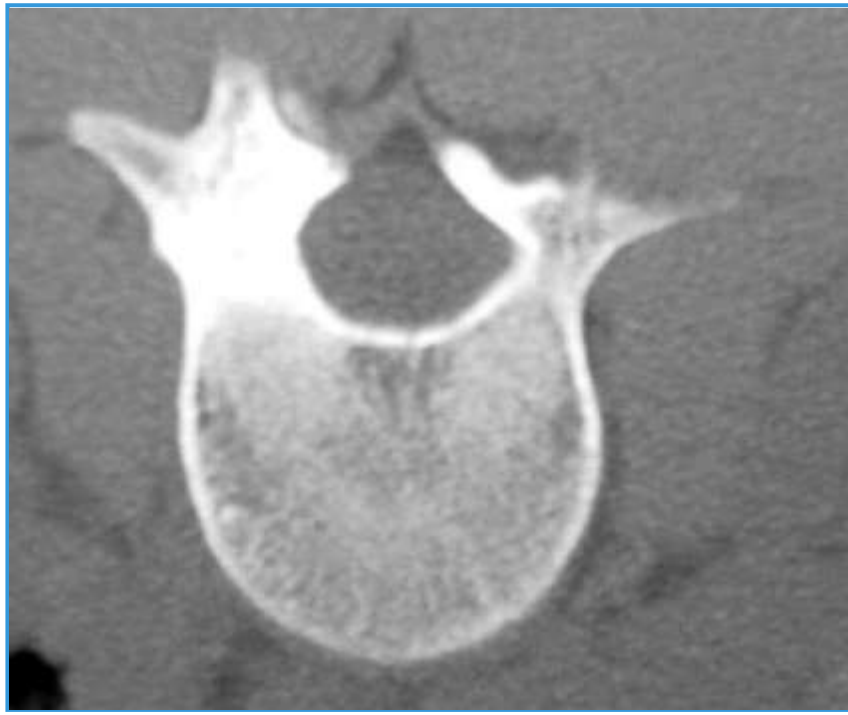
- some studies have shown that oblique does not provide more diagnostic information than AP and lateral radiographs but does increase radiation exposure

- CT

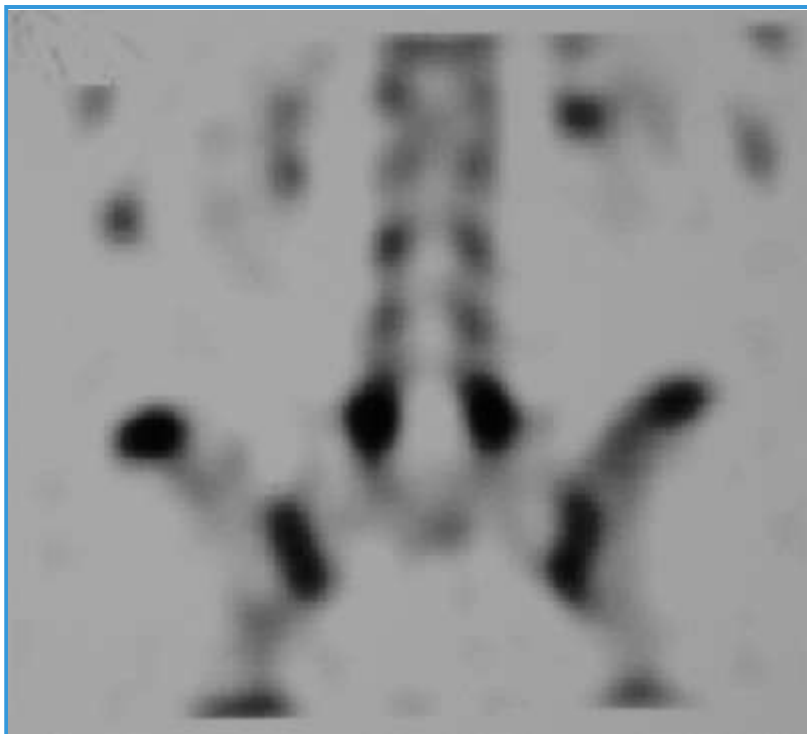
- indications
 - best study to delineate anatomy of lesion



- findings
 - pars stress reaction will show up as sclerosis on x-rays and CT scan



- single photon emission computer tomography (SPECT)

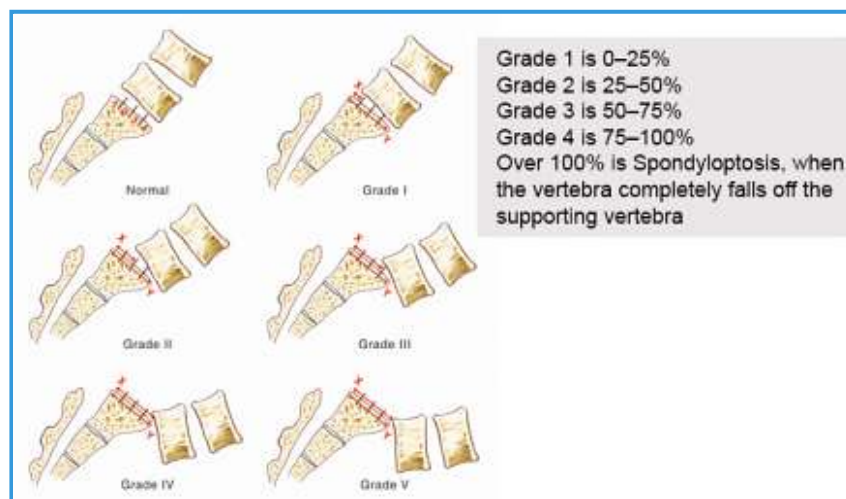


- indications
 - previously considered the best diagnostic adjunct when plain radiographs are negative; however, now rarely performed given unnecessary radiation exposure
 - can also detect osteoid osteomas, sacroiliitis, osteitis pubis, and disc herniation
- techniques
 - combines technique of bone scan with CT in order to help localize an area of abnormal activity seen on bone scan
- MRI
 - indications
 - negative radiographs with high suspicion
 - very acute presentation
 - any neurological deficits
 - sensitivity & specificity
 - recent studies have shown MRI to be as sensitive and specific as SPECT, with the additional benefit of avoiding radiation exposure
- bone scan
 - indications

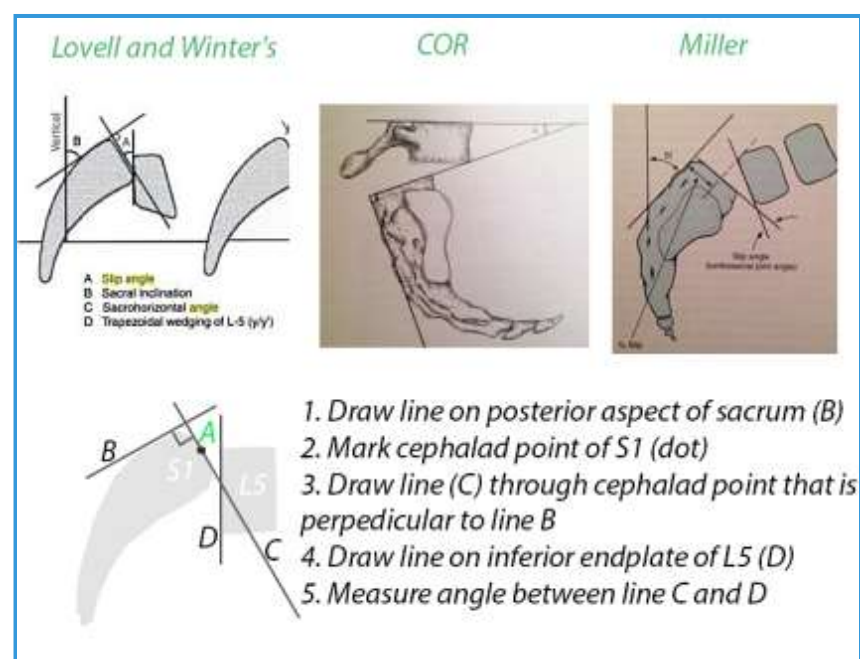
- excellent screening tool for low back pain in children or adolescents
- sensitivity & specificity
 - most sensitive (however lesion may be cold)

○ Spondylolisthesis

- radiographs
 - views
 - lateral x-ray used to measure slip angle and grade.
 - flexion and extension radiographs used to evaluate instability
 - measurements
 - slip grade

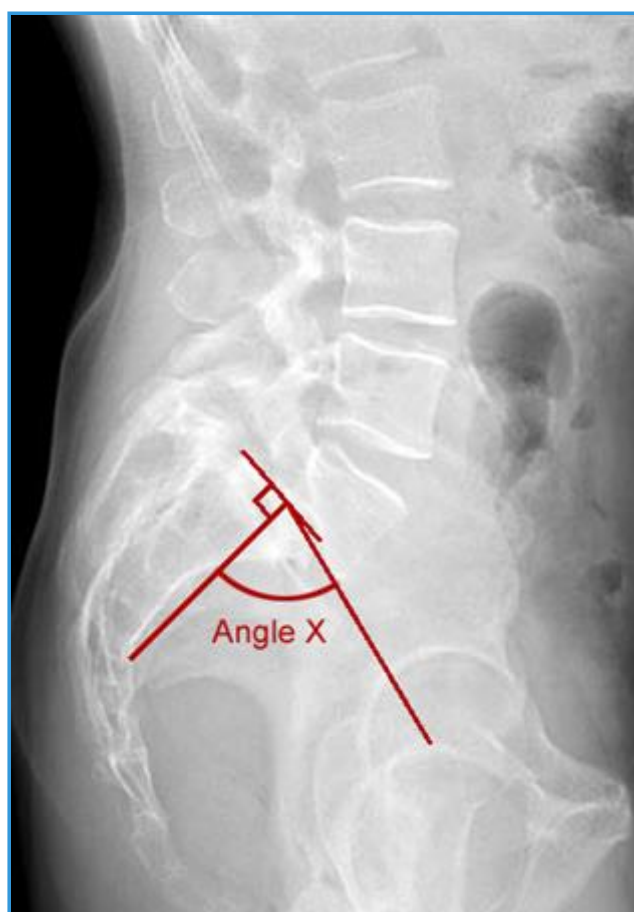
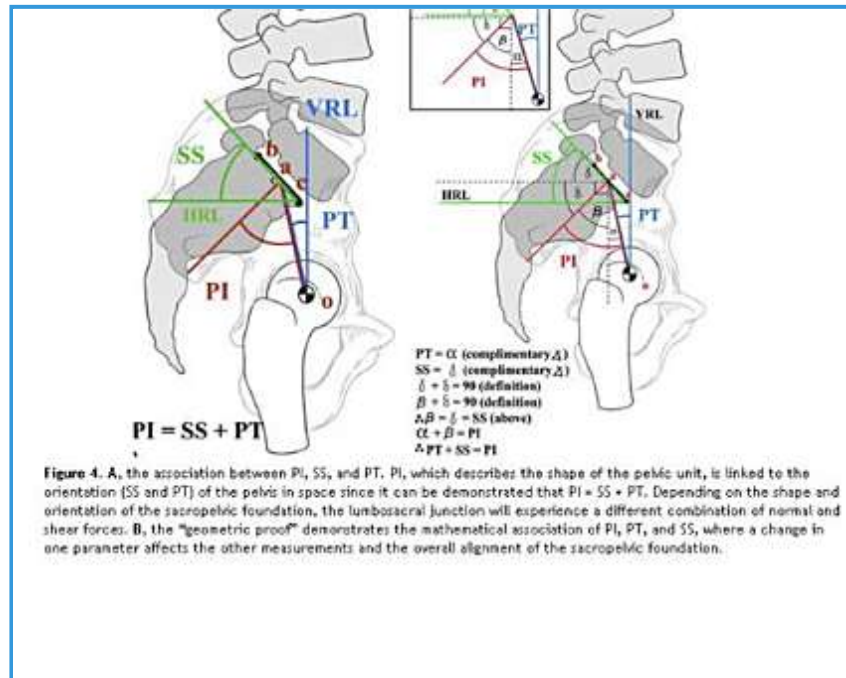


- slippage on plain lateral radiographic imaging measured in accordance to the vertebra below
 - the caudal vertebra is divided into four parts
 - Grade I means a translation of the cranial vertebra of up to 25%
 - Grade II of up to 50%
 - Grade III of up to 75%
 - Grade IV up to 100%
 - Grade V describes the ptosis of the cranial vertebra
- slip angles
 - methodology to determine slip angle

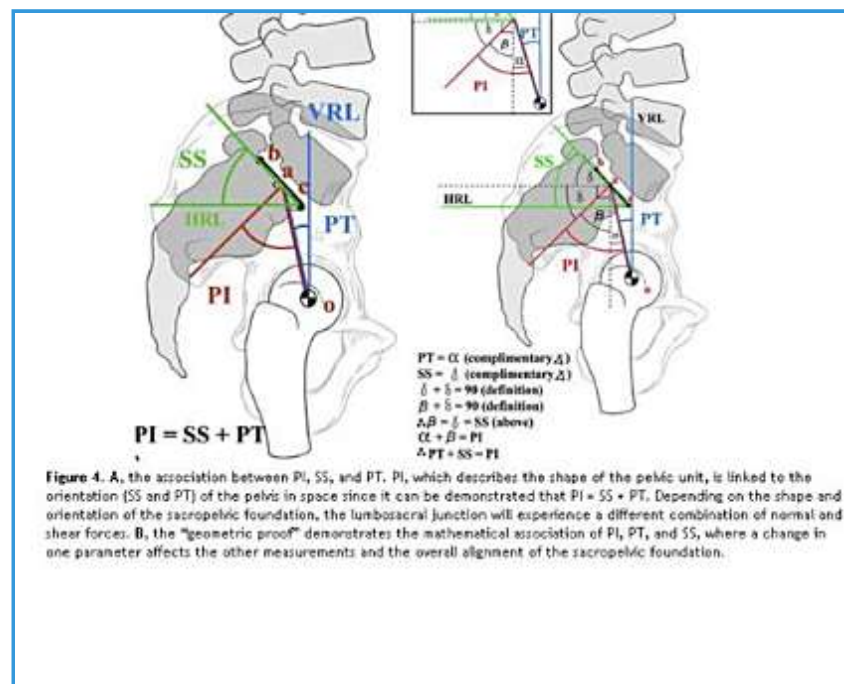


- most important determinant for nonunion and pain

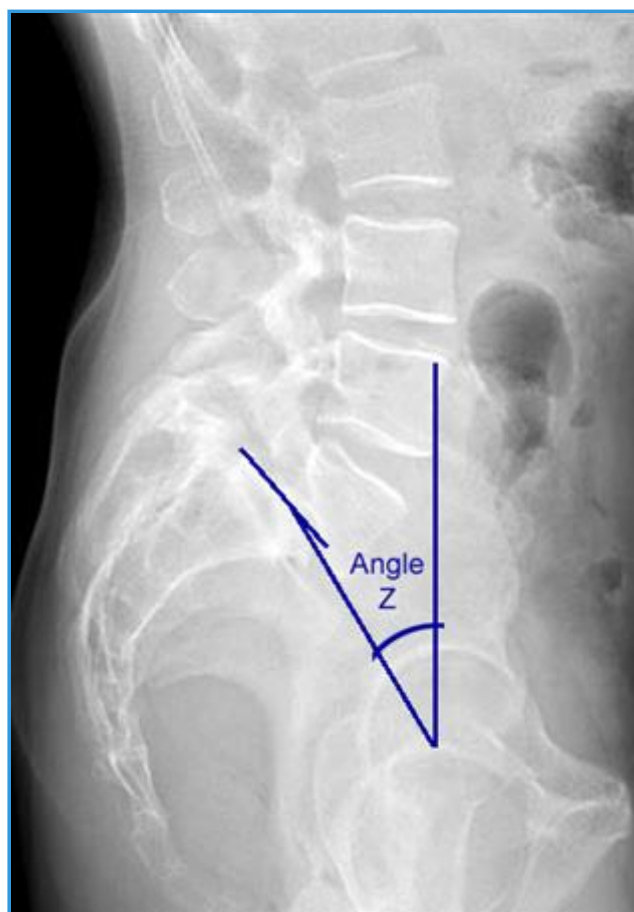
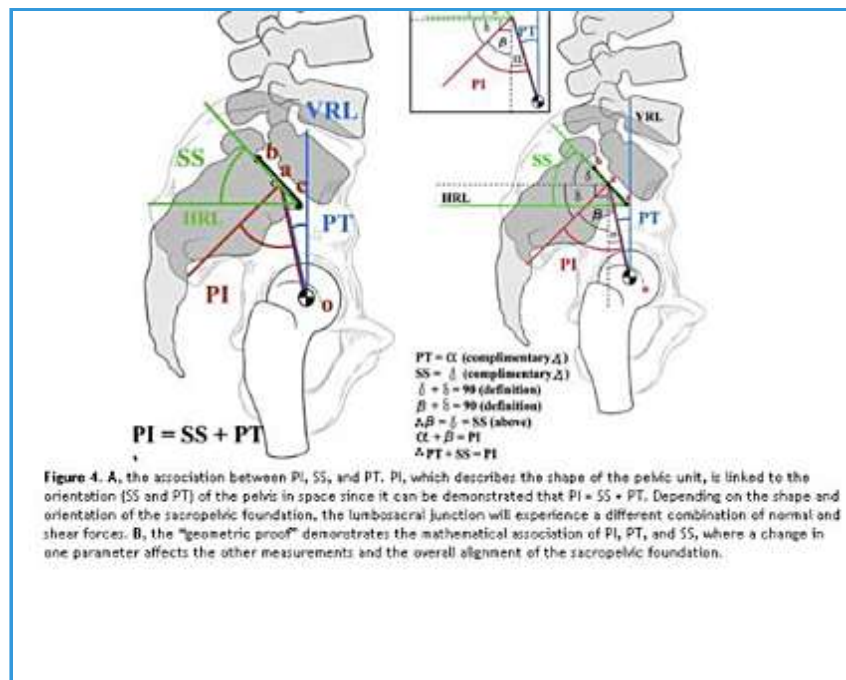
- angle >45-50 degrees associated with greater slip progression, instability, and development of post-op pseudo
- pelvic incidence



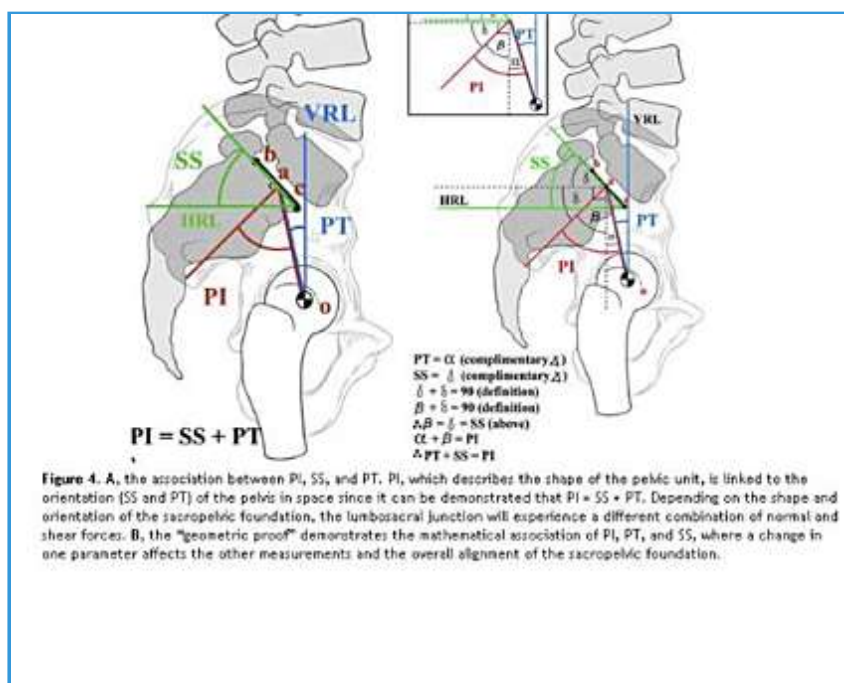
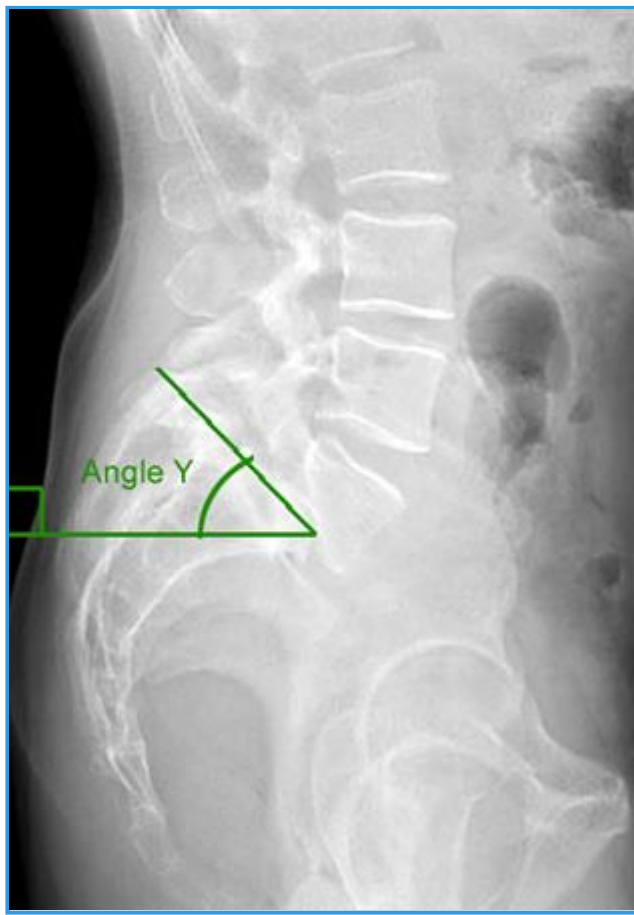
- pelvic incidence = pelvic tilt + sacral slope
- a line is drawn from the center of the S1 endplate to the center of the femoral head
- a second line is drawn perpendicular to a line drawn along the S1 endplate, intersecting the point in the center of the S1 endplate
- the angle between these two lines is the pelvic incidence (see angle X in figure above)
- correlates with severity of disease
- pelvic incidence has direct correlation with the Meyerding-Newman grade



■ pelvic tilt



- pelvic tilt = pelvic incidence - sacral slope
- a line is drawn from the center of the S1 endplate to the center of the femoral head
- a second vertical line (parallel with side margin of radiograph) line is drawn intersecting the center of the femoral head
- the angle between these two lines is the pelvic tilt (see angle Z in figure above)
- sacral slope



- sacral slope = pelvic incidence - pelvic tilt
- a line is drawn parallel to the S1 endplate
- a second horizontal line (parallel to the inferior margin of the radiograph) is drawn
- the angle between these two lines is the sacral slope (see angle Y in the figure above)

■ CT

- best study to diagnose and delineate anatomy of pars defect

■ MRI

- indicated if neurologic symptoms present
- useful to diagnose associated central and foraminal stenosis

• Treatment

○ Nonoperative

- **observation alone** (no activity limitations)
 - indications
 - asymptomatic patients

- regardless of slip grade which does not correlate with clinical presentation
- return to in contact sports is controversial
 - limited evidence to guide surgeons following surgical management, decision must be individualized
 - some data shows patients who stop sports for at least 3 months have improved outcomes compared to those who continue to play
- outcomes
 - typically do well and remain asymptomatic
- **physical therapy & activity restriction**
 - indications
 - symptomatic isthmic spondylolysis
 - symptomatic low-grade spondylolisthesis
 - technique
 - physical therapy should be done for 6 months and include
 - hamstring stretching
 - pelvic tilts
 - abdominal strengthening
 - outcomes
 - most improve and do not require surgery
 - watch low grade dysplastic carefully as there is a higher chance of progression
- **bracing for 6 to 12 weeks**
 - indications
 - acute pars stress reaction spondylolysis
 - isthmic spondylolysis that has failed to improve with physical therapy
 - low grade spondylolisthesis that has failed to improve with physical therapy
 - technique
 - typically a TLSO
 - outcomes
 - brace immobilization is superior to activity restriction alone for acute stress reaction spondylolysis
- Operative
 - **pars interarticularis repair**
 - indications
 - L1 to L4 isthmic defect that has failed nonoperative management
 - multiple pars defects

- outcomes
 - typically superior to fusion procedures, preserves motion
- **L5-S1 posterolateral fusion, +/- ALIF, +/- sacroiliac fusion**
 - indications
 - L5 spondylolysis that has failed nonoperative treatment
 - low grade spondylolisthesis (Meyerding Grade I and II) that
 - has failed nonoperative treatment
 - is progressive
 - has neurologic deficits
 - is dysplastic due to high propensity for progression
 - return to sport
 - some evidence to support that ALIF may help return to competitive sports
 - most surgeons allow return to noncontact sports 3-6 months following fusion and return to contact sports 6-12 months (controversial)
 - outcomes
 - patients typically do well and return to sport in 3-6 months
- **L4-S1 posterolateral fusion, +/- reduction , +/- sacroiliac fusion, +/- ALIF**
 - indications
 - high grade spondylolytic spondylolisthesis (Meyerding Grade III, IV, V)
 - reduction is extremely controversial with no accepted guidelines
 - outcomes
 - patients typically do well but may have greater motion limitations with multi-level fusion
 - over-aggressive reduction techniques may result in neurologic impairments

• Techniques

○ **Par interarticularis repair**

- approach
 - posterior midline approach to lumbar spine
- technique
 - repair pars defect with screw fixation, tension wiring, or screw and sublaminar hook technique
 - decompression indicated if clinical symptoms of stenosis

- contraindications
 - disc degeneration (obtain MRI for sx planning)
- **L5-S1 posterolateral fusion +/- ALIF**
 - approach
 - posterior midline approach to lumbar spine
 - technique
 - decompression only indicated if clinical symptoms of stenosis or radiculopathy
 - in-situ fusion with bone grafting / with or without instrumentation
 - postoperative
 - usually postoperative immobilization in a TLSO
- **L4-S1 posterolateral fusion, +/- reduction , +/- sacroiliac fusion, +/- ALIF**
 - approach
 - posterior midline approach to lumbar spine
 - technique
 - reduction
 - reduction may be done with instrumentation or positioning
 - pros of reduction
 - can restore sagittal alignment and reduce lumbosacral kyphosis
 - cons
 - risk of significant complications (8-30%) including
 - L5 is the most common nerve root injury with reduction
 - sexual dysfunction
 - catastrophic neurologic injury
 - fusion/decompression
 - usually instrumented
 - the addition of decompression and anterior-posterior (360 deg) fusion is associated with more in-hospital complications
 - the use of interbody cages in this population has decreased significantly, while costs associated with treatment in general have increased over time

• Complications

- Neurologic deficits
 - consider neuromonitoring during reduction, especially in a high-grade slip
 - L5 n. root injury is the most common neuro cx

- Pseudoarthrosis
- Slip Progression
- Hardware failure

- Prognosis

- Most symptomatic patients can be successfully managed nonoperatively
- In patients who fail non-operative management, spinal fusion results in 90% success rates
- Return to sports is controversial

41- Traumatic Spondylolisthesis Of Axis

Hangmans Fracture

- summary

- Traumatic Spondylolisthesis of Axis, also known as a Hangman's Fracture, is a traumatic fracture of the bilateral pars interarticularis of C2.
- Diagnosis is made with CT of the cervical spine.
- Treatment may be C-collar immobilization, halo immobilization, or surgical stabilization depending on displacement, angulation, and fracture stability.

- Etiology

- Mechanism
 - hyperextension
 - leads to fracture of pars
 - secondary flexion
 - tears PLL and disc allowing subluxation
- Associated injuries
 - 30% have concomitant c-spine fx

- Presentation

- Symptoms
 - neck pain
- Physical exam
 - patients are usually neurologically intact

- Imaging

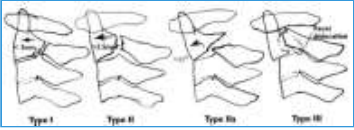
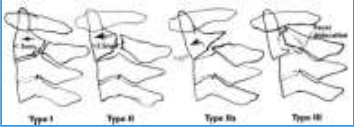
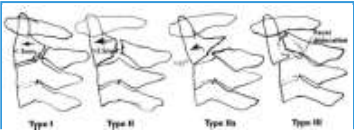
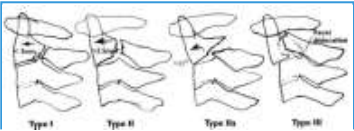
- Radiographs
 - flexion and extension radiographs show subluxation



- CT
 - study of choice to delineate fracture pattern
- MRA
 - consider if suspicious of a vascular injury to the vertebral artery

- Classification

- Levine and Edwards Classification
- (based on mechanism of injury)

	■ <i>Mechanism</i>	■ Characteristics	■ <i>Treatment</i>
■ Type I 	■ Axial compression and hyperextension	■ < 3mm horizontal displacement C2/3 ■ No angulation ■ C2/3 disc remains intact ■ S table fx pattern	■ Rigid collar x 4-6 weeks
■ Type II 	■ Hyperextension and axial load followed by rebound flexion	■ > 3mm of horizontal displacement ■ Significant angulation ■ Vertical fracture line ■ C2/3 disc and PLL are disrupted ■ U nstable fracture pattern	■ If < 5 mm displacement, reduction with traction then halo immobilization x 6-12 weeks ■ If > 5mm displacement,Â displacement, surgery or prolonged traction ■ Usually heal despite displacement (autofuse C2 on C3)
■ Type IIA 	■ Flexion-distraction	■ No horizontal displacement ■ Horizontal fracture line ■ Significant angulation	■ Avoid traction in Type IIA. ■ Reduction with gentle axial load + hyperextension, then compression halo immobilization for 6-12 weeks.
■ Type III 	■ Flexion-distraction followed by hyperextension	■ Type I fracture with associated bilateral C2-3 facet dislocation ■ Rare injury pattern	■ Surgical reduction of facet dislocation followed by stabilization required.

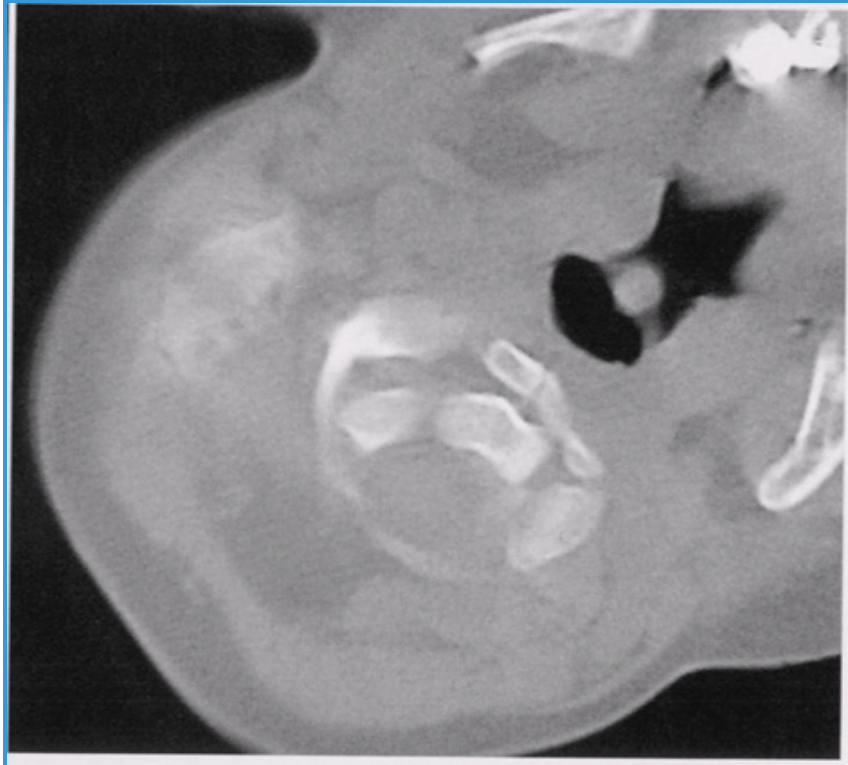
- Treatment

- Nonoperative
 - **rigid cervical collar x 4-6 weeks**
 - indications
 - Type I fractures (< 3mm horizontal displacement)
 - **closed reduction followed by halo immobilization for 8-12 weeks**
 - indications
 - Type II with 3-5 mm displacement
 - Type IIA
 - reduction technique
 - Type II use axial traction combined + extension
 - Type IIA use hyperextension (avoid axial traction in Type IIA)
- Operative

- **reduction with surgical stabilization**
 - indications
 - Type II with > 5 mm displacement and severe angulation
 - Type III (facet dislocations)
 - technique
 - anterior C2-3 interbody fusion
 - posterior C1-3 fusion
 - bilateral C2 pars screw osteosynthesis

42- Atlantoaxial Rotatory Displacement Aard

Images



- summary

- Atlantoaxial Rotatory Displacement is a pediatric cervical spine rotatory instability caused by C1-C2 subluxation or facet dislocation
- The most common presentation is a young child who presents with torticollis.
- Diagnosis is made by dynamic CT scan of the cervical spine.
- Treatment can be a soft collar, halter traction, halo traction, or surgical fusion depending on the chronicity of the condition.

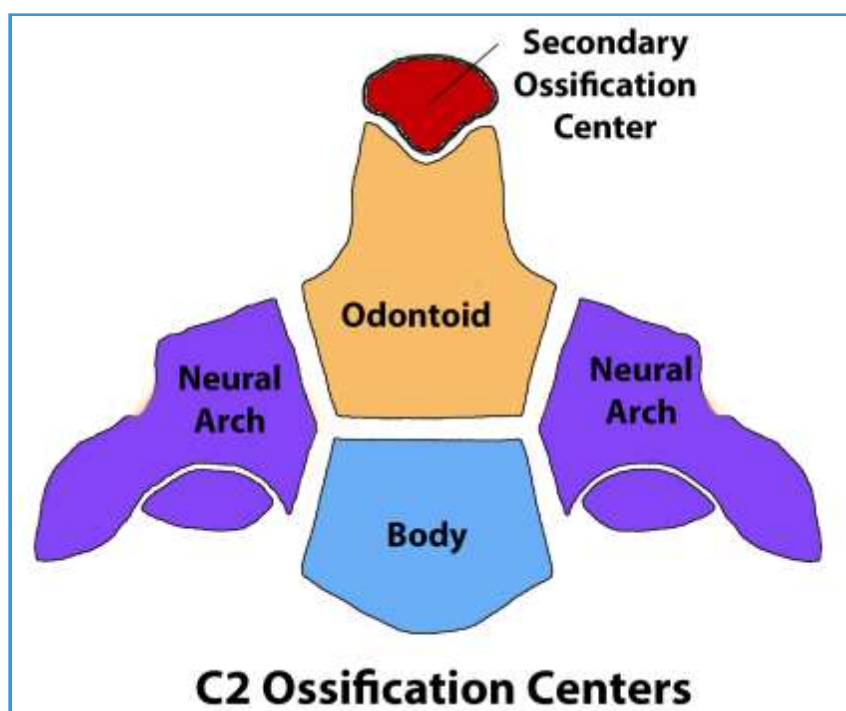
- Etiology

- Mechanism
 - spectrum of disease that ranges from mild subluxation to fixed facet dislocation
- Pathophysiology
 - common causes include
 - infection (~35%)
 - may have history of pharyngitis or otitis media
 - Grisel's disease is the condition of AARD following a respiratory infection or retropharyngeal abscess
 - thought to be linked to lymphatic edema in area of cervical spine
 - trauma (~24%)

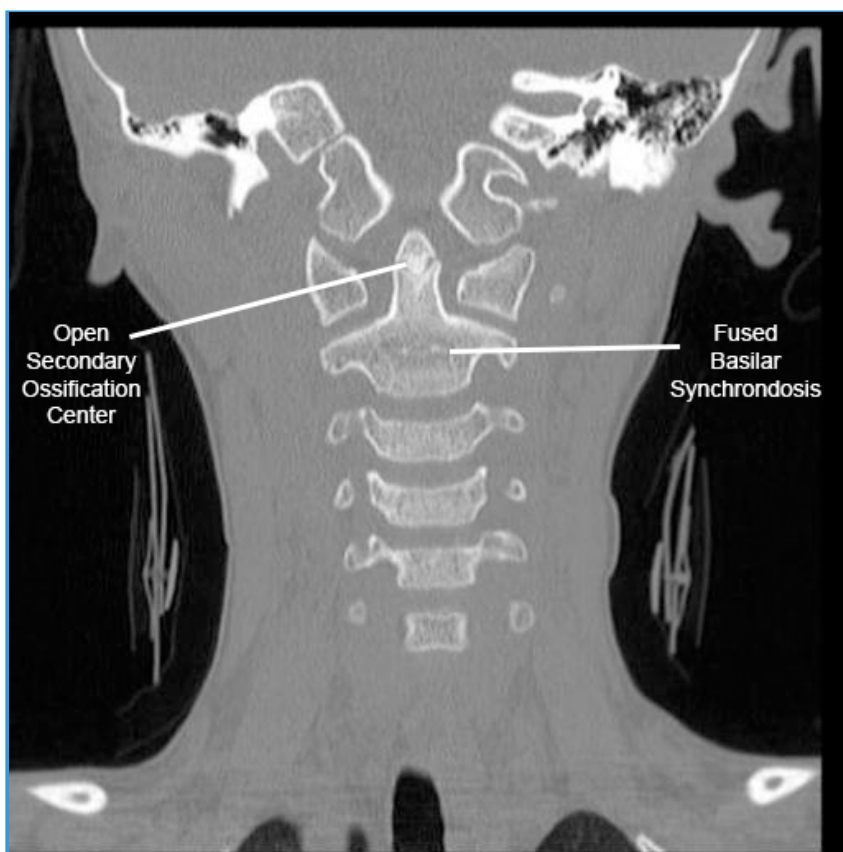
- recent head or neck surgery (~20%)
- idiopathic
- associated conditions
 - Down's syndrome
 - rheumatoid arthritis
 - tumors
 - congenital anomalies
- pathoanatomy
 - mechanism is thought to be related to ligamentous laxity
 - transverse ligament integrity
 - transverse ligament is intact
 - spinal canal stenosis can only occur with severe rotation and facet dislocation
 - transverse ligament is ruptured
 - and there is a component of anterolisthesis (> 5mm), then spinal canal stenosis can occur with less rotation (45 degrees)
 - vertebral arteries may also be at risk

• Anatomy

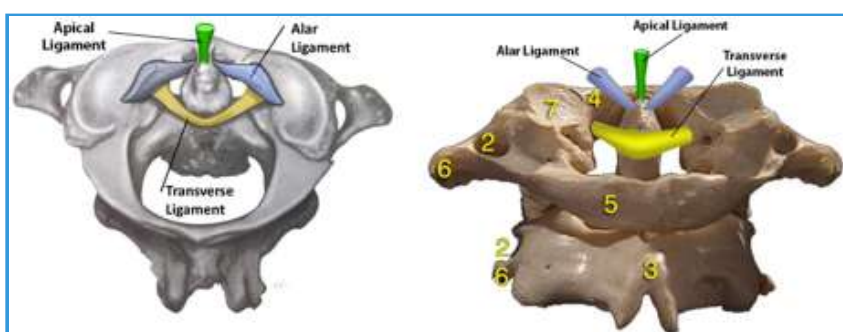
- Axis Osteology
 - axis has odontoid process (dens) and body
 - embryology
 - develops from five ossification centers



- subdental (basilar) synchondrosis is an initial cartilagenous junction between the dens and vertebral body that does not fuse until ~6 years of age

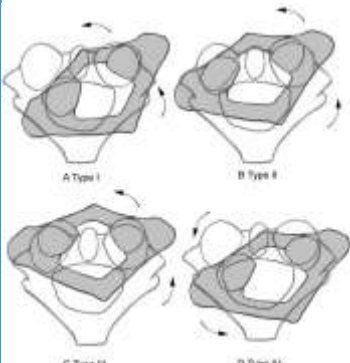
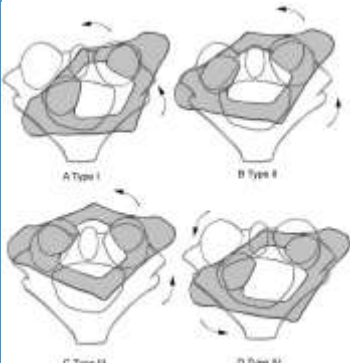
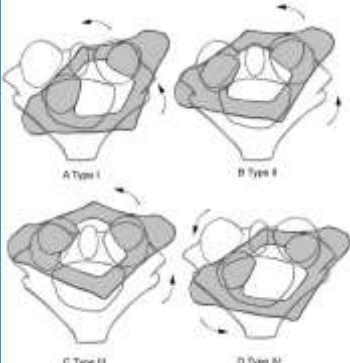
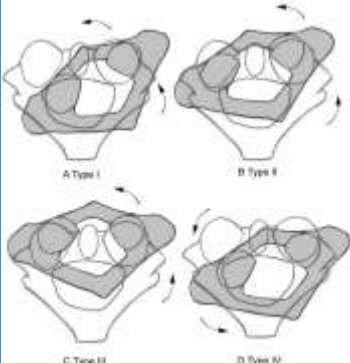


- the secondary ossification center appears at ~ age 3 and fuses to the dens at ~ age 12
- Occipital-C1-C2 ligamentous stability
 - provided by the odontoid process and its supporting ligaments
 - transverse ligament



- limits anterior translation of the atlas
- apical ligaments
 - limit rotation of the upper cervical spine
- alar ligaments
 - limit rotation of the upper cervical spine

• Classification

○	Fielding Classification of AARD	
Type I	- Unilateral facet subluxation with intact transverse ligament - Odontoid acts as a pivot point with 1 facet subluxating anteriorly, 1 facet subluxating posteriorly. - Most common and benign type	
Type II	- Unilateral facet subluxation with 3 to 5 mm of anterior displacement. - Injured Transverse ligament 1 facet acts as a pivot point and 1 lateral mass is displaced anteriorly	
Type III	- Bilateral anterior facet displacement of > 5 mm. - Rare with a higher risk of neurologic involvement or instantaneous death. - Both lateral masses are displaced	
Type IV	- Posterior displacement of the atlas (C1) (with odontoid fracture, or hypoplastic dens) - Rare with a higher risk of neurologic involvement or instantaneous death.	

• Physical Exam

○ Symptoms

- tilted head
- neck pain
- headache

○ Physical exam

- ipsilateral rotation and contralateral tilt of the head in relation to the lateral mass of C1
 - chin rotated to the side opposite the facet subluxation (e.g. right sided facet subluxation will have chin rotated to the left)
- contra-lateral sternocleidomastoid may be spastic
 - sternocleidomastoid (SCM) spasm occurs on the SAME side as the chin (e.g. right sided facet subluxation will have chin rotated to the left, and left SCM will be spastic)
 - this protective spasticity occurs to reduce further subluxation
 - C1-C2 subluxation (and resultant chin position) is primary, SCM spasm is secondary/reactive

- in contrast to congenital muscular torticollis where the SCM spasm occurs on the OPPOSITE side of the chin (e.g. left SCM spasm will rotate the head to the right, and chin will be on the right)
 - SCM spasm is primary
- reduced cervical rotation

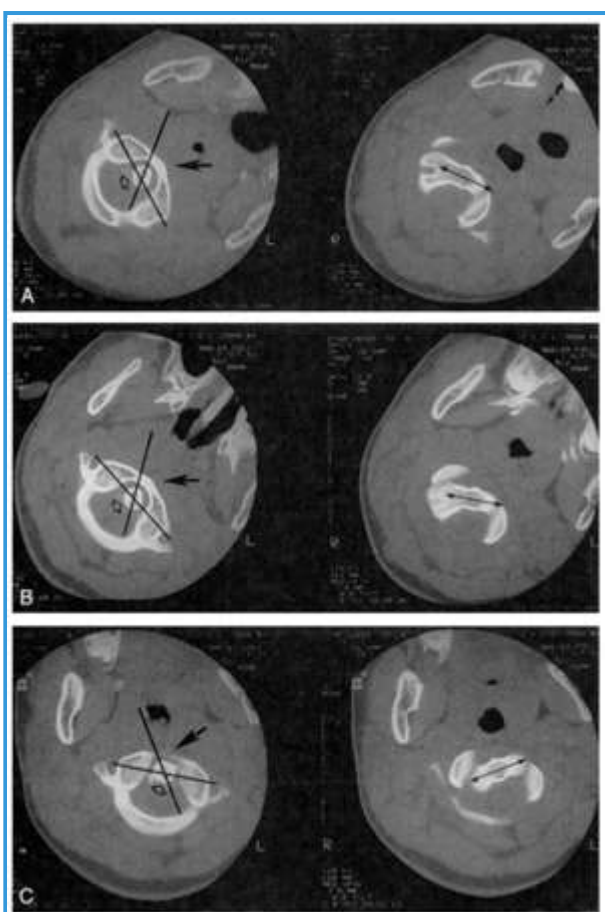
• Imaging

○ Radiographs

- recommended views
 - AP, open-mouth odontoid
 - look for variation in size and distance from midline of C2 lateral masses (reflects rotation)
 - lateral
 - facet joint appears anterior and wedge shaped instead of normal oval shape
 - cervical flexion & extension views
 - may be useful to exclude instability
 - may be difficult due to position of head and resisted neck motion

○ Dynamic CT

- is diagnostic gold standard
- take CT with head straight forward, and then in maximal rotation to right and left
 - will see fixed rotation of C1 on C2 which does not change with dynamic rotation



○ MRI

- of little value unless neurologic symptoms

- Treatment

- Nonoperative

- **soft collar, NSAIDs, exercise program**
 - indications
 - subluxation present for < 1 week (traumatic or Grisel's disease)
 - many patients probably reduce spontaneously before seeking medical attention
 - **head halter traction, NSAIDs, benzodiazepines, then hard collar x 3 months**
 - indications
 - subluxation persists > 1 week
 - persistent torticollis in spite of soft collar (above) x 2 weeks
 - technique
 - small amount (5 lbs.) usually enough
 - either in hospital or at home
 - muscle relaxants and analgesics may be needed
 - **halo traction, then halo vest x 3 months**
 - indications
 - subluxation persists > 1 mos.
 - failed halter traction x 2 weeks (above)

- Operative

- **posterior C1-C2 fusion**
 - indications
 - subluxation persists > 3 mos
 - neurologic deficits present
 - failed halo traction x 2 weeks
 - recurrent subluxation

- Complications

- Missed diagnosis
 - diagnosis is often missed delayed

43- Congenital Muscular Torticollis

Images



- SUMMARY

- Congenital Muscular Torticollis is a musculoskeletal deformity caused by the abnormal contraction of the sternocleidomastoid muscle.
- The condition typically presents in infants and children with a persistent head tilt toward the involved side.
- Diagnosis is made clinically with the presence of a palpable neck mass from a contracted sternocleidomastoid muscle with the chin rotated towards the contralateral side.
- Treatment is typically passive stretching with the condition resolving within a year. Surgical lengthening of the SCM muscle is indicated with failed response to at least 1 year of stretching.

- Epidemiology

- Incidence
 - most common cause of infantile torticollis
 - 0.3 - 2.0%
- Demographics
 - 3:2 male to female ratio
- Anatomic location
 - neck
- Risk factors
 - oligohydramnios
 - first pregnancy (limited intrauterine space)

- traumatic delivery
- breech delivery

- Etiology

- Pathophysiology
 - contracture of the sternocleidomastoid (SCM)
 - cervical rotational deformity with chin rotation away from the affected side and head tilt towards the affected side
 - suspected muscle injury from compression and stretching of SCM
 - venous outflow obstruction
 - compression leading to decreased blood supply and subsequent compartment syndrome
- Associated conditions
 - associated with other packaging disorders
 - developmental dysplasia of the hip (5 - 15% association)
 - metatarsus adductus
 - calcaneovalgus feet
 - plagiocephaly (asymmetric flattening of the skull)
 - occurs on contralateral side
 - congenital atlanto-occipital abnormalities

- ANATOMY

- Muscles
 - sternocleidomastoid muscle (SCM)
 - origins
 - sternal head - anterior surface of manubrium sterni
 - clavicular head - superior surface of medial third of clavicle
 - insertions
 - lateral mastoid process on temporal bone
 - lateral occipital bone
 - innervation
 - cranial nerve XI - spinal accessory nerve
 - at risk when operatively releasing SCM
 - function
 - ipsilateral neck flexion, contralateral head rotation

- PRESENTATION

- Symptoms

- head tilt and rotation
- painless passive motion
- Physical exam
 - inspection
 - palpable neck mass from contracted SCM
 - usually noted within the first four weeks of life or during newborn exam



- head tilt & rotation
 - neck tilt towards the affected SCM
 - chin rotation away from the affected SCM



- conduct routine baby exam
 - assess visual function, auditory assessment, and neurologic exam
 - examine for hip dysplasia, foot deformities, as well as spine abnormalities
- motion
 - in older children - restriction of rotation and lateral flexion of neck
 - mass becomes a tight band

• IMAGING

- Radiographs
 - recommended views
 - AP and lateral cervical spine
 - indications
 - head tilt and rotation with no palpable mass present

- rule out other bony conditions that can cause torticollis
- CT
 - recommended views
 - dynamic CT scan
 - scan at C1-C2 level with head straight, then in maximum rotation to left and right
 - indications
 - rule out atlantoaxial rotatory subluxation
- MRI
 - recommended views
 - MRI brain and cervical spine
 - indications
 - rule out non-muscular and central causes of torticollis
- Ultrasound
 - indications
 - head tilt and rotation with decreased ROM in the presence of a palpable mass
 - findings
 - larger and hyperechoic (due to fibrosis) SCM on involved side when compared to contralateral side
 - differentiate congenital muscular torticollis from more serious underlying neurologic or osseous abnormalities

• DIFFERENTIAL

- Atlantoaxial rotatory subluxation
 - painful (compared to painless for congenital muscular torticollis)
 - post-traumatic or post-infectious (Grisel's disease)
- Klippel-Feil syndrome
 - classic triad:
 - short webbed neck
 - low posterior hairline
 - limited cervical range of motion
- Ophthalmologic and vestibular conditions
- Lesions of central and peripheral nervous system

• TREATMENT

- Nonoperative
 - **passive stretching**

- indications
 - condition present for less than 1 year
 - less than 30° limitation in ROM
- outcomes
 - 90-95% respond to passive stretching in the first year of life
- Operative
 - **bipolar release of SCM or Z-lengthening**
 - indications
 - failed response to at least 1 year of stretching
 - outcomes
 - good outcomes (92% success), even in older children
 - facial asymmetry can improve as long as release done prior to 10 years of age

• TECHNIQUES

- **Passive stretching**
 - technique
 - opposite of the deformity
 - lateral head tilt away from affected side
 - chin rotation toward the affected side
- **Bipolar release of SCM or Z-lengthening**
 - technique
 - short, proximal incision behind the ear to divide SCM
 - single or dual incision to reach sternal and clavicular attachments of SCM
 - complications
 - SCM branch of CN XI (spinal accessory nerve) is at risk

• COMPLICATIONS

- Permanent rotational deformity
 - risk factors
 - left untreated or unnoticed
- Positional plagiocephaly
 - risk factors
 - left untreated or unnoticed
- Craniofacial deformities
 - facial asymmetry
 - facial hemihypoplasia

- Compensatory scoliosis

- Prognosis

- Typically resolves with stretching within the first year
- If left untreated
 - permanent rotational deformity
 - positional plagiocephaly
 - craniofacial deformities
 - facial asymmetry
 - facial hemihypoplasia
 - compensatory scoliosis

44- Adolescent Idiopathic Scoliosis

Images



- summary

- Adolescent Idiopathic Scoliosis is a coronal plane spinal deformity which most commonly presents in adolescent girls from ages 10 to 18.
- Diagnosis is made with full-length standing PA and lateral spine radiographs.
- Treatment can be observation, bracing, or surgical management depending on the skeletal maturity of the patient, magnitude of deformity, and curve progression.

- Epidemiology

- Incidence
 - most common type of scoliosis
 - incidence of 3% for curves between 10 to 20°
 - incidence of 0.3% for curves > 30°
- Demographics
 - most commonly presents in children 10 to 18 yrs
 - 10:1 female to male ratio for curves > 30°
 - 1:1 male to female ratio for small curves
 - right thoracic curve most common

- left thoracic curves are rare and indicate an MRI to rule out cyst or syrinx

- Etiology

- Pathophysiology

- unknown
 - potential causes
 - multifactorial
 - hormonal (melatonin)
 - brain stem
 - proprioception disorder
 - platelet
 - calmodulin
 - abnormal development of neurocentral synchondrosis (NCS)
 - cartilaginous plate that forms between the centrum and posterior neural arches
 - closure occurs in characteristic order
 - cervical NCS by 5-6 years old
 - lumbar NCS by 11-12 years old
 - thoracic NCS by 14-17 years old
 - most have a positive family history

- Curve Progression

- risk factors for progression (at presentation)
 - curve magnitude
 - before skeletal maturity
 - $> 25^\circ$ before skeletal maturity will continue to progress
 - after skeletal maturity
 - $> 50^\circ$ thoracic curve will progress $1-2^\circ$ / year
 - $> 40^\circ$ lumbar curve will progress $1-2^\circ$ / year
 - remaining skeletal growth
 - younger age
 - < 12 years at presentation
 - Tanner stage (< 3 for females)
 - Risser Stage (0-1)
 - Risser 0 covers the first 2/3rd of the pubertal growth spurt
 - correlates with the greatest velocity of skeletal linear growth
 - open triradiate cartilage
 - peak growth velocity

- is the best predictor of curve progression
 - in females it occurs just before menarche and before Risser 1 (girls usually reach skeletal maturity 1.5 yrs after menarche)
 - most closely correlates with the Tanner-Whitehouse III RUS method of skeletal maturity determination
 - if curve is $>30^\circ$ before peak height velocity there is a strong likelihood of the need for surgery
- curve type
 - thoracic more likely to progress than lumbar
 - double curves more likely to progress than single curves

• Classification

- King-Moe Classification
 - five part classification to describe thoracic curve patterns and help guide surgeons implanting Harrington instrumentation
 - [link to King-Moe classification \(not testable\)](#)
- Lenke Classification
 - more comprehensive classification based on PA, lateral, and supine bending films
 - helps to decide upon which curves need to be included within the fusion construct
 - [link to Lenke classification \(not testable\)](#)

• Presentation

- School screening
 - patients often referred from school screening where a 7° curve on scoliometer during Adams forward bending test is considered abnormal
 - 7° correlates with 20° coronal plane curve
- Physical exam
 - special tests
 - Adams forward bending test



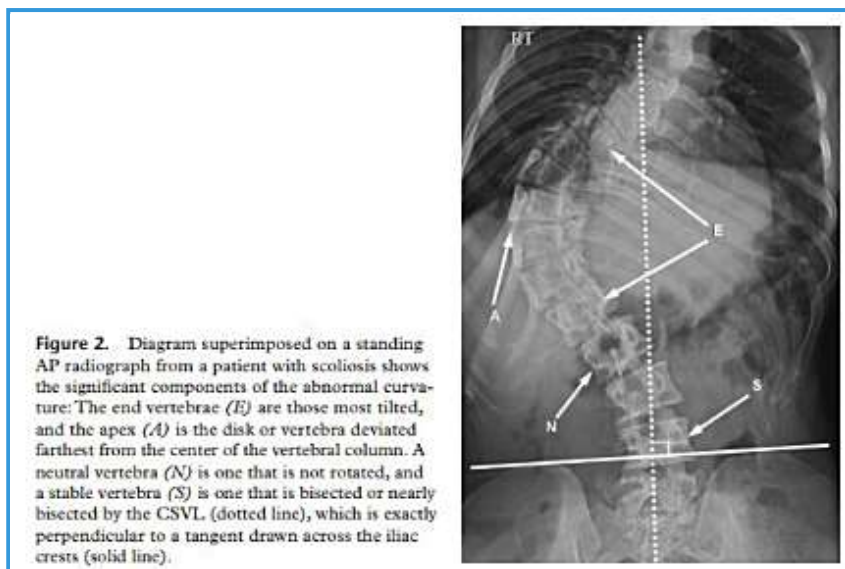
- axial plane deformity indicates structural curve
 - forward bending sitting test
 - can eliminate leg length inequality as cause of scoliosis
- other important findings on physical exam
 - leg length inequality
 - midline skin defects (hairy patches, dimples, nevi)
 - signs of spinal dysraphism
 - shoulder height differences
 - truncal shift
 - rib rotational deformity (rib prominence)
 - waist asymmetry and pelvic tilt
 - cafe-au-lait spots (neurofibromatosis)
 - foot deformities (cavovarus)
 - can suggest neural axis abnormalities and warrant a MRI
 - asymmetric abdominal reflexes
 - perform MRI to rule out syringomyelia

• Imaging

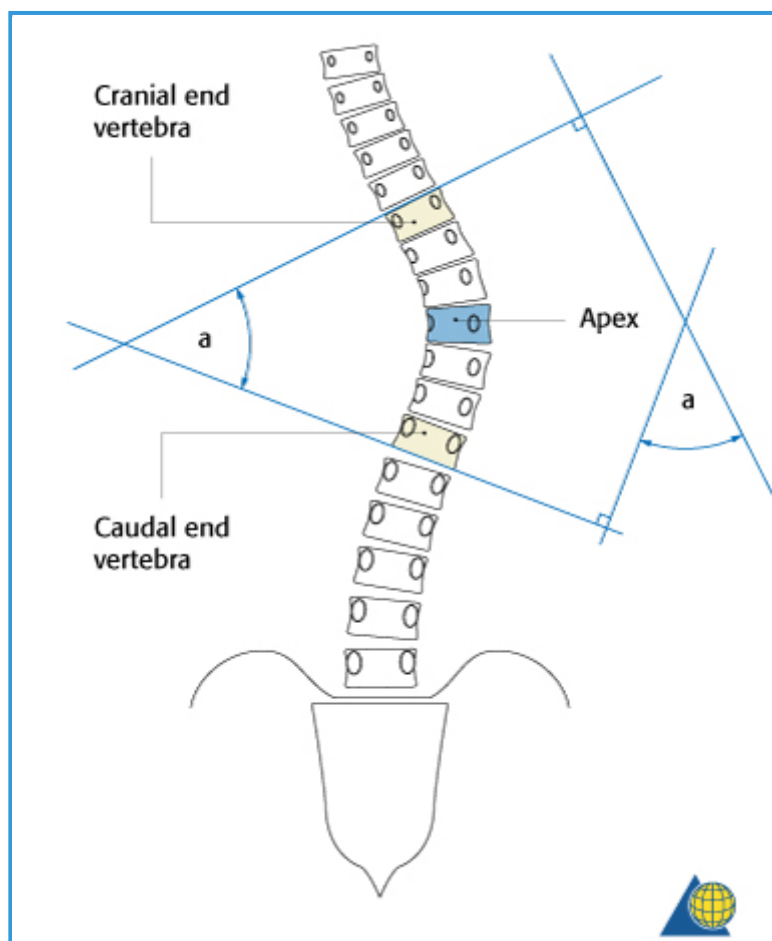
○ Radiographs

- recommended views
 - standing PA and lateral
- Cobb angle
 - $> 10^\circ$ defined as scoliosis
 - intra-interobserver error of $3-5^\circ$
- spinal balance
 - coronal balance is determined by alignment of C7 plumb line to central sacral vertical line
 - sagittal balance is based on C7 plumb from center of C7 to the posterior-superior corner of S1

- stable zone
 - between lines drawn vertically from lumbosacral facet joints
- stable vertebrae
 - most proximal vertebrae that is most closely bisected by central sacral vertical line
- neutral vertebrae



- rotationally neutral (spinous process equal distance to pedicles on PA xray)
- end vertebrae
 - end vertebra is defined as the vertebra that is most tilted from the horizontal apical vertebra



- apical vertebrae
 - the apical vertebrae is the disk or vertebra deviated farthest from the center of the vertebral column
- clavicle angle
 - best predictor of postoperative shoulder balance
- MRI
 - should extend from posterior fossa to conus
 - purpose is to rule out intraspinal anomalies

- indications to obtain MRI
 - atypical curve pattern (left thoracic curve, short angular curve, apical kyphosis)
 - rapid progression
 - excessive kyphosis
 - structural abnormalities
 - neurologic symptoms or pain
 - foot deformities
 - asymmetric abdominal reflexes
 - a syrinx is associated with abnormal abdominal reflexes and a curve without significant rotation

- Treatment

- Based on skeletal maturity of patient, magnitude of deformity, and curve progression
- Nonoperative
 - **observation alone**
 - indications
 - cobb angle $< 25^{\circ}$
 - technique
 - obtain serial radiographs to monitor for progression
 - **bracing**
 - indication
 - cobb angle from 25° to 45°
 - only effective for flexible deformity in skeletally immature patient (Risser 0, 1, 2)
 - goal is to stop progression, not to correct deformity
 - outcomes
 - 50% reduction in need for surgery with compliant brace wear of at least 13 hours a day
 - poor prognosis with brace treatment associated with
 - poor in-brace correction
 - hypokyphosis (relative contraindication)
 - male
 - obese
 - noncompliant (effectiveness is dose-related)
 - the number needed to treat (NNT) is four in highly compliant patients

- Sanders staging system
 - predicts the risk of curve progression despite bracing to >50 degrees in Lenke type I and III curves
 - uses anteroposterior hand radiograph and curve magnitude to assess risk of progression despite bracing
- Operative treatment
 - **posterior spinal fusion**
 - indications
 - cobb angle > 45°
 - can be used for all types of idiopathic scoliosis
 - remains gold standard for thoracic and double major curves (most cases)
 - **anterior spinal fusion**
 - indications
 - best for thoracolumbar and lumbar cases with a normal sagittal profile
 - **anterior / posterior spinal fusion**
 - indications
 - large curves (> 75°) or stiff curves
 - young age (Risser grade 0, girls <10 yrs, boys < 13 yrs)
 - in order to prevent crankshaft phenomenon

• Techniques

- **Bracing**
 - recommended for 16-23 hours/day until skeletal maturity or surgical intervention deemed necessary (actual wear minimum 12 hours required to slow progression)
 - brace types
 - curves with apex above T7
 - Milwaukee brace (cervicothoracolumbosacral orthosis)
 - extends to neck for apex above T7
 - apex at T7 or below
 - TLSO
 - Boston-style brace (under arm)
 - Charleston Bending brace is a curved night brace
 - bracing success is defined as <5° curve progression
 - bracing failure is defined

- 6° or more curve progression at orthotic discontinuation (skeletal maturity)
- absolute progression to >45° either before or at skeletal maturity, or discontinuation in favor of surgery
- skeletal maturity is defined as
 - Risser 4
 - <1cm change in height over 2 visits 6 months apart
 - 2 years postmenarchal
- **Posterior spinal fusion**
 - fusion levels
 - goals
 - fusion should include enough levels to adequately maintain sagittal and coronal balance while being as minimal as safely possible to preserve motion
 - typical fusion from proximal end vertebra to one or two levels cephalad to the stable vertebra
 - double and triple major curves fuse to the distal end vertebra
 - Harrington technique
 - recommends one level above and two levels below the end vertebrae if these levels fall within the stable zone
 - Moe technique
 - recommends fusion to the neutral vertebrae
 - Lenke technique
 - recommends including all major curves in the fusion and minor curves that are not flexible or are kyphotic
 - L5 level
 - Cochran found increase incidence of low back pain with fusion to L5, and to a lesser extent L4.
 - therefore, whenever possible, avoid fusion to L4 and L5
 - pelvis
 - it is almost never required to fuse to the pelvis in idiopathic scoliosis
 - pedicle screw fixation
 - screw insertional torque correlates with resistance to screw pullout
 - resistance to screw pullout increases by
 - undertapping by 1mm
 - curve correction
 - segmental pedicle screw fixation allows increased coronal plane correction while lessening the need for anterior releases

- ASF with instrumentation
 - advantage
 - better correction while saving lumbar fusion levels
 - disadvantage
 - increased risk of pseudarthrosis when thoracic hyperkyphosis is present
 - fusion levels
 - typically fuse from end vertebra to end vertebra
- **Neurologic Monitoring**
 - monitoring with somatosensory-evoked potentials (SSEPs) and/or motor-evoked potentials (MEPs) is now the standard of care
 - motor-evoked potentials can provide an intraoperative warning of impending spinal cord dysfunction
 - neurologic event defined as drop in amplitude of > 50%
 - if neurologic injury occurs intraoperatively consider
 - check for technical problems
 - check blood pressure and elevate if low
 - check hemoglobin and transfuse as necessary
 - lessen/reverse correction
 - administer Stagnaras wake up test
 - remove instrumentation if the spine is stable

• Complications

- Neurologic injury
 - paraplegia is 1:1000
 - increased risk with kyphosis, excessive correction, and sublaminar wires
- Pseudoarthrosis (1-2%)
 - presents as late pain, deformity progression, and hardware failure
 - an asymptomatic pseudarthrosis with no pain and no loss of correction should be observed
- Infection (1-2%)
 - presents as late pain
 - incision often looks clean
 - *Propionibacterium acnes* most common organism for delayed infection (requires 2 weeks for culture incubation)
 - attempt I&D with maintenance of hardware if not loose and within 6 months
- Flat back syndrome

- early fatigability and back pain due to loss of lumbar lordosis
- rare now that segmental instrumentation addresses sagittal plane deformities
 - decreased incidence with rod contouring in the sagittal plane and compression/distraction techniques
- treat with revision surgery utilizing posterior closing wedge osteotomies
 - anterior releases prior to osteotomies aid in maintenance of correction
- Crankshaft phenomenon
 - rotational deformity of the spine created by continued anterior spinal growth in the setting of a posterior spinal fusion
 - can occur in very young patients when PSF is performed alone and the anterior column is allowed continued growth
 - avoided by performing anterior discectomy and fusion with posterior fusion in very young patients
- SMA syndrome (superior mesenteric artery [SMA] syndrome)
 - compression of 3rd part of duodenum due to narrowing of the space between SMA and aorta
 - SMA arises from anterior aspect of aorta at level of L1 vertebrae
 - presents with symptoms of bowel obstruction in first postoperative week
 - associated with electrolyte abnormalities
 - nausea, bilious vomiting, weight loss
 - risk factors
 - height percentile <50%; weight percentile < 25%
 - sagittal kyphosis
 - treat with NG tube and IV fluids
- Hardware failure
 - late rod breakage can signify a pseudarthrosis
- Emergency department visits
 - most often for minor medical complaints
 - associated with older age at the time of surgery and more fusion levels

• Prognosis

- Natural history
 - increased incidence of acute and chronic pain in adults if left untreated
 - curves > 90° are associated with cardiopulmonary dysfunction, early death, pain, and decreased self image

45- Congenital Scoliosis

Images



- summary

- Congenital Scoliosis is a congenital spinal deformity that occurs due to the failure of normal vertebral development during 4th to 6th week of gestation.
- Diagnosis is made with AP and lateral full spine radiographs. MRI is required to assess for neural axis abnormalities.
- Treatment can be observation or surgical management depending on the specific anatomical anomaly, and curve progression.

- Epidemiology

- Prevalence
 - estimated at 1% to 4% in the general population

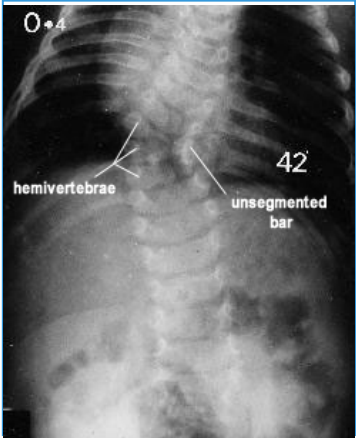
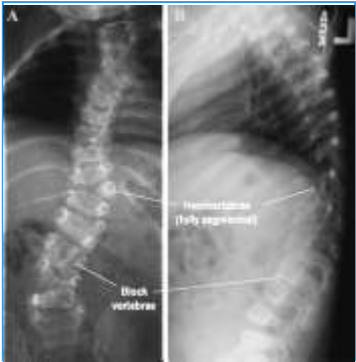
- Etiology

- Mechanism
 - caused by a developmental defect in the formation of the mesenchymal anlage
- Causes
 - most cases occur spontaneously
 - maternal exposures
 - diabetes
 - alcohol
 - valproic acid
 - hyperthermia

- Genetic
 - uncertain
- Associated conditions
 - may occur in isolation or with associated conditions
 - with associated systemic anomalies, up to 61%
 - cardiac defects - 10%
 - genitourinary defects - 25%
 - spinal cord malformations
 - with underlying syndrome or chromosomal abnormality
 - VACTERL syndrome
 - in 38% to 55%
 - characterized by vertebral malformations, anal atresia, cardiac malformations, tracheo-esophageal fistula, renal, and radial anomalies, and limb defects
 - Goldenhar/OculoAuricularVertebral Syndrome
 - hemifacial microsomia and epibulbar dermoids
 - Jarcho-Levin Syndrome/Spondylocostal dysostosis
 - short trunk dwarfism, multiple vertebral and rib defects and fusion
 - most commonly autosomal recessive
 - often associated with thoracic insufficiency syndrome (TIS)
 - caused by shortening of the thorax and rib fusions
 - result is thorax is unable to support lung growth and respiratory decompensation
 - Klippel-Feil syndrome
 - short neck, low posterior hairline, and fusion of cervical vertebrae
 - Alagille syndrome
 - peripheral pulmonic stenosis, cholestasis, facial dysmorphism

- Classification

Classification of Congenital Scoliosis		
Failure of Formation	- Fully segmented hemivertebra -has normal disc space above and below	
	- Semisegmented hemivertebra -hemivertebra fused to adjacent vertebra on one side with disk on the other	
	- Unsegmented hemivertebra -hemivertebra fused to vertebra on each side	
	- Incarcerated hemivertebra -found within lateral margins of the vertebra above and below	
	- Unincarcerated hemivertebra -laterally positioned	
	- Wedge vertebra	
Failure of Segmentation	- Block vertebra (bilateral bony bars)	
	- Bar body (unilateral unsegmented bar is common and likely to progress)	
Mixed	- Unilateral unsegmented bar with contralateral hemivertebra (most rapid progression)	



- Imaging
 - Radiographs
 - recommended views
 - AP and lateral plain films usually sufficient to confirm diagnosis
 - CT
 - indications

- judicious use recommended due to radiation exposure
- 3D CT useful to better delineate posterior bony anatomy and define type for surgical planning

○ MRI

- indications
 - all patients with congenital scoliosis prior to surgery to evaluate for neural axis abnormality (found in 20-40%) including
 - Chiari malformation
 - tethered cord
 - syringomyelia
 - diastematomyelia
 - intradural lipoma
 - technique
 - sedation required in infants so may be delayed if no surgery is planned and no neuro deficits
- #### ○ Additional medical studies
- important to obtain studies for associated abnormalities
 - renal ultrasound or MRI
 - echocardiogram if suspicion for cardiac manifestations

● Treatment

○ Nonoperative

- **observation and bracing**
 - indications for observation
 - absence of documented progression, ie:
 - incarcerated hemivertebrae
 - nonsegmental hemivertebrae
 - some partially segmented hemivertebrae
 - bracing
 - not indicated in primary treatment of congenital scoliosis (no effectiveness shown)
 - may be used to control supple compensatory curves, but effectiveness is unproven

○ Operative

- **posterior fusion (+/- osteotomies and modest correction)**
 - indications
 - hemi-vertebrae opposite a unilateral bar that does not require a vertebrectomy at any age. this otherwise will relentlessly progress

until fused.

- older patients with significant progression, neurologic deficits, or declining respiratory function
- having many pedicle screws may decrease crankshaft phenomenon and obviate the need for an anterior fusion.
- **anterior/posterior spinal fusion +/- vertebrectomy**
 - indications
 - young patients with significant progression, neurologic deficits, or declining respiratory function
 - girls < 10 yrs
 - boys < 12 yrs
 - patients with failure of formation with contralateral failure of segmentation at any age that requires hemi-vertebrectomy and/or significant correction. This may be done from a posterior approach
 - technique
 - nutritional status of patient must be optimized prior to surgery
- **distraction based growing rod construct**
 - indications
 - may be used in an attempt to control deformity during spinal growth and delay arthrodesis
 - outcomes
 - need to be lengthened approximately every 6 months for best results
- **osteotomies between ribs**



- indications
 - multiple (>4) fused ribs with potential for thoracic insufficiency syndrome
- outcomes
 - long-term follow up is needed to determine efficacy. the downside is this may make the chest stiff and hurt pulmonary function.
- **Hemi-Vertebrectomy** - usually done from a posterior approach, particularly with kyphosis.
 - indications - age 3-8 years (younger is difficult to get good anchor purchase)
 - progressive or significant deformity

• Techniques

- **Spinal arthrodesis +/- vertebrectomy/osteotomy**
 - in situ arthrodesis, anterior/posterior or posterior alone
 - indications
 - unilateral unsegmented bars with minimal deformity
 - hemiepiphysiodesis
 - indications
 - intact growth plates on the concave side of the deformity
 - patients less than 5 yrs. with < 40-50 degree curve
 - mixed results

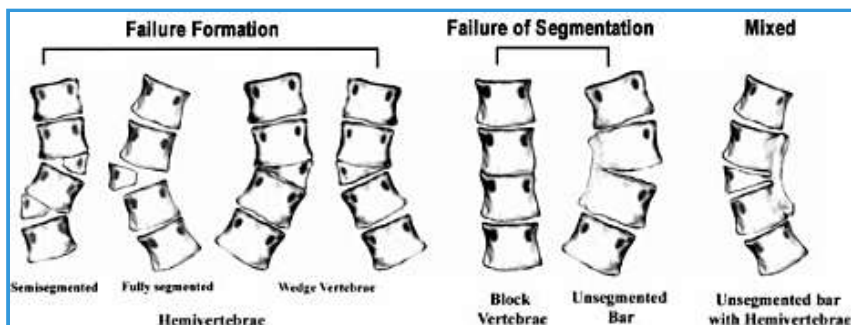
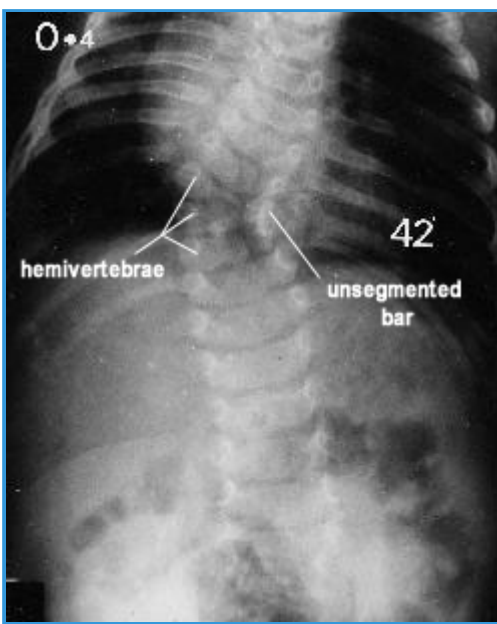
- osteotomy
 - osteotomy of bar
- hemivertebrectomy
 - hemivertebrae with progressive curve causing truncal imbalance and oblique takeoff
 - often caused by a lumbosacral hemivertebrae
 - patients < 6 yrs. and flexible curve < 40 degrees best candidates
- spinal column shortening resection
 - indications
 - deformities that present late and have severe decompensation
 - rigid, severe deformities
 - pelvic obliquity, fixed

• Complications

- Crankshaft phenomenon
 - a deformity caused by performing posterior fusion alone
- Short stature
 - growth of spinal column is affected by fusion
 - younger patients affected more
- Neurologic injury
 - surgical risk factors include
 - overdistraction or shortening
 - overcorrection
 - harvesting of segmental vessels
 - somatosensory and motor evoked potentials important
- Soft-tissue compromise
 - nutritional aspects of care essential to ensure adequate soft tissue healing

• Prognosis

- Dependent on potential for progression and early intervention
- Progression



- most rapid in the first 3 years of life
- anterior failure of formation is rapidly progressive and often results in paralysis; anterior failure of segmentation can be rapidly progressive but rarely results in paralysis
- determined by the morphology of vertebrae. Rate of progression from greatest to least is:
 - unilateral unsegmented bar with contralateral hemivertebra >
 - greatest potential for rapid progression (5 to 10 degrees/year)
 - unilateral unsegmented bar >
 - fully segmented hemivertebra >
 - unincarcerated hemivertebra >
 - incarcerated hemivertebra >
 - unsegmented hemivertebra >
 - block vertebrae
 - little chance for progression (<2 degrees/year)
- presence of fused ribs increases risk of progression

46- Pathologic Scoliosis

Images



- summary

- Pathologic Scoliosis is a form of scoliosis resulting from a benign bone tumor most commonly located in the posterior elements of the spine.
- Diagnosis is made with full-length standing spine radiographs to determine the severity of the curve. A CT scan is useful to assess for the size and location of the underlying lesion.

- Treatment is observation and NSAIDs for small and minimally symptomatic curves. Surgical resection of the lesion is indicated for painful, progressive scoliosis.

- Epidemiology

- Demographics
 - can occur in all age groups

- Etiology

- Causes
 - osteoid osteomas
 - occur in the apex of the concavity of the curve



- curves are typically rigid
 - can occur in the vertebral body or posterior elements
 - demonstrate same histology as osteoid osteomas in the peripheral skeleton
 - osteoblastomas
 - larger lesion than osteoid osteoma
 - pain is usually less severe than osteoid osteoma
- Mechanism
 - scoliosis is thought to develop in response to painful paraspinal muscle spasms

- Presentation

- Symptoms
 - back pain
 - most commonly at night
 - pain relieved by anti-inflammatories
 - less relief reported with osteoblastomas

- Physical exam
 - posterior trunk
 - curvature of the spine
 - usually mild
 - neurological exam
 - may have neurological deficits with osteoblastoma
 - findings dependent on level of lesion

- Imaging

- Radiographs
 - AP/Lateral of spine



- can determine level and severity of curvature
 - findings
 - lesion is defined by cortical thickening with radiolucent nidus
 - osteoid osteoma is less than 2 cm in diameter by definition
 - osteoblastoma is greater than 2 cm
- CT scan



- fine cut best for outlining lesion and determining treatment plan
- MRI
 - good for showing proximity to neurovascular structures
 - may only show soft tissue edema and not the nidus
- Bone scan
 - markedly increased uptake in area of lesion

• Treatment

- Non-operative
 - **NSAIDs, observation**
 - indications
 - minimal curve
 - outcomes
 - may take up to 36 months to resolve
 - osteoblastomas usually do not respond to NSAIDS
- Operative
 - **en bloc resection of lesion**
 - indications
 - painful, progressive scoliosis

- outcomes
 - resolution of curve if removed with 15-18 months of onset of curve in child less than 11 years old
- **radiofrequency ablation of lesion**
 - indications
 - usually not an option due to proximity of neurological structures of spine
 - case by case basis based on 3D studies (CT, MRI)

- Prognosis

- Outcomes good with treatment
 - most cases of scoliosis due to osteoid osteoma will resolve after resection of tumor if
 - performed within 15-18 months of onset of curvature
 - child is less than 11 years of age

47- Juvenile Idiopathic Scoliosis

Images



- summary

- Juvenile Idiopathic Scoliosis is a coronal plane spinal deformity which most commonly presents in children between ages 4 and 10.
- Diagnosis is made with full-length standing PA and lateral spine radiographs. MRI studies are indicated in children <10 years old with a curve > 20°.
- Treatment can be observation, bracing, or surgical management depending on the skeletal maturity of the patient, magnitude of deformity, and curve progression.

- Epidemiology

- Incidence
 - 15% of all idiopathic scoliosis cases
- Demographics
 - females > males
- Anatomic location
 - most commonly appear as a right main thoracic curve

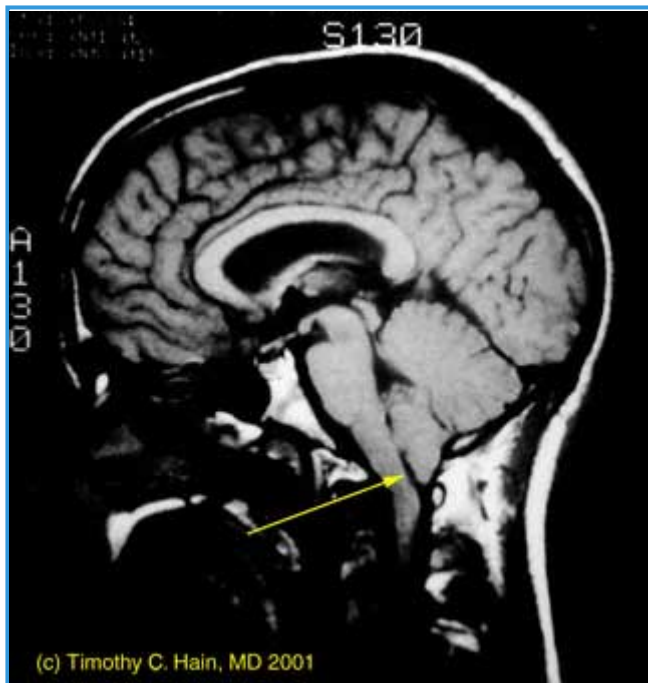
- Etiology

- Associated conditions

- high incidence of neural axis abnormalities (18-25%)
 - syringomyelia
 - cyst or tubular cavity within spinal cord



- can be seen in a scoliotic curve without rotation
 - can manifest as an asymmetric umbilicus reflex
- Arnold-Chiari syndrome
 - cerebellar tonsils are elongated and protruding through the opening of the base of the skull and blocking CSF flow)



- tethered cord
- dysraphism
- spinal cord tumor

• Classification

- Early onset scoliosis (EOS)
 - early-onset scoliosis is a broader category including scoliosis in children <10 years old. It includes
 - infantile idiopathic scoliosis
 - juvenile idiopathic scoliosis
 - congenital scoliosis

- neurogenic scoliosis
- syndromic scoliosis
 - Marfan's
 - Down's syndrome

- Presentation

- History
 - important to determine when deformity was first noticed and any observed progression
 - get perinatal history
- Presentation
 - failure to develop bowel and bladder control by age ~ 3 or 4 may indicate neurologic involvement
 - patients often referred from school screening where a 7° curve on scoliometer during Adams forward bending test is considered abnormal
 - 7° correlates with 20° coronal plane curve
- Physical exam
 - general inspection
 - cafe-au-lait spots (neurofibromatosis)
 - leg length inequality
 - shoulder height differences
 - truncal shift
 - waist asymmetry and pelvic tilt
 - foot deformities (cavovarus)
 - can suggest neural axis abnormalities and warrant a MRI
 - spine inspection
 - midline skin defects
 - hairy patches
 - dimples (signs of spinal dysraphism)
 - nevi
 - rib rotational deformity (rib prominence)
 - Adams forward bending test



- axial plane deformity indicates structural curve
- forward bending sitting test
 - can eliminate leg length inequality as cause of scoliosis
- neurologic
 - motor
 - upper and lower extremities exam
 - reflexes
 - abnormal abdominal reflexes
 - associated with the presence of a syrinx
 - gently stroking each abdominal quadrant should cause contraction of the abdominal muscles
 - clonus
 - Hoffman sign
 - Babinski
- gait analysis

• Imaging

- Radiographs
 - PA and lateral upright images are used to assess curve severity
 - treatment based on Cobb angle
 - Cobb angle
 - $> 10^\circ$ defined as scoliosis
 - intra-interobserver error of $3-5^\circ$
 - bending radiographs can help determine which curves require fusion
- MRI
 - indicated in children < 10 years old with a curve $> 20^\circ$
 - even in the absence of neurologic symptoms
 - must rule out neural axis abnormalities (e.g., syringomyelia)
 - presence of left-sided thoracic curve

- Treatment

- Nonoperative

- **observation**

- indications

- curves $< 20^{\circ}$

- technique

- frequent radiographs to observe for curve progression

- **bracing**

- indications

- curves $20 - 50^{\circ}$

- designed to prevent curve progression, not correct the curve

- relative contraindication to bracing is thoracic hypokyphosis

- technique

- 16-23h/day until skeletal growth completed or surgery indicated

- Operative

- **non-fusion procedures (growing rods, VEPTR)**

- indications

- curves $> 50^{\circ}$ in small children with significant growth remaining

- allows continued spinal growth over unfused segments

- definitive PSF + ASF performed when the child has grown and is closer skeletal maturity

- traditional growing rods associated with greater curve correction and truncal height gain than VEPTR constructs

- **anterior / posterior spinal fusion**

- indications

- curves $> 50^{\circ}$ in younger patients

- required in order to prevent crankshaft phenomenon

- **posterior spinal fusion**

- indications

- curve $> 50^{\circ}$ in older patients near skeletal maturity

- remains gold standard for thoracic and double major curves (most cases)

- **anterior spinal fusion**

- indications

- curve $> 50^{\circ}$

- best for thoracolumbar and lumbar cases with a normal sagittal profile

- Complications

- Crankshaft phenomenon

- Prognosis

- High risk of progression
 - 70% require treatment (50% bracing, 50% surgery)
- Very few experience spontaneous resolution
- Can be fatal if not treated appropriately

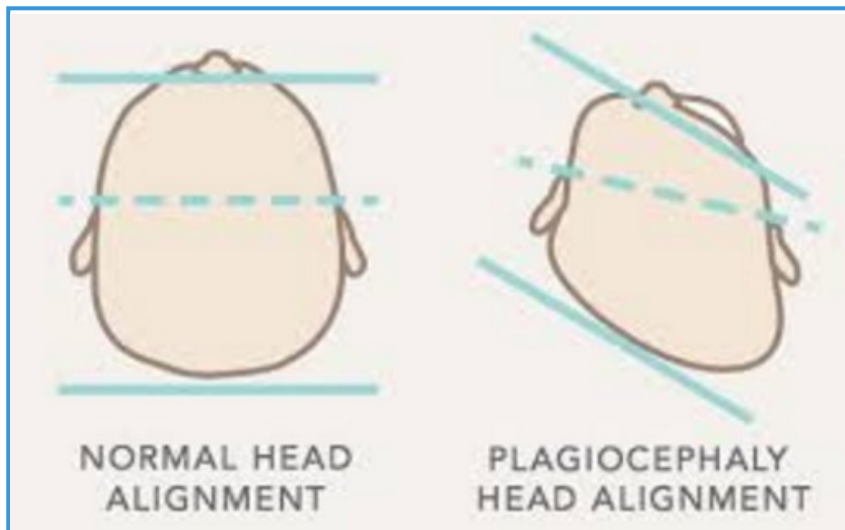
48- Infantile Idiopathic Scoliosis

Images



- summary
 - Infantile Idiopathic Scoliosis is a coronal plane spinal deformity which most commonly presents in children ages 3 years or less.
 - Diagnosis is made with full-length PA and lateral spine radiographs. MRI studies are indicated to rule out syrinx, tumor, or tethered cord.
 - Treatment can be observation, bracing, or surgical management depending on the skeletal maturity of the patient, magnitude of deformity, and curve progression.
- Epidemiology
 - Incidence
 - 4% of idiopathic scoliosis cases
 - Demographics
 - males > females
 - Anatomic location
 - usually left thoracic
 - Risk factors
 - family history
- Etiology

- Pathophysiology
 - pathoanatomy
 - may adversely affect growth of alveoli and normal development of the thoracic cage
- Genetics
 - autosomal dominant with variable penetrance
- Associated conditions
 - plagiocephaly (skull flattening)



- congenital defects
- neural axis abnormalities
 - 22% of patients with curves $> 20^\circ$ will be affected
 - 80% of these patients will need neurosurgical involvement
- thoracic insufficiency syndrome
 - characterized by decreased thoracic growth and lung volume
 - leads to pulmonary hypertension and cor pulmonale
 - pulmonary function impairment associated with curves $> 60^\circ$
 - cardiopulmonary issues associated with curves $> 90^\circ$

• Anatomy

- Osteology
 - the T1-L5 spinal segment grows fastest in the 1st five years of life
 - the height of the thoracic spine increases by 2 times between birth and skeletal maturity

• Classification

- Infantile Idiopathic Scoliosis consists of
 - resolving type
 - progressive type
- Early onset scoliosis
 - early-onset scoliosis is a broader category that includes scoliosis in children < 10 years. It includes

- infantile idiopathic scoliosis (this topic)
- juvenile idiopathic scoliosis
- congenital scoliosis
- neurogenic scoliosis
- syndromic scoliosis
 - Marfan's
 - Down's syndrome

- Presentation

- History
 - age deformity was first noticed and any observed progression
 - perinatal history
 - developmental milestones
- Presentation
 - most present with deformity
 - excessive drooling may reflect neurologic condition
- Physical exam
 - inspection
 - cafe-au-lait spots (neurofibromatosis)



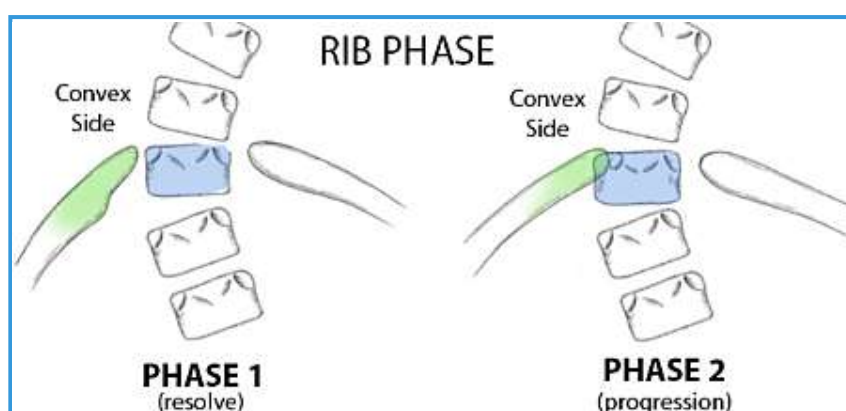
- patches of hair
- dimpling over the spinal region
 - dimpling outside of the gluteal fold is usually benign
- nevi or other tumors may be indicative of spinal dysraphism
- plagiocephaly (skull flattening)
- neurologic
 - motor
 - document developmental milestones
 - evaluate for cavovarus feet
 - upper and lower extremities exam
 - reflexes
 - abnormal abdominal reflexes
 - associated with the presence of a syrinx

- clonus
- Hoffman sign
- Babinski
- gait analysis

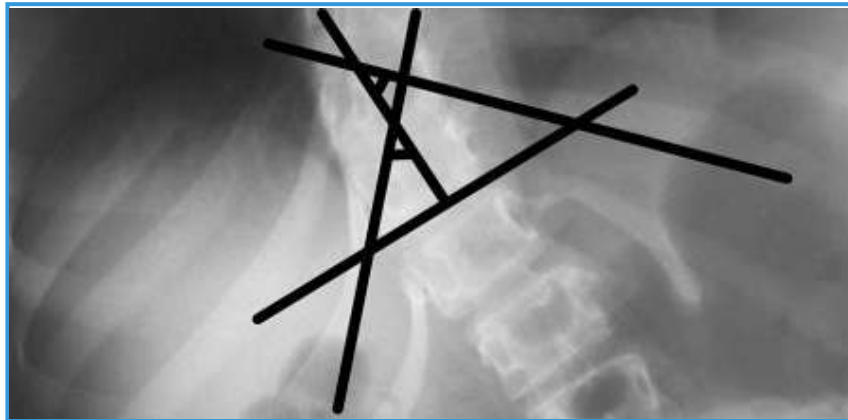
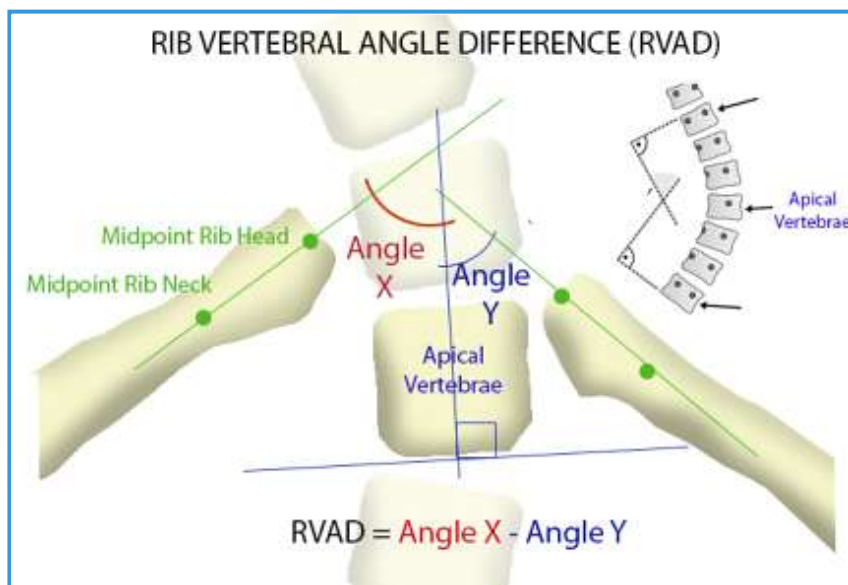
• Imaging

○ Radiographs

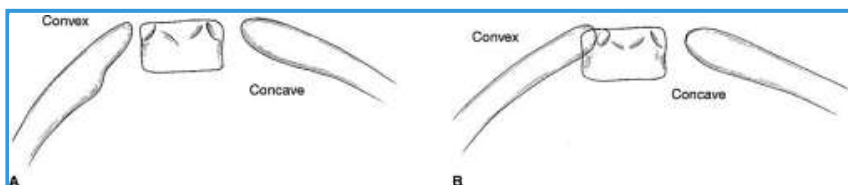
- recommended views
 - standing PA and lateral
 - supine in infants unable to stand (will make curve appear less severe)
- findings
 - look for congenital vertebral defects
- measurements
 - cobb angle
 - > 20 degrees associated with progression
 - rib phase



- technique
 - convex rib head position with respect to the apical vertebrae
- findings
 - phase 1 - no rib overlap
 - phase 2 - rib overlap with the apical vertebrae
 - high risk for curve progression
- RVAD (rib vertebrae angle difference, Mehta angle)
 - technique



- measure angle between the endplate and rib (line between midpoint of rib head and neck)
- RVAD = difference of 2 rib-vertebral angles
- findings



- $> 20^\circ$ is linked to high rate of progression
- $< 20^\circ$ is associated with spontaneous recovery

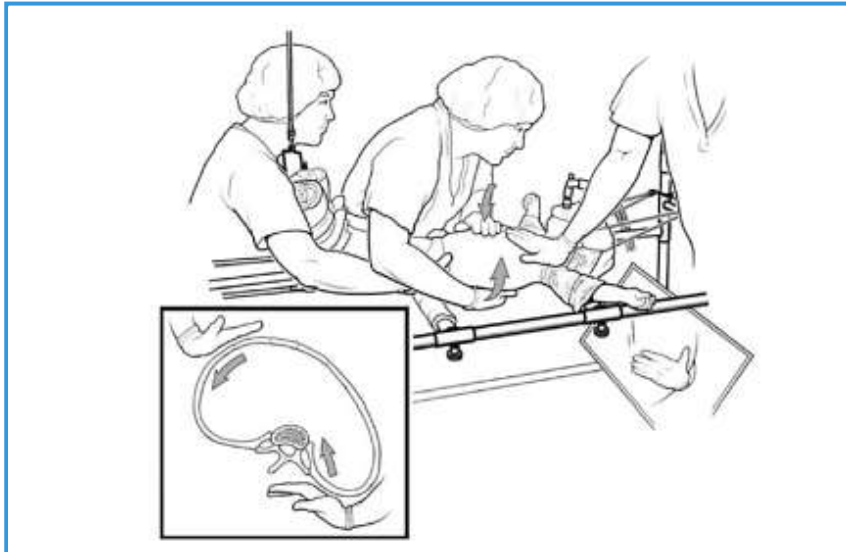
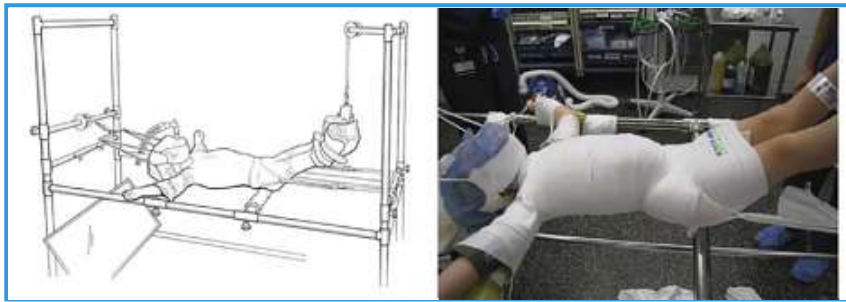
○ MRI

- obtain MRI of spine first to rule out
 - tether
 - cyst
 - tumor
 - syrinx (20% incidence)

• Treatment

○ Nonoperative

- **observation alone (most resolve spontaneously)**
 - indications
 - Cobb angle $< 30^\circ$
 - RVAD $< 20^\circ$
 - 90% will resolve spontaneously
- **serial Mehta casting (derotational) or thoracolumbosacral orthosis (TLSO)**



- indications
 - flexible curves
 - Cobb angle $> 30^\circ$
 - RVAD $> 20^\circ$
 - phase 2 rib-vertebrae relationship (rib-vertebral overlap)
- mechanism
 - functions to straighten the spine in young patients
 - in older patients it serves as an adjunctive measure prior to definitive treatment

■ bracing

- indications
 - incompletely corrected curves after Mehta casting
 - late presenting cases where the spine is still flexible

○ Operative

■ growing rod construct (dual rod or VEPTR)

- indications
 - Cobb > 50 to 60 degrees
 - failed Mehta casting or bracing
- fusion
 - delay until as close to skeletal maturity as possible
 - fusion before age 10 years results in pulmonary compromise
- outcomes
 - improvement in FVC pulmonary function with implementation of growing construct

• Techniques

○ Growing rod construct (dual rod or VEPTR)

- permits growth of affected part of spine up to 5 cm
- dual rods or VEPTR
 - use anchors proximally and distally
 - serial lengthening
 - required every six to eight months

- Complications

- High rate of complications with surgical treatment

- Prognosis

- Progression
 - most resolve spontaneously
 - if progressive by age 5, >50% of children will have a curve > 70°
 - Mehta predictors of progression
 - Cobb angle > 20°
 - RVAD > 20°
 - phase 2 rib-vertebral relationship (rib-vertebral overlap)
 - Prognosis
 - progressive curves have poor outcomes and must be treated
 - can be fatal if not treated appropriately

49- Neuromuscular Scoliosis

Introduction

- Defined as an irregular spinal curvature caused by disorders of the brain, spinal cord, and muscular system .
- Neurogenic curves (relative to idiopathic curves) tend to be
 - more rapidly progressive
 - may progress after maturity
 - associated with pelvic obliquity
 - are longer and involve more vertebrae (may involve cervical vertebrae)
 - have a higher rate of pulmonary complications with surgery

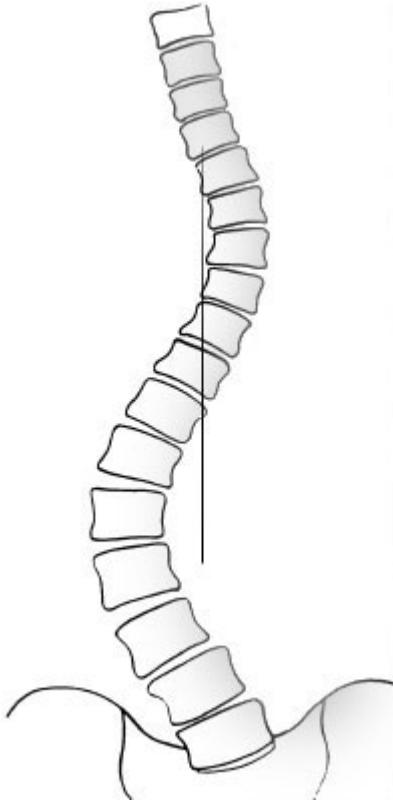
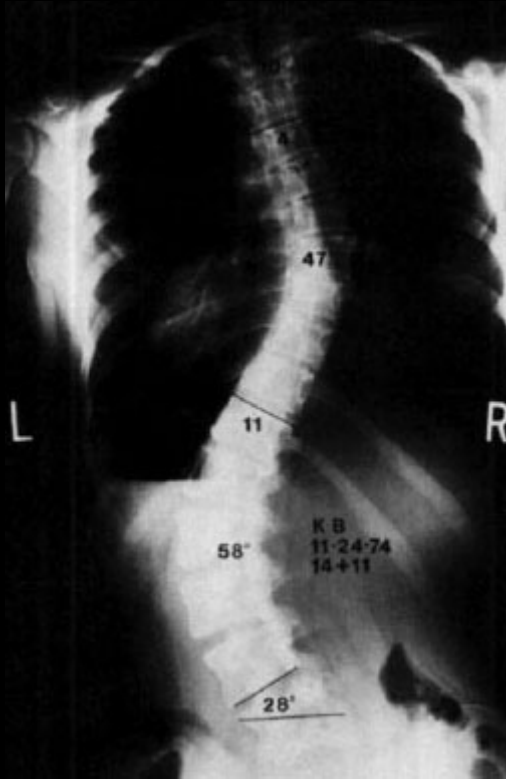
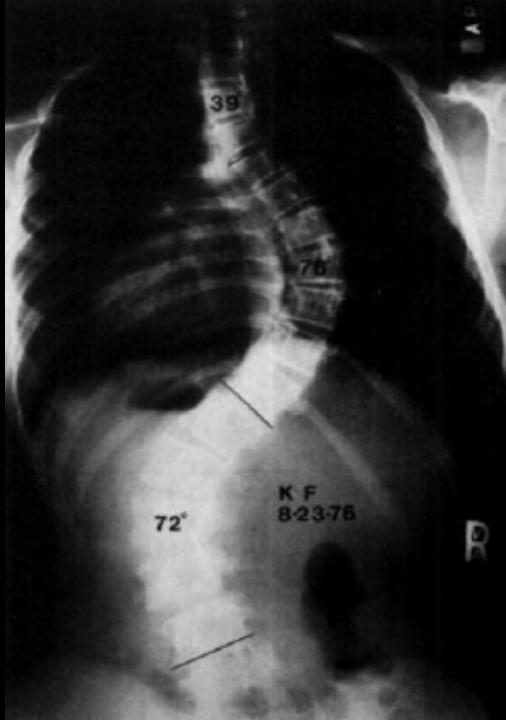
Classification & Treatment

- Outcomes
 - surgical correction of spinal fusion is only treatment that has a documented beneficial impact on deformity
 - parents and caretakers report excellent improvement in the child's quality of life after deformity correction
 - Increased risk of wound complications with:
 - Poor nutritional status (serum albumin <3.5 g/dL)
 - Immunocompromised status (WBC <1,500 cells/ucL)
 - Presence of a ventriculoperitoneal (VP) shunt
 - Severe spastic quadriplegia nonambulatory status with seizures

Classification and Treatment (for more detail go to disease content)			
Category	Disease	Nonoperative Treatment	Operative Treatment
Upper motor neuron	Cerebral palsy ▶	Boston-type underarm bracing until puberty (age 10-12) and wheelchair modification	- Group I treat with PSF with instrumentation - Group II treat with PSF +/- ASF with instrumentation and fusion to pelvis (Luque-Galveston) - Indications for surgery - curve > 50°

			○ worsening pelvic obliquity with sitting imbalance
	Rett Syndrome ▶	Bracing for C-shaped curves	• Bracing ○ C shaped curves • Posterior Spinal Fusion indications ○ thoracic curve that interfere with sitting and balance ○ C shaped curves that do not respond to bracing
Muscle Weakness	Spinal muscular atrophy ▶	Boston-type underarm bracing until puberty (age 10-12)	• Treat with PSF with fusion to pelvis for improved wheelchair sitting ○ address hip contractures before PSF ○ may lead to temporary loss of upper extremity function
	Muscular dystrophy ▶	bracing is contraindicated	• PSF with or without fusion to pelvis (fusion to pelvis is controversial) ○ indications ■ absolute curve > 20° ■ progressive curve ○ Treat early before pulmonary function declines (curve from 20 to 30°)
Paralytic Syndromes	Spinal bifida and spinal cord injuries ▶	bracing is contraindicated	• ASF/PSF with instrumentation and pelvic fixation ○ anterior fusion required because minimal posterior element to obtain fusion
	Polio ▶	Boston-type underarm bracing until puberty (age 10-12)	• PSF

50- King Classification Of Ais

Type I		DESCRIPTION • S shaped or double curve in which both the thoracic and lumbar curve cross the midline • Lumbar curve larger and stiffer than the thoracic curve TREATMENT • this type of curve is usually fuse down to L4 (via a posterior approach) or down to L3 (anterior approach)	
Type II		DESCRIPTION • S shaped or double curve in which both the thoracic and lumbar curve cross the midline • Thoracic curve larger and stiffer than the lumbar curves. TREATMENT • often a thoracic fusion will suffice for these patients (or down to L1)	
Type III		DESCRIPTION • Thoracic curve crosses midline and lumbar curve does not cross midline TREATMENT • thoracic fusion	
Type IV		DESCRIPTION • Long thoracic curve in which L5 is	



centered over sacrum but L 4 tilts into long thoracic curve

TREATMENT
 • fuse thru L4

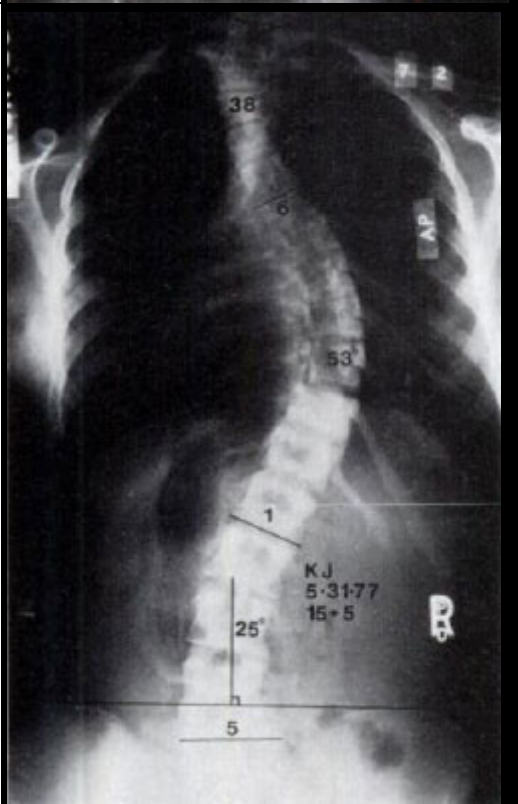


Type
 V



DESCRIPTION
 Thoracic curve and T1 tilts to upper curve

TREATMENT
 Use thru T2;Â do not assume that the upper (left) thoracic curve is non-structural without proof, and if there is any question, fuse the upper thoracic spine as well as the lower thoracic spine;



51- Lenke Classification Of Ais

A

CURVE TYPE				
Type	Proximal Thoracic	Main Thoracic	Thoracolumbar/Lumbar	Description
1	Non-Structural	Structural (Major)*	Non-Structural	Main Thoracic (MT)
2	Structural	Structural (Major)*	Non-Structural	Double Thoracic (DT)
3	Non-Structural	Structural (Major)*	Structural	Double Major (DM)
4	Structural	Structural (Major)*	Structural	Triple Major (TM) [§]
5	Non-Structural	Non-Structural	Structural (Major)*	Thoracolumbar/Lumbar (TL/L)
6	Non-Structural	Structural	Structural (Major)*	Thoracolumbar/Lumbar-Main Thoracic (TL/L-MT)

STRUCTURAL CRITERIA
(Minor Curves)

Proximal Thoracic - Side Bending Cobb $\geq 25^\circ$
- T2-T5 Kyphosis $\geq 20^\circ$

Main Thoracic - Side Bending Cobb $\geq 25^\circ$
- T10-L2 Kyphosis $\geq 20^\circ$

Thoracolumbar/Lumbar - Side Bending Cobb $\geq 25^\circ$
- T10-L2 Kyphosis $\geq 20^\circ$

LOCATION OF APEX
(SRS Definition)

CURVE APEX
Thoracic T2-T11/T2 Disc
Thoracolumbar T12-L1
Thoracolumbar/Lumbar L1/2 Disc-L4

MODIFIERS

Lumbar Spine Modifier	Center Sacral Vertical Line to Lumbar Apex
A	CSVL between pedicles
B	CSVL touches apical body(ies)
C	CSVL completely medial

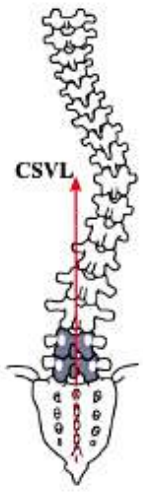
Thoracic Sagittal Profile T5-T12	
- (Hypo)	$<10^\circ$
N (Normal)	$10^\circ - 40^\circ$
+ (Hyper)	$>40^\circ$

Curve Type (1-6) + Lumbar Spine Modifier (A, B, C) + Thoracic Sagittal Modifier (-, N, +) = Classification (e.g. 1B+): _____

B

LUMBAR SPINE MODIFIER RULES
A, B, C

- Examine upright coronal radiograph.
- Accept pelvic obliquity $<2^\circ$. If $>2^\circ$, then must block out leg length inequality to level pelvis.
- Draw CSVL = Center Sacral Vertical Line with a fine tipped pencil/marker. Bisection proximal sacrum and drawn vertical to parallel lateral edge of radiograph.
- Stable Vertebra - Most proximal lower thoracic or lumbar vertebra most closely bisected by CSVL. If a disc is most closely bisected, then choose next caudad vertebra as stable.
- Apex of curve is the most horizontal and laterally placed vertebral body or disc.
- SRS Definitions**
Thoracic Curves T2-T11+12 disc
Thoracolumbar Curves T12-L1
Lumbar Curves L1-2 disc to L4



Introduction

- Note: To our knowledge the Lenke classification has never appeared on the OITE or on the the ABOS Part I.
- The Lenke classification for adolescent idiopathic scoliosis has gained popularity and consists of three steps
 - Label primary curve at Type 1-6
 - Assign lumbar modifier (A,B,C)
 - Assign sagittal modifier (-,N,+)

Step 1: Identification of primary curve (Type 1-6)

1. Measure regional curves

- proximal thoracic (PT)
- main thoracic (MT)
- thoracolumbar/lumbar (TL/L)

2. Identify major curve (biggest curve)

- always either MT (Type 1-4) or .MT/L (Type 4*,5,6)

3. Determine if minor curve is structural or not

- definition of structural

- > 25° in coronal plane on standing AP and do not bend out to < 25° on bending films
- OR > 20° in sagital plane

4. Assign Type 1-6 based on chart below

Curve Type	Curve Name	PT **	MT	TL/L
Type 1	MT	-	Structural (major*)	-
Type 2	Double thoracic (DT)	Structural	Structural (major*)	-
Type 3	Double major (DM)	-	Structural (major*)	Structural
Type 4	Triple major (TM)	Structural	Structural (major*)	Structural (major*)
Type 5	TL/L	-	-	Structural (major*)
Type 6	TL/L-MT	-	Structural	Structural (major*)
Structural (major*) - has largest cobb angle and is always structural. In Type 4 can be either MT or FL/L depending on which Cobb is larger **If PT is the largest curve, then by default assign major curve to MT				

Step 2: Assignment of Lumbar modifiers (A,B,C)

- Identify apical lumbar vertebrae (ALV)
 - is the inferior lumbar body that falls outside of the curve
- Draw central sacral vertical line (CSVL) and see where it sits in relationship to pedicles of ALV
- Assign modifier
 - **A** if CSVL passes between pedicles of apical lumbar vertebrae (ALV)
 - CSVL falls between pedicles of the lumbar spine up to stable vertebra
 - **B** modifier if CSVL touches pedicle of apical lumbar vertebrae (ALV)
 - **C** modifier if CSVL does not touch apical lumbar vertebrae (ALV)
 - apex of lumbar curve falls completely off the midline depicting a curve with complete apical translation off the CSVL

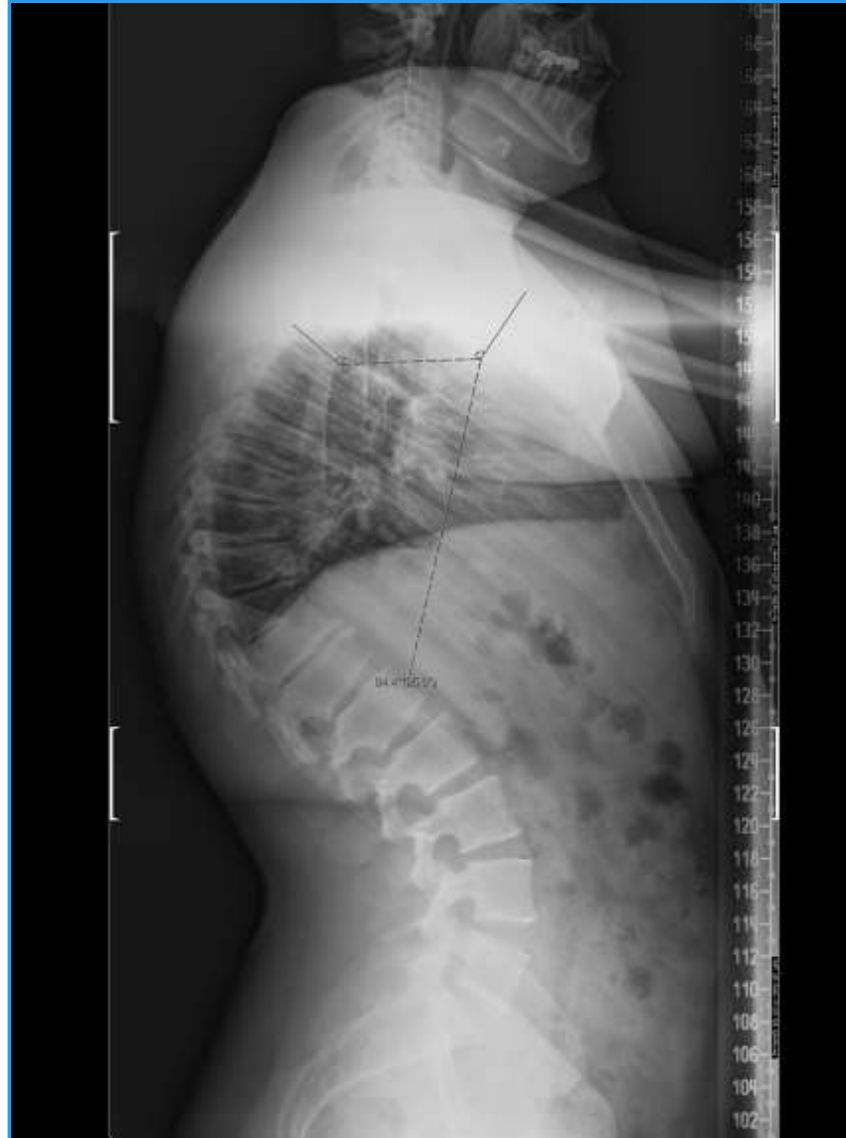
Step 3: Assignment of Sagittal thoracic modifier (-, N, +)

- Measure sagital Cobb from T5 to T12
- Assign modifier
 - hypokyphotic (-) if < 10°
 - normal if 10-40°

- hyperkyphotic (+) if $>40^\circ$

52- Scheuermanns Kyphosis

Images



- summary
 - Scheuermann's Kyphosis is a rigid form of spinal kyphosis caused by anterior wedging of >5 degrees across three consecutive vertebrae, most commonly in the thoracic spine.
 - Diagnosis is made with standard and hyperextension lateral radiographs of the thoracic spine.
 - Treatment can be observation or surgical management depending on the severity of kyphosis, presence of neurological deficits, and/or persistent and progressive pain.
- Epidemiology
 - Incidence
 - 0.4% to 8.3%
 - most common type of structural kyphosis in adolescents

- typical age of onset is from 10-12 years age with small subset adult onset
- Demographics
 - M:F ratio between 2:1 and 7:1
- Anatomic location
 - usually in thoracic spine
 - less common form occurs in thoracolumbar/lumbar region (see below)

• Etiology

- Pathoanatomy
 - exact pathophysiology is unknown but several theories
 - osteonecrosis of anterior apophyseal ring
 - herniation of disc material leading to loss of anterior disc height
 - relative osteoporosis leading to compression deformity
 - altered biomechanics leading to anterior wedging and subsequent growth arrest
 - most widely accepted theory suggests that the kyphosis and vertebral wedging are caused by a developmental error in collagen aggregation which results in an abnormal end plate
- Genetics
 - autosomal dominant inheritance pattern now accepted
- Associated conditions
 - orthopaedic manifestations
 - Lumbar hyperlordosis
 - spondylolysis in lumbar region (33%)
 - scoliosis (33%)
 - dural cysts
 - compensatory tightness of anterior shoulder, hamstrings, and iliopsoas muscle
 - non-orthopaedic manifestations
 - pulmonary issues in curves exceeding 100 degrees

• Classification

- Thoracic Scheuermann's Kyphosis
 - most common form
 - curve from T1/2 to T12/L1 with apex between T6-T8
 - better prognosis
- Thoracolumbar/lumbar Scheuermann's Kyphosis

- far less common form
- curve from T4/5 to L2/3 with apex near the thoracolumbar junction
- associated with increased back pain
- more likely to be progressive and symptomatic
- more irregular end-plates noted on radiographs, less vertebral body wedging

• Presentation

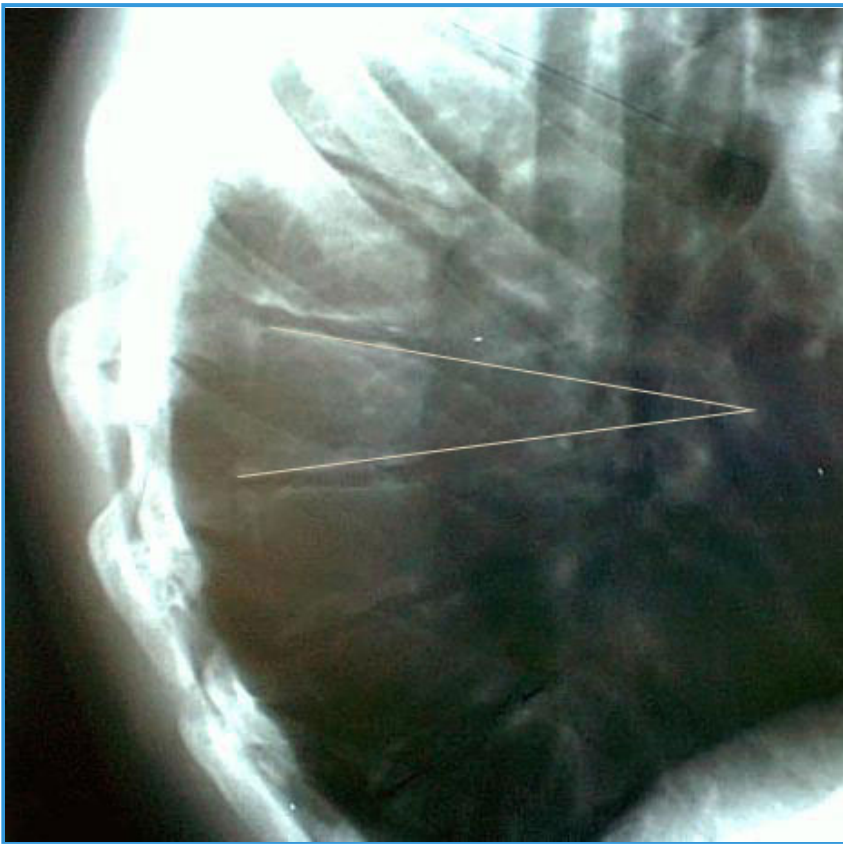
- Symptoms
 - may complain of thoracic or lumbar pain
 - cosmetic concerns
- Physical exam



- increased kyphosis which has a sharper angulation when bending forwards
 - normal thoracic kyphosis is between 20 degrees and 45 degrees
- may have a compensatory hyperlordosis of the cervical and/or lumbar spine
- tight hamstrings, iliopsoas, and anterior shoulder
- neurological deficits rare but need full examination

• Imaging

- Radiographs
 - recommended
 - AP and lateral spine
 - findings
 - anterior wedging across three consecutive vertebrae >5 degree



- disc narrowing
- endplate irregularities
- Schmorl's nodes (herniation of disc into vertebral endplate)
- scoliosis
- compensatory hyperlordosis
- spondylolysis on dedicated lumbar films if patient has low back pain
- determine sagittal balance by dropping C7 plumb line
- hyperextension lateral radiograph
 - supine lateral radiograph with patient lying in hyperextension over a bolster
 - can help differentiate from postural kyphosis
 - Scheuermann's kyphosis usually relatively inflexible on bending radiograph
- CT scan
 - usually not needed
- MRI
 - controversial as to whether it is indicated prior to surgery to look for associated disc herniation , epidural cyst, spinal cord abnormalities, and spinal stenosis



- will show vertebral wedging, dehydrated discs, and Schmorl's nodes (herniation of disc into vertebral endplate)
- any neurological symptom or deficit warrants evaluation with MRI

- Treatment

- Nonoperative

- **stretching, observation, physical therapy**

- indications

- kyphosis $< 60^\circ$ and asymptomatic (mild symptoms)
 - most patients fall in this group and can be treated with observation alone

- modalities

- physical therapy

- postural improvement exercises and back extensor strengthening
 - core muscle strengthening for patients with spondylolysis
 - limited effectiveness

- **bracing with an extension-type orthosis (Jewitt type - with high chest pad)**

- indications

- kyphosis 60° - 80° most effective in those with growth remaining

- outcomes

- patient compliance is often an issue
 - most favorable in curves $< 65^\circ$, correction of $> 15^\circ$ in brace
 - usually does not lead to correction but can stop progression

- Operative

- **posterior spinal fusion ± osteotomy ± anterior release**
 - indications
 - kyphosis > 75 degrees
 - neurologic deficit
 - spinal cord compression
 - severe pain in adults
 - techniques
 - Smith-Petersen osteotomy
 - best for long sweeping, global kyphosis
 - less than the typical 10° sagittal plane correction per level given rigidity
 - anterior release
 - technique of the past, rarely done now due to pedicle screw constructs
 - fusion
 - dual rod instrumentation usually performed
 - outcomes
 - studies show 60-90% improvement of pain with surgery (no correlation with amount of correction)
 - studies suggest residual curves >75° lead to worse functional outcomes

• Techniques

- **PSF with dual rod instrumentation +/- anterior release and interbody fusion**
 - approach
 - posterior midline to thoracic spine
 - arthrodesis
 - current recommendation is to include entire kyphotic Cobb angle and stop distally to include the first stable sagittal vertebra (first vertebra bisected by the posterior sacral vertical line)
 - previously stopped distally at first lordotic disc but had high incidence of distal junctional kyphosis
 - fixation technique
 - usually a combination of pedicle screws and hooks
 - intra canal hooks may be dangerous at apex of curve as they can potentially compress spinal cord
 - do not always have to instrument at apex

- correction technique
 - Cantelever - usually two rods placed in top anchors then brought down to bottom pedicle screws
 - Compression across posterior anchors
 - posterior spine shortening technique of Ponte
 - indicated in stiff curves where correction is needed
 - done by removing spinous processes at apex, ligamentum flavum, and performing facet joint resection
 - goal is to obtain correction to final kyphosis of 40-50°
 - in situ bending usually difficult to do and not helpful
- anterior release and fusion
 - thorascopic anterior discectomy may help avoid morbidity of thoracotomy, but usually not needed
- neuromonitoring
 - motor and sensory evoked potentials must be monitored intraoperative

• Complications

- Neurologic complications
 - reported rate of 0.6-0.8%
 - higher than idiopathic scoliosis corrective surgeries
 - typically due to spinal cord stretching/lengthening (need to ensure there is enough posterior column shortening)
 - neuromonitoring changes warrant reversal of correction
 - overall incidence of complications does not differ between anterior/posterior versus posterior alone procedure
- Distal junctional kyphosis
 - occurs in 20-30% of patient
 - avoid by
 - making proper selection of fusion levels (use the first stable sagittal vertebra)
 - avoid overcorrection (correction should not exceed 50% of original curve)
- Proximal junctional kyphosis
 - typically secondary to overcorrection and negative sagittal balance
 - less common than distal junctional kyphosis
- Pseudarthrosis
- Hardware failure

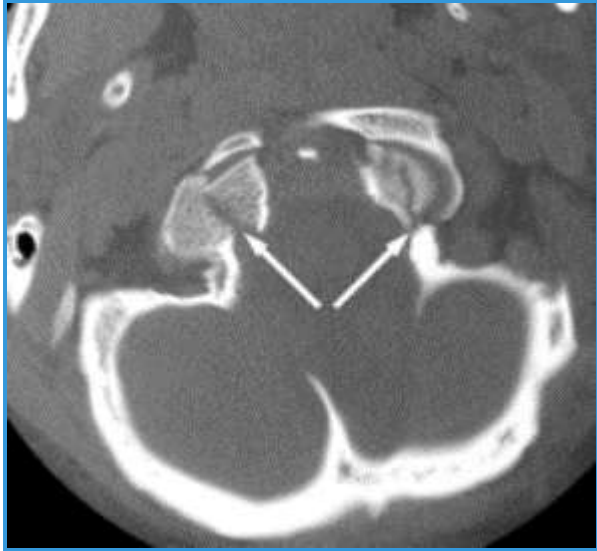
- Loss of correction
- Superior mesenteric artery syndrome
 - rare

- Prognosis

- Back pain in adults that very rarely limits daily activities (mild curves with a mean of 71 degrees)
- Curves >75 degrees are likely to cause severe thoracic pain
- Studies suggest at least some progression in 80% of patients but not often to severe deformity
- Long-standing compensatory lumbar hyperlordosis may lead to lumbar spondylolysis

53- Occipital Condyle Fractures

Images



- Summary

- Occipital condyle fractures are traumatic injuries that involve articulation between the base of the skull and the cervical spine.
- Diagnosis of the fracture is best made with a CT scan. An MRI and/or flexion-extension radiographs are used to evaluate for associated occipitocervical instability.
- Most fractures are treated with immobilization with a cervical orthosis. Occipitocervical fusion is indicated in the rare cases where occipitocervical instability is present.

- Epidemiology

- Incidence
 - relatively uncommon.
 - approximately 1-3% of population with blunt craniocervical trauma.
 - often missed due to low diagnosis sensitivity of plain radiographs.
 - reported incidence is increasing due to increased utilization of CT scans.

- ETIOLOGY

- Pathophysiology
 - terminology
 - occipital condyle fractures represent a subset of basilar skull fractures.
 - mechanism

- high energy trauma to the head/neck
 - motor vehicle accident
 - fall from height.
- low energy trauma to head and neck
 - occasionally seen in ground level falls in elderly due to direct blow to the skull.
- pathoanatomy
 - fracture patterns are dependent on the directional forces applied to the craniocervical junction at the time of the injury including
 - axial compression
 - horizontal sheer due to a direct blow on the skull
 - rotation
 - lateral bending
- Associated injuries
 - orthopaedic manifestations
 - spinal cord injuries in 31% of cases
 - neurological deficits may be acute (63% of cases) or delayed (37% of cases)
 - cervical fractures
 - vertebral artery injury
 - polytrauma
 - medical manifestations
 - intracranial bleeding
 - brainstem and vascular lesions
 - elevated ICP

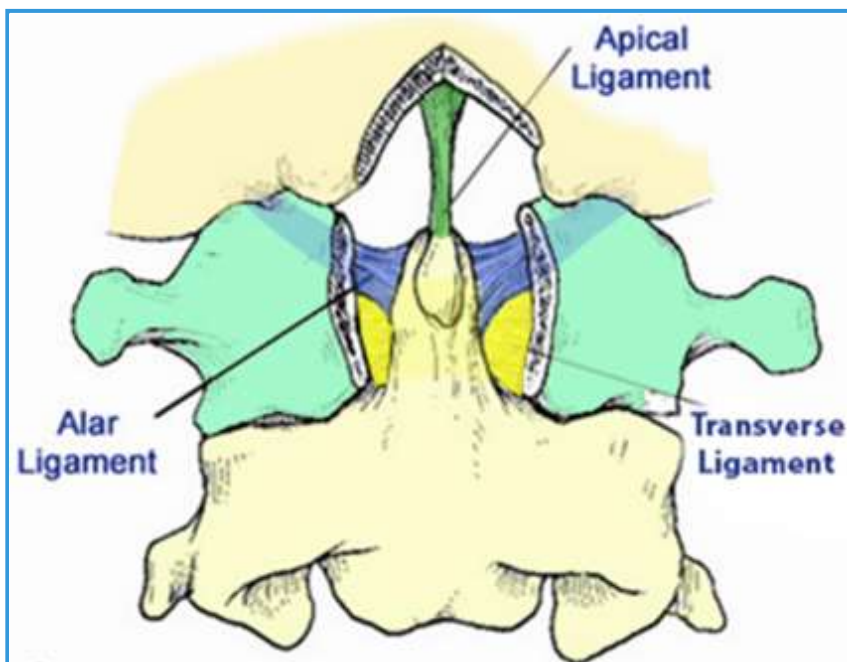
• Anatomy

- Osteology
 - occipital condyle morphology
 - occipital condyles are paired oval prominences of the occipital bone.
 - form the lateral aspects of the foramen magnum.
 - occipitoatlantal joint (occiput/C1)
 - articulation
 - each occiput articulates with a shallow dish-like joint on the superior aspect of the lateral mass of C1.
 - joint morphology allows for large range of flexion and extension of craniocervical junction.
 - ligamentous stability

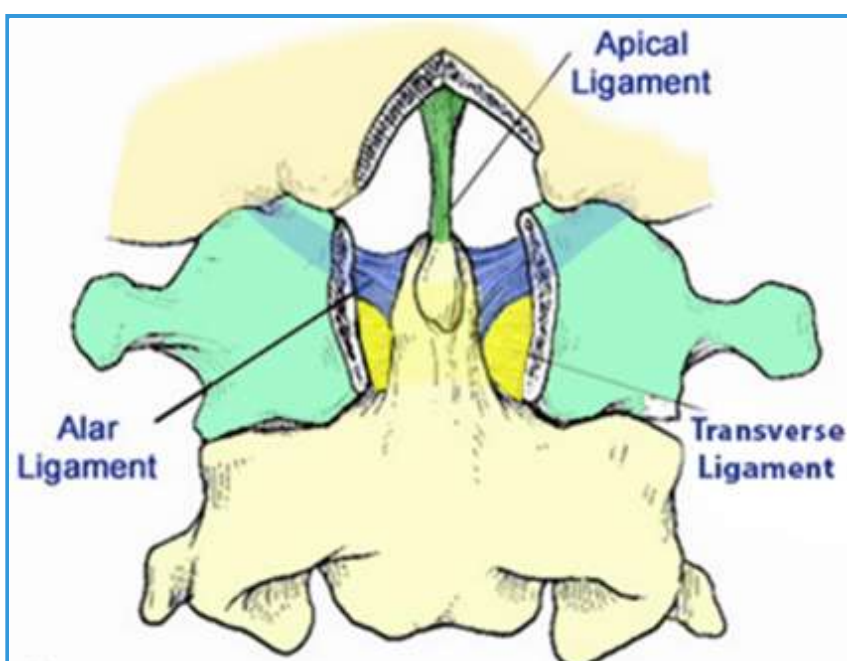
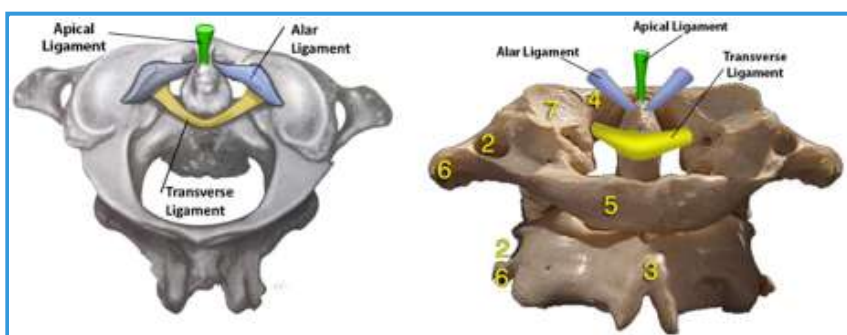
- provided by a combination of
 - occipitoatlantal joint capsule
 - alar ligaments (dens to each occipital condyle)

○ Ligaments

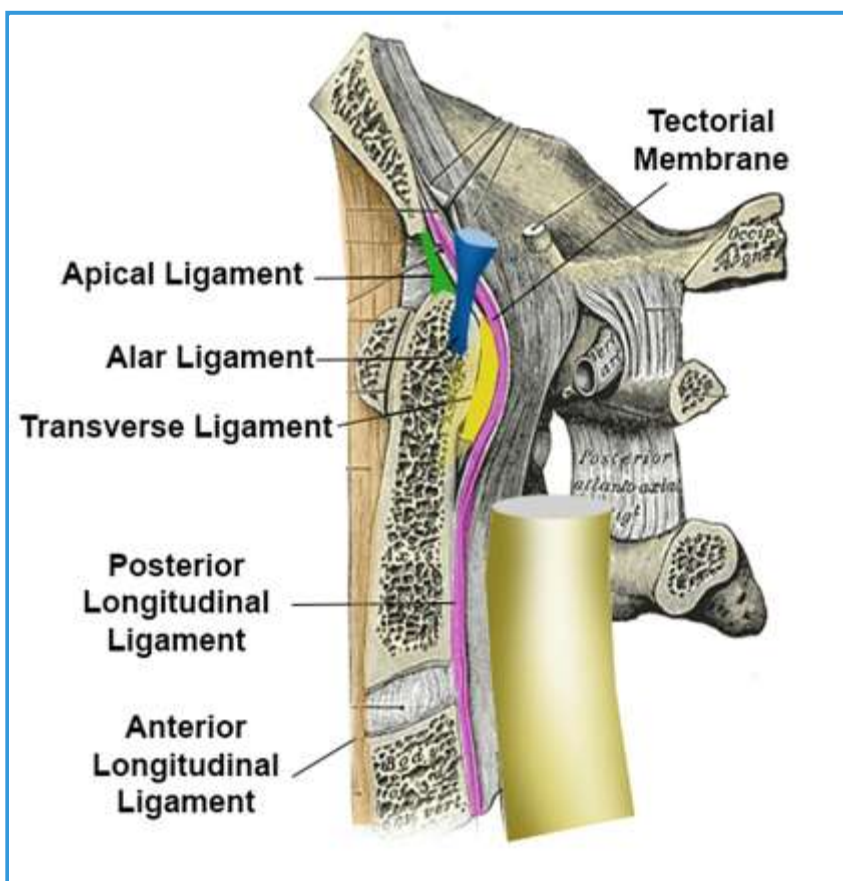
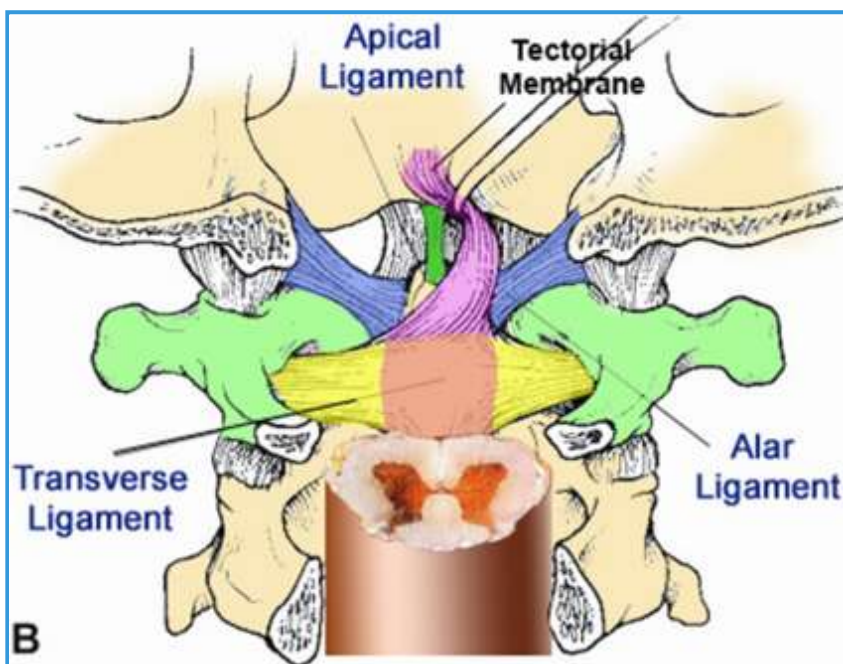
- intrinsic ligaments are located within the spinal canal, provide most of the ligamentous stability. They include
 - transverse ligament
 - connects the posterior odontoid to the anterior atlas arch, inserting laterally on bony tubercles.
 - primary stabilizer of atlantoaxial junction.
 - paired alar ligaments



- connect the odontoid to the occipital condyles.
 - relatively strong and contributes to occipitocervical stability.
- apical ligament



- runs vertically between the odontoid and foramen magnum.
 - relatively weak midline structure.
- tectorial membrane

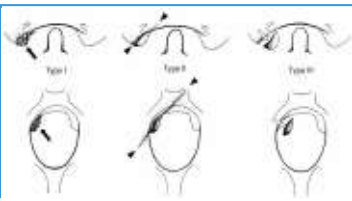
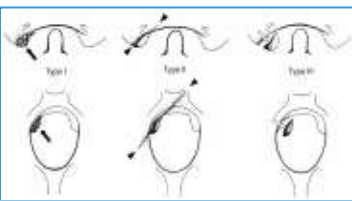


- connects the posterior body of the axis to the anterior foramen magnum and is the cephalad continuation of the PLL.
- Vascular system
 - vertebral artery
 - occipital condyles are in proximity to vertebral arteries.
- Nervous system
 - occipital condyles in close proximity to
 - medulla oblongata
 - spinal cord
 - lower cranial nerves (CN IX - CN XII)
 - C2 nerve root
- Biomechanics
 - occipitoatlantoaxial complex (craniocervical junction)
 - function
 - an anatomic complex that provides stability and function of craniocervical junction (occiput to C2).
 - includes 6 articulations
 - 2 occipitoatlantal joints

- 2 paired lateral C1-C2 facets/joints
- 1 dens-anterior arch of C1 articulation
- 1 posterior midline atlantoaxial joints
- three ligamentous structure connect C2 directly to base of skull (thereby skipping C1)
 - apical ligament
 - alar ligament
 - tectorial membrane

• Classification

○ ■ Anderson and Montesano Classification of Occipital Condyle Fractures

■ Type I	■ 3% of OC fracture ■ Impaction-type fracture with comminution of the occipital condyle ■ Due to compression between the occipitoatlantal joint ■ Stable injury due to minimal fragment displacement into the foramen magnum	■ 
■ Type II	■ 22% of OC fractures ■ Basilar skull fracture that extends into one- or both occipital condyles ■ Due to a direct blow to skull and a sheer force to the occipitoatlantal joint ■ Stable injury as the alar ligament and tectorial membrane are usually preserved	■ 
■ Type III	■ 75% ■ Avulsion fracture of condyle in region of the alar ligament attachment (suspect underlying occipitocervical dissociation) ■ Due to forced rotation with combined lateral bending. ■ Has the potential to be unstable due to craniocervical disruption	■ 

• Presentation

○ History

- clinical presentation is highly variable
- often a history of high energy trauma with associated head injury (head injury, vertebral artery injury, spinal cord injury)

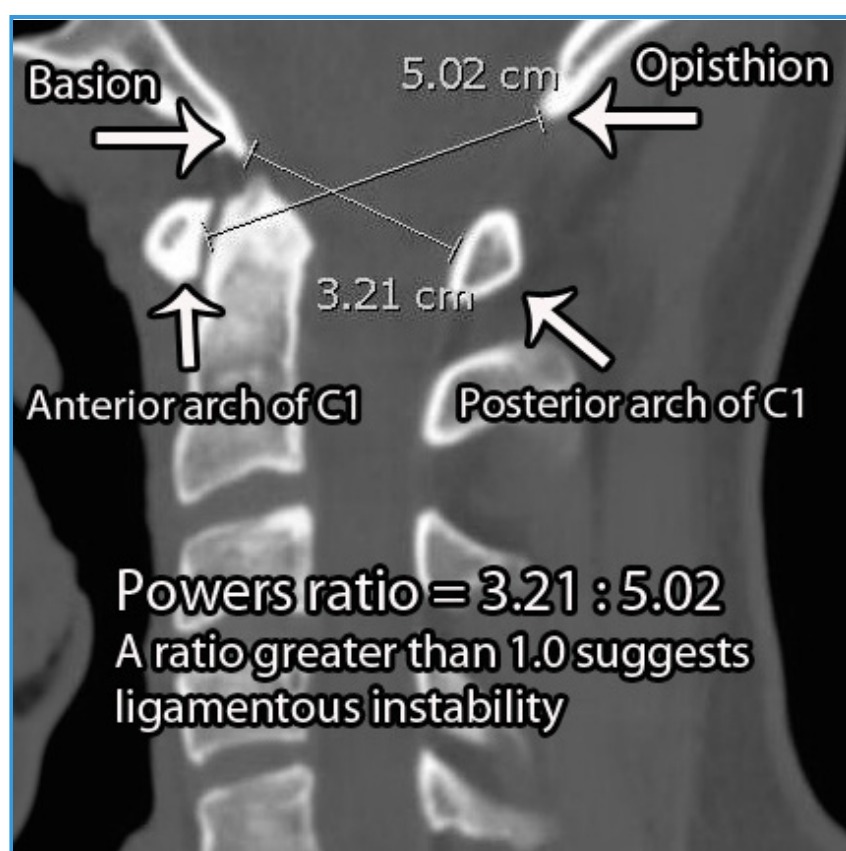
○ Symptoms

- high cervical pain
- neck stiffness
- double vision
- upper and lower extremity weakness

- Physical examination
 - inspection
 - look for trauma to skull (e.g, skull laceration)
 - ROM
 - remove collar and evaluate limited motion
 - limited cervical ROM may elicit pain
 - neurologic
 - extremity exam
 - rectal exam
 - lower cranial nerve exam
 - deficits most commonly affect CN IX, X, and XI

- Imaging

- Radiographs
 - recommended views
 - AP, lateral, open-mouth AP view
 - alternative views
 - flexion and extension views
 - findings
 - diagnosis rarely made on plain radiographs due to superimposition of structures (maxilla, occiput) blocking view of occipital condyles
 - open-mouth AP view may depict occipital condyle injuries
 - measurements
 - Powers ratio
 - used to diagnosis occipitocervical dislocation
 - technique
 - Powers ratio = C-D/A-B



- C-D: distance from basion to posterior arch
 - A-B: distance from anterior arch to opisthion
 - significance
 - ratio of ~ 1 is normal
 - if > 1.0 concern for anterior dislocation
 - if ratio < 1.0 raises concern for posterior dislocation, odontoid fractures, or ring of atlas fractures
 - O-C2 angle
 - technique
 - angle between McGregor line and C2
 - significance
 - needs to be established prior to OC fusion to prevent postoperative dysphagia by causing a significant change relative to the preoperative O-C2 angle
 - C2 to T1 lordotic alignment
- CT
 - indications
 - diagnostic method of choice
 - usually obtained as routine CT imaging in high-energy trauma patients
 - clinical criteria
 - altered consciousness
 - occipital pain and tenderness
 - impaired CCJ motion
 - lower cranial nerve paresis
 - motor paresis
 - views
 - must include cranial-cervical junction with thin-section technique
 - findings
 - occiput fracture
 - may see migration of fragment into spinal canal
 - joint diastasis (2mm or less is considered normal)
- CT angiogram
 - indications
 - concern for vertebral artery injury
 - surgical planning to identify location of vertebral artery
- MRI
 - indications
 - evaluation of soft-tissue craniocervical trauma

- spinal cord or brain stem ischemia
- findings
 - edema or fluid collection in the occipitoatlantal joint representing rupture of the occipitoatlantal joint capsule
 - edema or fluid collection consistent with avulsion injury of alar ligament from dens or occiput
- MRA (Magnetic Resonance Angiogram)
 - indications
 - considered with suspected vascular injury

• Differential

- Key differential
 - occipitocervical instability
 - atlas fractures
 - odontoid fracture

• Treatment

- Nonoperative
 - **immobilization with cervical orthosis**
 - indications
 - indicated in vast majority of low energy fractures
 - Type 1 and 2
 - Type 3 without overt instability
 - modalities
 - semi-rigid or rigid cervical collar
 - usually worn for 6 weeks
- Operative
 - **occipitocervical fusion**
 - indications
 - very rarely indicated
 - Type 3 with overt instability
 - neural compression from displaced fracture fragment
 - associated occipital-atlantal or atlanto-axial injuries

• Techniques

- **Occipitocervical fusion**
 - approach
 - posterior midline incision with patient in prone position

- Mayfield retractor used to obtain proper craniocervical alignment
 - establish preoperative O-C2 angle with lateral fluoroscopy prior to draping
- deep dissection
 - if performing C1 lateral mass screw fixation work within safe zone and do not dissect above the posterior arch of C1 more than 1 cm lateral to midline to avoid injury to vertebral artery
- instrumentation
 - length
 - posterior segmental instrumented fusion is usually performed from the occiput to C3
 - occipital
 - occipital plates usually allow for 3 or 4 total screws with adjustable rod holders
 - occipital screws
 - usually unicortical to avoid injury to venous sinus
 - major dural venous sinuses are located just below the external occipital protuberance and are at risk of penetrative injury
 - some institutions prefer bicortical screws but they come at increase risk
 - occipital screw safe zone
 - the safe zone for occipital screws is located within an area measuring 2 cm lateral and 1 cm inferior to the external occipital protuberance along the superior nuchal line
- C1 lateral mass screws
 - often skipped due to angle at base of skull making it more difficult to place a rod
 - may choose a unilateral screw to provide some rotational stability to C1 ring
- C2 fixation
 - pars, pedicle screws, transarticular, or translaminar screws all options
- C3 fixation
 - standard lateral mass screws aimed cephalad and lateral to avoid vertebral artery
- arthrodesis
 - perform decortication of occiput, posterior arch of C1, and lamina of C2

- may require autogeneuous bone grafting or bone allograft
- postoperative immobilization
 - patients frequently immobilized in halo or hard cervical orthosis for 6-12 weeks to obtain fusion

- Complications

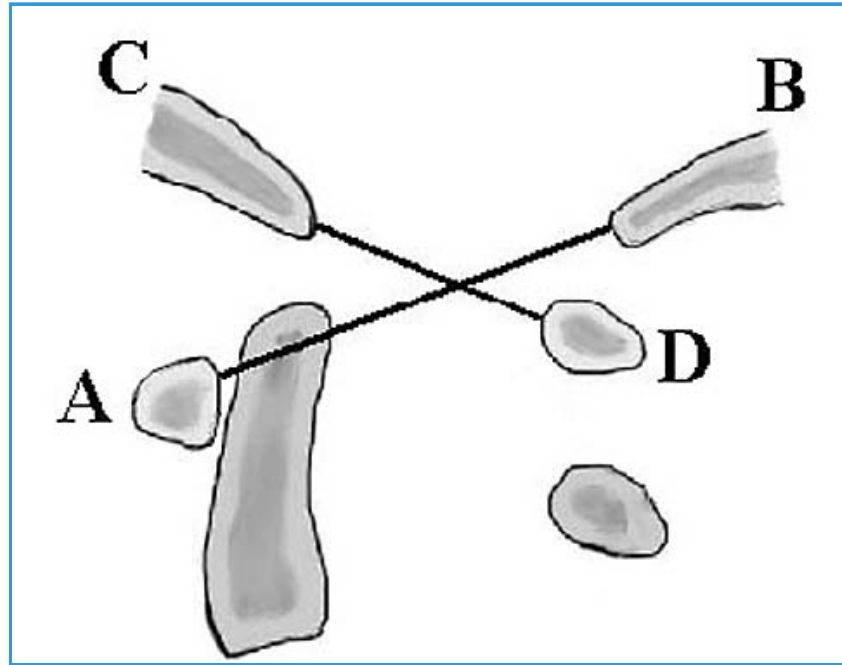
- Nonoperative
 - neck pain & stiffness
- Operative
 - intracranial venous sinus injury (occipital screws)
 - vertebral artery injury (C1 lateral mass screws)
 - adjacent segment disease
 - neck pain & stiffness

- Prognosis

- high mortality rate (11%) due to associated injuries.
 - rate has decreased due to improvement in first responder cervical spine precautions.

54- Occipitocervical Instability

Images



• Summary

- Occipitocervical instability can be traumatic or acquired through a degenerative process such as rheumatoid arthritis or Down's Syndrome.
- Diagnosis is usually confirmed with a combination of CT scan, MRI, and lateral flexion-extension radiographs.
- Traumatic instability is treated with occipitocervical fusion. Acquired instability is treated with observation or occipitocervical fusion depending on the presence of neurologic deficits.

• Epidemiology

- traumatic occipitocervical instability
 - incidence
 - ~15-30% of cervical spine injuries occur at the occipitocervical junction
 - prevalence
 - identified in 19% fatal cervical injuries
- acquired occipitocervical instability
 - most frequently seen in Down syndrome population

- usually asymptomatic and identified in screen for surgery or special olympic participation

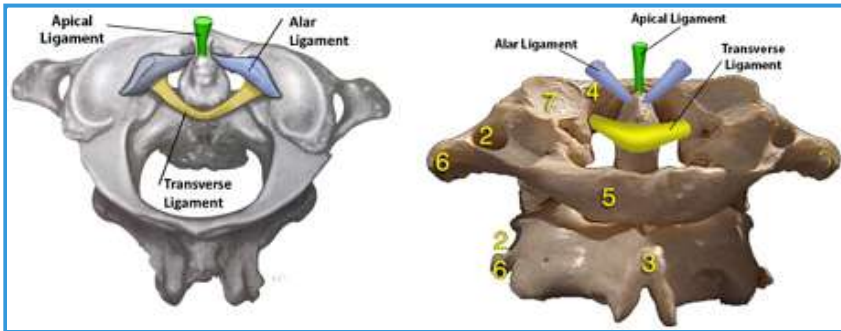
- Etiology

- Terminology
 - also called
 - atlanto-occipital dissociation (AOD)
 - occipitocervical dislocation
- Pathophysiology
 - traumatic
 - mechanism of injury
 - high-energy trauma
 - translation or distraction injuries that destabilize the occipitocervical junction
 - pathoanatomy
 - head most often displaces anteriorly
 - acquired
 - pathoanatomy
 - due to bony dysplasia or ligament and soft-tissue laxity
- Associated conditions
 - atlantoaxial instability
 - also seen in Down syndrome patients
 - neurologic deficits
 - vertebral or carotid artery injuries
 - Down Syndrome

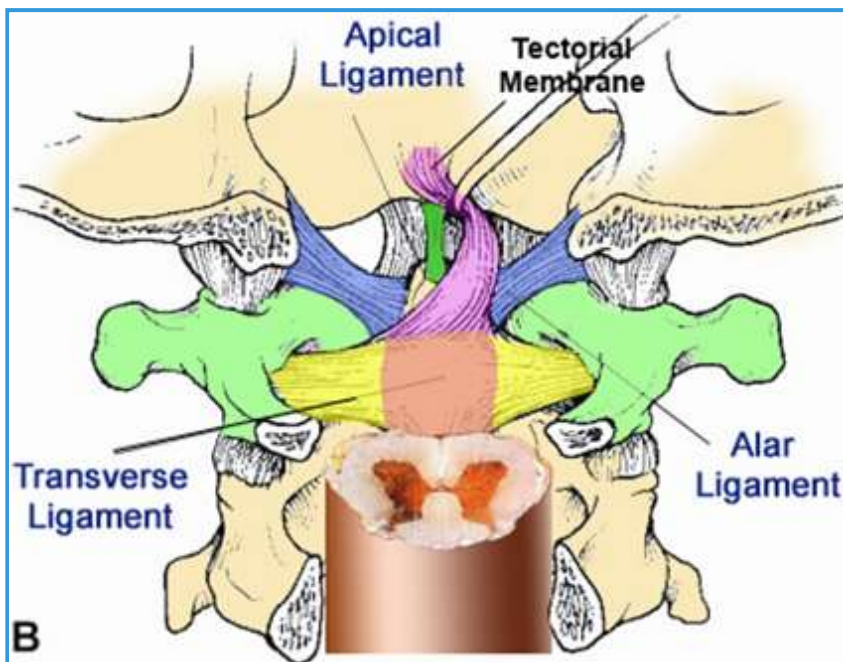
- Anatomy

- Osteology
 - morphology
 - occipital condyles are paired prominences of the occipital bone
 - oval or bean shaped structures forming lateral aspects of the foramen magnum
 - joint articulations
 - intrinsic relationship between occiput, atlas and axis to form the occipitoatlantoaxial complex or CCJ
 - 6 main synovial articulations
 - anterior and posterior median atlanto-odontoid joints
 - paired occipitoatlantal joints

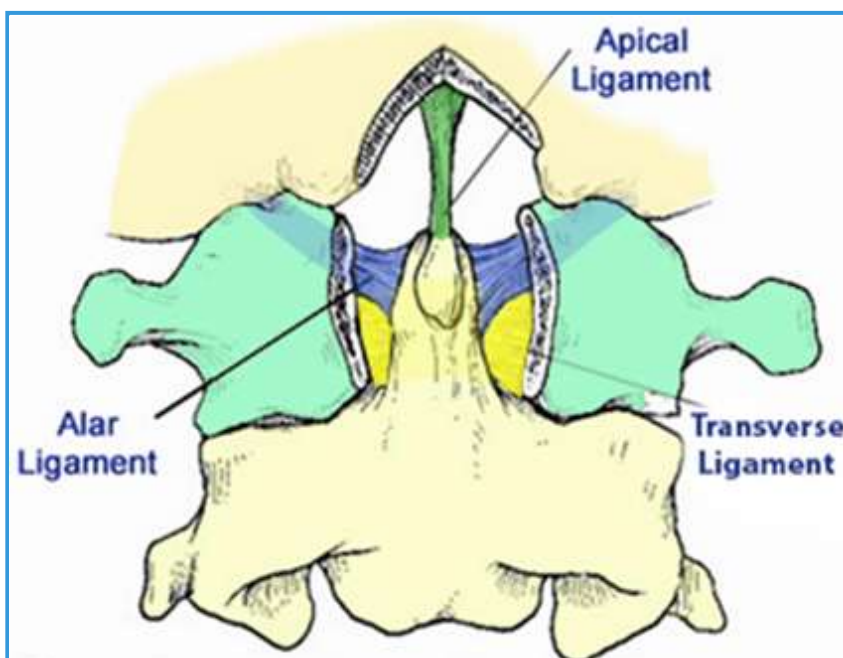
- paired atlantoaxial joints
- Ligaments
 - intrinsic ligaments are located within the spinal canal, provide most of the ligamentous stability. They include
 - transverse ligament



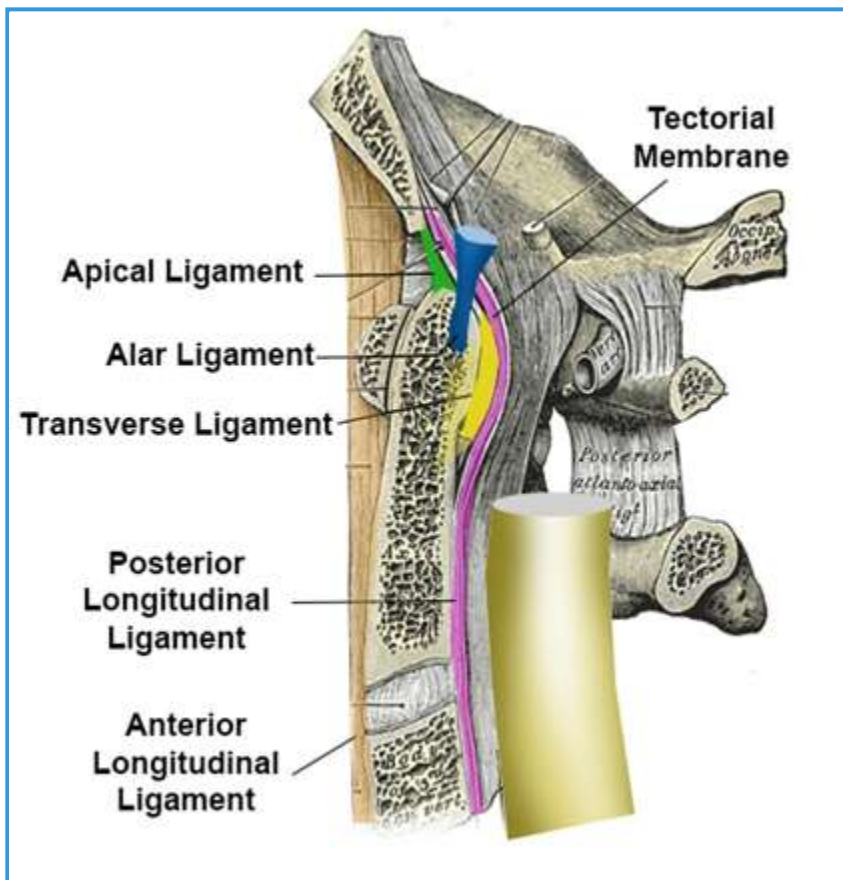
- primary stabilizer of atlantoaxial junction
- connects the posterior odontoid to the anterior atlas arch, inserting laterally on bony tubercles.
- paired alar ligaments



- connect the odontoid to the occipital condyles
- relatively strong and contributes to occipitalcervical stability
- apical ligament



- relatively weak midline structure
- runs vertically between the odontoid and foramen magnum.
- tectorial membrane



- connects the posterior body of the axis to the anterior foramen magnum and is the cephalad continuation of the PLL
- Vascular system
 - occipital condyles in proximity to vertebral arteries
- Nervous system
 - proximity of the occipital condyles to:
 - medulla oblongata
 - spinal cord
 - lower cranial nerves (CN IX - CN XII)

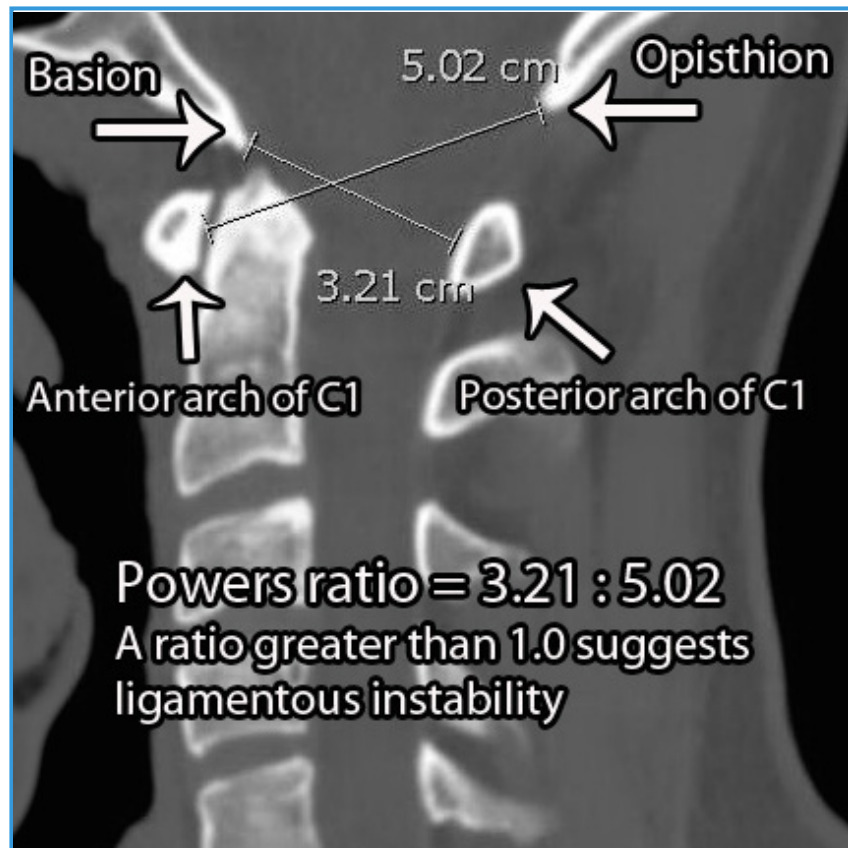
• Classification

○	■ Traynelis Classification (direction of displacement)		
	■ Type	■ Anterior occiput dislocation	■
	■ Type II	■ Longitudinal dislocation	■
	■ Type III	■ Posterior occiput dislocation	■
○	■ Harbourview Classification System (degree of instability)		
	■ Stage I	■ Minimal or non-displaced, unilateral injury to craniocervical ligaments	■ Stable
	■ Stage II	■ Minimally displaced, but MRI demonstrates significant soft-tissue injuries. Stability may be based on traction test	■ Stable or Unstable
	■ Stage III	■ Gross craniocervical misalignment (BAI or BDI > 2mm beyond normal limits)	■ Unstable

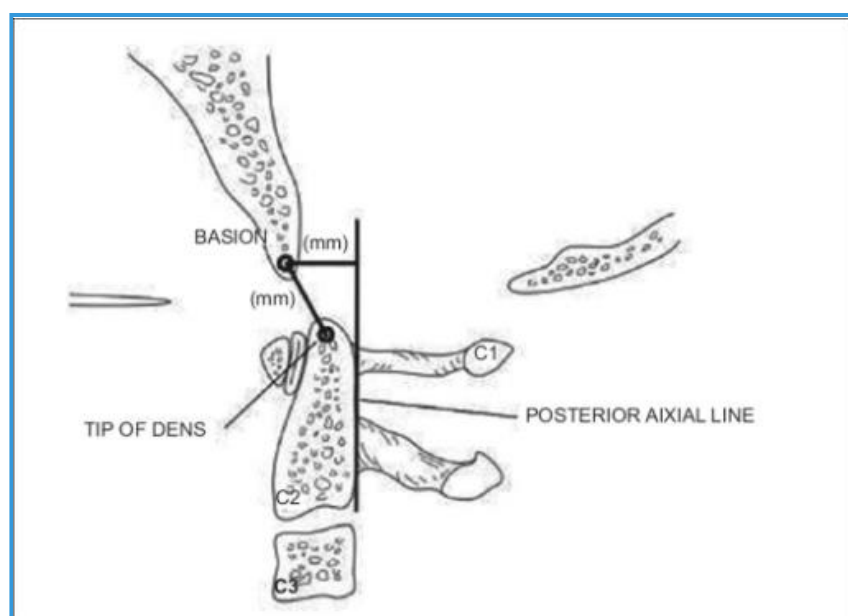
• Imaging

- Radiographs
 - recommended views
 - AP, lateral and odontoid views

- findings
 - low sensitivity in detecting injury (57%)
- measurements
 - used to diagnosis occipitocervical dislocation
 - Powers ratio = C-D/A-B



- C-D: distance from basion to posterior arch
- A-B: distance from anterior arch to opisthion
 - significance
 - ratio ~ 1 is normal
 - if > 1.0 concern for
 - anterior dislocation
 - ratio < 1.0 raises concern for
 - posterior atlanto-occipital dislocation
 - odontoid fractures
 - ring of atlas fractures
- Harris rule of 12



- basion-dens interval or basion-posterior axial interval
 - >12mm suggest occipitocervical dissociation

- indications
 - considered gold standard for osseous injuries of the spine
- views
 - midsagittal CT reconstruction
- CT angio
 - indications
 - evaluate for injury to vertebral artery
 - identify anatomy of vertebral artery prior to occipitocervical fusion
- MRI
 - indications
 - suspected ligamentous injury with preserved alignment or occult injury
 - neurological deficits

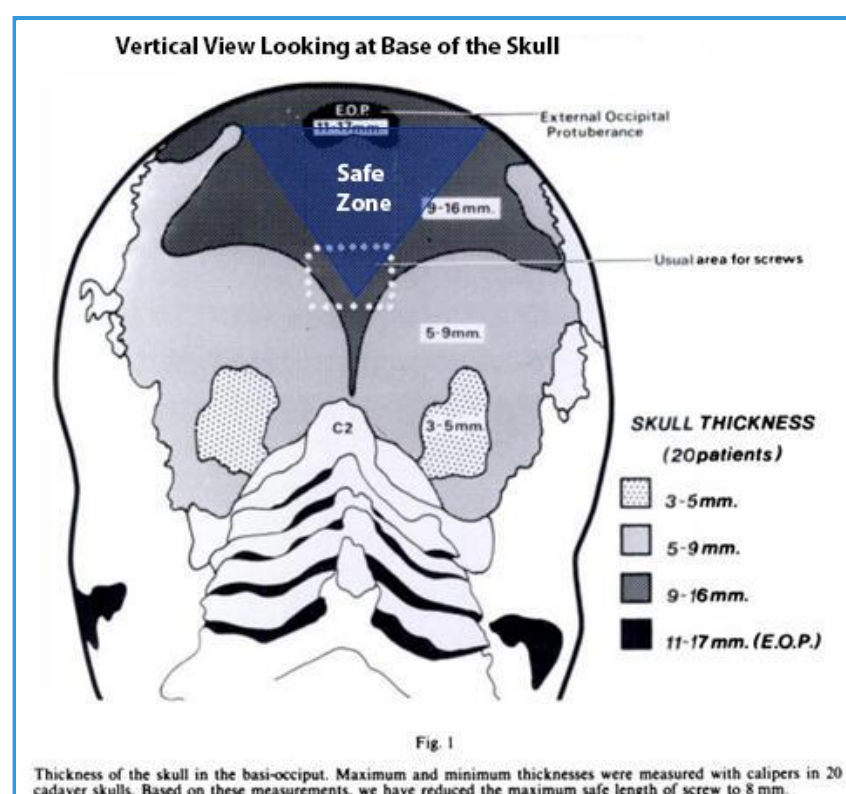
• Treatment

- Nonoperative
 - **provisional stabilization while avoiding traction**
 - indications
 - traumatic instability with distraction of the occipitoatlantal joint
 - techniques
 - halo vest
 - tongs
 - prolonged cervical orthosis is not recommended due to poor stabilization of the AOJ
 - outcomes
 - use of traction should be avoided in most cases
 - traction may be considered in stage 2 injuries when MRI demonstrates soft-tissue injury with preserved alignment
- Operative
 - **occipitocervical fusion**
 - indications
 - most traumatic cases require stabilization
 - acquired cases when evidence of myelopathy or significant symptomatic neck pain
 - invagination and atlanto-axial impaction secondary to inflammatory arthropathy (e.g., rheumatoid arthritis)
 - tumor

• Technique

○ Occipitocervical fusion

- approach
 - posterior midline incision with patient in prone position
 - Mayfield retractor used to obtain proper craniocervical alignment
 - establish preoperative O-C2 angle with lateral fluoroscopy prior to draping
- deep dissection
 - if performing C1 lateral mass screw fixation work within safe zone and do not dissect above the posterior arch of C1 more than 1 cm lateral to midline to avoid injury to vertebral artery
- instrumentation
 - length
 - posterior segmental instrumented fusion is usually performed from the occiput to C3
 - occipital
 - occipital plates usually allow for 3 or 4 total screws with adjustable rod holders
 - occipital screws
 - usually unicortical to avoid injury to venous sinus
 - major dural venous sinuses are located just below the external occipital protuberance and are at risk of penetrative injury
 - some institutions prefer bicortical screws but they come at increase risk
 - occipital screw safe zone
 - the safe zone for occipital screws is located within an area measuring 2 cm lateral and 1 cm inferior to the external occipital protuberance along the superior nuchal line



- C1 lateral mass screws
 - often skipped due to angle at base of skull making it more difficult to place a rod
 - may choose a unilateral screw to provide some rotational stability to C1 ring
- C2 fixation
 - pars, pedicle screws, transarticular, or translaminar screws all options
- C3 fixation
 - standard lateral mass screws aimed cephalad and lateral to avoid vertebral artery
- arthrodesis
 - may require bone grafting or removal of bony fragments compressing neurovascular structures.

- Complications

- Nonunion
- Bleeding
 - Internal Carotid Artery
 - Vertebral Artery

55- Atlantoaxial Instability

- etiology

- The atlantoaxial joint is an important "transitional zone" in the cervical spine
 - prone to instability by both degenerative and traumatic processes.
- Pathophysiology
 - adult causes
 - degenerative
 - Down's syndrome
 - Rheumatoid Arthritis
 - Os odontoideum
 - traumatic
 - Type I odontoid fracture (very rare)
 - Atlas fractures
 - Transverse ligament injuries
 - pediatric causes
 - degenerative
 - JRA
 - Morquio's Syndrome
 - lysosomal storage disorder
 - trauma/infection
 - rotatory atlantoaxial subluxation

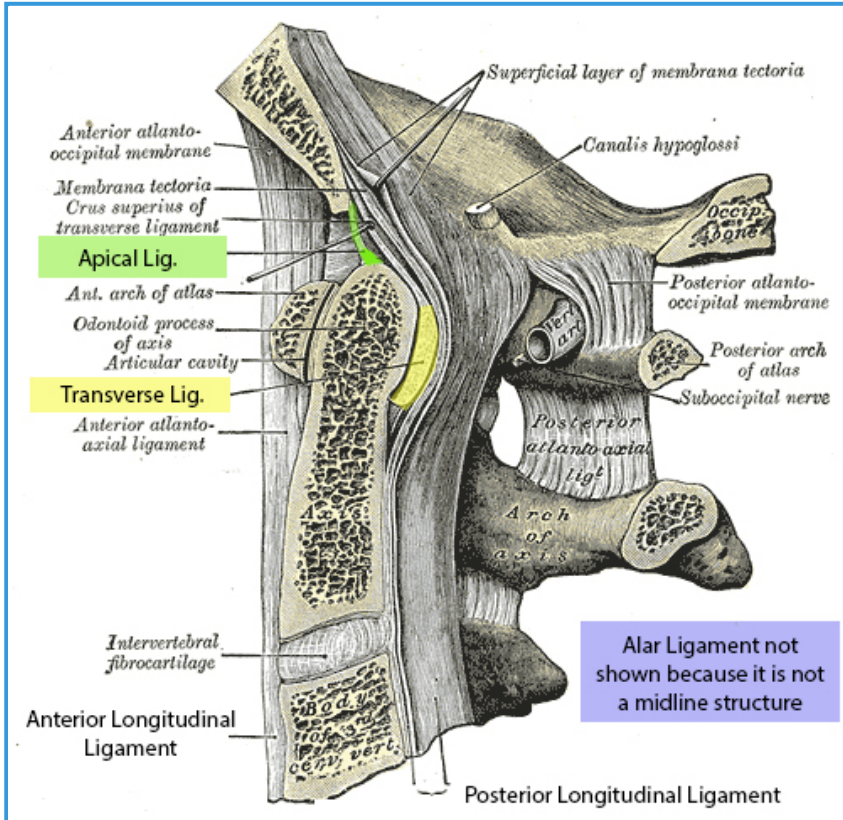
- Anatomy

- Osteology
 - bony articulations
 - C1-C2 facet joints
- Ligaments
 - transverse apical alar ligament complex

Transverse Apical Alar Ligament Complex

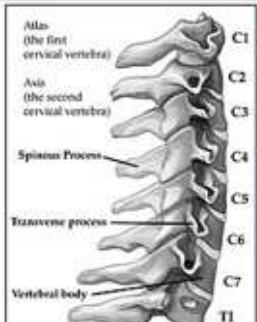
The diagrams illustrate the Transverse Apical Alar Ligament Complex from different perspectives:

- Top-left:** Anterior view of a vertebra showing the Apical Ligament (green), Alar Ligament (blue), and Transverse Ligament (yellow).
- Top-right:** Superior view of a vertebra showing the Apical Ligament (green), Alar Ligament (blue), and Transverse Ligament (yellow).
- Bottom-left:** 3D model of a vertebra with numbered points (1-6) and ligaments highlighted. The Apical Ligament is green, the Alar Ligament is blue, and the Transverse Ligament is yellow.
- Bottom-right:** Superior view of C1 on C2 showing the Axis: spinous process, Superior articular facet, atlas, Posterior arch, atlas, Dens, Transverse lig., atlas, and Anterior arch, atlas. A legend indicates:
 - Red line: Anterior arch, atlas
 - Orange line: Superior articular facet, atlas
 - Blue line: Dens
 - Green line: Anterior arch, atlas



- transverse ligament
 - most important stabilizer
- apical ligament
 - single midline structure
- alar ligaments
 - paired parasagittal ligament
- Biomechanics
 - the atlantoaxial joint provides ~50% of rotation in the cervical spine

Cervical Osteology & Kinematics



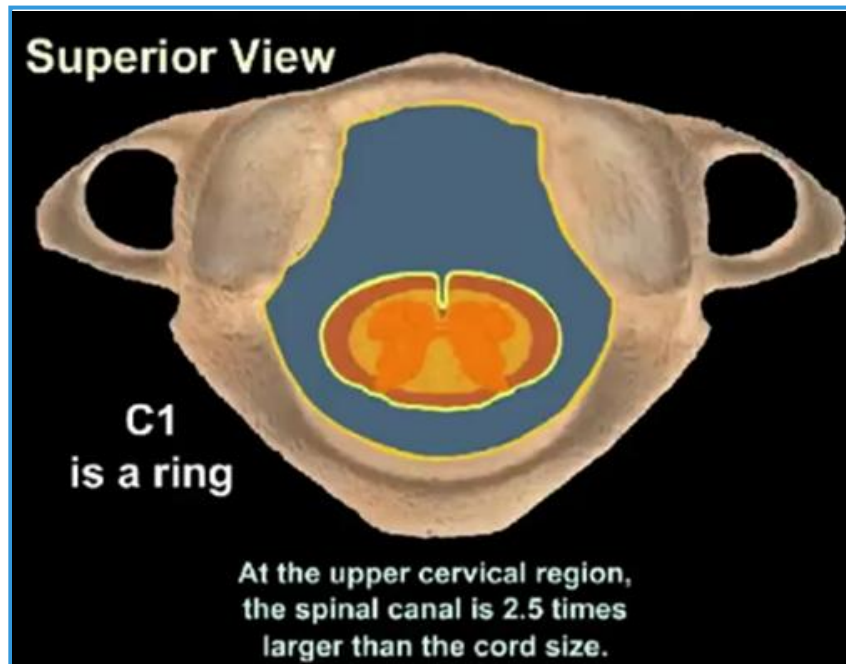
	Blind Spinous Process	Transverse Foramen / Vert?	Flexion/ Extension	Rotation	Lateral Bend
C1	Occiput-C1		50	4	8
C2	C1 (Atlas)	None	Yes / Yes		
C3	C2 (Axis)	Yes	Yes / Yes	10	50
C4	C3	Yes	Yes / Yes		
C5	C4	Yes	Yes / Yes		
C6	C5	Yes	Yes / Yes	50 (10/level)	50 (10/level)
C7	C6	Yes	Yes / Yes		
T1	C7 (VP)	No (95%)	Yes / No	60 (12/level)	60
Total Motion			110	100	68

- this is enabled by the peg (C2)-ring(C1) anatomy

- Physical Exam

- Symptoms
 - symptomatic

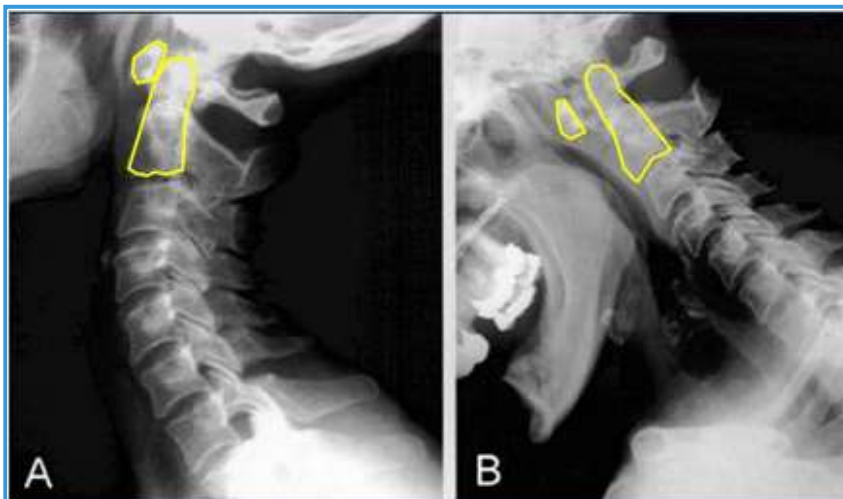
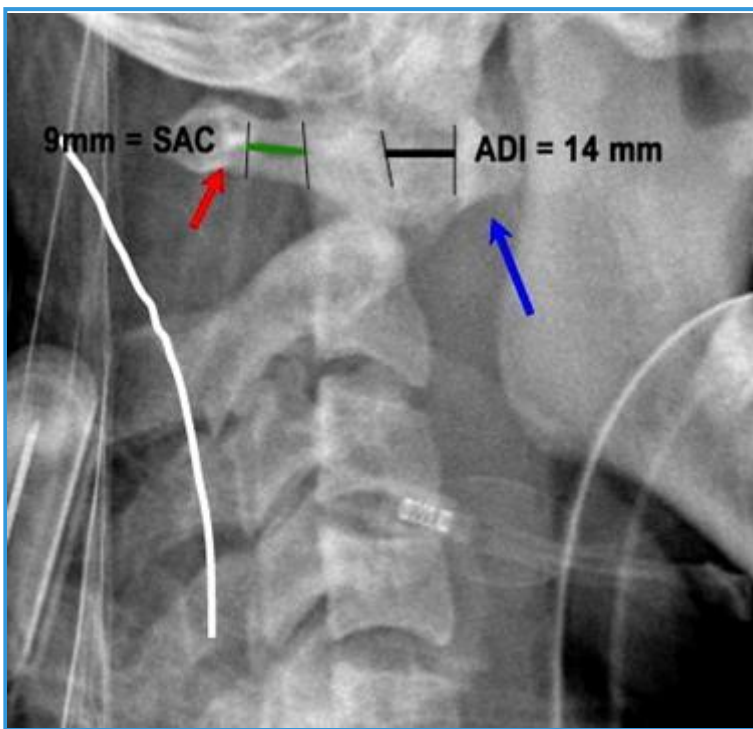
- neck pain
- neurologic symptoms
- Physical exam
 - neurologic deficits
 - often appear late in disease process due to capacious nature of spinal canal at the C1 level



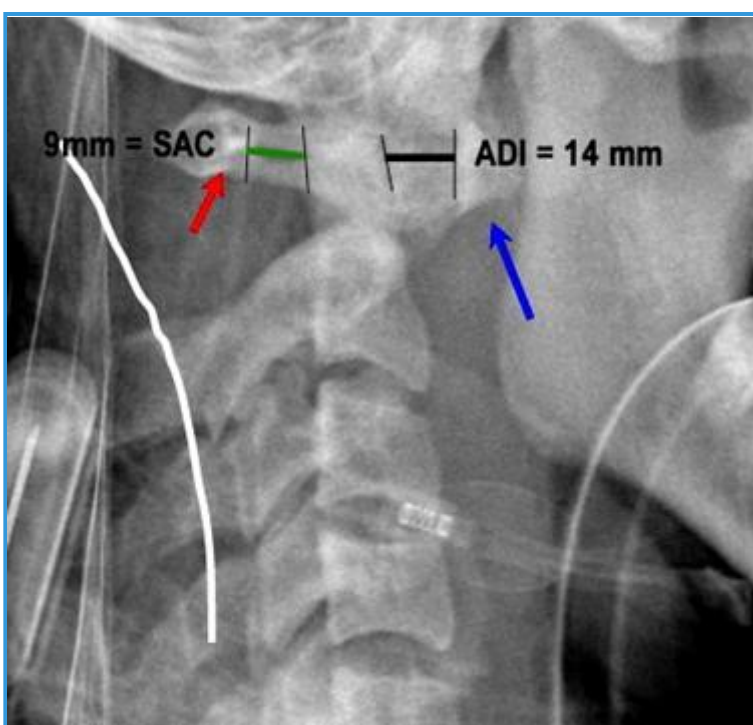
- myelopathic symptoms
 - hyperreflexia (patellar tendon reflex)
 - muscles weakness
 - broad based gait
 - decreased hand dexterity
 - loss of motor milestones
 - bladder problems

- Imaging

- Radiographs
 - flexion-extension xrays
 - atlanto-dens interval (ADI)

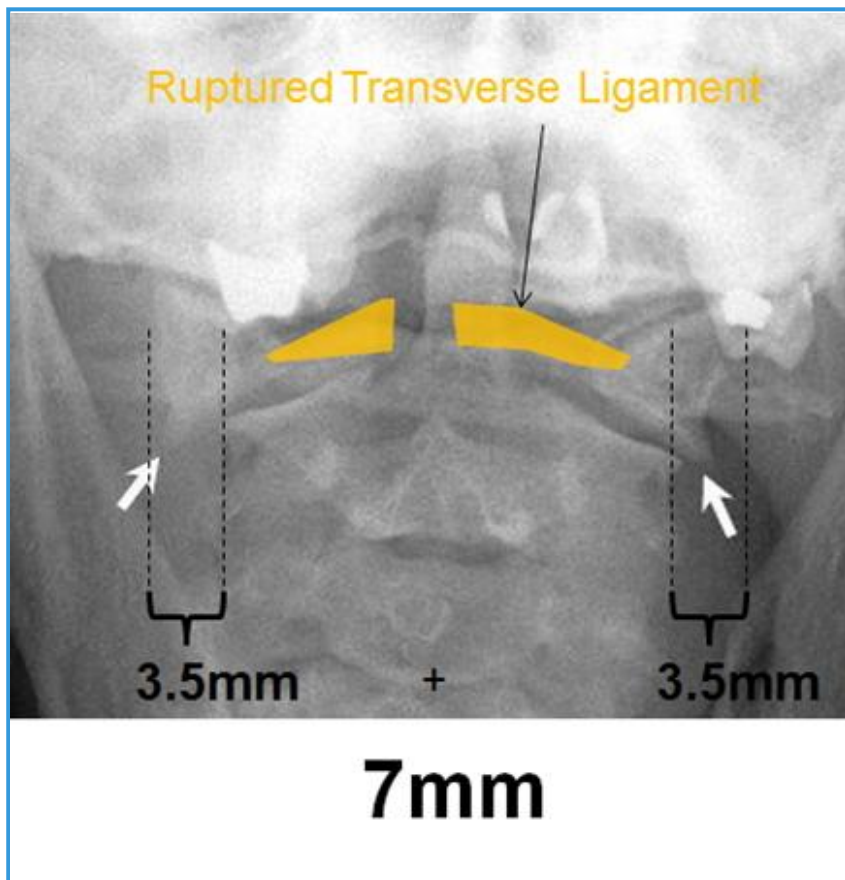


- measurement
 - distance between odontoid process and the posterior border of the anterior arch of the atlas
- adult parameters
 - > 3.5mm considered unstable
 - > 10mm indicates surgery in RA
- other
 - must get preoperative flexion-extension radiographs to clear all high-risk patients for any type of surgery
- space-available-cord (SAC) = posterior atlanto-dens-interval (PADI)

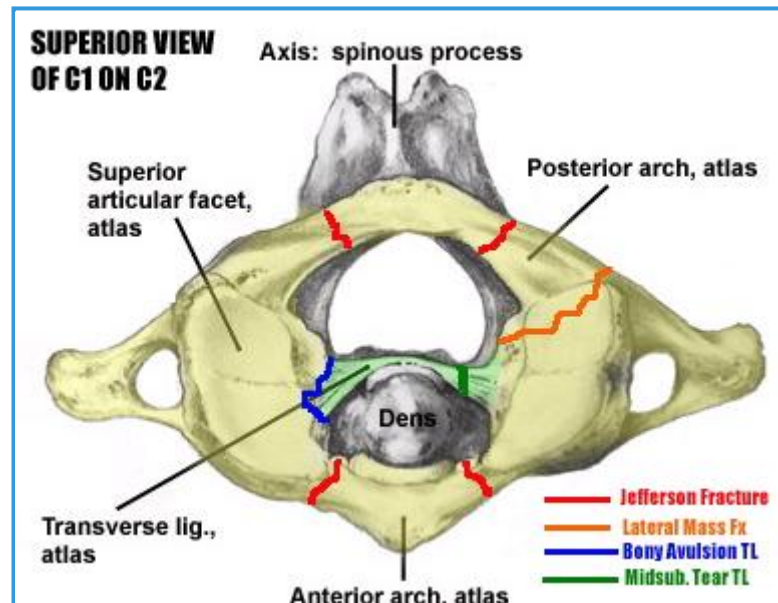


- measurement
 - distance from posterior surface of dens to anterior surface of posterior arch of atlas

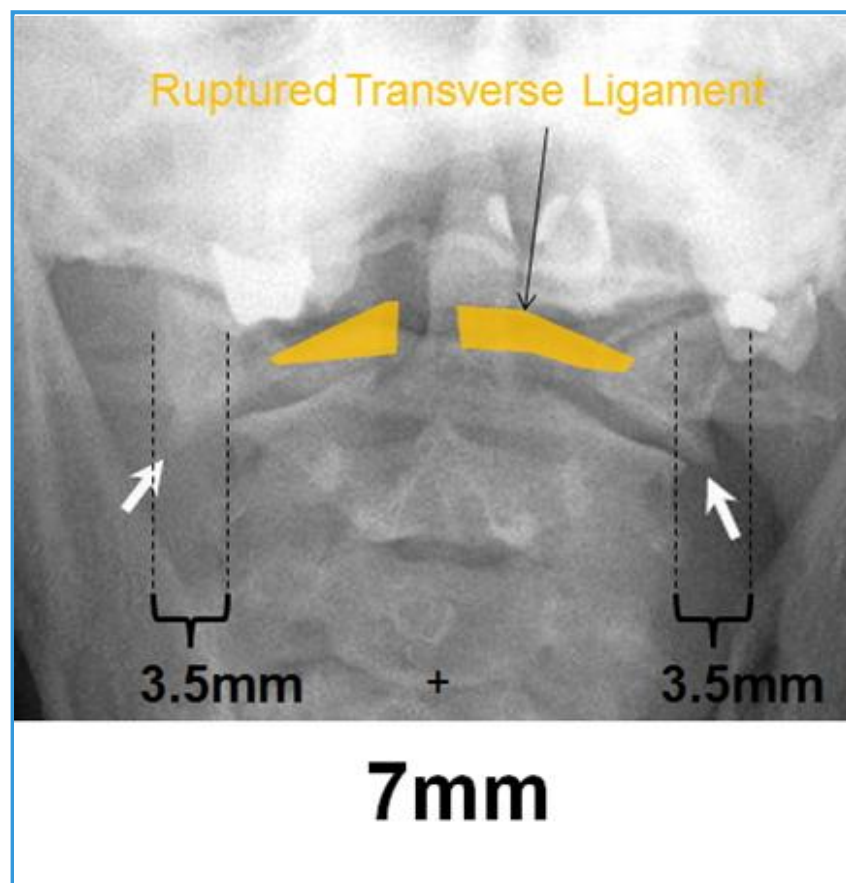
- adult parameters
 - in adults with RA < 14 mm associated with increased risk of neurologic injury and is an indication for surgery
- open mouth odontoid



- sum of lateral mass displacement
 - measurement
 - lateral mass are connect by ring of C1, and therefore can only be displaced relative to each other if



- there is a bony fracture (disruption of the ring)
- the transverse ligament is ruptured



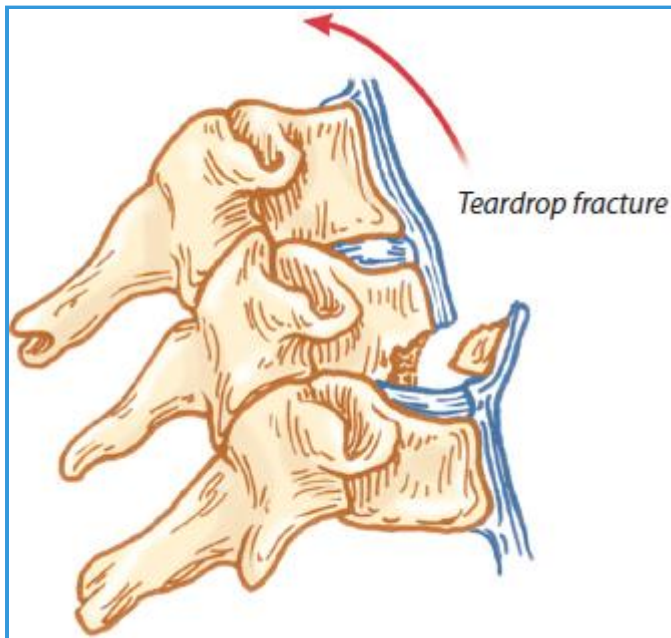
- transverse ligaments binds them together
- adult parameters
 - if > 8.1 mm, then a transverse ligament rupture is assured and the injury pattern is considered unstable

- Treatment

- Determined by specific condition
 - adult atlantoaxial instability
 - Down's syndrome
 - Rheumatoid Arthritis
 - Os odontoideum
 - Odontoid fracture
 - Atlas fractures
 - Transverse ligament injuries
 - pediatric atlantoaxial instability
 - JRA
 - Morquio's Syndrome
 - Rotatory atlantoaxial subluxation

56- Extension Teardrop Fracture Cervical Spine

Images



- summary
 - Extension Teardrop Fractures of the cervical spine are subaxial cervical spine fractures caused by forced extension of the neck with resulting avulsion of the anteroinferior corner of the vertebral body.
 - Diagnosis can be made with lateral radiographs of the cervical spine.
 - Treatment is usually immobilization in a hard collar as the injury is mechanically stable.
- Epidemiology
 - Incidence
 - rare
- Etiology
 - Pathophysiology
 - extension mechanism causes disruption of the anterior longitudinal ligament (ALL)
 - represents a true avulsion often of an anterior osteophyte
 - distinguish from a flexion teardrop fracture
 - larger fragment produced by compression
 - extension teardrop fractures are stable in flexion, and unstable in extension

- not considered as severe as flexion teardrop fractures
- Associated conditions
 - central cord syndrome
 - buckling of the ligamentum flavum into canal during hyperextension phase of injury
 - risk factors
 - elderly
 - anterior osteophytes and posterior infolded ligamentum flavum
 - can be seen in diving accidents
 - not usually associated with spinal cord injuries

- Presentation

- Symptoms
 - neck pain
- Physical exam
 - patients are usually neurologically intact
 - may have symptoms of central cord syndrome

- Imaging

- Radiographs
 - recommend views
 - AP and lateral of cervical spine
 - findings
 - avulsion fracture from attachment of the ALL to the inferior corner of the vertebral body



- usually a thin fracture fragment
- fragment is usually triangular in shape - reminiscent of a teardrop

- may see anterior disc space widening

- MRI

- may help distinguish extension injury from flexion injury
- edema will be located anteriorly in extension injury

- Treatment

- Nonoperative

- **immobilization in hard collar**
 - indications
 - most injuries

57- Clay Shoveler Fracture Cervical Spinous Process Fractures

Images



- summary

- Clay-shoveler Fractures are an avulsion-type spinous process fracture in the lower cervical or upper thoracic spine.
- Diagnosis is made with lateral radiographs of the cervical spine.
- Treatment is usually rest and pain control as the injuries are mechanically stable.

- Epidemiology

- Incidence
 - rare
- Demographics
 - direct trauma to posterior spinous process
 - indirect trauma
 - sudden muscular/ligamentous pull in flexion or extension
- Anatomic location
 - most commonly C7 , but can affect C6 to T3
 - usually occurs midway between the spinous tip and lamina
- Risk factors
 - labourers
 - racket or contact sports
 - motor vehicle accidents

- Etiology

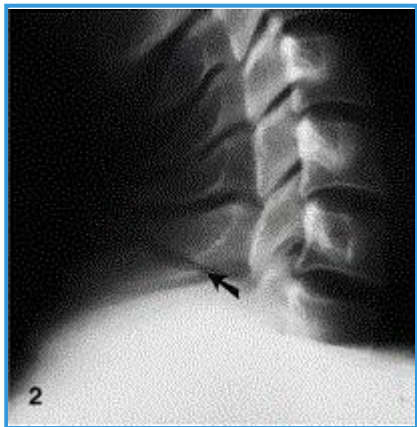
- Associated conditions
 - usually occurs in isolation
 - other orthopaedic injuries to consider
 - lamina fracture
 - facet dislocations

- Presentation

- Symptoms
 - sudden onset of pain between the shoulder blades or base of neck
 - reduced head/neck ROM
- Physical exam
 - inspection
 - localized swelling and tenderness
 - crepitus
 - motion
 - document flexion-extension of cervical spine
 - neurovascular examination

- Imaging

- Radiographs
 - recommended views



- cervical +/- thoracic xrays that should always be obtained on evaluation
 - alternative views
 - flexion and extension views
 - findings
 - lateral view



- fracture line is usually obliquely oriented with the fragment displaced posteroinferior
- AP view



- double spinous process shadow is suggestive of displaced fracture

○ CT

- indications



- method of choice
- routine CT imaging in high-energy trauma patients
- clinical criteria
 - altered consciousness
 - midline spinal pain or tenderness
 - impaired CCJ motion
 - lower cranial nerve paresis
 - motor paresis
- views
 - fracture is best seen on lateral view
- MRI
 - indications
 - not required in isolation
- Treatment
 - Nonoperative
 - **NSAIDS, rest, immobilization in hard collar for comfort**
 - indications
 - most common treatment for pain control
 - modalities
 - short term treatment with hard collar
 - outcomes
 - usually high union rates and excellent clinical outcomes

- Operative
 - **surgical excision**
 - indications
 - persistent pain or non-union
 - failed conservative treatment

- Complications

- Chronic pain
- Neck stiffness

- Prognosis

- Stable injury in isolation
- Very rarely associated with neurological injury
- High union rate

58- Cervical Lateral Mass Fracture Separation

- Summary

- Cervical Lateral Mass Fracture Separations of the lateral mass-facet are uncommon cervical spine injuries characterized by a high degree of instability and neurological deficits.
- Diagnosis is made with CT scan of the cervical spine.
- Treatment is usually posterior decompression and two-level instrumented fusion.

- Epidemiology

- Demographics
 - male : female ratio = 2:1
 - mean age 35 yrs (20-70yrs)
- Anatomic location
 - C6 > C5 > C7 > C4 > C3

- Etiology

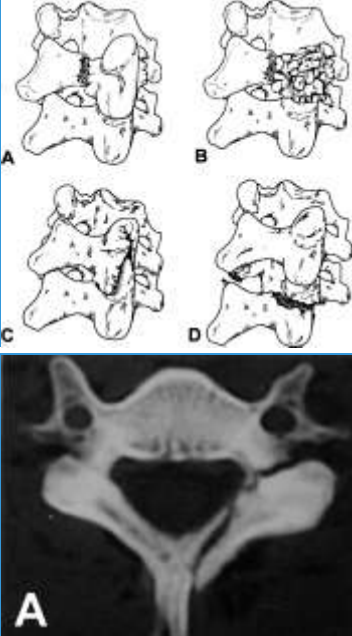
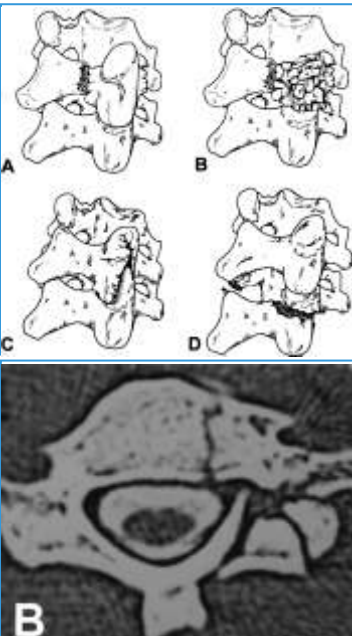
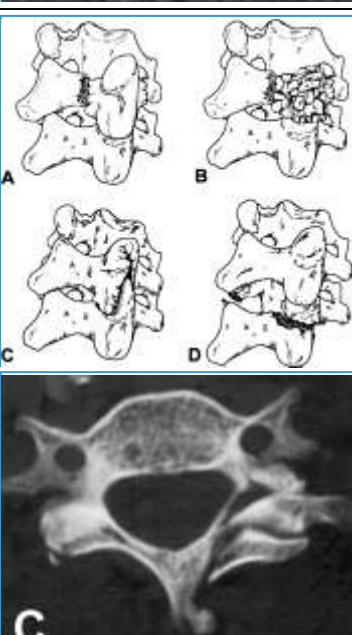
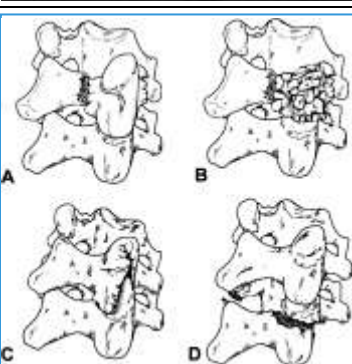
- Pathophysiology
 - mechanism of injury
 - traffic accident, falls, heavy object landing on head
 - hyperextension, lateral compression and rotation of the cervical spine
- Associated conditions
 - instability
 - affect 2 levels
 - because of involvement of the superior facet and inferior facet on either side of the fractured articular mass
 - anterior translation (listhesis)
 - fractured vertebrae (77%)
 - superior adjacent vertebrae (24%)
 - inferior adjacent vertebrae (10%)
 - coronal translation (33%)

- vertebral body collapse (33%)
 - lower in Type A Separation fracture subtypes

- Classification

- Kotani Classification

■ Kotani Classification

■ <i>Fracture Type</i>	■ <i>Fracture Description</i>	■ Rates of Anterior Translation (same level)	■ <i>Rates of Anterior Translation (adjacent level)</i>	■
■ Type A - Separation fracture	■ 2 fracture lines of unilateral lamina and pedicle	■ 91%	■ 20%	■ 
■ Type B - Comminution type	■ Multiple fracture lines with lateral wedging in coronal plane	■	■ 50%	■ 
■ Type C - Split type	■ Vertical fracture line in the coronal plane, with invagination of the superior articular process of the caudal vertebra	■ 80%	■ 0%	■ 
■ Type D - Traumatic spondylolysis	■ Bilateral horizontal fracture lines of the pars interarticularis, leading to separation of the anterior-posterior spinal elements	■ 100%	■ 50%	■ 

● Presentation

- History
 - commonest mechanisms (Allen and Ferguson classification)
 - extension-compression
 - lateral flexion
 - results in Type B Comminuted subtype
 - flexion-distraction
- Symptoms
 - neurologic symptoms common (up to 66%)
 - radicular pain, radiculopathy or spinal cord injury/myelopathy
 - can be classified by Frankel grade or ASIA impairment scale
- Physical exam
 - inspection
 - torticollis, paravertebral muscle spasm
 - neurovascular
 - radicular pain and numbness
 - myelopathy
- Imaging
 - Radiographs
 - recommended views
 - AP, lateral, oblique views
 - findings
 - disc space narrowing
 - often difficult to detect on plain radiographs
 - instability
 - >3.5mm displacement
 - >10deg kyphosis
 - >10deg rotation difference compared with adjacent vertebra
 - sensitivity and specificity
 - low sensitivity
 - 38% pickup rate on plain radiographs
 - CT
 - indications
 - to further evaluate fracture morphology
 - fracture line extends
 - rostrally/caudally into adjacent superior/inferior facets
 - ventrally into foramen transversarium, transverse process and pedicle

- dorsally into lamina

- findings

- translation of fractured/adjacent vertebrae in sagittal and coronal planes
- uncovertebral joint subluxation
- degree of vertebral body destruction

- MRI

- findings

- disruption of ligaments
 - 50-75% rupture of anterior longitudinal ligament (ALL)
 - 30-35% disruption of posterior longitudinal ligament (PLL)
 - 10-75% disruption interspinous and supraspinous ligaments (ISL and SSL)
- disruption of intervertebral disc
- bone bruising

- Treatment

- Nonoperative

- **NSAIDS, rest, immobilization**

- indications
 - stable injuries without neurological deficit
 - hyperextension/rotation is poorly immobilized in a halo
- techniques
 - Miami J collar
 - halo vest
- outcomes
 - long term results of non-operative treatment are less desirable
 - may be successful in the absence of instability
 - surveillance is necessary to detect late instability and persistent pain
 - spontaneous fusion rate is only 20%

- Operative

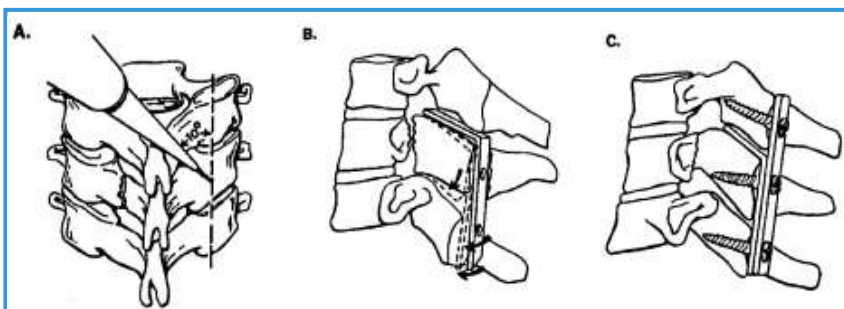
- **posterior decompression and two-level instrumented fusion**

- indications
 - most cases require surgery
 - main injured structures are posterior, thus preferred approach is posterior

- also indicated for nonoperatively managed cases with late instability and persistent pain
- techniques
 - two-level lateral mass or pedicle screw and rod fixation



- lateral mass plating



- outcomes
 - risk of anterior disc space collapse and late kyphotic deformity
 - midline fusion does not control rotation
- **two-level ACDF**
 - indications
 - if mostly reduced and don't need posterior approach to obtain direct reduction
 - controls anterior collapse and rotation
 - techniques
 - using iliac crest bone graft
- **single posterior pedicle screw**



- indications
 - Type A Separation fracture without instability
- **anterior and posterior decompression and fusion**
 - indications
 - if additional anterior column support is needed
 - if anterior approach is attempted initially, with unsuccessful reduction because of complicated fracture morphology or late presentation

- Complications

- Vertebral artery injury
 - from pedicle screw placement
- Late kyphotic deformity
- Late instability (anterior translation)
- Chronic neck pain and radiculopathy

59- Subaxial Cervical Vertebral Body Fractures

- Summary

- Subaxial Cervical Vertebral Body Fractures are a subset of cervical spine injuries that consist of compression fractures, burst fractures, flexion teardrop fractures, and extension teardrop avulsion fractures.
- Diagnosis is made with radiographs of the cervical spine. CT scan can be helpful for fracture characterization and surgical planning.
- Treatment can be nonoperative or surgical stabilization depending on fracture pattern, mechanical stability, and the presence of neurological deficits.

- Etiology

- Types
 - compression fracture
 - characterized by
 - compressive failure of anterior vertebral body without disruption of posterior body cortex and without retropulsion into canal
 - often associated with posterior ligamentous injury
 - burst fracture



- characterized by
 - fracture extension through posterior cortex with retropulsion into the spinal canal
 - often associated with posterior ligamentous injury
- prognosis
 - often associated with complete and incomplete spinal cord injury
- treatment
 - unstable and usually requires surgery
- flexion teardrop fracture



- characterized by
 - anterior column failure in flexion/compression

- posterior portion of vertebra retropulsed posteriorly
 - posterior column failure in tension
 - larger anterior lip fragments may be called 'quadrangular fractures'
- prognosis
 - associated with SCI
- treatment
 - unstable and usually requires surgery
- extension teardrop avulsion fracture



- characterized by
 - small fleck of bone is avulsed of anterior endplate
 - usually occur at C2
 - must differentiate from a true teardrop fracture
- mechanism
 - extension
- prognosis
 - stable injury pattern and not associated with SCI
- treatment
 - cervical collar

• Subaxial Spine Injury Classification

- Allen and Ferguson classification(of subaxial spine injuries)
 - typically used for research and not in clinical setting
 - based solely on static radiographs appearance and mechanisms of injury
 - six groups represent a spectrum of anatomic disruption and include
 1. flexion-compression
 2. vertical compression

3. flexion-distraction
4. extension-compression
5. extension-distraction
6. lateral flexion

- Radiographic description classification (of subaxial spine injuries)
 - more commonly used in clinical setting
 - includes
 - compression fracture
 - burst fracture
 - flexion-distraction injury
 - facet dislocation (unilateral or bilateral)
 - facet fracture

- Presentation

- Symptoms
 - incomplete vs. complete cord injury

- Imaging

- Must determine if there is a posterior ligamentous injury so MRI often important

- Treatment

- Nonoperative
 - **collar immobilization for 6 to 12 weeks**
 - indications
 - stable mild compression fractures (intact posterior ligaments & no significant kyphosis)
 - anterior teardrop avulsion fracture
 - **external halo immobilization**
 - indications
 - only if stable fracture pattern (intact posterior ligaments & no significant kyphosis)
- Operative
 - **anterior decompression, corpectomy, strut graft, & fusion with instrumentation**
 - indications
 - compression fracture with 11 degrees of angulation or 25% loss of vertebral body height

- unstable burst fracture with cord compression
- unstable tear-drop fracture with cord compression
- minimal injury to posterior elements
- early decompression (< 24 hours) has been shown to improve neurologic outcomes compared with delayed (>/ 24 hours) decompression
- **posterior decompression, & fusion with instrumentation**
 - indications
 - significant injury to posterior elements
 - anterior decompression not required

60- Cervical Spondylosis

Images



- summary

- Cervical Spondylosis represents the natural degenerative process of the cervical motion segment which can lead to cervical radiculopathy, cervical myelopathy, or axial neck pain.
- Diagnosis can be made with plain radiographs of the cervical spine.
- Treatment can be observation, medical management, or surgical management depending on the severity and chronicity of pain, presence of instability or, presence of neurological deficits.

- Epidemiology

- Incidence
 - typically begins at age 40-50
 - 85% of patients >65 years of age demonstrate spondylotic changes regardless of symptomatology
- Demographics
 - more common in men than women
- Anatomic location
 - most common levels are C5-6 > C6-7 because they are associated with the most flexion and extension in the subaxial spine
- Risk factors

- excessive driving
- smoking
- lifting
- professional athletes

- Pathophysiology

- Pathoanatomy

- Spondylosis is a natural aging process of the spine
 - characterized by degeneration of the disc and the four joints of the cervical motion segment which include
 - two facet joints
 - two uncovertebral joints of Luschka)
 - Degenerative cycle includes
 - disc degeneration
 - disc desiccation, loss of disc height, disc bulging, and possible disc herniation
 - joint degeneration
 - uncinata spurring and facet arthrosis
 - ligamentous changes
 - ligamentum flavum thickening and infolding secondary to loss of disc height
 - deformity
 - kyphosis secondary to loss of disc height with resulting transfer of load to the facet and uncovertebral joints, leading to further uncinata spurring and facet arthrosis
 - Associated conditions
 - often leads to the clinical conditions of
 - cervical radiculopathy
 - cervical myelopathy
 - discogenic neck pain

- Mechanism of Neurologic Compression

- Nerve root compression

- leads to the clinical condition of radiculopathy
 - foraminal spondylotic changes
 - secondary to chondrosesous spurs of facet and uncovertebral joints
 - posterolateral disc herniation or disc-osteophyte complex

- between posterior edge of uncinata and lateral edge of posterior longitudinal ligament (PLL)
 - affects the exiting nerve root (C6/7 disease will affect the C7 nerve root)
 - foraminal soft disc herniation
 - affects the exiting nerve root (C6/7 disease will affect the C7 nerve root)s
- Central cord compression (central stenosis)
 - leads to the clinical condition of myelopathy
 - occurs with canal diameter is $< 13\text{mm}$ (normal is 17mm)
 - worse during neck extension where the central cord is pinched between
 - degenerative disc (anterior)
 - hypertrophic facets and infolded ligamentum (posterior)
- Imaging
 - Radiographs
 - common radiographic findings include
 - degenerative changes of uncovertebral and facet joints
 - osteophyte formation
 - disc space narrowing
 - endplate sclerosis
 - decreased sagittal diameter (cord compression occurs with canal diameter is $< 13\text{mm}$)
 - incidence
 - radiographic findings often do not correlate with symptoms
 - lateral
 - important to look for sagittal alignment and size of spinal canal
 - oblique
 - important to look for foraminal stenosis which often caused by uncovertebral joint arthrosis
 - flexion and extension views
 - important to look for angular or translational instability
 - look for compensatory subluxation above or below the spondylotic/stiff segment
 - MRI
 - axial imaging is the modality of choice and gives needed information on the status of the soft tissues. It may show
 - disc degeneration

- spinal cord changes (myelomalacia)
 - preoperative planning
- has high rate of false positive (28% greater than 40 will have findings of HNP or foraminal stenosis)
- CT myelography
 - can give useful information on bony anatomy
 - most useful when combined with intrathecal injection of contrast (myelography) to see status of neural elements
 - contrast is given via C1-C2 puncture and allowed to diffuse caudally or given via a lumbar puncture and allowed to diffuse proximally by putting the patient in Trendelenburg position.
 - particularly useful in patients that can not have an MRI (pacemaker) or has artifact from hardware
- Discography
 - controversial and rarely indicated in cervical spondylosis
 - approach is similar to that used with ACDF
 - risks include esophageal puncture and disc infection

- Clinical Presentation

- Axial neck pain
- Cervical Radiculopathy
- Cervical Myelopathy

61- Pseudosubluxation Of The Cervical Spine

- summary

- Pseudosubluxation of the Cervical Spine is a physiologic radiographic variant of the cervical spine of young children caused by the horizontal nature of the facet joints in younger ages.
- Diagnosis is made radiographically with a relative anterior translation of C2 on C3 of up to 4 mm, that resolves with cervical spine extension.
- Treatment is observation as the condition resolves with time as the cervical facet joints become more vertical with age.

- Epidemiology

- Incidence
 - around 20% of children admitted for polytrauma will demonstrate this incidental finding
 - no associations with gender, trauma, intubation status or injury severity have been demonstrated
- Demographics
 - seen in children less than 8 years
- Anatomic location
 - C2 on C3 is most common
 - C3 on C4 is second most common

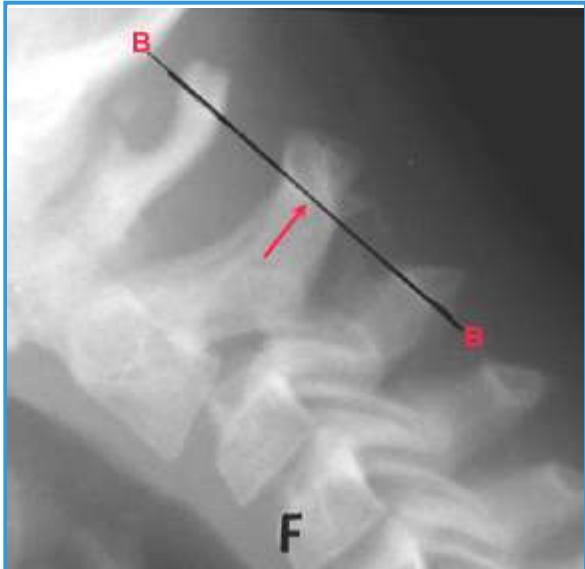
- Etiology

- Pathophysiology
 - caused by the horizontal nature of the facet joints at younger ages
 - facet joints become more vertical with age

- Imaging

- Radiographs
 - recommended views
 - lateral radiograph with flexion and extension

- findings
 - reduction of subluxation with extension xrays
 - absence of anterior soft-tissue swelling (usually seen with traumatic cause)
- measurements
 - Swischuk's line



- spinolaminar line drawn from spinolaminar point on C1 to C3
- spinolaminar point on C2 should be within 1.5 mm of spinolaminar line
- helpful to differentiate pseudosubluxation from true injury

• Differential

- True traumatic subluxation
 - factor that support pseudosubluxation as opposed to true traumatic subluxation include
 - reduction of subluxation with neck extension
 - spinolaminar line within 1.5mm of C2
 - no history or physical findings of significant trauma
 - absence of anterior soft-tissue swelling
 - true traumatic subluxation may be caused by
 - Hangman's fx



- Treatment

- Nonoperative

- **observation**

- indications

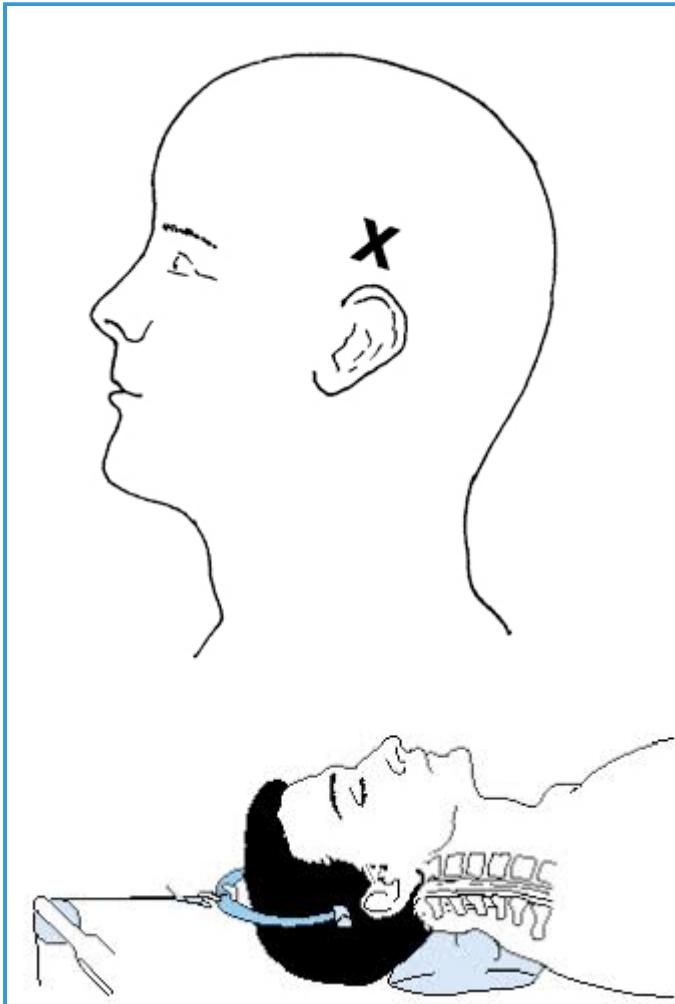
- psuedosubluxation

- outcomes

- no association with increased morbidity or mortality has been associated with this condition

62- Closed Cervical Traction

Images



- Indications

- Indications
 - subaxial cervical fractures with malalignment
 - unilateral and bilateral facet dislocations
 - displaced odontoid fractures
 - select hangman's fractures
 - C1-2 rotatory subluxation
- Contraindications
 - patient who is not awake, alert, and cooperative
 - presence of a skull fracture may be a contraindication

- Patient position

- Preferred setting
 - emergency room, operating room, ICU for close observation and frequent fluoroscopy/radiographs
- Patient position
 - supine with reverse trendelenburg or use of arm and leg weights can help prevent patient migration to the top of the bed with addition of

weights.

- Sedation

- small doses of diazepam can be administered to aid in muscle relaxation
- however patient must remain awake and able to converse

- Pin Placement

- Pin placement (Gardner-Wells pins)

- pin placement is 1 cm above pinna, in line with external auditory meatus and below the equator of the skull.
 - if the pin is placed too anterior, the temporalis muscles and superficial temporal artery and vein are at risk
 - an anterior pin will apply an extension moment to the cervical spine
 - if the pin is placed too posterior, it can apply a flexion moment to the cervical spine.
 - a posterior pin with a flexion moment may facilitate reduction of a facet dislocation.

- Pin tightness

- On Gardner-Wells tongs, pins are tightened until spring loaded indicator protrudes 1 mm above surface
 - this is the equivalent of 139 newtons (31 lbs) of force
 - overtightening by 0.3 mm leads to 448 newtons (100 lbs)
 - failure of temporal bone occurs at 965 +/- 200 newtons (216 lbs)
 - note Mayfield pins are tightened to 60 lbs
- overtightening of the pins can result in penetration of the inner table of the calvarium
 - this may cause cerebral hemorrhage or abscess

- Pin strength

- stainless steel pins have higher failure loads than titanium and MRI-compatible graphite and should be used with traction of > 50lbs.

- Reduction with Serial Traction

- Serial traction

- an initial 10lbs is added.
- weights are increased by 10lb increments every 20 minutes
- serial exams and radiographs are taken after each weight is placed
- maximal weight is controversial
 - some authors recommend weight limits of 70 lbs
 - recent studies report that up to 140 lbs is safe

- Reduction maneuvers
 - reduction of a unilateral facet dislocation
 - reduction maneuver performed after facet is distracted to a perched position
 - maintain axial load and rotate head 30-40 degrees past midline, in the direction of the dislocation
 - stop once resistance is felt, and confirm with radiographs
 - reduction of bilateral facet dislocation
 - reduction maneuver performed after facet is distracted to a perched position
 - palpate the stepoff in the spinal process posteriorly and apply an anterior directed force caudal to the level of the dislocation
 - rotate the head 40 degrees beyond midline in one direction, and then rotate 40 degrees in the other direction while axial traction is maintained.

- Complications

- Failure to reduce
 - a bilateral, irreducible facet dislocation is unstable and should be treatment with urgent open reduction after an MRI is performed..
- Change in neurologic exam
 - with any change in the neurologic exam the weights should be removed and an MRI should be obtained.

63- Cervical Adjacent Segment Disease

- summary

- Cervical Adjacent Segment Disease is the radiographic degeneration of the disc or facets at the caudal or cephalad segment adjacent to a previous cervical surgical fusion construct.
- Diagnosis can be made with plain radiographs of the cervical spine.
- Treatment is observation and medical management for patients with mild symptoms. Surgical management is indicated in patients that have failed conservative treatment.

- Epidemiology

- Incidence
 - studies have estimated a 1.6 to 2.4% annual incidence of clinically relevant ASD
 - predicted 25.6% ASD rate at 10 years for patients undergoing ACDF
- Demographics
 - females have a higher risk factor for the development of adjacent segment disease
 - patients under the age of 60 have an increased risk for the development
- Anatomic location
 - the lowest three segments of the subaxial spine are the most commonly affected (C4-5, C5-6, and C6-7)
 - C5-6 has the highest risk
 - unclear as to whether this level is more prone to natural progression of spondylosis or sensitive to adjacent segment disease
 - C2-3 has the lowest risk
- Risk factors
 - smoking is the strongest associated patient factor
 - female sex
 - less than 3 segments included in the fusion construct
 - speculated that fewer motion segments remaining reduces the risk of adjacent segment degeneration

- C5-6 and C6-7 segments are left adjacent to the fusion construct
 - anatomically the most mobile segments of the cervical spine with the highest rates of degeneration
- preoperative MRI and myelography demonstrating dura mater indentation and disc protrusion, especially at the C5-6 and C6-7 levels
- no decrease in risk with fusion vs. nonfusion procedures (i.e. posterior foraminotomy, anterior discectomy)

• Etiology

○ Forms

- adjacent segment degeneration
 - radiographic changes of degeneration at levels adjacent to a spinal fusion with or without clinical symptoms
 - adjacent level ossification (ALOD)



- large anterior marginal osteophyte that forms adjacent to a fused construct
 - unclear whether this leads to adjacent segment disease
 - adjacent segment disease (ASD)
 - development of clinical radiculopathy or myelopathy correlating to a motion segment adjacent to the fusion construct
- ### ○ Pathophysiology
- ASD

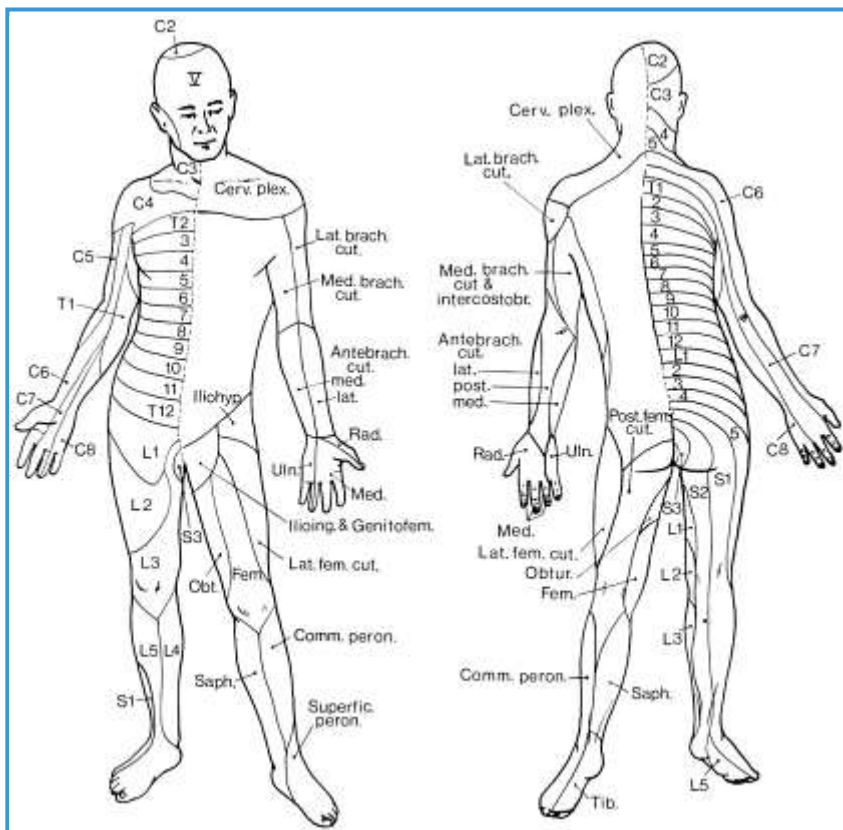
- increased motion at the adjacent disc space to compensate for the rigid fused segment
 - supraphysiologic motion, increased stress, and shear strain leads to accelerated degeneration of the disc space
 - increase intradiscal pressure ensues from the compensatory increase in motion and stress
 - increased disc herniation, loss of disc height, osteophyte formation
 - results in cervical foraminal and central canal stenosis which can lead to clinical radiculopathy and myelopathy
 - clinical data does not entirely support this as cervical disc arthroplasty, which preserves spinal segment motion, does not reduce ASD
- damage to the anterior longitudinal ligament and longus colli muscle at the time of surgery
- placement of needle marker into incorrect disc space when localizing the operative level
 - potentially minimize
- ALOD
 - etiology unclear, but speculated to be an inflammatory reaction that occurs from increased proximity of anterior cervical plate to the adjacent disc space
 - plate placed within 5 mm of the adjacent disc increases ossification risk
 - heterotopic bone formation in the anterior longitudinal ligament

- Classification

■ Park and Associates Classification of Adjacent Level Ossification		
■ Grade 0	■ No adjacent level ossification	■ 
■ Grade 1	■ Ossification extending less than 50% of the disc space	■ 
■ Grade 2	■ Ossification extending greater than 50% of the disc space	■ 
■ Grade 3	■ Complete bridging of the adjacent disc space	■ 

- Presentation

- Symptoms
 - radiculopathy
 - pain in dermatome corresponding to adjacent motion segment to previous fusion construct
 - motor weakness corresponding to the root level adjacent to a previous fusion construct
 - myelopathy
 - gait instability
 - hand clumsiness
 - urinary abnormalities
- Physical exam
 - inspection
 - examine surgical wound
 - motion
 - assess flexion-extension, side bending, and rotational motion
 - document which portion of ROM is painful
 - neurological exam
 - assess fine touch sensation in dermatomal pattern



- patients with sensory changes should be assessed for peripheral nerve compression (e.g. cubital tunnel and carpal tunnel syndromes)
- assess motor strength

Grading Motor Strength Grade	
0/5	No muscle movement
1/5	Visible muscle movement, but no movement at the joint
2/5	Movement at the joint, but not against gravity
3/5	Movement against gravity, but not against added resistance
4/5	Movement against resistance, but less than normal
5/5	Normal strength

- assess reflexes
 - hyperreflexia may suggest myelopathy
- provocative tests
 - Hoffman's test - flicking the long finger with positive finding being an involuntary ipsilateral thumb IP joint flexion, which suggests myelopathy
 - Spurling's test - provocative test with compression applied to an extended, rotated, and bent neck to the affected side
 - positive finding suggests radiculopathy
 - shoulder abduction test - lifting the arm above the head reduces or relieves symptoms, suggesting radiculopathy
 - L'hermitte sign - forced neck flexion causes electric sensation down entire body suggesting myelopathy

- Radiographs
 - recommended views
 - AP
 - lateral
 - flexion-extension views
 - findings
 - disc space narrowing
 - foraminal stenosis
 - posterior osteophytes
 - facet arthropathy
 - anterior marginal osteophyte extending from adjacent vertebral body
 - degenerative changes on radiographs do not always correlate with clinical symptoms
- CT
 - indications
 - assess for pseudoarthrosis
 - assess for ossification of posterior longitudinal ligament
 - views
 - sagittal and axial views are most useful
- MRI
 - indications
 - determine if there is foraminal or central canal stenosis at the adjacent segment
 - views
 - axial and sagittal views are most useful

• Differential

- Key differential (top 5)
 - pseudoarthrosis
 - progressive degenerative disc disease
 - indolent infection
 - myelopathy at a segment not adjacent to the fused segment
 - radiculopathy at a segment not adjacent to the fused segment

• Treatment

- Nonoperative treatment
 - **oral medications, activity modifications, physical therapy, +/- brief period of immobilization**

- indications
 - first line of treatment for radiculopathy and mild myelopathy without impairment
 - modalities
 - oral medications
 - NSAIDs
 - use caution in elderly patients due to risk of gastric bleeding
 - gabapentin
 - commonly used for nerve and associated pain
 - narcotics
 - should be avoided for any chronic condition
 - brief period of immobilization
 - some studies show it is beneficial
 - severe myelopathy should be surgically addressed to avoid stepwise deterioration
- Operative
 - **extension of fusion construct to affected levels**
 - indications
 - clinical radiculopathy consistent with the adjacent segment that have not responded well to nonoperative treatment
 - myelopathy
 - inclusion of C5-6 and/or C6-7 into the fusion construct
 - highest likelihood of developing ASD
 - place anterior plate >5 mm from the adjacent level
 - reduces the risk of adjacent level ossification
 - including >3 levels has a reduced risk of developing further ASD
 - **cervical total disc replacement**

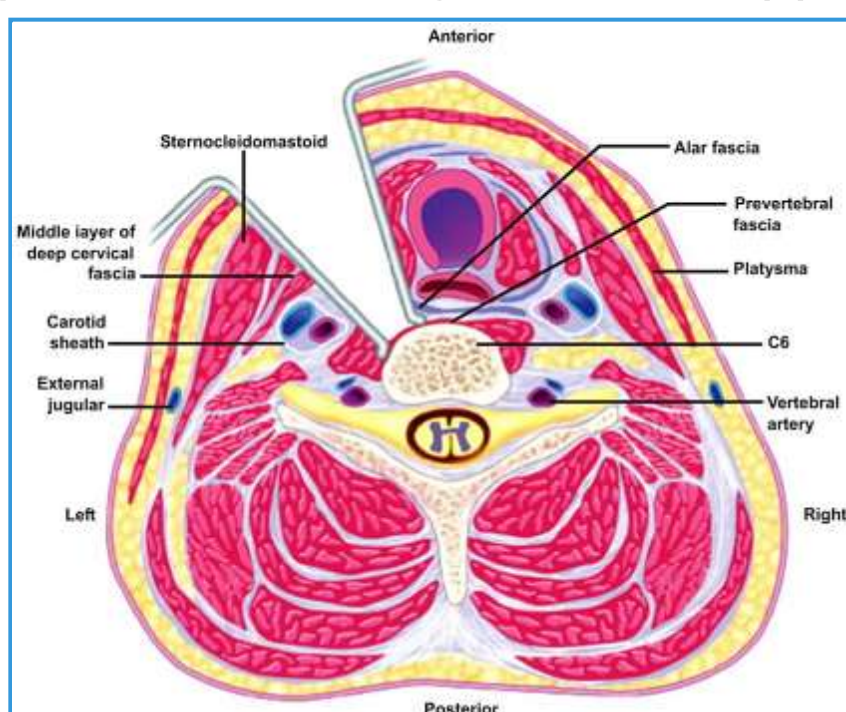


- indications
 - single level involvement
- as an index procedure does not appear to have a protective effect on ASD
 - large meta-analyses suggest possible decrease in reoperation rates
- for the treatment of ASD appears equivalent to ACDF
- reduced risk of adjacent segment ossification compared to anterior cervical plating

- Technique

- **Oral medications, activity modifications, and physical therapy**
 - techniques:
 - NSAIDs, tramadol, tylenol, and gabapentin
 - should be first-line treatment with symptomatic ASD
 - activity modification
 - avoidance of exacerbating activities
 - can reduce pain by avoiding flare ups
 - avoiding down-gazing activities

- can advise patients against excessive cell phone use, excess computer use, driving with bad posture, etc.
 - physical therapy
 - strengthening of paraspinal muscles
 - improved posture
 - desensitization
 - hot and cold therapy
 - spinal traction
 - manual or mechanical
 - traction allows for expansion of the neuroforamen and reduces nerve compression temporarily
- **Extension of fusion construct to affected levels**
 - approach
 - anterior vs. posterior
 - approach dictated by location of pathology (anterior vs posterior) and clinical symptoms (neck pain, unilateral arm pain, myelopathy)
 - anterior right vs. left
 - unless a ENT study performed to evaluation function of RLN, always assume a deficit if prior anterior surgery and use prior approach to protect contralateral nerve
- **Cervical disc replacement**
 - technique
 - single level disease adjacent to previous fusion construct
 - performed through anterior approach



- critical to align the center of rotation in the both the sagittal and coronal planes

• Complications

- Progression of ASD

- following surgical treatment of ASD by extending fusion construct to affected levels further development of symptomatic degeneration of the newly adjacent segment
- treatment
 - revision surgery to include affected segment

- Prognosis

- Despite a high incidence of clinically relevant ASD, the natural history of cervical spondylosis remains high
 - studies have demonstrated radiographic degenerative findings >80% of asymptomatic unfused patients >60 years of age
 - prevalence of radiographic adjacent segment degeneration in arthrodesis patients range from 25% to 91%
- Increased revision surgery rates
 - overall reoperation rates reported between 6.1 to 25.6%
 - annual reoperation rates reported as high as 0.7 to 3.7%

64- Syrxinx And Syringomyelia

Images



- Definitions

- Definitions

- syringomyelia
 - a syrinx (fluid filled cavity) within the spinal cord that progressively expands and leads to neurologic deficits
 - syringobulbia
 - a syrinx within the brain stem that leads to neurologic symptoms

- Epidemiology

- Synringomyelia

- incidence
 - prevalence of the disease is about 8.4 cases per 100,000 people
 - demographic
 - occurs more frequently in men than in women
 - usually appears in the third or fourth decade of life

- Etiology

- Pathophysiology

- usually result from lesions that partially obstruct CSF flow including
 - craniocervical junction abnormalities
 - more than 50% related to Chiari malformations (CM)

- herniated cerebellar tonsils act as pistons obstructing subarachnoid space at foramen magnum creating pressure wave in subarachnoid space with each heartbeat
- spinal cord trauma
 - found in 4-10% of patients with spinal cord injury
 - may become apparent years after the injury
- spinal cord tumors
 - 30% of patients with a spinal cord tumor develop a syrinx
- post-infectious (e.g. meningitis)
 - due to scarring from arachnoiditis
- Associated conditions
 - developmental scoliosis
 - 25% to 80% of cases of syringomyelia may have scoliosis
 - neural axis malformations found in 1.8% to 25% of patients initially diagnosed with idiopathic scoliosis depending on case series and referral patterns
 - Klippel-Feil deformity
 - Charcot's joints
 - occurs in < 5% with syringomyelia
 - often involves shoulder joint

• Presentation

- Syringomyelia
 - symptoms
 - symptoms usually begin insidiously between adolescence and age 45
 - occipital headache
 - sometimes exacerbated by Valsalva maneuver
 - back pain
 - radicular pain
 - neurologic deficits
 - syringomyelia often presents with a central cord syndrome
 - physical exam
 - reflexes
 - asymmetric abdominal reflexes
 - asymmetric and/or hyperactive reflexes
 - asymmetric sweating
 - spasticity
 - motor

- asymmetric muscle bulk
 - weakness
- sensory
 - deficits in pain and temperature sensation in a capelike distribution over the back of the neck
 - light touch and position and vibration sensation are usually not affected
- deformity
 - lower extremity contracture and deformity
 - scoliosis
- Syringobulbia
 - symptoms related to cranial nerve involvement
 - tongue weakness and atrophy (CN XII)
 - sternocleidomastoid & trapezius weakness (CN XI)
 - dysphagia and dysarthria (CN IX, CN X)
 - facial palsy (CN VII)

• Imaging

- Radiographs
 - relative lack of apical lordosis may indicate presence of syrinx
 - scoliosis series for evaluation of scoliosis
- CT
 - not applicable for characterization of syrinx, only for associated scoliosis
- MRI
 - diagnosis of syrinx made by MRI
 - obtain MRI with gadolinium enhancement to rule out associated tumor
 - indications for MRI in patients with scoliosis
 - abnormal curve (e.g. double curve, apex left)
 - neurologic deficit
 - infantile or juvenile age at onset
 - male gender with atypical or large curve
 - thoracic kyphosis >30 degrees

• Histopathology

- Gross pathology
 - cavitation of spinal cord gray matter
 - syrinx in continuity with or adjacent to central canal

- inner layer of gliotic tissue

- Differential Diagnosis

- Hydromyelia
- Gliopendymal cysts
- Myelomalacia
- Cystic tumors
- Persistent central canal

- Treatment

- Nonoperative
 - **observation**
 - indications
 - if asymptomatic, non-enlarging syrinx, most pediatric neurosurgeons recommend against prophylactic surgery
 - orthopaedic management may include observation or bracing during neurosurgical and neurologic evaluations but results of bracing mixed
- Operative
 - **decompression of the foramen magnum and upper cervical cord +/- shunting**
 - indications
 - cranial nerve deficits
 - extremity motor weakness
 - cerebellar findings
 - sensory deficit
 - technique
 - done prior to spinal arthrodesis
 - outcomes
 - effect of decompression on neurologic signs and symptoms is variable but supported due to propensity of deficits to progress
 - some evidence shows neurosurgery alone may improve spinal deformity
 - but scoliosis still likely to progress in large curves or children >8 years old
 - **spinal fusion**
 - indications
 - depends on age of presentation and curve characteristics

- technique
 - timing of orthopaedic intervention debatable
 - most recommend waiting 3 to 6 months after neurosurgical decompression

- Complications

- In general, same as for idiopathic scoliosis
 - Increased risk of neurologic deterioration including paralysis if fusion done with undiagnosed syrinx

- Prognosis

- Natural history
 - not well defined
 - prognosis depends on degree of spinal deformity and neurologic deficits
 - multiple authors report resolution or improvement in syrinx size and neurologic deficits

65- Sacroiliitis

Images



- summary
 - Sacroiliitis is an inflammatory condition of the sacroiliac joint that can cause persistent low back and posterior pelvic pain.
 - Diagnosis is made with MRI studies with contrast showing fluid/inflammation at the SI joint and possible abscess.
 - Treatment is usually nonoperative with NSAIDs and rest, with IV antibiotics reserved for infections. Surgical debridement is indicated in the presence of an abscess.
- Epidemiology
 - Demographics
 - most commonly presents in teen to middle-aged individuals
 - males > females
 - Associated conditions
 - commonly part of ankylosing spondylitis or Reiter's syndrome
- Etiology
 - Pathophysiology
 - can stem from traumatic event or infection
 - pregnancy may lead to increased incidence in some females
 - often stems from chronic inflammation of SI joints
 - can lead to fibrosis and ossification within SI joint
 - Associated conditions

- ankylosing spondylitis
 - associated with HLA-B27
 - 1-2% of all individuals will have HLA-B27
- Reiter's syndrome
 - oligoarticular arthritis, conjunctivitis and urethritis
- joint arthritis

• Presentation

- Symptoms
 - pain with prolonged standing
 - difficulty climbing stairs
 - generalized low back pain
 - weakness from hip musculature on affected side
 - morning stiffness
- Physical exam
 - FABER test
 - pain with flexion, abduction, and external rotation of hip
 - ankylosing spondylitis associated with
 - spinal flexion deformities
 - starting in T and L spines

• Imaging

- Radiographs
 - may show some erosive changes in the bone, but it's not specific
 - may show calcifications or sclerosis within SI joint
- MRI is study of choice
 - use gadolinium
 - T2's show fluid/inflammation at the SI joint and maybe an abscess

• Studies

- Labs
 - WBC
 - usually normal
 - can be elevated with infection
 - ESR/CRP
 - usually elevated
 - blood cultures
 - are positive in 50%

- HLA-B27
 - check for rheumatoid factor (should be negative for true Ankylosing spondylitis)

- Treatment

- Depends on cause
 - infection
 - **IV antibiotics**
 - until symptoms and the CRP resolve
 - then put on orals antibiotic
 - **surgery**
 - may be necessary if this fails or if there is a large abscess
 - trauma or overuse
 - **rest, activity modification, NSAIDs, corticosteroid injections**
 - indications
 - most resolve with soft tissue rest and activity modification
 - pregnancy
 - **observation**
 - typically resolves after childbirth
 - part of larger spondylopathy
 - **aggressive PT, NSAIDs, TNF inhibitors**
 - severe symptoms may require TNF inhibitors or other similar medications

- Prognosis

- Depends on cause but most patients will eventually resolve the episode and continue without issues

66- Sacral Insufficiency Fracture

- summary

- Sacral Insufficiency Fractures are fragility fractures of the sacral spine that occur more commonly in elderly women with osteoporosis.
- Diagnosis can be made with inlet and outlet radiographs of the pelvis. CT or MRI may be helpful for fracture characterization and operative planning.
- Treatment is usually observation and pain control. Surgical management is indicated for patients with progressive pain and/or difficulty ambulating that fail nonoperative treatment.

- Epidemiology

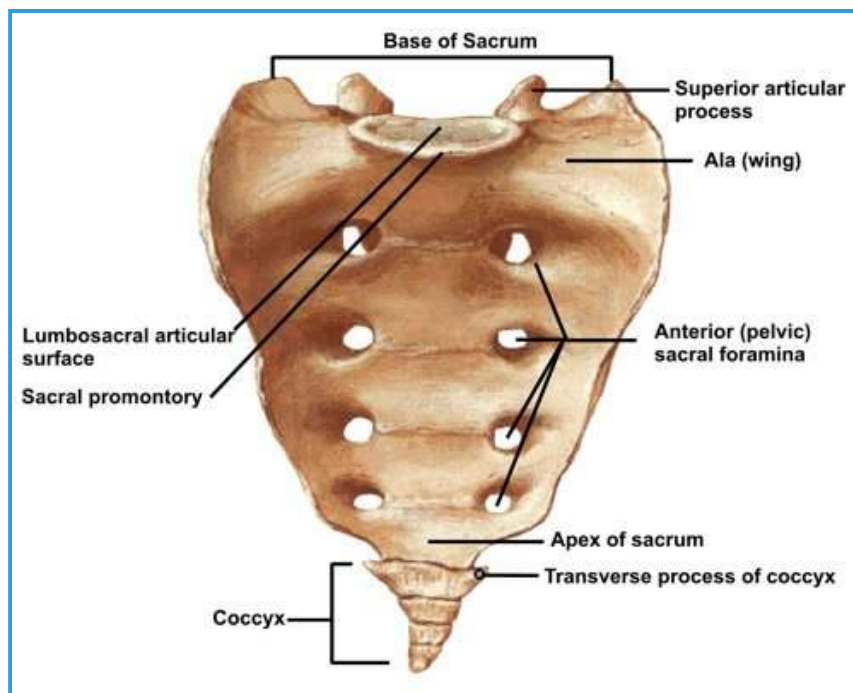
- Incidence
 - 1% of women > 55 years old
 - increases with age
 - estimated to increase by 23% each year
- Demographics
 - females more commonly affected 2:1
 - average age is 69 years old
- Risk factors
 - osteoporosis
 - vitamin D deficiency
 - rheumatoid arthritis
 - prolonged immobilization
 - long-term steroid use
 - pelvic radiation

- Etiology

- Pathophysiology
 - mechanism of injury
 - low energy trauma (i.e. ground level fall)
- Associated conditions
 - other fragility fractures (i.e. distal radius, vertebral, hip)

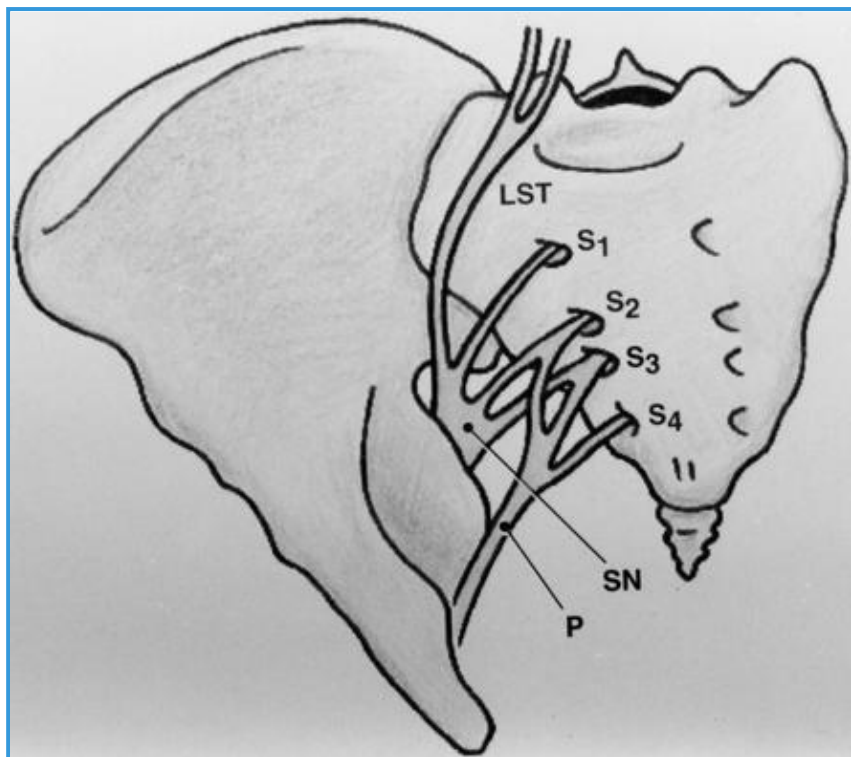
- Anatomy

- Osteology



- formed by fusion of 5 sacral vertebrae
- articulates with
 - 5th lumbar vertebra proximally
 - coccyx distally
 - ilium laterally at sacroiliac joints
- contains 4 foramina which transmit sacral nerves

- Nerves



- L5 nerve root runs on top of sacral ala
- S1-S4 nerve roots are transmitted through the sacral foramina
 - S1 and S2 nerve roots carry higher rate of injury
- lower sacral nerve roots (S2-S5)
 - function
 - anal sphincter tone / voluntary contracture
 - bulbocavernosus reflex
 - perianal sensation
 - unilateral preservation of nerves is adequate for bowel and bladder control

- Biomechanics
 - transmission of load distributed by first sacral segment through iliac wings to the acetabulum

•
 Classification

○ ■ Denis Classification		
■ Zone 1	■ Fracture lateral to foramina	■  
■ Zone 2	■ Fracture through foramina	■  
■ Zone 3	■ Fracture medial to foramina into the spinal canal	■  

•
 Presentation

- History
 - low-energy trauma (i.e. ground level fall)
- Symptoms
 - pain

- groin, low back, buttock
- worse with weightbearing
- Physical exam
 - limited hip motion
 - neurologic deficits are rare

- Imaging

- Radiographs
 - recommended views
 - AP
 - lateral
 - inlet view



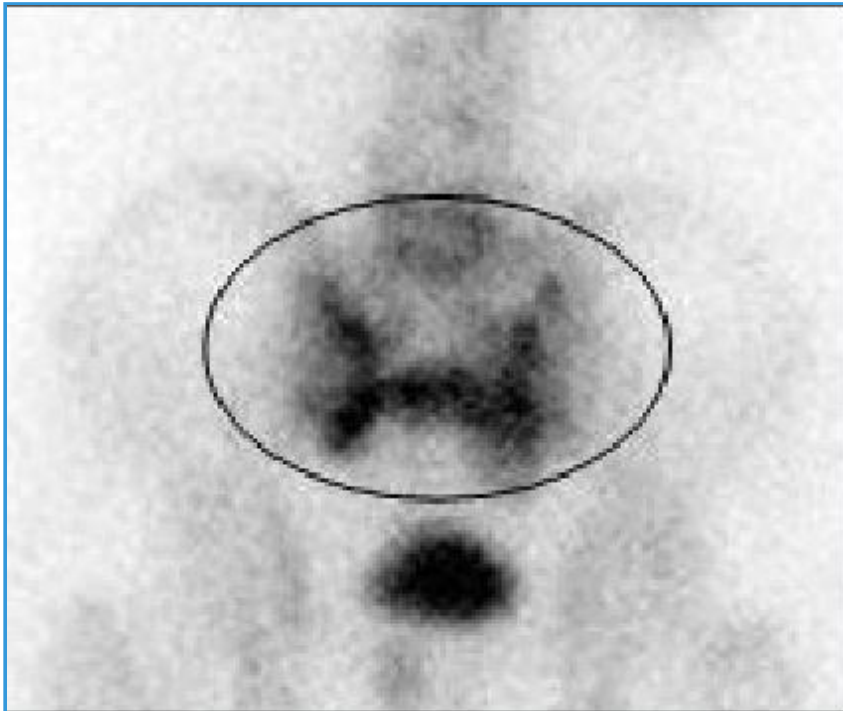
- best assessment of sacral spinal canal and superior view of S1
- outlet view



- provides true AP of sacrum

- CT
 - indications
 - negative radiographs but high suspicion for fracture
 - confirmed fracture on radiographs

- MRI
 - indications
 - negative radiographs and CT but high suspicion for occult fracture
- Bone scan
 - indications
 - no longer used
 - findings
 - Honda or H sign



- seen with H-type fractures

• Studies

- Serum labs
 - evaluate for causes of osteoporosis

• Treatment

- Nonoperative
 - **observation, mobilization, analgesia, osteoporosis screening & treatment**
 - indications
 - first line of treatment
- Operative
 - **sacroplasty**



- indications
 - minimally displaced zone 1 injuries after failed nonoperative treatment
- **ORIF**
 - indications
 - displaced zone 1 injuries after failed nonoperative treatment
 - zone 2 or 3 injuries after failed nonoperative treatment

• Techniques

○ **Sacroplasty**

- technique
 - injection of polymethylmethacrylate cement
- complications specific to this treatment
 - cement leakage
 - avoid sacroplasty in displaced fractures due to risk of symptomatic cement leakage

○ **ORIF**

- technique
 - unilateral iliosacral screws



- place 2 parallel 7-8mm cannulated screws perpendicular to the fracture plane
 - 2 screws have more stability than 1 screw
 - screws should cross midline
 - stability is dependent on the strength of the sacral cancellous bone
- use washers to prevent penetration of the screw head through the lateral cortex of the posterior part of the ilium
- trans-sacral screw



- place 6mm screw through the sacral corridor of S1
- posterior bridging plate
 - place plate against sacrum and posterior part of ilium
 - acts as tension band
- complications specific to this treatment
 - implant loosening
 - hardware failure

• Complications

- Non-union
- Persistent pain

67- Sacroiliac Joint Dysfunction

- summary

- Sacroiliac Joint Dysfunction is a degenerative condition of the sacroiliac joint resulting in lower back pain.
- Diagnosis is made clinically with pain just inferior to the posterior superior iliac spine that is made worse with hip flexion, abduction, and external rotation.
- Treatment is usually conservative with pain management, physical therapy, and injections. Surgical management is indicated in patients with progressive symptoms who fail nonoperative management.

- Epidemiology

- Incidence
 - is frequently overlooked and can explain up to 15% to 30% of cases of lower back pain in the outpatient setting
- Risk factors
 - previous lumbar spine fusion
 - especially when there is >3 levels involved
 - considered analogous to adjacent segment disease
 - pregnancy and vaginal delivery
 - previous trauma to the pelvis
 - prior iliac crest bone graft harvesting

- Etiology

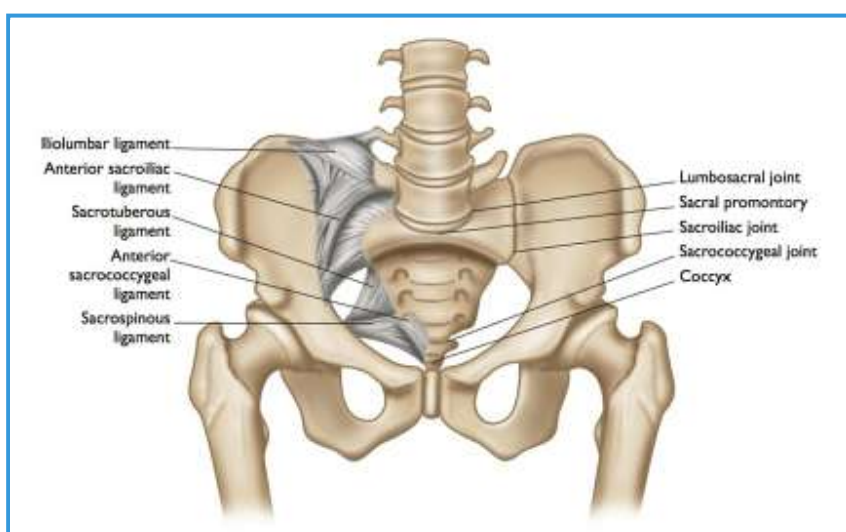
- Pathophysiology
 - idiopathic mechanism is the most common
 - believed to be a result of repetitive trauma to the SI joint
 - can begin insidiously or acutely
 - pain is hypothesized to be generated from
 - ligamentous/capsule tension
 - extraneous compression or shear forces
 - hypomobility or hypermobility

- increased levels of estrogen or relaxin during third trimester of pregnancy leading to hypermobility of the SI joint
 - aberrant joint mechanics
 - myofascial or kinetic chain imbalances
 - inflammation
- intra-articular mechanisms
 - arthritis
 - inflammation and degeneration of the SI joint
 - occurs in nearly 100% of patients with spondyloarthropathies
 - ankylosing spondylitis
 - Reiter's syndrome
 - results in subchondral sclerosis, subchondral cysts, osteophytes, joint space narrowing, intra-articular gas and ankylosis
 - infection
 - usually the result of hematogenous spread
 - typically unilateral involvement
 - organisms:
 - Staphylococcus aureus
 - Pseudomonas aeruginosa
 - Cryptococcus organisms
 - Mycobacterium tuberculosis
 - predisposing factors:
 - immunosuppression
 - endocarditis
 - IV drug abuse
 - metabolic
 - leads to early degeneration of the joint
 - diseases:
 - calcium pyrophosphate crystal deposition
 - gout
 - ochronosis
 - hyperparathyroidism
 - renal osteodystrophy
 - acromegaly
 - tumors
 - primary
 - very rare for SI joint
 - most common types:
 - giant cell tumor

- synovial villadenomas
 - chondrosarcomas
- secondary (metastatic)
 - most common
 - pelvis accounts for 40% of all osseous metastasis (2nd to spine)
- extra-articular mechanisms
 - enthesopathy
 - inflammation of the ligamentous attachments to the SI joint
 - frequently occurs with spondyloarthropathies
 - more frequently the posterior ligaments
 - insufficiency fractures
 - osteoporotic fractures in elderly patients
 - repetitive trauma in athletes and military recruits
 - post-traumatic
 - more common after lateral compression pelvic ring injuries
- Genetics
 - HLA-B27
 - associated with ankylosing spondylitis
- Associated conditions
 - orthopaedic conditions
 - lumbar spinal fusion
 - post-traumatic arthritis
 - metastatic tumors
 - medical conditions & comorbidities
 - ankylosing spondylitis
 - gout
 - pseudogout
 - infections

• Anatomy

○ Osteology



- articulation of the ilium and the sacrum
 - largest axial joint in the body
- considered synovial even though the superior 75% is not synovial
- joint surface area of 17.5 cm²
- articular surface changes with age
 - flat until puberty
 - by age 30 ridges form on the the iliac articular surface
 - synovial surface begins to erode by age 50
 - ankylosis is common in men by age 50
- Muscles
 - gluteus maximus
 - has fibrous extensions that attach to the anterior and posterior joint capsule
 - has attachments into the sacrotuberous ligament
 - gluteus medius
 - erector spinae
 - latissimus dorsi
 - biceps femoris
 - has attachments to the sacrotuberous ligament
 - oblique and transverse abdominus
- Ligament
 - anterior joint capsule and ligaments
 - are relatively thin
 - posterior interosseous ligament
 - forms the posterior border of the joint capsule
 - there is usually a rudimentary or absent posterior joint capsule
 - sacrotuberous ligament
 - attaches from the anterior sacrum and SI joint to the ischial tuberosity
 - sacrospinous ligament
 - attaches from the anterior sacrum and SI joint to the ischial spine
- Innervation
 - anterior innervation
 - L2-S2 ventral rami and sacral plexus
 - posterior innervation
 - L4-S4 dorsal rami
- Biomechanics
 - SI joint functions as a triplanar shock absorber
 - dissipates loads of the upper trunk and facilitates parturition

- can withstand a medial directed load six times greater than the lumbar spine
- fails in 1/20th the axial load of the lumbar spine
- sacral compression with weightbearing results creates "keystone in arch" effect
 - muscles with fibers perpendicular to SI joint also generate compression
- loss of SI joint motion hinders ability to dissipate forces
- complex motion at the SI joint:
 - gliding
 - rotation
 - tilting
 - nodding (nutation)
 - most common form of motion
 - described as the backward rotation of the ilium on the sacrum
 - counternutation is the forward rotation of the ilium on the sacrum
 - translation
- joint motion is limited to $<4^\circ$ of rotation and 1.6 mm of translation
- motion of the joint progressively decreased with age
 - age 40-50 for men
 - greater than 50 for women

• Presentation

○ Symptoms

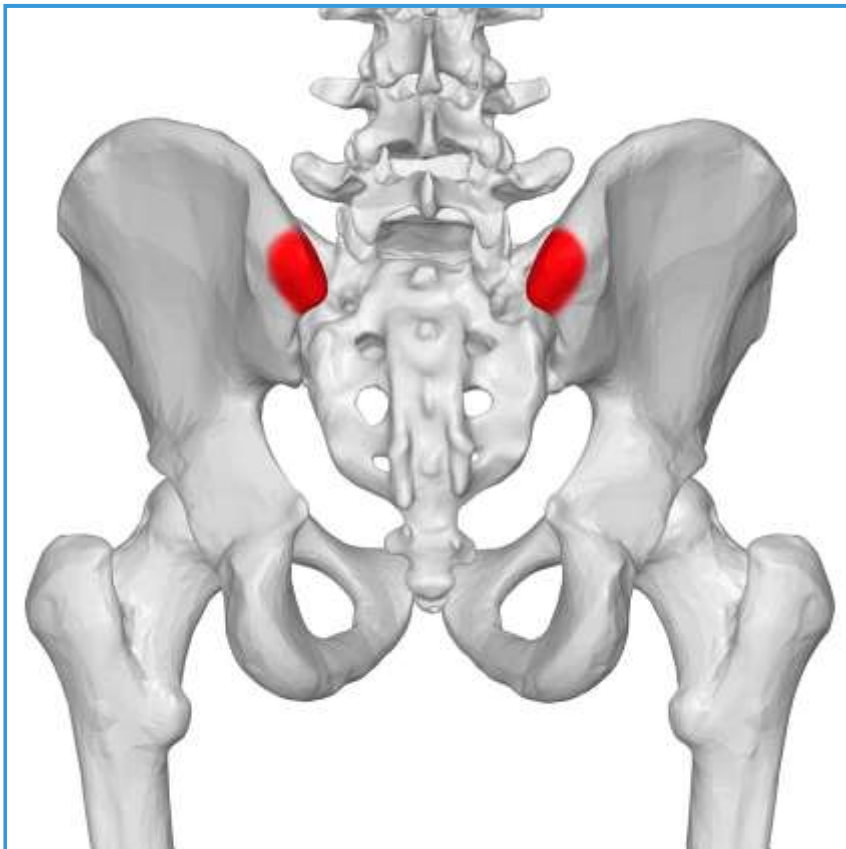
- pain patterns
 - pain usually present just inferior to the posterior superior iliac spine
 - frequent pain referral area of other spine pathologies
 - only 4% of patients will complain of pain above L5
 - can radiate past the knee and into the foot
 - wearing a tight fitting belt may improve symptoms

○ Physical exam

- inspection
 - patients may have an antalgic gait
- palpation
 - identify focal areas of tenderness
 - sacral sulcus (most tender location)



- posterior superior iliac spine (second most tender location)



- motion
 - evaluate hip and knee for underlying pathologies
- neurovascular
 - in isolated SI joint dysfunction patients are neurovascularly intact
 - pain-inhibited weakness may be present
- provocative tests
 - overview
 - based on a battery of tests, no single test has 100% diagnostic accuracy
 - >3 positive tests is highly suggestive of the diagnosis
 - Patrick's test (FABER)

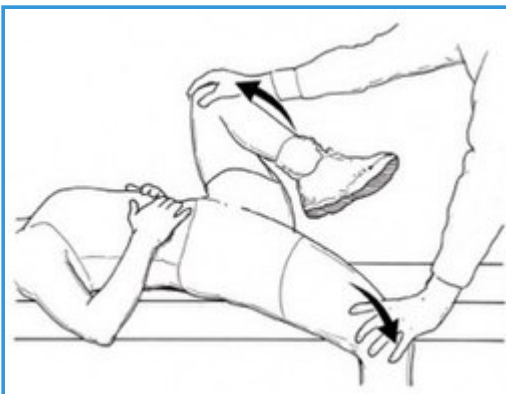


- also called flexion, abduction and external rotation test (FABER)

- patient will report pain in the SI joint with this maneuver
 - groin pain suggests iliopsoas tendonitis or internal hip pathology
- Fortin's finger test



- considered positive if patient localizes pain twice to region inferomedial to PSIS
- Gaenslen's test



- performed with the affected side hip extended off examination table and unaffected side hip and knee flexed and held by patient
 - shearing across SI joint causes pain
- SI compression test



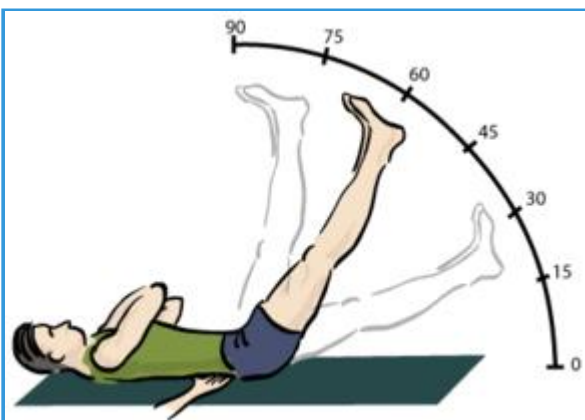
- performed with patient laying lateral on exam table
- medial directed force applied over the iliac crest on the affected side
- reproduction of pain is considered positive
- anterior sacral thrust test



- performed with patient positioned prone on the examination table
- anteriorly directed force is applied to the sacrum
- test is considered positive if pain is reproduced in the SI joint
- SI distraction test



- with the patient supine on the examination table a posteriorly directed force over the ASIS
- test is considered positive when pain is reproduced in the SI joint
- straight leg raise



- used to detect radiculopathy due to herniated disc
- usually negative in setting of SI joint dysfunction
- may be positive if leg brought above 60° of elevation
- caused by increased SI joint motion at this level of elevation

• Imaging

- Radiographs
 - recommended views

- AP, lateral, internal oblique, external oblique, inlet, and outlet views of the pelvis
 - to rule out other pelvic pathology
- flamingo views
 - indicated when there is suspicion of pelvic instability
 - alternating single leg standing films of the pelvis
- SI joint views



- AP, lateral, flexion and extension views of the lumbar spine
 - to identify other spinal pain generators
- findings
 - joint space narrowing
 - subchondral sclerosis
 - subchondral cysts
 - osteophytes
 - ankylosis
- sensitivity and specificity
 - up to 25% of asymptomatic patients over the age of 50 will have abnormal SI joints in radiographs
- CT
 - indications
 - has poor diagnostic power compared to SI joint injections
 - deformity correction or surgical intervention is planned
 - views
 - pelvis and sacrum
 - sagittal and coronal views
 - 3D reconstructions

- MRI
 - indications
 - done to exclude other diagnoses
 - identification of tumors, infectious process, or soft tissue components
- Bone scan
 - indications
 - studies have reported on the predictive power of SI joint pathology with SI joint injections
 - sensitivity and specificity
 - specificity - 90%
 - sensitivity - 12%
 - positive predictive value - 86%
 - negative predictive value - 72%

- Differential

- Key differential (top 5)
 - lumbar spinal stenosis
 - degenerative disc disease
 - hip osteoarthritis
 - hip labral tear
 - lumbar disc herniation

- Treatment

- Nonoperative
 - **oral medication, physical therapy, pelvic belt, and prolotherapy**
 - indications
 - first line of treatment
 - modalities
 - oral medications
 - mainly involve NSAIDS to reduce inflammatory process associated with pain
 - opioid medications should be used sparingly
 - minimum of 4 week of non-operative modalities trial before proceeding with SI joint injection
 - physical therapy
 - +/- hot/cold therapy
 - treatment focuses on addressing core muscle strengthening, proprioception, and flexibility to correct lumbopelvic and hip

biomechanics

- pelvic belt
 - belt that applies medial directed force on greater trochanters



- 4 to 8 inch wide belt that is applied around the greater trochanters
 - external device that mimics the function of ligaments
 - limits the motion and shear forces across the SI joint by providing compression
 - prolotherapy (controversial)
 - phenol or glucose-based solutions injected at the base of ligamentous complexes to induce scarring
 - generates inflammatory response resulting in fibroblastic migration and resultant scar that stabilizes joint
 - outcomes
 - most effective in the acute phase of pain
 - pelvic belt more effective for SI joint pain following pregnancy
 - prolotherapy more effective in the setting of ligamentous laxity
- **SI joint corticosteroid injections**
 - indications
 - second line of treatment
 - outcomes
 - 60% success rate in pain relief at 6 months
 - >75% reduction in SI joint pain following a single injection is confirmatory of the diagnosis
 - >50% reduction in SI joint pain following two injections
 - lower success rate in patients with previous lumbar fusion
- **radiofrequency ablation**
 - indications

- third line of treatment
- technique
 - targets lateral branches of the sacral nerve roots
- outcomes
 - efficacy is limited due to the inability to denervate the anterior neural structures of the SI joint

○ Operative

■ **open SI joint arthrodesis**

- indications
 - confirmed diagnosis of SI joint dysfunction as primary pain generator
 - poor response to nonoperative treatment options
 - patients with aberrant SI anatomy, sacral dysmorphism, or revision surgery
 - previously infection was the only indication for arthrodesis
- outcomes
 - new literature with favorable outcomes in appropriately selected patients

■ **minimally Invasive SI joint arthrodesis**

- indications
 - confirmed diagnosis of SI joint dysfunction as primary pain generator
 - poor response to nonoperative treatment
 - normal SI joint anatomy
- outcomes vs. open
 - shorter hospital stay
 - smaller incision
 - theoretical decrease in surgical site infections
 - decreased limitation of postoperative weightbearing
 - quicker return to full weightbearing than open arthrodesis
 - decreased blood loss

● Techniques

○ **SI joint corticosteroid injections**

- technique
 - performed under fluoroscopy or ultrasound guidance
 - studies have shown that without imaging the injection is in the SI joint only 22% of the time

- can be used as both a diagnostic and therapeutic injection
 - no more than 3 injections in a 6 month period or 4 injections in 1 year
- **Radiofrequency ablation**
 - technique
 - targets lateral branches of the sacral nerve roots
 - dorsal nerve ramus ablation
 - L5-S3 dorsal rami innervate SI joint
- **Open SI joint arthrodesis**
 - approach
 - performed through posterior approach (anterior is limited by vital neurovascular structures)
 - technique
 - cartilage is removed and bone graft is packed into the obliterated space
 - stabilized with posterior plate and screws, iliosacral screws, or cage construct
 - made protected weight bearing for 12 weeks following surgery
- **Minimally invasive SI joint arthrodesis**
 - approach
 - percutaneous placement of implants
 - technique
 - newer techniques involve triangular titanium porous coated implants
 - "fusion" occurs by bone growth onto the implant rather than direct fusion of the joint
 - requires multiple implants placed across SI joint to achieve stability
 - complications
 - patients with a dysmorphic sacrum have a higher risk of iatrogenic nerve injury

• Complications

- Surgical site infections
 - risk factors
 - immunocompromised
 - smoking
 - diabetes
- Wound complications
 - risk factors
 - open surgical technique (wound is located in the dependent position)

- Nerve injury
 - risk factors
 - minimally invasive technique
 - sacral dysmorphism
 - injury to the L5, S1, or S2 nerve roots
- Pseudoarthrosis
 - occurs in up to 5% of cases
 - revision arthrodesis with open surgical technique

- Prognosis

- Natural history of disease
 - quality of life of patients with SIS is more affected than patients with chronic obstructive pulmonary disease and mild heart failure
 - equivalent to patients with hip and knee arthritis

68- Ossification Posterior Longitudinal Ligament

Images



- summary

- Ossification Posterior Longitudinal Ligament is an idiopathic cervical spine anomaly that is a common cause of cervical myelopathy in the Asian population.
- Diagnosis is made with lateral radiographs of the cervical spine. CT scan is the study of choice to determine the extent and thickness of the ossification.
- Treatment is observation in patients with minimal symptoms. Surgical decompression followed by stabilization is indicated for patients with myelopathy.

- Epidemiology

- Demographics
 - Asian
 - most common in but not limited to
 - men > women
- Anatomic location
 - most common levels are C4-C6

- 95% of ossification is located in C spine

- Etiology

- Pathophysiology

- cause is unclear but likely multifactorial
 - associated factors
 - diabetes
 - obesity
 - high salt-low meat diet
 - poor calcium absorption
 - mechanical stress on posterior longitudinal ligament

- Presentation

- Symptoms

- often asymptomatic
 - symptoms and exam findings consistent with symptoms of myelopathy

- Physical exam

- findings of myelopathy

- Imaging

- Radiographs

- lateral radiograph often shows ossification of PLL



- important to evaluate sagittal alignment of cervical spine

- MRI

- study of choice to evaluate spinal cord compression

- CT

- study of choice to delineate bony anatomy of ossified posterior longitudinal ligament

- Treatment

- Nonoperative
 - **observation**
 - indicated only in patient with mild symptoms who are not candidates for surgery
- Operative
 - **direct or indirect surgical decompression followed by stabilization**
 - indications
 - indicated in most patients with significant symptoms

- Techniques

- **Interbody fusion without decompression**
 - indications
 - in patients with dynamic myelopathy
 - technique
 - theory behind technique is that by removing motion at stenotic levels trauma to the cord is eliminated
- **Anterior corpectomy with or without OPLL resection**
 - indications
 - indicated in patient with kyphotic cervical spine where posterior decompression is not an option
 - technique
 - one method to avoid a dural tear is to perform a corpectomy, and instead of removing the OPLL from the dura, allow it to "float" in the corpectomy site
- **Posterior laminoplasty or laminectomy with fusion**
 - indications
 - only effective in lordotic spine as it allows the spinal cord to drift away from the anterior compression of the OPLL
 - considered a safer and preferable approach due to the difficulty of resecting the OPLL off the dura from an anterior approach
 - techniques
 - fusion should be performed with laminectomy to avoid post-laminectomy kyphosis
 - complications

- there is a risk of postoperative OPLL growth

- Complications

- Recurrence of OPLL
 - recurrence reduced with
 - complete resection
 - leaving OPLL to float in corpectomy site

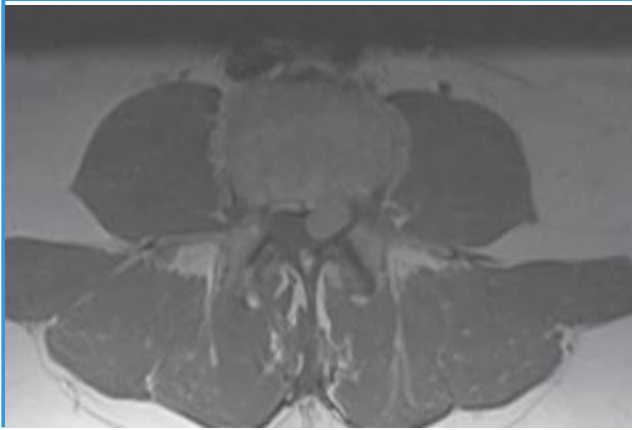
69- Spinal Cord Tumors

Images

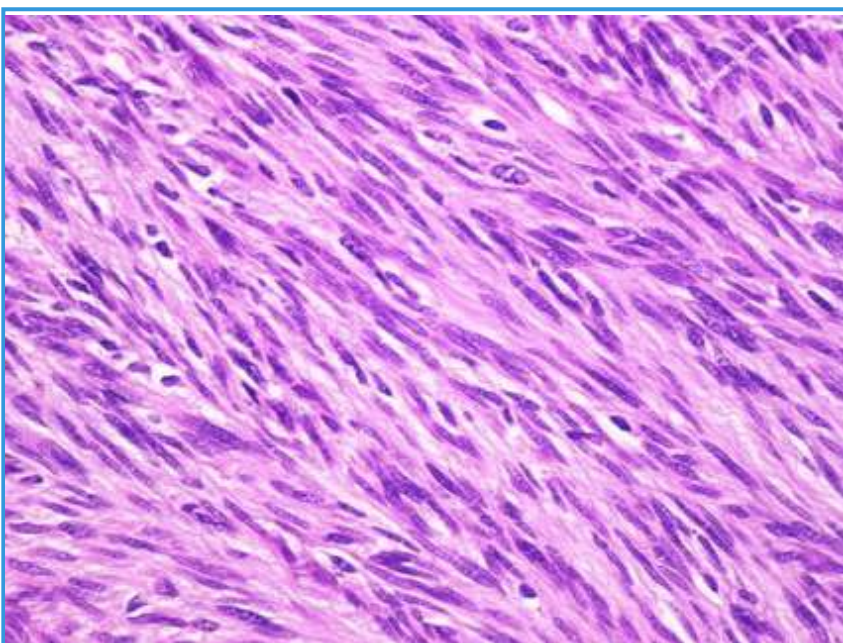


- Epidemiology
 - Primary central nervous system (CNS) tumor of the spine is classified as
 - intradural extramedullary
 - intradural intramedullary
 - extradural
 - Epidemiology
 - primary CNS tumors most common intracranially
 - 2-4% occur in the spine
 - 850-1,700 diagnosed in United States annually
- Intradural Extramedullary Tumors
 - Epidemiology
 - account for 60-70% of all primary CNS spinal cord tumors
 - typically present with symptoms related to
 - central cord compression
 - radicular pain
 - deep seated back pain
 - most intense at night
 - associated cauda equina-like symptoms
 - Schwannoma
 - incidence
 - most common intradural tumor along with meningiomas
 - peak incidence in 40s-50s
 - equal occurrence between men and women

- most are benign, with malignant subtypes
- arise from dorsal nerve root
- may be associated with
 - neurofibromatosis type II
- imaging
 - MRI exhibits mass arising from dorsal root

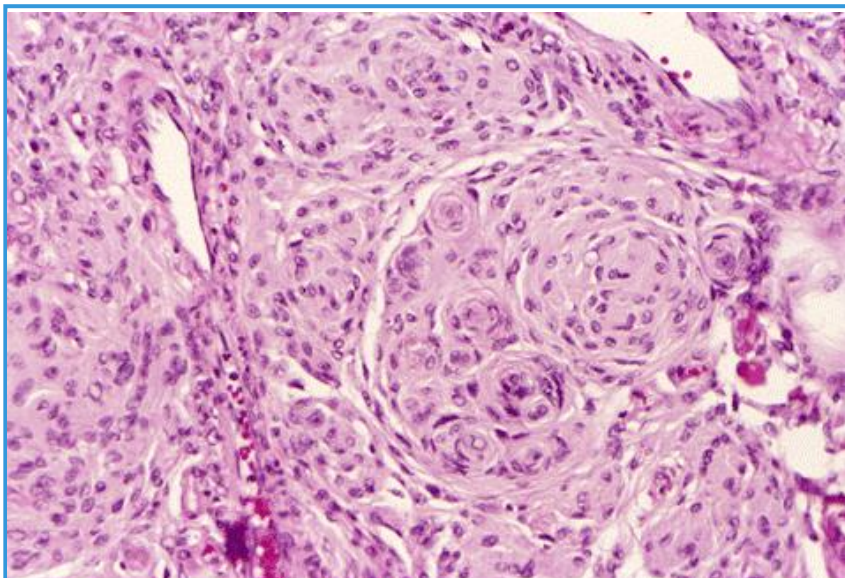


- T1 shows isotense mass
 - T2 shows hyperintensity
- common locations:
 - cervical spine (31%)
 - cauda equina (24%)
 - thoracic spine (22%)
 - upper cervical spine (16%)
 - conus medullaris (4%)
- histology
 - difficult to distinguish from neurofibroma
 - biphasic, Antoni A (hypercellular) and B (hypocellular) pattern
 - elongated nerve cells in collagen background



- S-100 positive
- treatment
 - surgical resection
 - post-operative radiation for malignant tumors
- Meningioma
 - incidence

- accounts for 25% of all primary spinal cord tumors
- most often occurs in:
 - women (80%)
 - thoracic spine
- peak incidence during 5th and 6th decades of life
- risk factors include:
 - neurofibromatosis type II
 - previous history of radiation
- imaging
 - MRI
 - well-circumscribed, dura-based lesion
 - on T1, iso- or hypointense
 - on T2, slightly hypertensive with homogenous enhancement with contrast
- histology
 - lobulated architecture
 - may contain meningotheelial whorls

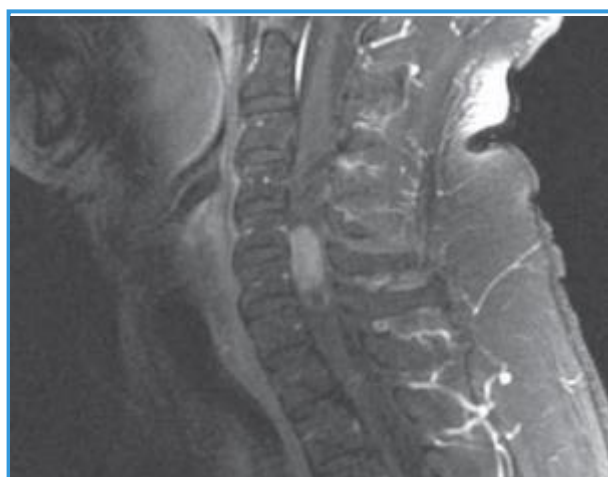


- treatment
 - if symptomatic, surgical resection
 - can be curative with complete resection
 - for recurrence, radiation should be considered

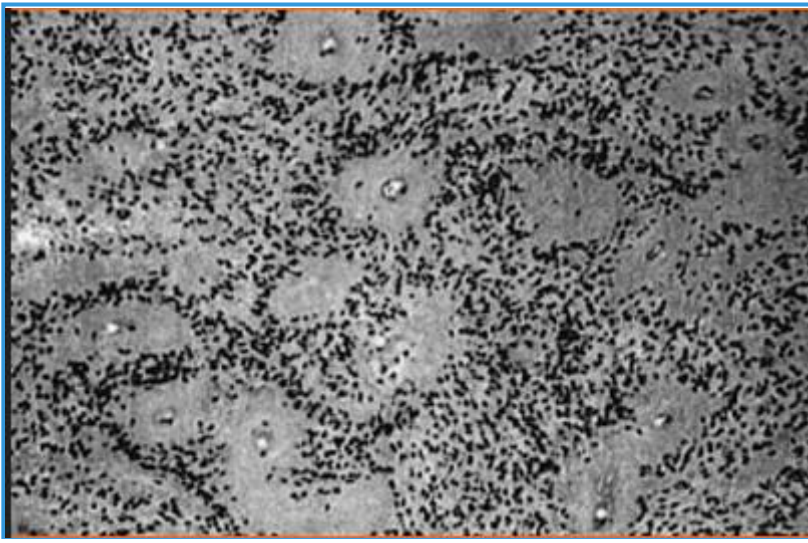
• Intradural Intramedullary Tumors

- Epidemiology
 - account for 20-30% of all intradural tumors in adults and 50% in children
 - typically present with symptoms related to:
 - local or radicular pain
 - motor deficits (65%)
 - sensory deficits (60%)
 - sphincter dysfunction (38%)
 - often initial symptom

- Ependymoma
 - incidence
 - most common intradural intramedullary primary CNS tumor
 - classified as:
 - benign
 - myxopapillary (40-50%)
 - cellular (42%)
 - malignant
 - anaplastic
 - imaging
 - myxopapillary
 - on MRI, encapsulated lesion in the filum terminale
 - on T1, hypo- or isointense
 - on T2, hyper intense
 - heterogeneous on contrast enhancement
 - other features typically seen are:
 - vertebral body scalloping
 - neural foraminal enlargement
 - scoliosis
 - tumor seeding in the sacrum
 - cellular
 - on MRI, similar to myxopapillary
 - distinguishing characteristic
 - polar cysts



- hemorrhage
 - histology
 - cellular, monomorphic cells
 - characteristic rosettes and pseudorosettes



- treatment
 - gross total resection
 - good prognosis, especially if planes are maintained
- Astrocytoma
 - incidence
 - most are benign (30%)
 - peak incidence in third decade of life
 - most common in children (80-90% of intramedullary tumors)
 - imaging
 - on MRI
 - fusiform appearance with irregular margins
 - On T1, hypo- or isointense
 - On T2, hyper intensive with variable contrast enhancement
 - typically found in cervicothoracic junction in children
 - histology
 - hypercellular, mitotic figures
 - eosinophilic granules are common
 - treatment
 - gross total resection difficult due to infiltrative nature
 - radiation typically used to supplement surgery
 - chemotherapy may be beneficial
- Extradural Tumors
 - Metastasis
 - extramedullary
 - representative of advancing systemic disease
 - 'drop' metastases from cranial lesion possible
 - spread via CSF
 - intramedullary
 - rare, <1% of all systemic malignancies
 - most commonly from:

- lung
 - breast
- imaging
 - rapidly expanding, progressive on MRI
 - intramedullary commonly found in cervical region and conus medullaris
- treatment
 - surgical resection rare
 - control burden with radiation and/or chemotherapy
 - intramedullary metastases associated with less than 3 month life expectancy
- Lymphoma
 - incidence
 - rare
 - imaging
 - entire neuroaxis should be analyzed via MRI
 - on T2, ill-defined hyperintense lesion with marked homogeneous contrast enhancement
 - less cord enlargement
 - usually found in cervical spine
 - treatment
 - methotrexate

70- Cerebral Palsy Spinal Disorders

Images



- summary

- Spinal Disorders in Cerebral Palsy are thought to be caused by muscle weakness and truncal imbalance and most commonly present with progressive scoliosis.
- Diagnosis is made with full-length spine radiographs.
- Treatment can range from observation, bracing, or surgical management depending on the severity of underlying medical conditions, skeletal maturity of the patient, magnitude of deformity, and curve progression.

- Epidemiology

- Scoliosis common in children with cerebral palsy
 - overall incidence is 20%
 - the more involved and severe the cerebral palsy, the higher the likelihood of scoliosis
 - spastic quadriplegic at highest risk , especially if no ability to sit independently.
 - for bedridden children incidence approaches 100%
 - spinal deformity is rare in children who are able to ambulate

- Etiology

- See Cerebral Palsy General
- Pathophysiology

- muscle weakness and truncal imbalance has been implicated as primary etiology (little evidence to support)
- pelvic obliquity leads to deforming forces on spine and scoliosis
- Associated conditions
 - Scoliosis in patients with cerebral palsy differs from idiopathic scoliosis in that
 - curves are more likely to progress
 - (scoliosis progresses 1° to 2° per month starting at age 8 to 10 years)
 - curve begins at earlier age
 - curve is a long, stiff C-shaped curve
 - left sided curves are not uncommon
 - curve has greater sagittal plane deformity (kyphotic or lordotic)
 - associated with pelvic obliquity,
 - skeletal maturity is delayed in CP
 - bracing is less effective
 - longer fusions to the pelvis are often necessary
 - patients are more medically fragile and a multi-disciplinary approach is often necessary

• Classification

- Weinstein classification
 - Group I - double curves with thoracic and lumbar component and minimal pelvic obliquity
 - Group II - large lumbar or thoracolumbar curves with marked pelvic obliquity

• Evaluation

- Treatment of cerebral palsy spine disorders requires a careful risk-benefit analysis. Therefore it is important to have a thorough understanding of the medical history and functional status.
- History
 - clinical history
 - perinatal history
 - growth & development
 - all medical treatment
 - functional status
 - patients nutritional status

- respiratory function
- sitting / standing posture
- upper and lower extremities function
- communication skills
- acuity of hearing and vision

○ Physical Exam

- muscular-skeletal exam
 - motion, tone, and strength
 - hamstring contracture's (lead to decreased lumbar lordosis)
 - hip contractures (lead to excessive lumbar lordosis)
- spine exam
 - look at flexibility of curve
 - spinal balance and shoulder height
 - pelvic obliquity

• Imaging

○ Radiographs

- introduction
 - important just to use same radiographic technique in patients over time
 - technique often determined by functional status of patient
 - do standing or erect films whenever possible
- standard AP & lateral
 - look for rib deformity, wedging, and spinal rotation
 - be sure to evaluate for spondylolisthesis on lateral (incidence of 4-21% in patients with spastic diplegia)
- bending films
 - important to evaluate flexibility of curve
 - use push-pull radiographs or fulcrum bending radiographs if patient can not cooperate

○ MRI

- preoperative MRI is not routinely performed for patients undergoing spinal deformity surgery
- indications for MRI include
 - rapid curve progression
 - change in neurologic exam

• Treatment

- Nonoperative
 - **observation, custom seat and/or bracing, botox injections**
 - indications
 - nonprogressive curves $< 50^\circ$
 - early stages in patients < 10 years of age
 - goal is to delay surgery until an older age
 - outcomes
 - custom seat orthosis
 - helpful with seating but does not affect natural course of disease
 - bracing
 - TLSO is helpful to improve sitting balance but does not affect natural course of disease
 - some studies have supported use as a palliative measure to slow progression in skeletally immature patients only
 - botox
 - competitive inhibitor of presynaptic cholinergic receptor with a finite lifetime (usually last 2-3 months)
 - provide some short term benefit in patients with spinal deformity
- Operative
 - **PSF with/without extension to the pelvis**
 - indications
 - Group I curves 50° to 90° in ambulators that is progressive or interfering with sitting position
 - patient > 10 yrs of age
 - adequate hip range of motion
 - stable nutritional and medical status
 - indications to extend to pelvis
 - technique
 - treated as idiopathic scoliosis with selective fusion
 - can result in worsening pelvic obliquity and sitting imbalance
 - **PSF +/- ASF with/without extension to pelvis**
 - indicated for
 - Group I curves $>90^\circ$ and in non-ambulators
 - Group II curves
 - children who have not yet reached skeletal maturity (avoid crankshaft phenomenon)
 - **growing rod distraction**
 - indications

- young patient age
- technique

• Preoperative Assessment & Planning

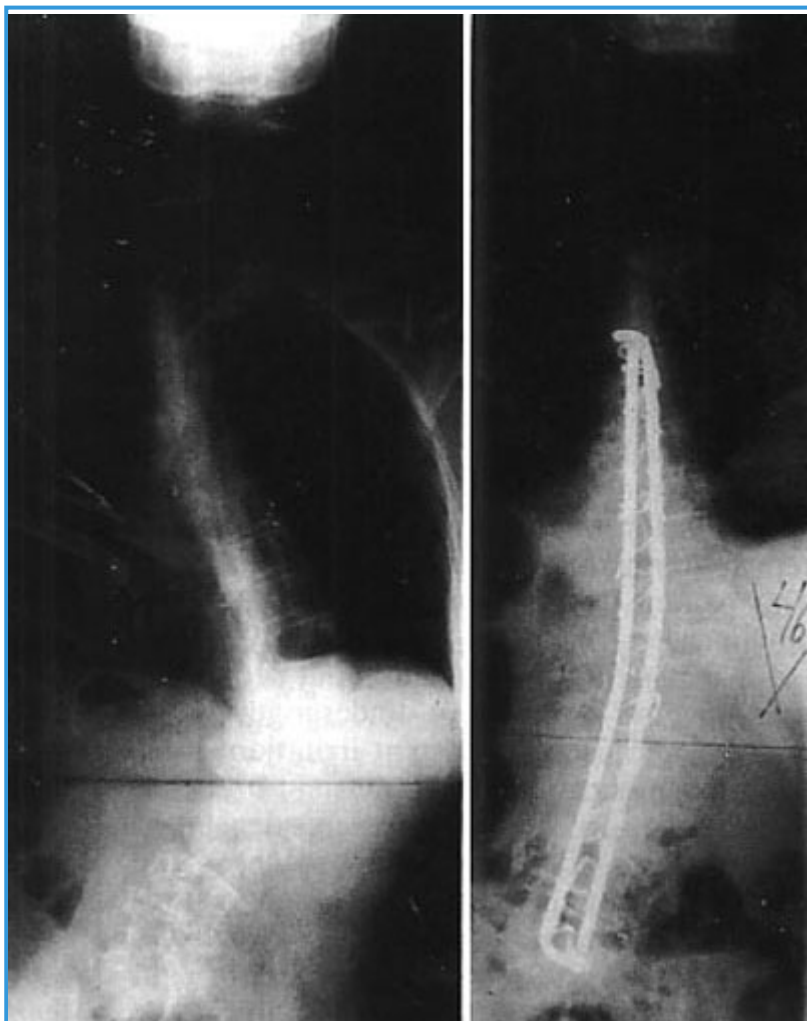
- Overview
 - treatment of cerebral palsy spine disorders is complicated by medical comorbidities
 - all patients should have a thorough multidisciplinary approach
- Nutritional status
 - increase complications (infection, length of intubation, longer hospital stays)
 - associated with poor nutritional status (weight less than fifth percentile)
 - be sure patient has adequate nutrition before surgery (serum albumin > 3.5 g/dL, consider gastrostomy tube if not)
- Respiratory status
 - difficult to do formal pulmonary functional capacity testing
 - can use respiratory history, clinical evaluation, and chest radiographs
- GI evaluation
 - preoperative management of GERD is important in prevention of aspiration pneumonia
- Neurologic function
 - if patients have seizure disorder (common) be sure it is under control
 - if patient taking valproic acid, obtain bleeding time as these patients may have increased risk of bleeding

• Techniques

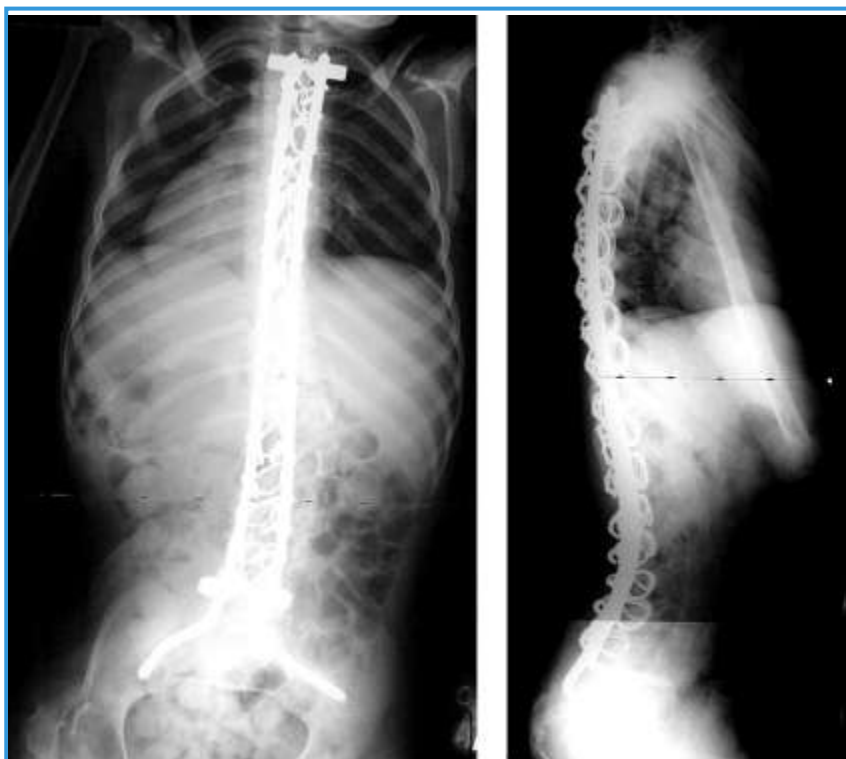
- **Goals of Surgery**
 - obtain painless solid fusion with well corrected, well balanced spine with level pelvis
 - decision to proceed with surgery must include careful assessment of family's goals and careful risk-benefit analysis
- **Fusion levels**
 - proximal fusion should extend to T1 or T2 (otherwise risk of proximal thoracic kyphosis)
 - distal fusion depends on curve pattern
 - due to long curves in CP often extends to L4 or L5
 - extend to pelvis whenever pelvic obliquity is > 15°

- **Posterior fixation techniques**

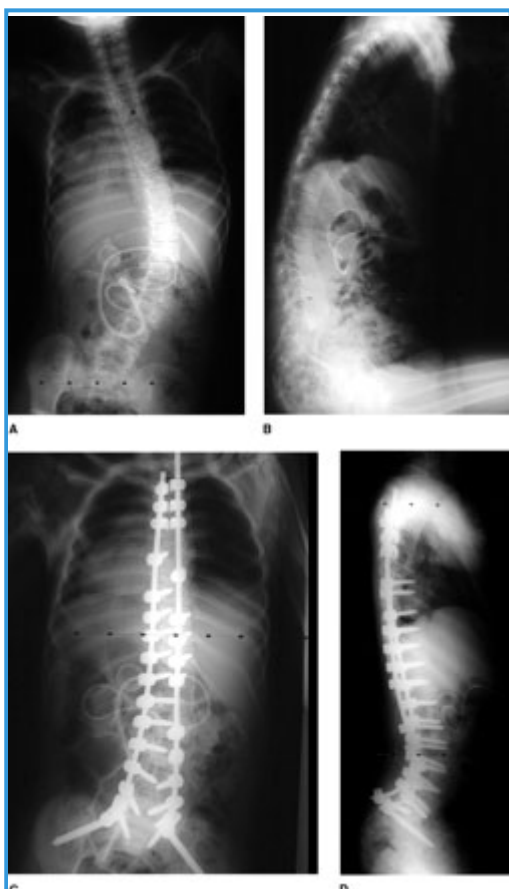
- Luque rod with sublaminar wires technique



- Unit rod with sublaminar wires technique



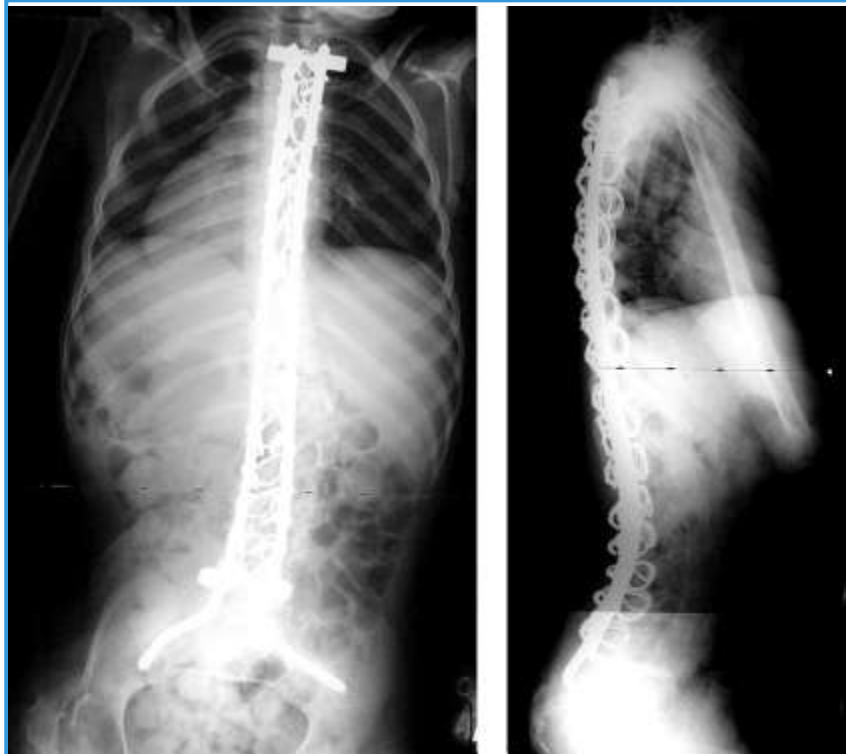
- Pedicle screw fixation technique



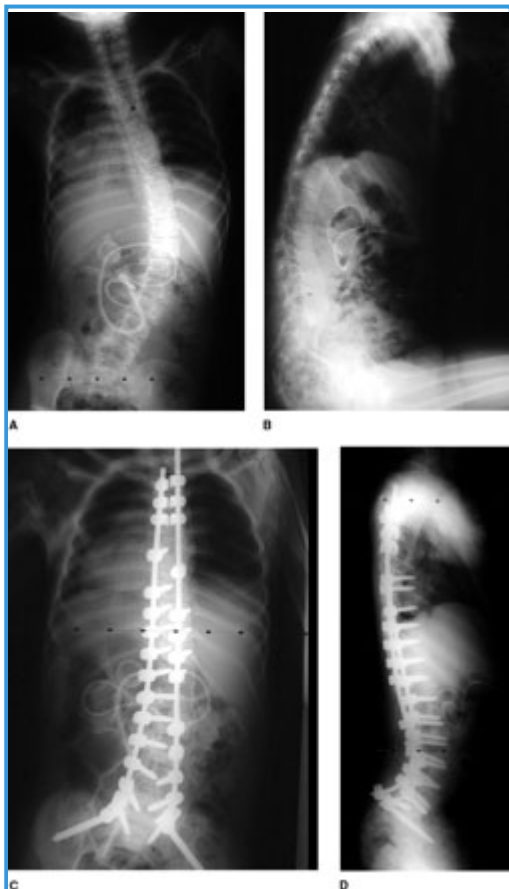
- may provide better correction and eliminate need for anterior surgery

○ Pelvic fixation techniques

- Galveston Technique



- technique to fuse to pelvis with goal of a stability and truncal balance and a level pelvis
- caudal ends of rods are bent from lamina of S1 to pass into the posterosuperior iliac spine and between the tables of the ileum just anterior to the sciatic notch
- bilateral sacral screws
- iliosacral screws



- spinopelvic transiliac fixation
- Dunn-McCarthy technique (S-contoured rod that wraps over sacral ala)

○ Anterior and Posterior Techniques

- use of anterior procedures decreasing with improved posterior constructs
- higher complication rate in anterior surgery in CP spinal deformity than idiopathic scoliosis

- decrease complication rate if A/P done on same day verses staging procedure (improved nutritional status, decreased blood loss, short length of hospitalization)
- **Preoperative traction**
 - may be option in severe and rigid curve
- **Postoperative bracing**
 - usually not required
 - may be used in patients with osteoporosis or tenuous fixation

• Complications

- Implant failure
 - sometimes may be asymptomatic and not require treatment
 - includes penetration of pelvic limb of unit rod into pelvis
- Pulmonary complications
 - chronic aspiration
 - pulmonary insufficiency most common complication in recent study
 - pneumonia
- GI complications
 - GERD
 - poor nutrition and delayed growth
- Neurologic complications
 - seizures
- Wound infection
 - more common in CP than idiopathic scoliosis
 - occurs in 3-5% and usually can be treated with local wound debridement alone



- Death (0-7%)

• Prognosis

- Natural history
 - the larger the curve the more likely it is to progress
 - larger curves are associated with pelvic deformity and obliquity
 - some studies show increase incidence of decubitus ulcer in patients with larger curves, other studies did not

71- Diastematomyelia

- summary

- Diastematomyelia is a congenital spinal condition caused by a fibrous, cartilaginous, or osseous bar creating a longitudinal cleft in the spinal cord.
- Diagnosis is made with a prenatal ultrasound in the 3rd trimester.
- Treatment is observation if patient is asymptomatic. Surgical resection is indicated if patient is symptomatic or has neurological deficits.

- Epidemiology

- Demographics
 - typically presents in childhood
 - adult presentation is rare
- Anatomic location
 - more common in lumbar spine (L1 to L3)

- Etiology

- Pathoanatomy
 - a congenital anomaly believed to be caused by persistence of neuroenteric canal
 - present during 3rd and 4th week of gestation
 - leads to sagittal division of the spinal cord or cauda equina
 - if the cord does not reunite distally to the spur, it is considered a diplomyelia (true duplication of the cord)
- Associated conditions
 - congenital scoliosis
 - as high as 79% in some series
 - tethering of cord

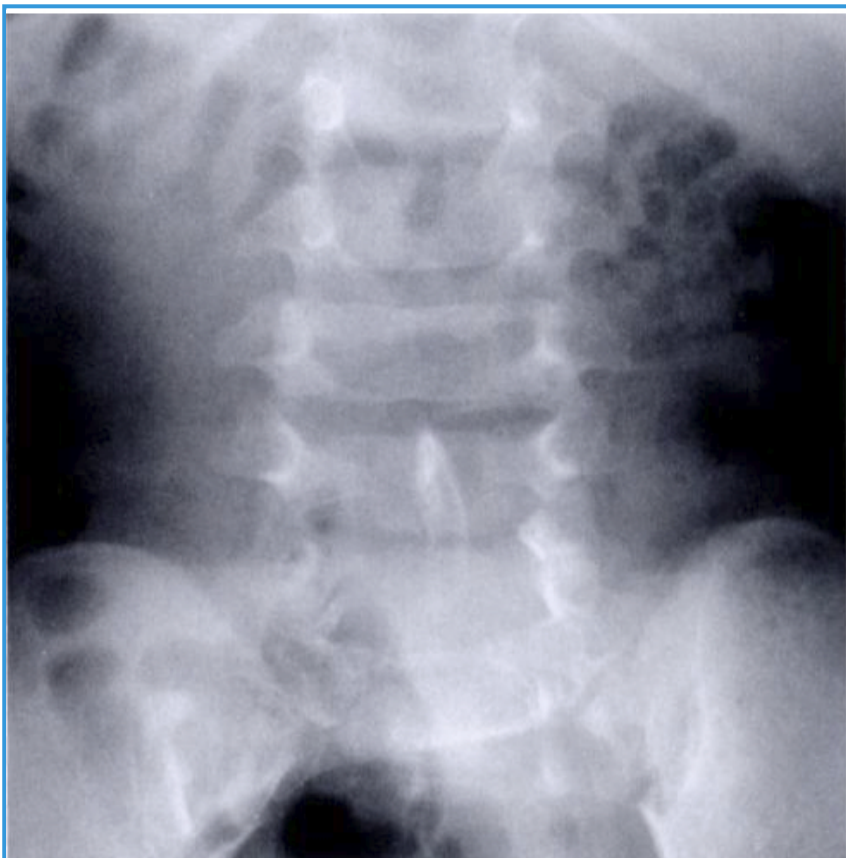
- Presentation

- Symptoms
 - muscle atrophy
 - weakness
 - bladder or bowel incontinence

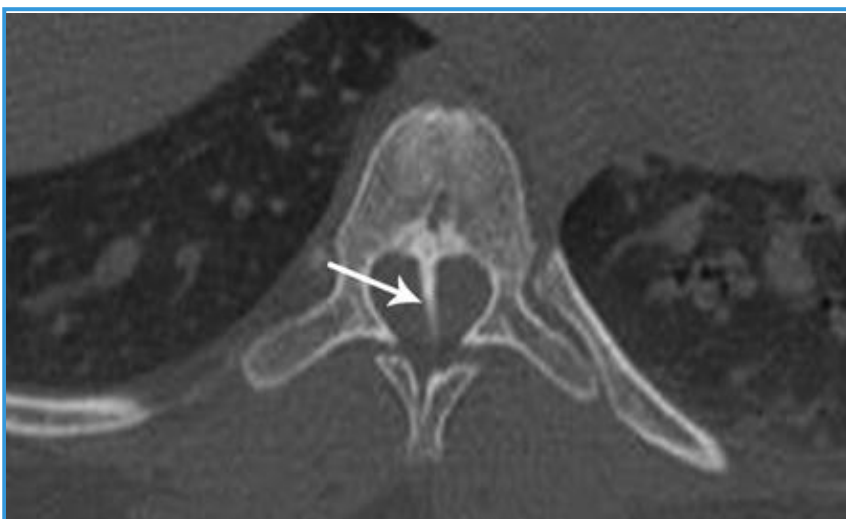
- Physical exam
 - sensory loss
 - reflex asymmetry
 - spinal cutaneous manifestations (>50% of patients)
 - hairy patch (hypertrichosis)
 - dimple
 - subcutaneous mass
 - teratoma
 - lower extremity deformity
 - cavus foot
 - club foot
 - claw toes

- Imaging

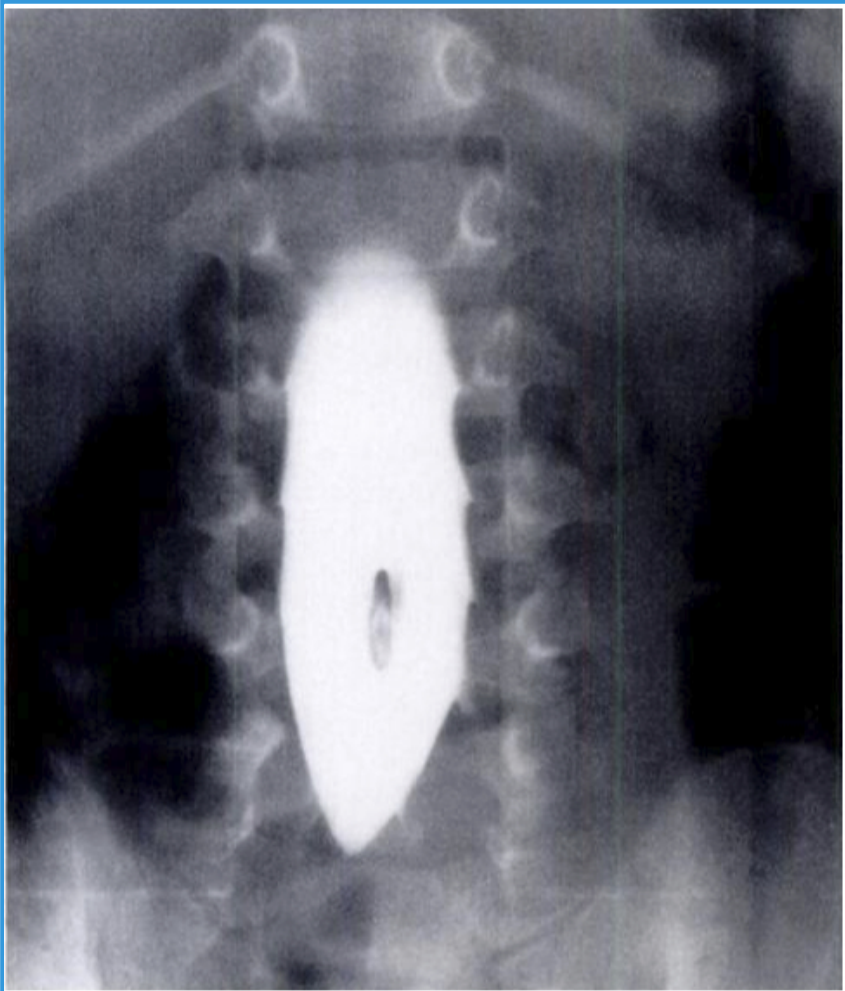
- Prenatal ultrasound
 - may be diagnosed in utero, during the third trimester
- Radiographs
 - interpedicular widening is suggestive



- CT
 - helpful to delineate bony anatomy



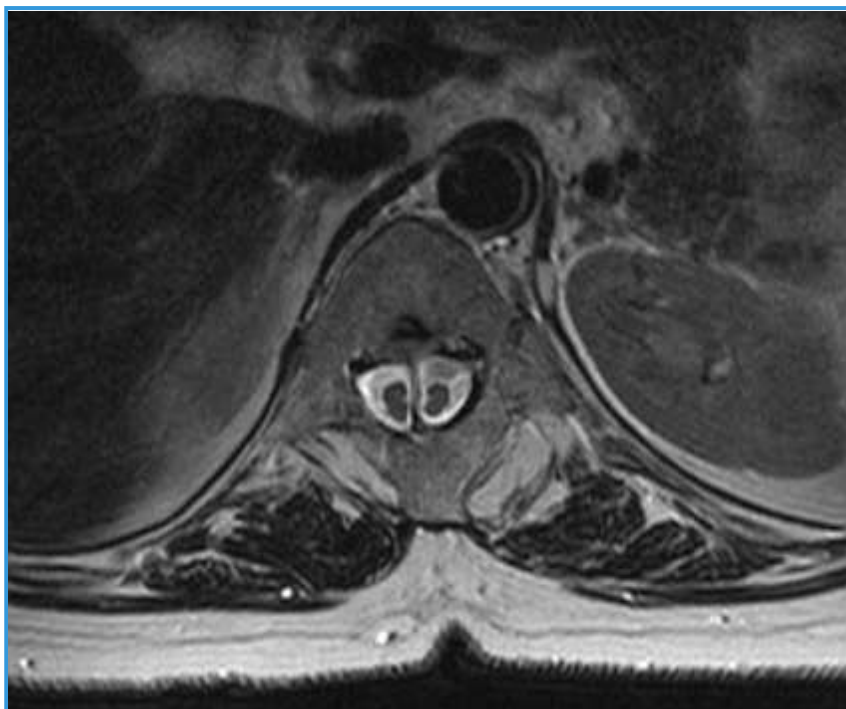
- Myelography



- spurs are often undetectable by plain radiographs or CT, especially if they are fibrous or there is rotation from concomitant scoliosis
- myelography is a useful adjuvant

- MRI

- required to evaluate degree of neurologic compression



- Treatment

- Nonoperative

- **observation alone**

- indications

- may be observed if patient is asymptomatic and does not have neurologic sequelae
- must watch closely for progressive neurological deterioration

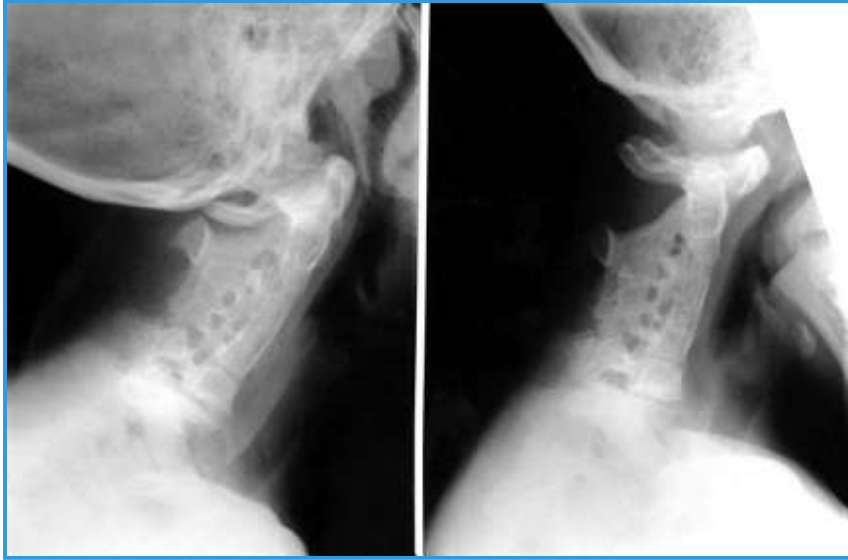
- Operative

- **surgical resection**

- indications
 - surgery is indicated if patient is symptomatic or has neurologic deficits
 - must resect diastematomyelia before correction of spine deformity
- must resect and repair the duplicated dural sac

72- Klippel Feil Syndrome

Images



- Summary

- Klippel-Feil Syndrome is a rare congenital condition caused by failure of normal segmentation or formation of cervical somites during embryological development that leads to abnormalities in multiple cervical segments.
- Diagnosis is made from physical examination, medical history and imaging findings including congenital fusion of 2 or more cervical vertebrae.
- Treatment is usually observation with restriction of contact sports if the anomaly extends proximal to C2. Surgical management is indicated in the presence of myelopathy, basilar invagination, or atlantoaxial instability.

- Etiology

- Pathophysiology
 - mechanism
 - due to failure of normal segmentation or formation of cervical somites at 3-8 weeks' gestation
- Genetics
 - SGM1 gene (Chr 8)
 - Notch and Pax genes
- Associated conditions
 - orthopedic conditions
 - congenital scoliosis
 - Sprengel's deformity (30%)



- medical conditions & comorbidities
 - renal disease (aplasia in 33%)
 - auditory issues (deafness in 30%)
 - congenital heart disease/cardiovascular (15-30%)
 - brainstem abnormalities/basilar invagination



- congenital cervical stenosis
 - MRI to rule out intraspinal cord abnormalities
- atlantoaxial instability (~50%)
- adjacent level disease (100%)

- degeneration of adjacent segments of cervical spine that has not fused is common due to increased stress

- Classification

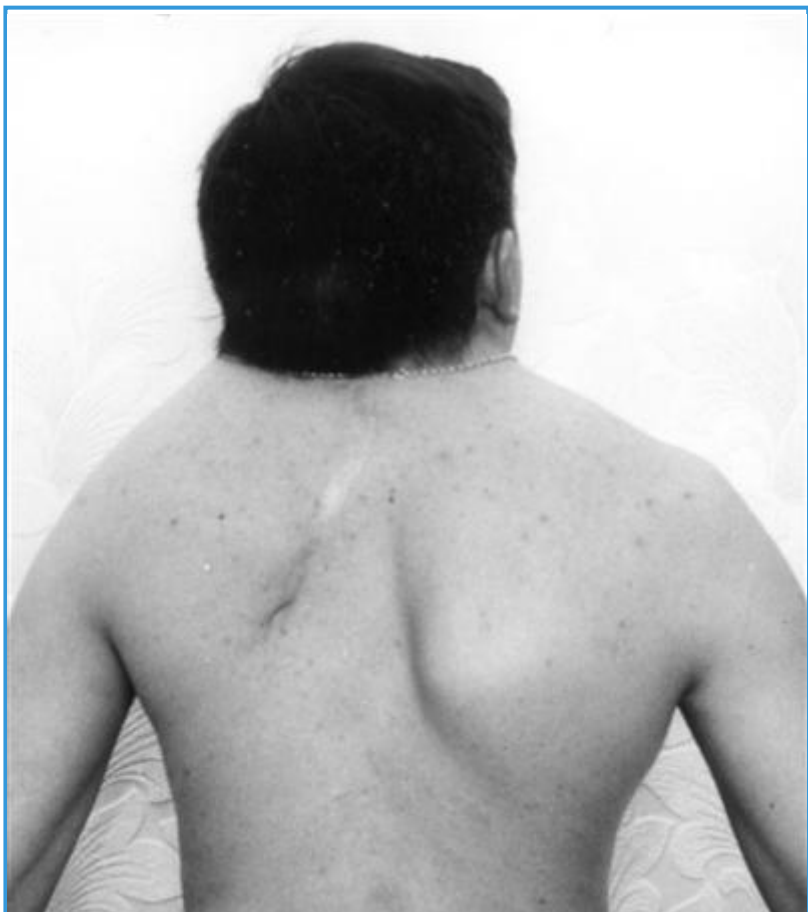
- KFS classification

■ KFS classification		
■ Type I	■ Extensive fusion of most or all of the cervical spine	■
■ Type II	■ Fusion of only 1 or 2 vertebrae in the cervical spine	■
■ Type III	■ Fusion exists in part of the thoracic and/or lumbar spine, in addition to Type I or Type II KFS	■

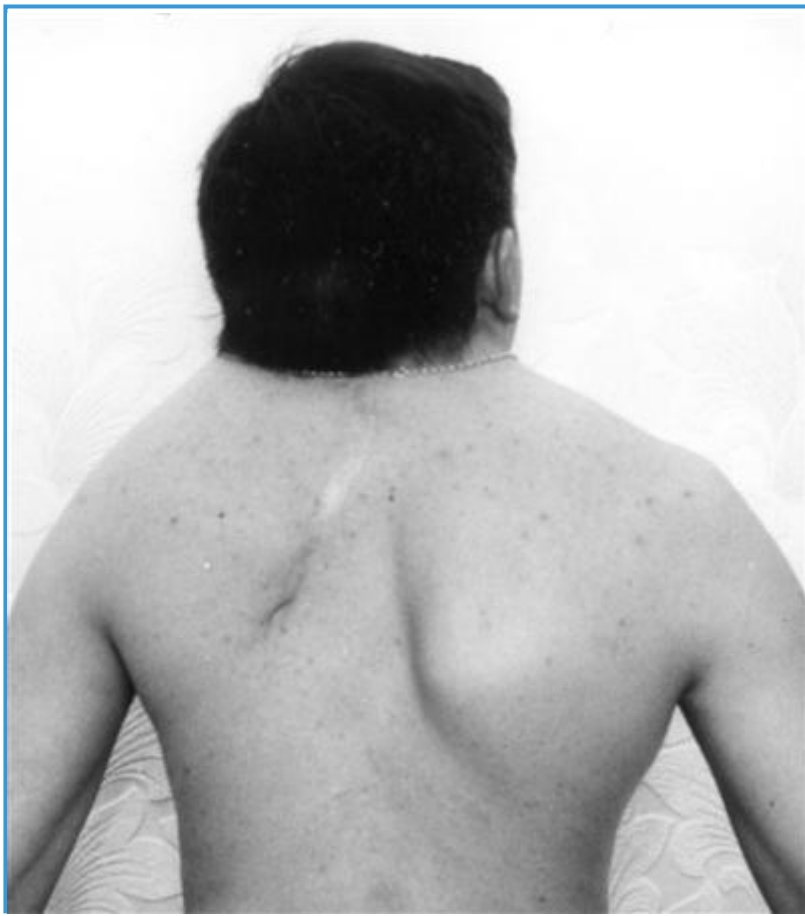
- Despite this original classification, none is widely accepted
 - extent and locations of fusions is important
 - fusions above C3
 - more likely to be symptomatic and require abstaining from contact sports
 - fusions below C3
 - less likely to be symptomatic and most likely to have a normal life span

- Presentation

- Symptoms
 - stiff neck
 - Physical exam
 - inspection
 - classic triad (seen in fewer than 50%)
 - low posterior hairline



- short webbed neck



- limited cervical ROM
- other findings
 - high scapula (Sprengel Deformity)



- jaw anomalies
- partial loss of hearing
- torticollis
- scoliosis

- Imaging

- Radiographs
 - recommended views
 - AP, lateral, and odontoid views
 - findings
 - fusion



- may be craniocervical (occiput to C2), subaxial, or both
- basilar invagination
 - is seen on lateral view
 - defined as dens elevation above McRae's line
- atlantoaxial instability
 - is present when the atlanto dens interval (ADI) is >5 mm
 - cervical spinal canal stenosis is seen when spinal cord canal <13 mm
- degenerative changes
 - degenerative disease of the cervical spine is seen in 100%
- calcifications
 - calcifications may be seen within the intervertebral space
 - resolution within 6 months is common

• Differential

- congenital scoliosis
- postinfection/spine inflammatory disorders
- Mayer-Rokitansky-Kaster syndrome
- Sprengel's deformity

• Treatment

- Nonoperative
 - **observation with ability to participate in contact/collision sports**
 - indications

- asymptomatic patients with fusions of 1-2 disc spaces below C3
- **observation and abstain from contact/collision sports**
 - indications
 - asymptomatic patients with fusion involving C2
 - most common presentation
 - long fusions
 - modalities
 - counseling important to avoid activities that place the neck at high risk of injury
 - contact sports, gymnastics, football, wrestling, trampoline, etc
- Operative
 - **surgical decompression and fusion**
 - indications
 - basilar invagination
 - chronic pain
 - myelopathy
 - associated atlantoaxial instability
 - adjacent level disease if symptomatic

73- Pediatric Intervertebral Disc Calcification

Images



- Summary

- Pediatric Intervertebral Disc Calcification is a very rare condition of unknown etiology.
- Textbook presentation is child with neck pain, fever, malaise, and an elevated ESR and presumably CRP.
- Treatment is typically conservative, and the disease is usually self-limiting with a favorable prognosis

- Epidemiology

- Incidence
 - <0.01%
- Demographics
 - 2:1 male to female ratio
 - 6-10 years
- Location
 - classically cervical spine
 - typical location lower cervical spine, specifically C6-C7, however can occur anywhere in the spine
 - thoracic, lumbar, and multiple level involvement have been rarely

- Risk factors
 - unknown

- Etiology

- Pathophysiology
 - unknown
 - possible pathophysiology causes:
 - trauma
 - inflammatory or infectious etiopathogenetic
 - aseptic necrosis
 - disorders of vitamin D metabolism
 - abnormal blood supply
- Genetics
 - no known genetic pattern

- Anatomy

- Intervertebral disc
 - annulus
 - nucleus pulposus

- Classification

- Single vs. Multiple Disc Levels
- Symptomatic vs. Asymptomatic

- Presentation

- Symptoms
 - neck pain (67-80%)
 - may present as acute, subacute, and chronic pain
 - torticollis (20-22%)
 - stiffness
 - low grade fever (10%)
 - weakness (rare)
- Physical exam
 - inspection
 - torticollis
 - motion
 - limited range of motion (14-33%)
 - neurovascular

- neurological deficit (11-38% according to some series, but in reality this is rare)

- Imaging

- Radiographs
 - recommended views
 - AP and lateral
 - findings
 - calcification of the disc
 - may appear as dense round or oval mass in the nucleus pulposus, or may be diffuse calcification of the disc at one or more discs
- CT
 - indications
 - may be used to rule out congenital fusion
- MRI
 - indications
 - neurologic deficits
 - concern for disc herniation
 - findings
 - diminished signal intensity on MRI

- Studies

- Labs
 - ESR
 - CRP

- Differential

- Congenital Fusion/Klippel-Feil Syndrome (KFS)
 - classic triad
 - short webbed neck
 - low posterior hairline
 - limited cervical range of motion
- Atlantoaxial rotatory subluxation
 - post-traumatic or post infectious (Grisel's disease)

- Treatment

- Nonoperative
 - **observation**

- indications
 - standard of care unless for vast majority of case
- modalities
 - analgesic and anti-inflammatory medications
 - neck collar
- outcomes
 - symptomatic improvement after several
 - 95% of patients have resolution within 6 months of presentation
 - radiographic resolution lags behind clinical resolution by many months at least

- Operative

- **neurologic decompression**

- indications
 - neurologic deficits with mass effect on spinal cord
 - intractable pain

- Complications

- Neurologic deficits (either nerve root or spinal cord)
 - incidence
 - extremely rare
 - may be associated with lesions in the annulus fibrosus

- Prognosis

- Natural history
 - generally accepted as self-limiting and has an excellent prognosis

74- Disk Space Infection Pediatric

Images



- summary
 - Disk Space Infections in the pediatric population are a common source of fever and low back pain caused by systemic infections in young children.
 - Diagnosis is made with blood cultures and MRI studies.
 - Treatment is bed rest , immobilization, and antibiotics for 4-6 weeks for early infection with no abscess . Surgical debridement followed by antibiotic treatment is indicated in the presence of an abscess and/or lack of improvement with nonoperative therapy.
- Epidemiology
 - Demographics
 - more common in pediatric patients relative to adults
 - more common in males
 - usually affects patients less than 5 years old
 - Anatomic location
 - most common in lumbar spine (50-60%)
- Etiology

- Pathophysiology
 - pathoanatomy
 - in children blood vessels extend from the cartilaginous end plate into the nucleus pulposus
 - this allows direct inoculation of the disc
 - infection may spread from the end plate to the disc space and vertebral body
 - in adult patients, blood vessels extend only to the annulus fibrosis
 - this limits the incidence of isolated disc space infections in adults
 - microbiology
 - staphylococcus aureus
 - is most common causative organism (>80%)
 - tuberculosis
 - always consider as organism, especially if patient is not improving with first line antibiotics
 - salmonella
 - in sickle cell anemia patients, salmonella may be the causative organism

- Anatomy

- Disc anatomy
 - in pediatric patients, blood vessels extend from the cartilaginous end plate into the nucleus pulposus
 - in adult patients, blood vessels extend only to the annulus fibrosis

- Presentation

- Symptoms depend on age of child
 - toddler
 - refusal to sit or walk, or painful limping
 - loss of appetite
 - fever (only 25% of patients will be febrile)
 - abdominal pain
 - older children
 - back pain with point tenderness
- Physical exam
 - tender to palpation over involved level
 - limited range of motion

- Imaging

- Radiographs

- radiographic findings are unreliable
 - earliest manifestation is at 1 week
 - findings
 - usually normal radiographs early in process
 - loss of lumbar lordosis may be earliest radiographic sign
 - disc space narrowing (10-21 days after infection begins)



- endplate erosion (10-21 days after infection begins)

- MRI

- diagnostic test of choice



- Studies

- Serum Labs

- ESR
 - high normal or mildly elevated
 - C-reactive protein
 - high normal or mildly elevated
 - WBC
 - high normal or mildly elevated

- Blood Cultures
 - blood cultures should be obtained to identify organism

- Treatment

- Nonoperative
 - **bedrest, immobilization, and antibiotics for 4-6 weeks**
 - indications
 - early infection with no abscess or displacement of thecal sac
 - modalities
 - initial treatment is with parenteral antibiotics directed at Staph aureus for 7-10 days
 - followup
 - watch serial labs to monitor efficacy of antibiotic treatment
 - CRP is the most sensitive in monitoring this patient's response to antibiotic therapy
 - obtain CT-guided biopsy if no response (rule out TB)
- Operative
 - **surgical debridement followed by antibiotic treatment**
 - indications
 - late infection
 - paraspinal abscess in the presence of neurologic deficits
 - limited responsiveness to nonoperative measures
 - technique
 - important to obtain cultures
 - followed with antibiotics and bracing

- Complications

- Long term narrowing of disk space
- Fusion between vertebra
- Back pain

75- Spine Surgical Site Infections

- Overview.

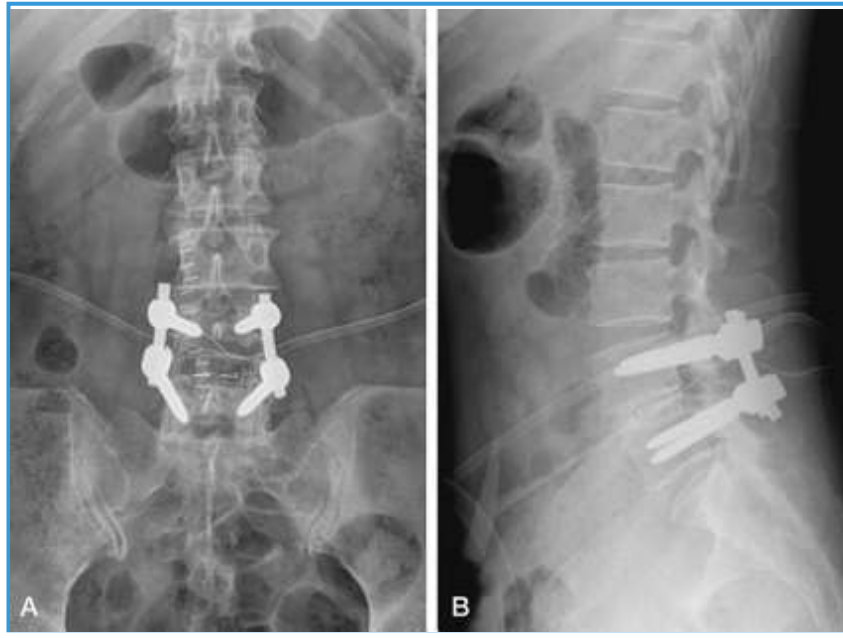
- Overview

- postoperative spine infections are a relatively common complication that has the potential to seriously compromise patient outcomes through
 - increased morbidity
 - increased mortality
 - increase reoperation
 - increased hospital stay
 - increased treatment costs
 - estimated to be \$200,000 per patient
 - worse overall long-term outcomes

- Epidemiology

- Incidence

- surgical site infection (SSI) general
 - the most common hospital acquired infection that occurs in the early postoperative period
 - spine surgical site infection (SSI)
 - occurs in .7% to 16% depending on type of spine surgery, approach, use of instrumentation, and indication for surgery
 - incidence of SSI in their series following orthopedic spinal operations is 2.0%
 - incidence of some procedures
 - lumbar micodisectomy
 - with prophylactic antibiotics has a reported 0.7% incidence of infection.
 - use of an operating microscope for disectomy doubles this rate to 1.4%.
 - lumbar fusion
 - risk of infection is higher with spinal fusion because of the presence of spinal instrumentation



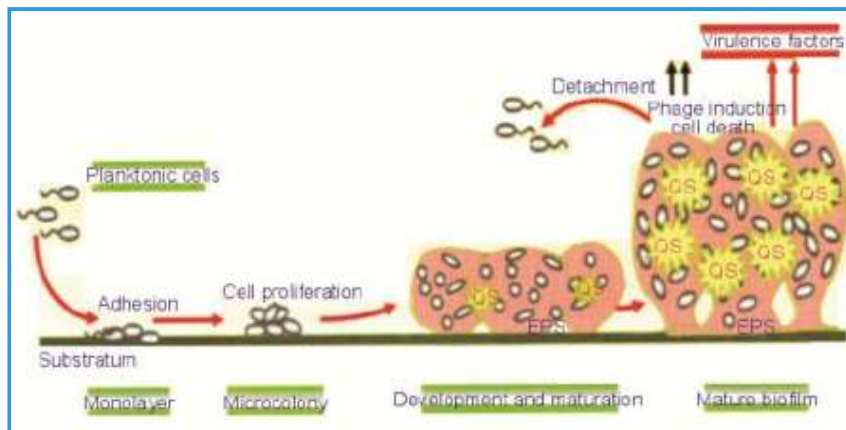
- in elective surgical instrumented cases, the incidence of infection has been reported to be 2.8% to 6%
- fracture stabilization/trauma
 - traumatic spine injury has an increased infection risk of up to 10%
 - greater local tissue hypoxia, longer ICU stays, and greater soft tissue damage, catabolic state leading to protein malnutrition, and greater comorbidities contribute to increased infection risk
 - risk factors associated with trauma-related SSIs:
 - multilevel spine surgery
 - treatment delay >160 hours
 - complete neurologic deficit
 - severe cognitive impairment
- anterior vs. posterior
 - posterior spine procedures have a statistically higher incidence of infection postoperatively compared with anterior instrumentation
 - combined anterior/posterior cases do not carry a higher risk of infection than does posterior surgery alone
- average time to infection
 - 14 months
- Risk factors
 - medical
 - patient age >70 years
 - may be confounded by older patients having more comorbidities
 - ASA score
 - diabetes mellitus
 - cardiovascular disease
 - malignancy

- long term steroid use
- previous lumbar surgery
- chronic obstructive pulmonary disease
- immunologic competency
- prior infection
- preoperative hospitalization >1 week
- malnutrition
- prior radiation
- lifestyle
 - obesity
 - smoking
 - nutritional status
 - malnourished patients are 15x more likely to develop an infection
 - ETOH
- intraoperative
 - transfusions
 - use of instrumentation
 - multiple staged interventions
 - amount of levels fused
 - operative room traffic (large number of nurses)
 - surgery lasting longer than 3 hours
 - blood loss >1 L
- hospital stay
 - duration of patient stay in the postanesthesia care unit
 - prolonged preoperative hospital stay

- Etiology

- Pathophysiology

- pathophysiology
 - instrumentation
 - the use of instrumentation has an important role in the development of postoperative infections
 - can cause local soft tissue irritation leading to inflammation and seroma formation that subsequently provides a fertile breeding ground for microorganisms to grow
 - adherence of bacteria to the surface of implants is promoted by a polysaccharide biofilm called glycocalyx that acts as barrier against host defense mechanisms and antibiotics



- metallosis from micromotion of the instrumentation leads to granuloma formation and provides yet another medium for bacterial colonization
- microbiology
 - staphylococcus aureus
 - 73%
 - most frequent microorganism found in spinal SSI is Staphylococcus aureus
 - 5-18% can be methicillin resistant staphylococcus aureus (MRSA)
 - staphylococcus epidermidis
 - increasing frequency in postoperative infections
 - enterococcus coli & enterococcus faecalis
 - patients with incontinence / faecal contamination
 - propionibacterium acnes (low virulence microorganisms)
 - patients with compromised immune system could present with surgical wound infected by low virulence microorganisms
 - late hardware infection
 - gram-negative rods
 - generally uncommon cause of SSI
 - trauma patients
 - severe neurologic injury
 - those in an immunocompromised state (injury severity score >18)
 - higher incidence seen with neuromuscular scoliosis patients (cerebral palsy, Duchenne's muscular dystrophy, etc.)
 - higher risk of soiling wound due to poor bowel and bladder control compounded with lack of baseline mobility
 - polymicrobial
 - almost exclusively a result of direct wound contamination during the post-operative period
 - fecal or urinary contamination of the wound in neuromuscular patients

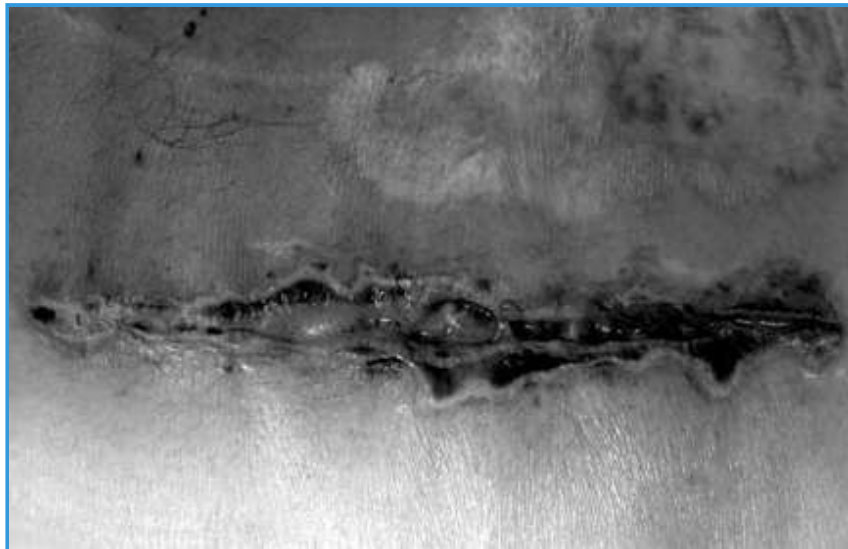
- Anatomy

- Muscles
 - psoas muscle
 - can be site of abscess extension from lumbar discitis
 - presents with hip and thigh pain
- Ligament
 - anterior longitudinal ligament
- Blood Supply
 - segmental spinal arteries

- Classification

- Anatomic
 - superficial
 - superficial infection are limited only to the skin or subcutaneous tissues without fascial involvement
 - deep
 - deep infections involve the fascia and/or muscle
 - unlikely to respond to the standard 6-week course of antibiotics alone
- Chronologic
 - early
 - early, if they occur within 3 weeks of the procedure
 - late
 - more than 4 weeks later
 - latent
 - years after surgery
- Mechanism
 - direct inoculation
 - contamination during surgery
 - substantial amount of bacteria are needed at the operative site to cause SSI
 - >10⁵ organisms
 - leads to infection within 30 days
 - early postoperative (outside-in) contamination
 - drains
 - seroma drainage creating outside-in contamination
 - soiling of wounds
 - late hematogenous contamination

- dental work
- foreign infection (UTI)
- Thalgott classification
 - based on host factors and severity of infection
 - host factors
 - A - normal
 - B - local or systemic disease (smoking, diabetes)
 - C - immunocompromised
 - anatomic factors
 - 1 - single organism (deep or superficial)
 - 2 - deep infection with multiple organisms
 - require an average of 3 irrigation and debridements
 - 3 - deep infection with multiple organisms and myonecrosis



- very difficult to manage and have poor outcomes

• Presentation

- History (optional)
 - night sweats
- Symptoms
 - wound drainage
 - most common presentation
 - increasing pain
 - increase with time
 - post-op pain should improve with time
 - constitutional symptoms
 - fever is the most common generalized finding with infection
 - temperature $>39^{\circ}\text{C}$ is worrisome for a bacterial deep wound infection
 - generalized sepsis
 - generalized malaise
 - lethargy

- confusion
- hypotension
- organ failure is an indication for emergent surgical debridement
 - condition usually presents as generalized malaise, lethargy, and even confusion
- Physical exam
 - wound
 - wound erythema or discharge common with superficial infections



- wound may be clean with deep infections
- drainage
 - persistent draining of a seroma will be clear
 - copious or purulent discharge consistent with infection
- tenderness
 - over surgical site

• Imaging

- Radiographs
 - indications
 - Plain radiographs of the spine are rarely useful for the diagnosis of early infection [8,9,16].
 - findings
 - acute
 - usually normal
 - late & latent
 - loss of disc height

- end plate erosion
- lucencies may be present around orthopedic hardware

○ CT

- indications
 - when concern for the fusion status and implant positioning
- views
 - best seen on sagittal and axial images
- findings
 - computed tomography scan may show multiple lesions involving the end plates
 - lytic lesions around the screws/implants



- presence of pseudoarthrosis

○ MRI

- indications
 - magnetic resonance imaging (MRI) is the most useful study to diagnose SSI [1,8-10,16]
 - magnetic resonance imaging (MRI) is the most useful imaging study, but it must be interpreted with caution
- technique
 - gadolinium enhancement improves the diagnostic accuracy of MRI and should be used whenever infection is suspected
 - gadolinium enhancement increases the sensitivity of MRI
- findings suggestive of infection
 - rim enhancement of a large fluid collection is pathognomonic for infection



- ascending epidural collections



- evidence of bony destruction



- progressive marrow changes and ascending epidural collections on MRI scans are also diagnostic of infection
- sensitivity and specificity
 - inflammatory response following surgery is similar to that seen with infection
- Bone scan
 - rarely used

- WBC-labeled may be helpful for identifying and infectious focus
- indications:
 - patient unable to tolerate MRI (e.g. pacemaker)

• Studies

○ Serum Labs

- HgBA1C
 - obtain preop for all diabetic patients
 - should be < 7.0
- WBC
 - White blood cell count is an unreliable indicator of infection.
- ESR
 - Erythrocyte sedimentation rate can remain elevated for up to 6 weeks after surgery
 - rising levels after 4th postoperative day can be suggestive of an infection
- CRP
 - C-reactive protein (CRP) levels normalize within 2 weeks
 - peaks around post-op day 2
 - persistent high levels or 2nd peak is concerning for infection
 - CRP is a more sensitive indicator of the presence of SSI
 - CRP has been reported to be the most sensitive clinical laboratory marker in assessing the presence of infection and treatment response
 - normalized CRP with improving ESR is suggestive of post-operative SSI resolution
- Albumin
 - < 3.5 g/DL is concerning for malnutrition
- transferrin
 - < 150 ug/dl is concerning for malnutrition

○ Cultures

- superficial skin cultures
 - superficial cultures, whether from the skin or drainage, do not reliably assist with identification of the causative organism
- aspiration
- intraoperative
 - intraoperative tissue cultures remain the gold standard for identification of the causative organism in SSI
 - cultures may be negative in latent infections

- culturing of removed hardware may yield offending organism due to bacteria "hiding" in the glycocalyx
 - obtained prior to antibiotic administration
- Intraoperative biopsy samples
 - gross anatomy
 - histology/frozen sections
 - immunostaining
- Differential
 - Key differential (top 4)
 - adjacent segment disease
 - inadequate decompression
 - postoperative seroma
 - postoperative hematoma
- Treatment
 - Nonoperative
 - **oral antibiotics and close observation**
 - indications
 - only indicated for mild superficial infections
 - Operative
 - **urgent surgical debridement, wound management +/- plastics, I D consult & targeted IV antibiotics**
 - indications
 - vast majority of cases
 - any infection that does not respond to antibiotics
 - unacceptable spinal deformity
 - neurologic deficits
 - progression of infection on follow-up MRI studies
 - indications for hardware removal
 - loose hardware
 - refractory infections
 - latent infection and fusion obtained
 - titanium implants are best for use in infection cases
 - indications to retain hardware
 - insufficient stability
 - lack of solid fusion
 - outcomes

- worse overall long term outcomes compared to index procedure without infection
- increased treatment costs

- **Techniques**

- **Oral antibiotics and close observation**

- technique
 - keflex, bactrim, clindamycin or augmentin
 - choice depends on pathogen of concern
 - keflex - MSSA
 - keflex 500 mg TID vs. 250 mg QID
 - bactrim - MRSA
 - clindamycin - PCN allergic
 - augmentin - anaerobes
 - local wound care
 - daily dressing changes
 - betadine ointment to surgical wound with dressing changes

- **Urgent surgical debridement, wound management +/- plastics, ID consult & targeted IV antibiotics**

- treatment goals:
 - eradicate infection
 - obtain wound healing
 - maintain mechanical integrity of instrumented fixation
 - maintain viability of the bone graft
- approach
 - utilize prior incision
 - remove necrotic edges of wound
 - should approach down to hardware to avoid dissecting into dura
 - extensive scar tissue around dural sac can make determination of dural sac difficult
- debridement
 - debride tissue in layered fashion
 - pulse lavage with NS +/- antibiotics
- instrumentation removal
 - remove loose hardware
- reinstrumentation / extension of instrumentation
 - restore stability of spine
 - upsize existing screws

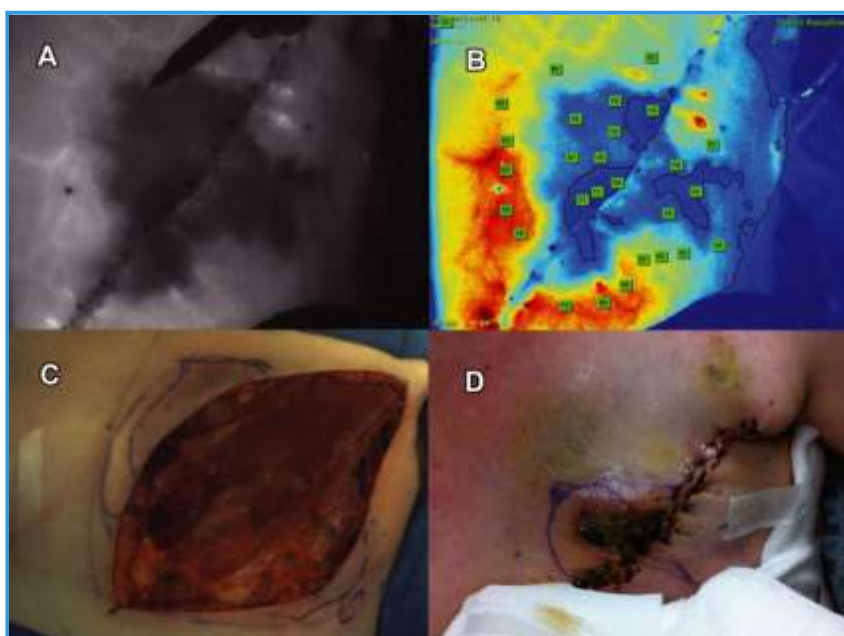
- extend proximally if needed
- consider anterior procedure
- wound management:
 - multiple debridement if needed
 - remove all devitalized muscle tissue
 - remove all loose bone graft
 - negative pressure wound management



- dressings and closed suction irrigation systems is becoming more popular in the clinical management of infected wounds to support the wound healing process
- muscles flaps and local rotational flaps for large soft tissue defects



- wound closure
 - non-braided suture
 - tension-free closure
 - may require paraspinal muscles flaps with plastic consults
 - may use SPY which helps determine vascularity of wound



- antibiotic beads

- drains
 - multiple drains (superficial and deep)
- wound vac
- targeted IV antibiotics
 - obtain culture if possible and treat with targeted agents
 - treatment depends on the culture results but generally infections with anaerobes as polymicrobial to be treated with broad spectrum antibiotics, such as vancomycin or metronidazole, administered i.v., for 6 weeks
 - usually require 6 weeks of IV antibiotics
 - obtain PICC line
 - monitor CRP / ESR
 - serial MRI usually not indicated
 - prolonged IV antibiotic therapy can delay hardware removal long enough to allow a solid fusion to occur

- Complications

- Wound Complication
- Pseudoarthrosis
- Neurologic deficits / paralysis
- Sepsis
- End Organ Failure
- Death
- Worse overall outcomes

- Prognosis

- Has the potential to seriously compromise patient outcomes

- Prevention

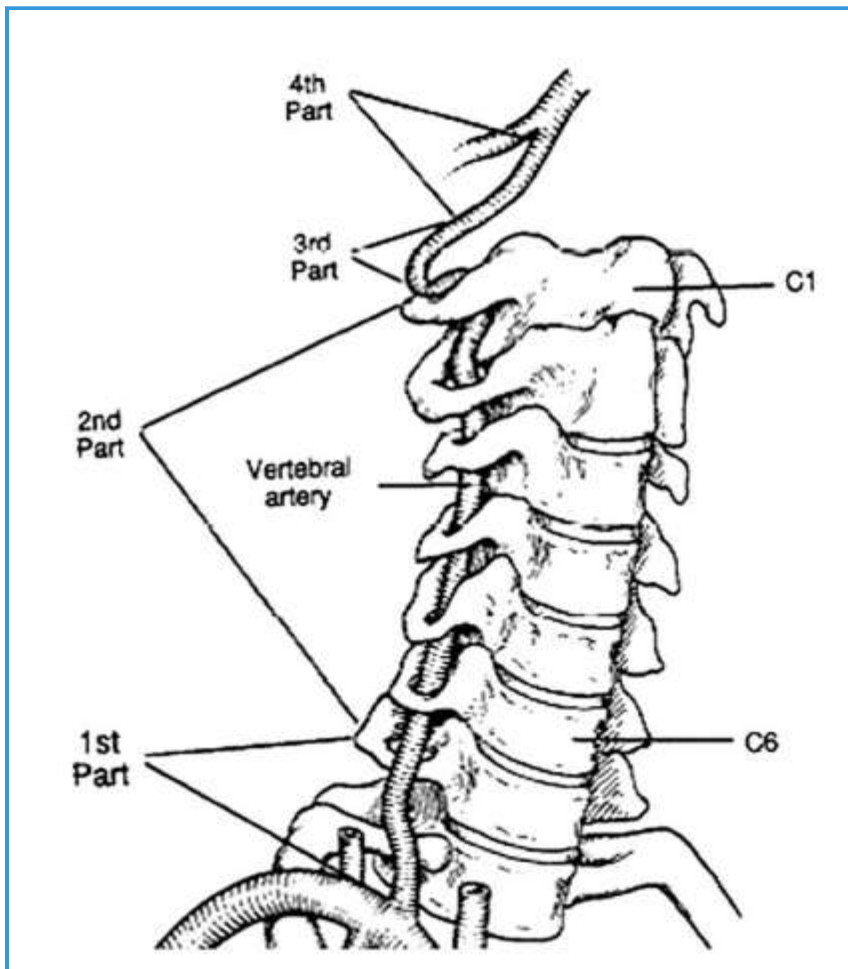
- Preoperative (prior to surgical admission)
 - decrease changeable risk factors
 - lifestyle
 - weight loss
 - smoking cessation
 - abstinence from EtOH and drugs
 - medical
 - glucose control
 - address other sites of infection

- UTI
 - Nasal swaps
 - povidone-iodine swabs for all patients or for MRSA carriers
- Intraoperative
 - skin preparation (non sterile)
 - shaving
 - clippers preferred over razor
 - isopropyl alcohol
 - surgical prep
 - room sterility
 - proper sterile technique
 - minimize room traffic
 - prepping and draping
 - preoperative antibiotics
 - indications
 - administered within 1 hour of skin incision
 - significantly decrease the incidence of postoperative spinal wound infections
 - some studies suggest may only decrease the severity of the infection
 - should be given before incision and repeated when the operation exceeds 4 hours
 - antibiotic selection
 - no PCN allergy
 - a first-generation cephalosporin (cefazolin most common) is the most commonly used prophylactic antibiotic
 - usually 2g Q8hrs for the first 24 hours
 - 3g Q8hr for obese patients (>100 kg of BMI $>35\text{kg/m}^2$)
 - PCN allergy
 - vancomycin or clindamycin are given to patients who are allergic to cephalosporins
 - vancomycin dosing 1000 mg Q12hrs
 - infusion needs to start $>1\text{hr}$ from incision to allow for sufficient tissue levels of antibiotic
 - clindamycin dosing 900 mg Q8hrs
 - patients at risk for MRSA should be treated with prophylactic vancomycin
 - length and complexity of surgery
 - decrease invasiveness of surgery (area of surgical bed)

- decrease time of surgery
 - decrease blood loss
- wound antibiotics
 - antibiotic irrigation (holy water)
 - mix with normal saline
 - vancomycin powder
 - The use of powdered vancomycin locally administered during surgery has been associated with reduced SSI rates
 - high local tissue concentrations for several several days post-op
 - vancomycin powder has been linked to increased gram-negative organism infections if they do occur
- betadine soaks
 - 0.3% betadine soak for 2 minutes
- frequent release of retractors during procedure
 - at least every 2 hours
 - reduces amount of tissue necrosis at the end of the procedure
- debridement of necrotic tissue at the end of the procedure
 - muscle tissue that was retracted may become necrotic from pressure necrosis
- hemostasis
 - seroma and hematoma can subsequently get infected
- drains
 - evacuates any postoperative hematoma or seroma
 - some studies have not found a difference in SSI with the use of drains
 - the routine use of drains is not recommended after single-level procedures by NASS
- vacuum-assisted closure
 - dressings/wound vac
- Postoperative
 - postoperative antibiotics
 - continued postoperatively for no longer than 24 hours

76- Vertebral Artery Injury

Images



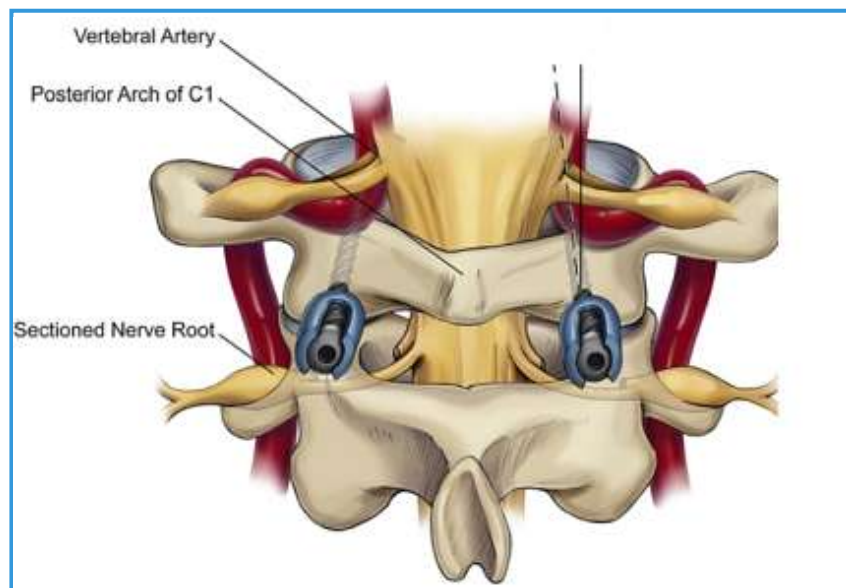
- Epidemiology

- Incidence of vertebral artery injury (VAI)
 - 0.5% of all trauma patients
 - 70% of VAI in blunt trauma has associated cervical fracture
 - 33%-39% of all cervical spine fractures
 - 0.3% anterior cervical spine surgery
 - 4.1-8.2% posterior cervical spine surgery (C1-2 transarticular screws)

- Etiology

- Pathophysiology
 - blunt traumatic injury
 - pathoanatomy
 - highest injury risk at point of entry into C6 transverse foramen
 - second highest risk at C1-2 articulation
 - iatrogenic injury during elective surgery
 - safe zone
 - C1: avoid dissection cephalad to the C1 posterior arch > 1.5 cm lateral to midline

- C1 lateral mass screw should be placed in a 10 degrees medial and 22 degrees cephalad trajectory



• Anatomy

- 4 arterial segments
 - V1
 - extraosseous
 - origin at subclavian artery, anterior to C7 transverse process, to the entry point of C6 transverse foramen
 - V2
 - within the transverse foramina of C6-C1
 - most traumatic injuries occur here
 - high risk during drilling, tapping, insertion of lateral mass or pedicle screws
 - V3
 - superior aspect of the arch of atlas to foramen magnum
 - VA is vulnerable during lateral exposure and laminectomy of C1
 - high risk of C1-2 transarticular screws are directed caudally and laterally
 - V4
 - intradural extension from foramen magnum to unite with contralateral vertebral artery
 - forms the basilar artery
- most injuries from cervical trauma in V2 (foraminal segment)
- Anomalous anatomy
 - reported prevalence of 2.7% in anterior cervical surgery
 - transverse foramen may be medial to or within 1.5mm of the uncovertebral joint
 - reported prevalence of 2.3-20% in the atlantoaxial region
 - high-riding C2 foramen
 - C2 pedicle erosion

- C2 lateral mass thinning

• Classification

○	■ Biffi VAI Injury Grading		
	■ Grade I	■ Arteriographic appearance of vessel dissection/intramural hematoma; <25% luminal stenosis	■
	■ Grade II	■ Intraluminal thrombosis or raised intimal flap; dissection/intramural hematoma with >25% luminal stenosis	■
	■ Grade III	■ Pseudoaneurysm	■
	■ Grade IV	■ Vessel occlusion	■
	■ Grade V	■ Vessel transection	■

• Presentation

- History
 - consists of recent:
 - cervical spine trauma
 - C1 or C2 fractures
 - subaxial facet fractures and dislocations
 - elective surgery of the cervical spine or craniocervical junction
- Symptoms
 - variable in presentation and time of onset
 - vertebrobasilar insufficiency manifests with
 - dizziness
 - vertigo
 - nausea
 - diplopia
 - blindness
 - ataxia
 - bilateral weakness
 - oropharyngeal dysfunction

• Imaging

- Radiographs
 - xrays of certain fracture patterns raise suspicion for VAI
- CT angiography (CTA)
 - identification of local occlusion or extravasation
 - sensitivity reported at 100%

- indications for the trauma patient (any single criteria is an indication)
 - unexplained central or lateralizing neurologic deficit
 - evidence of acute cerebral infarct on CT scan of head
 - GCS <9
 - evidence of diffuse axonal injury
 - facial fracture or Le Fort type-II or III fracture
 - cervical spine fracture or subluxation
 - C1, 2, 3 fracture
 - Fracture extension into the transverse foramen
 - VAI demonstrated in 20%
 - cervical spinal cord injury
 - hanging injuries
 - major thoracic injury or first-rib fracture
- Magnetic resonance angiography (MRA)
 - identification of local occlusions/stenosis
 - sensitivity 93.9%
 - indications
 - cervical spine fractures with neurologic deficits attributable to damaged vertebral or basilar artery perfusion
 - sensitivity and specificity

• Treatment

- Post-operative anticoagulation
 - goal is to prevent thromboembolic sequelae of injury
 - **intravenous heparin**
 - **acetylsalicylic acid (aspirin)**
 - indications
 - first line of treatment
 - modalities
 - heparin, aspirin, clopidogrel, IV thrombolysis, glycoprotein IIb/IIIa antagonists (abciximab, eptifibatide, tirofiban)
 - contraindications:
 - major intracranial infarction
 - intraspinal hematoma/arteriovenous fistula
- Operative reduction and stabilization as necessitated by fracture pattern
- Surgical techniques to control hemorrhage (see Techniques)
- Immediate intra-operative angiography
 - can assist intra-operative decision making

- Post-operative management following iatrogenic injury
 - observation
 - further intervention dictated by clinical course
 - immediate post-operative angiography
 - detects vascular complications
 - confirms adequate collateral cerebral circulation
 - allows embolization of fistulae or pseudoaneurysm

- Techniques

- **Hemostatic tamponade**
 - utilization of topical hemostatic agents, bone wax
 - if injured during C1-2 transarticular screw placement, can tamponade by screw insertion
 - risks include:
 - delayed hemorrhage
 - fistula formation
- **Microvascular repair**
 - allows restoration of normal blood flow
 - minimizes risk of ischemic complications
 - technically demanding
- **Direction ligation**
 - consider intraoperative angiography first to evaluate collateral circulation
 - risks certain morbidities
 - cerebellar infarction
 - loss of flow via the posterior inferior cerebellar artery (PICA)
 - isolated cranial nerve paresis
 - hemiplegia
- **IR-guided embolization**

- Complications

- Complications may occur days to years following injury
 - arteriovenous fistula
 - late-onset hemorrhage
 - pseudoaneurysm
 - may be delayed presentation
 - thrombosis with embolic incidents
 - cerebral ischemia/Stroke
 - persistent vertigo

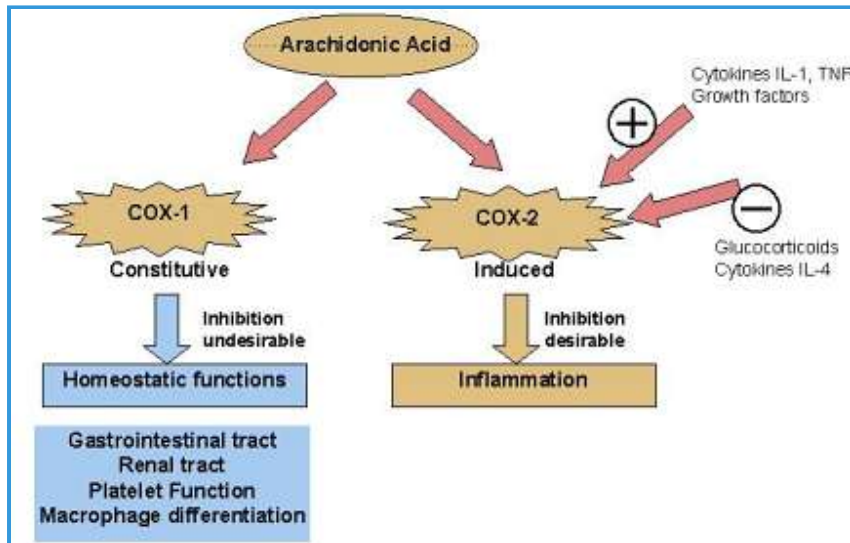
- death

- Prognosis

- Impact of VAI difficult to predict
- Many patients initially asymptomatic
 - some progress to cerebral ischemia or stroke with permanent neurologic deficit
- Variable symptomatology

77- Blood Loss Management In Spine Surgery

Images



• PREOPERATIVE

○ Establish Baseline labs

■ labs

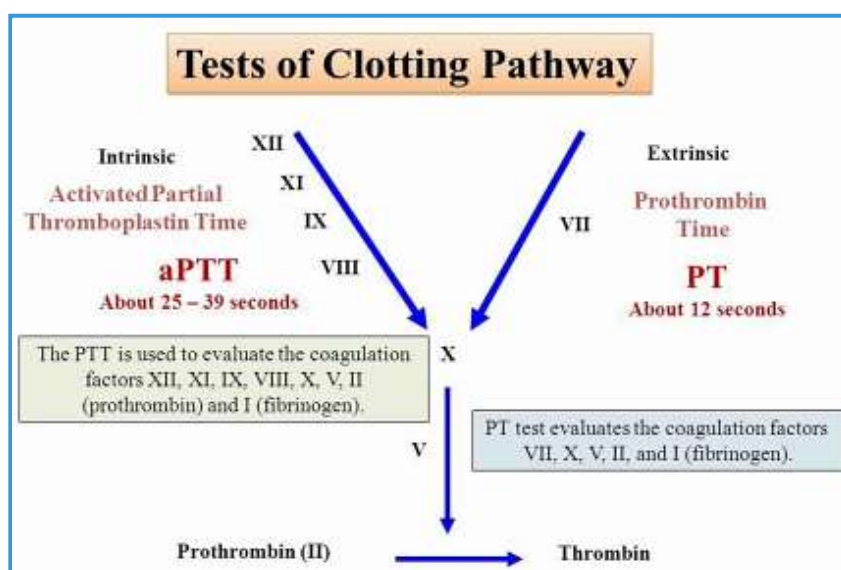
■ CBC

- hemoglobin & hematocrit
- platelets

■ Prothrombin time (PT)(INR)

- determines clotting time for the extrinsic coagulation cascade
 - factors I, II, V, VII, and X
 - normal result is 12-13 seconds
 - reported with International Normalized Ratio (INR)
 - normal range of 0.8 to 1.2
 - not correlated with increased transfusion rates

■ Partial thromboplastin time (PTT)



- assesses clotting time of the intrinsic clotting cascade

- factors XII, XI, IX, VIII, X, V, II
- normal range of 25-39 seconds
- not correlated with increased transfusion rates
- Fibrinogen
 - also known as factor I
 - normal range 200-400 mg/dL
 - below normal ranges have been associated with increased transfusion rates

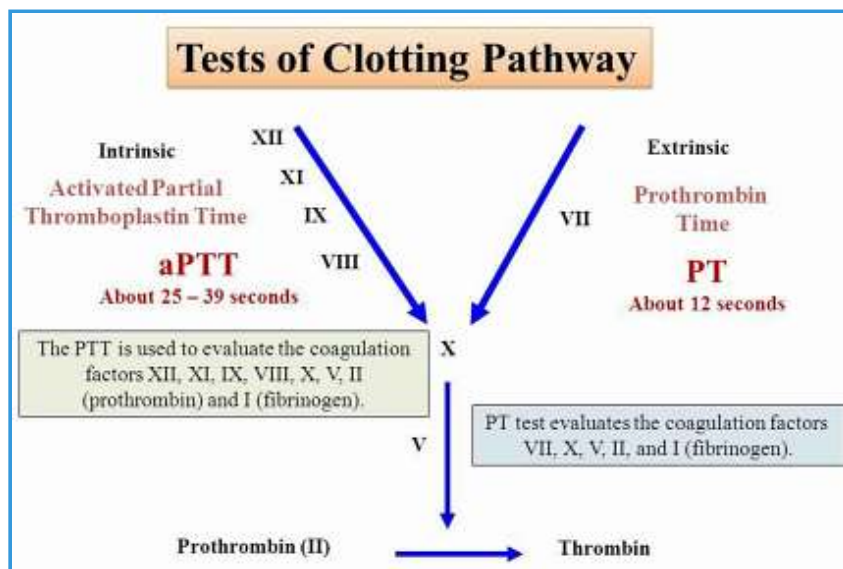
○ **Preoperative blood loss estimation**

- allows for cost-effective treatment with cell salvage systems, allogenic blood transfusions, and antifibrinolytic agents
- factors associated with increased blood loss
 - increased body mass index
 - lower body weight
 - mostly associated with increased transfusion requirements
 - lower starting blood volume
 - factor for pediatric spinal deformity
 - advanced age
 - bleeding diatheses
 - number of spinal levels
 - approximately 200 cc per lumbar level
 - use of instrumentation
 - revision spine surgery
 - iliac crest bone harvest
 - interbody fusions
 - trauma or tumor surgery
 - Cobb angle $>50^\circ$
 - longer expected surgical time
 - neuromuscular scoliosis
 - >6 levels fused for deformity surgery
 - Ponte osteotomies
 - vertebral column resection osteotomy
 - can lead to 65% total blood volume loss
- recommend obtaining a preoperative hemoglobin level of 5 g/dL greater than treating surgeons transfusion trigger

○ **Establish Baseline**

- labs
 - CBC
 - hemoglobin & hematocrit

- platelets
- Prothrombin time (PT)(INR)
 - determines clotting time for the extrinsic coagulation cascade
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○ Hemoglobin optimization

- goals
 - (focus on reducing allogenic blood transfusion intraoperatively and postoperatively)
 - vitamin supplementation
 - iron
 - major building block of hemoglobin and functions to bind oxygen in the porphyrin ring structure
 - supplementation provides material for hemoglobin synthesis
 - some studies have demonstrated a significant decrease in postoperative transfusions in patients with anemia-reducing vitamins
 - increased side effects

- constipation
 - heartburn
 - abdominal pain
- folate and vitamin B12 supplementation
 - are essential vitamins for DNA synthesis that is necessary for erythropoiesis
- anemia-associated vitamin supplementation
 - iron 256 mg/day, vitamin C 1 g/day, and folate 5 mg/day for 30-45 days preoperative have been associated with decreased transfusion rates
 - should only be used in patients with specific deficiency
- erythropoietin (EPO)
 - mechanisms
 - recombinant protein of natural glycoprotein produced by renal pericapillary cells
 - signals bone marrow cells to stimulate RBC production
 - outcomes
 - studies have demonstrated greater efficacy than preoperative autologous blood donation and reinfusion systems
 - costs
 - high cost associated with use
 - treatment cost equivalent to 4 units of allogenic blood transfusion
 - indications
 - recommended for high risk patients
 - preoperative Hb < 13g/dL
 - low body weight (< 50 kg)
 - surgeries when considerable blood loss is expected
 - administration
 - three dosing regimens have been proposed:
 - 600 IU/kg - 4 doses: preoperative days 21, 14, 7, and 0
 - 300 IU/kg - 15 doses: preoperative day 10 to postoperative day 4
 - 150 IU/kg - 9 doses: preoperative day 5 to postoperative day 3
- preoperative autologous blood donation
 - administration
 - preoperative procurement of 1 to 2 units of autologous blood

- performed at least 3 weeks from the planned surgery to allow for recovery of Hb levels
 - outcomes
 - current literature does not seem to support efficacy and cost effectiveness in the management of postoperative anemia
 - concerns that there is a high incidence of unused units
 - compulsion to transfuse patient
 - indications
 - may be of benefit in patients with normal Hb (>14 g/dL) undergoing procedures with high expected blood loss
 - may be performed in any patient with Hb > 11 g/dL and body weight >50 kg performed with sufficient time prior to procedure
 - preoperative embolization
 - indications
 - standard treatment for oncology cases with highly vascular tumors
 - renal cell carcinoma
 - technique
 - performed within 24 hours of the procedure
- **Discontinue Anticoagulating Medications**
 - goals
 - decrease risk of intraoperative bleeding without causing adverse event
 - NSAIDs
 - inhibit COX-1 and COX-2
 - nonaspirin platelet inhibitors (clopidogrel)
 - commonly prescribed after cardiac stenting
 - elective spine surgery should be postponed after such procedures
 - 6 weeks bare metal stents
 - 6 to 12 months drug-eluting stents
 - if urgent/emergent surgery may consider continuing medication
 - if discontinued, need to discuss risks and benefits
 - Plavix can be resumed 12 to 24 hours after surgery if there is no concern for epidural hematoma
 - long-term anticoagulants
 - risks of discontinuing
 - risk of thromboembolic event with discontinuation prior to procedure

- Warfarin
 - discontinue 5 days prior to procedure
 - goal INR <1.4
 - resuming immediately after procedure would lead to subtherapeutic INR for 8 to 10 days
 - may consider bridging agent with these patients
 - Low-molecular-weight heparin or unfractionated heparin
 - therapeutic dosing should be postponed minimum of 48 to 72 hours after spine surgery to prevent epidural hematoma
 - supplements
 - should be discontinued 14 days prior to surgery to minimize intraoperative blood loss
 - decrease platelet aggregation
 - garlic
 - ginkgo
 - ginseng
 - fish oil
 - flax seed oil
 - saw palmetto
 - inhibits clotting
 - chamomile
 - alter coagulation
 - vitamin E
 - vitamin K
 - green tea (contains vitamin K)
-

■ 8-16 Anticoagulating Medications			
■ <i>Drug</i>	■ <i>Plasma Half-Life (hours)</i>	■ <i>Effect on Bleeding</i>	■ <i>Minimum Cessation Prior to Surgery (days)</i>
■ Diclofenac	■ 1-2	■ Inhibits COX (reversibly)	■ 1
■ Ibuprofen	■ 2	■ Inhibits COX (reversibly)	■ 1
■ Indomethacin	■ 4-10	■ Inhibits COX (reversibly)	■ 3
■ Ketorolac	■ 5-7	■ Inhibits COX (reversibly)	■ 3
■ Etodolac	■ 6-7	■ Inhibits COX (reversibly)	■ 3
■ Sulindac	■ 8-16	■ Inhibits COX (reversibly)	■ 3
■ Naproxen	■ 12-17	■ Inhibits COX (reversibly)	■ 3
■ Piroxicam	■ 50	■ Inhibits COX (reversibly)	■ 7
■ Celecoxib	■ 11	■ Inhibits COX-2 (reversibly)	■ 1
■ Aspirin	■ 6	■ Inhibits COX (irreversibly)	■ 7
■ Clopidogrel	■ 1	■ Irreversibly inhibits platelet ADP receptors	■ 7
■ Prasugrel	■ 2-15	■ Irreversibly inhibits platelet ADP receptors	■ 7
■ Ticagrelor	■ 7-9	■ Reversibly inhibits platelet ADP receptors	■ 5
■ Ticlopidine	■ 20-50	■ Irreversibly inhibits platelet ADP receptors	■ 14
■ Warfarin	■ 20-60	■ Inhibits vitamin K-dependent clotting factor synthesis	■ 5
■ Enoxaparin (LMWH)	■ 3-5	■ Binds antithrombin and irreversibly blocks thrombin	■ 1
■ Unfractionated heparin	■ 0.5-2	■ Binds antithrombin and irreversibly blocks thrombin	■ 4-5 Hrs
■ Dabigatran	■ 7-14	■ Reversibly blocks thrombin	■ 3
■ Rivaroxaban	■ 5-13	■ Reversibly blocks factor Xa	■ 3
■ Apixaban	■ 9-14	■ Reversibly blocks factor Xa	■ 3
■ Edoxaban	■ 10-14	■ Reversibly blocks factor Xa	■ 3

○ Preoperative blood loss estimation

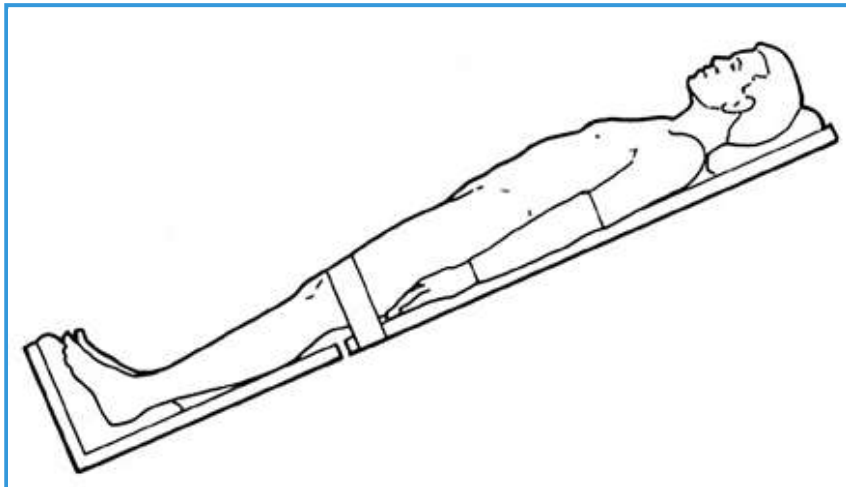
- allows for cost-effective treatment with cell salvage systems, allogenic blood transfusions, and antifibrinolytic agents
- factors associated with increased blood loss
 - increased body mass index
 - lower body weight

- mostly associated with increased transfusion requirements
 - lower starting blood volume
 - factor for pediatric spinal deformity
- advanced age
- bleeding diatheses
- number of spinal levels
 - approximately 200 cc per lumbar level
- use of instrumentation
- revision spine surgery
- iliac crest bone harvest
- interbody fusions
- trauma or tumor surgery
- Cobb angle $>50^\circ$
- longer expected surgical time
- neuromuscular scoliosis
- >6 levels fused for deformity surgery
- Ponte osteotomies
- vertebral column resection osteotomy
 - can lead to 65% total blood volume loss
- recommend obtaining a preoperative hemoglobin level of 5 g/dL greater than treating surgeons transfusion trigger

• Intraoperative Management

- Hypotensive anesthesia
 - administration of vasodilating agents to a goal systolic blood pressure of 50 - 80 mm Hg or MAP of 60 mm hg
 - well validated in pediatric scoliosis surgery
 - has been shown to decrease intraoperative blood loss by 55% without sequelae
 - reduces blood extravasation through surgical wound
 - does not affect bone bleeding (mostly venous bleeding)
 - complications:
 - concern for possible cord transfusion
 - neuromonitoring changes
 - address by increasing blood pressure, ensuring no halogenated gases, determine last time when gentamicin was given, and increase patient temperature
 - ischemic optic neuropathy

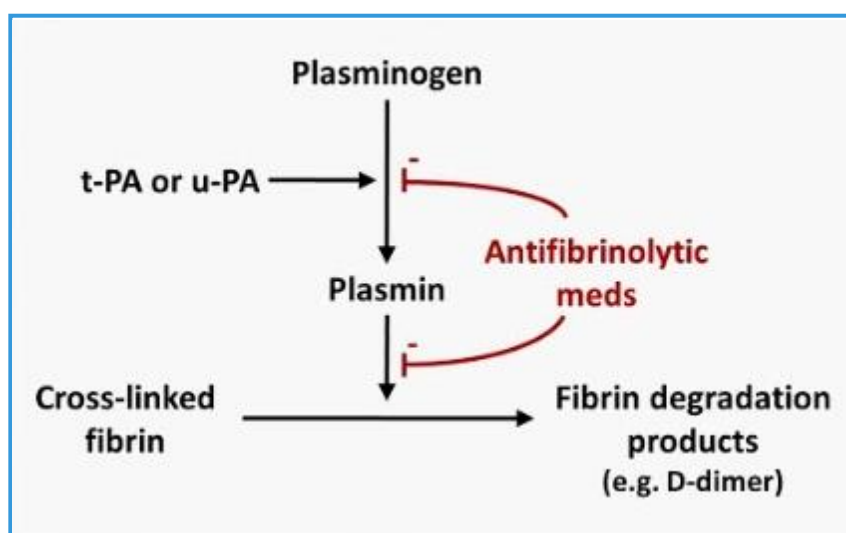
- Maintenance of normothermia
 - ideal to keep body temperature $>36^{\circ}\text{C}$
 - decrease in body temperature $>1^{\circ}\text{C}$ can increase blood loss by 16% and increase transfusion rates by 22%
 - hypothermia decreases platelet function and coagulation enzyme activity
 - increase OR temperature if needed
 - minimize exposed skin surface-area until drapping
- Patient positioning
 - reverse trendelenburg positioning



- decrease central venous pressure
- Jackson frames that allows abdomen to hang freely



- decrease intra-abdominal pressure and pressure on inferior vena cava
 - prevent congestion in Batson venous plexus
- Tranexamic acid (TXA)
 - lysine derivative that competitively blocks plasmin binding sites on fibrin
 - results in a decrease in fibrinolysis and stabilized clot formation

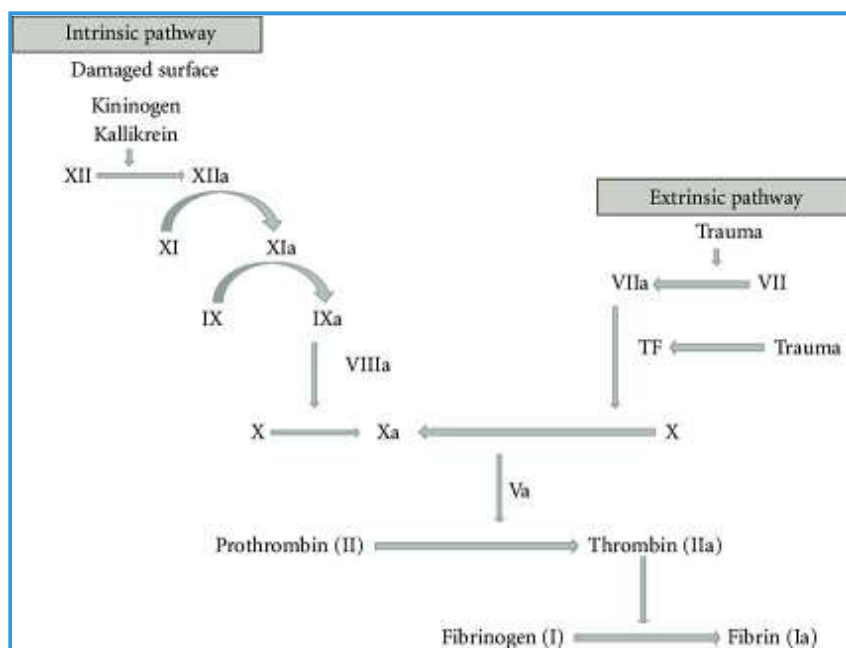


- 6 to 10 times more potent than epsilon aminocaproic acid
- multiple studies have demonstrated a significant reduction in operative blood loss and transfusion rates with perioperative administration
 - no increased risk of DVT and PE
 - does not alter PT and PTT times
- multiple dosing regimens and routes of administration utilized
 - IV, oral, and topical all appear equally efficacious
- contraindications:
 - history of CVA
 - allergy
 - severe CAD
- side effects:
 - seizures
 - binds to glycine and GABA channels leading to a reduced seizure threshold
- Desmopressin
 - vasopressin analog
 - increases factor VIII and von Willebrand factor
 - limited data in spine surgery
 - useful treating patients with von Willebrand's disease
- Surgical techniques
 - local anesthetic with epinephrine
 - can prevent dermal bleeding over long cases
 - 1:500,000 epinephrine
 - subperiosteal elevation
 - preserves vasculature of paraspinal muscles
 - electrocautery
 - monopolar
 - soft tissue and periosteal elevation
 - ensure not to violate ligamentum in the interlaminar space
 - could go intradural
 - bipolar
 - ideal for hemostasis near neural structures
 - epidural space
 - coagulating bleeding epidural veins
 - saline-irrigated radiofrequency bipolar hemostatic sealers
 - contracts vascular collagen at temperatures $<100^{\circ}\text{C}$
 - unipolar cautery reaches temperature $>300^{\circ}\text{C}$

- studies have shown substantial blood loss reduction in pediatric deformity surgery
- increased surgical cost of \$493 per case
- wound-packing
 - surgical areas that are not being addressed should be packed
 - decreases low-pressure bleeding
 - saline-soaked sponges or patties
 - can be combined with thrombin or epinephrine for greater hemostasis control
- Aminocaproic acid
 - lysine derivative that competitively inhibits plasmin
 - results in decreased fibrinolysis
 - studies have demonstrated decreased blood loss with aminocaproic acid in arthroplasty
 - lower cost than TXA
 - does not decrease seizure threshold
- Topical hemostatic agents

Type of Agent	Agent	Product	Mechanism of Action	Advantages	Disadvantages
Passive	Bone wax	Generic bone wax	Physically occludes bleeding bone channels	Highly effective on bone surfaces	Remains indefinitely, promotes chronic inflammatory reaction, serves as nidus for infection, hinders local osteogenesis
	Gelatin-based sponge	Gelfoam (Pfizer), Gelfilm (Pfizer), Surgifoam (Ethicon)	Serves as a mechanical matrix to facilitate clotting	Liquefies in <1 wk, dissolves in 4–6 wk, has neutral pH, has minimal effect on osteogenesis	Has potential to swell to twice its original size, leading to neural compression
	Oxidized cellulose	Surgicel (Ethicon)	Swells into gelatinous mass as it absorbs blood (always apply dry), mechanical matrix facilitates clotting, reduces surrounding pH contributing to coagulative necrosis	Dissolves in 2–6 wk, has local antimicrobial effect due to low pH	Has swelling potential as it absorbs blood, leading to neural compression; low pH inactivates thrombin and inhibits osteogenesis
	Microcrystalline collagen	Avitene (Davol), Instat (Johnson & Johnson), Heistat (Integra LifeSciences)	Platelets adhere to its fibrils, platelet activate through so-called release reaction	Absorbs in <8 wk, has minimal swelling potential	Can bind to neural tissues, temporarily inhibits osteogenesis
Active	Thrombin	THROMBIN-JMI (King Pharmaceuticals), Evithrom (Omrix Biopharmaceuticals), rhThrombin (ZymoGenetics)	Promotes conversion of fibrinogen to fibrin	Fast-acting	Immunogenic reaction with bovine thrombin
	Hemostatic matrix (gelatin plus thrombin)	Floseal (Baxter), Surgiflo (Ethicon)	Gelatin granules swell, providing tamponade effect Thrombin converts fibrinogen to fibrin	Fast-acting Tamponade effect helps local arterial bleeding, absorbs in 4–6 wk	Requires some local bleeding for fibrinogen source Can swell up to 20% 10 min after application
	Fibrin sealant (thrombin plus fibrinogen)	Tisseal (Baxter), Evicel (Ethicon)	Thrombin converts fibrinogen to fibrin, fibrinogen forms clot	Provides end products for clot formation, is effective in heparinized patients	None

- collagen agents
 - stimulate the intrinsic pathway of coagulation cascade to promote hemostasis



- microfibrillar collagen
 - dry, fine, white powder
 - must be applied with dry surgical instruments to a dry field
- fibrin sealant
 - consists of two separate mixtures
 - one contains fibrin and factor XIII
 - one contains thrombin and calcium
 - combining the mixtures creates a fibrin seal where it is sprayed
- platelet-rich plasma
 - centrifugation of patient's blood to isolate plasma with high contents of platelets, growth factors, and clotting factors
 - proposed benefit of improved hemostasis, wound healing and recovery
- platelet-poor plasma
 - isolated from centrifugation process
 - combined with thrombin and calcium to provide an autologous fibrin sealant
- gelfoam sponges
 - manufactured from animal-skin gelatin and processed into sponge-form
 - isolated use exerts mostly mechanical hemostasis against low-pressure bleeders
 - can be soaked with thrombin, which can act as a scaffold for the coagulation cascade
 - excess gelfoam should be removed as it may interfere with bone healing
- topical hemostatic agents do not appear to be cost-effective in total joint arthroplasty cases
 - beneficial in spine surgery to promote hemostasis without inflicting harm to adjacent neural structures

- topical TXA
 - typically administered near the end of the procedure to control postoperative bleeding
 - decreases fibrinolysis and stabilizes clot formation
 - may be an alternative route of administration in patients with higher risk of complications
 - history of MI, CAD, or CVA
- gelatin-thrombin matrix
 - commonly used in spine surgery to control epidural bleeding
 - brand names include Floseal and Surgiflo
 - consists of porcine or bovine gelatine matrix combined with human derived thrombin
 - acts of the end stage of the coagulation cascade leading to fibrin formation
- Reinfusion systems (cell saver)
 - recycles intraoperative blood loss for later transfusion
 - can be transfused intraoperatively during longer procedure
 - shed blood is filtered, washed, and transfused within 6 to 8 hours from the procedure
 - serves as an alternative to allogenic blood transfusion
 - theoretical benefits of minimizing wound complications and hematoma formation
 - need to avoid suctioning antibiotic irrigation, povidone-iodine solution, and irrigation $>42^{\circ}$ C into the circuit
 - indications:
 - religious beliefs that preclude allogenic blood transfusion
 - large number of autoantibodies that makes allogenic blood stock incompatible
 - contraindications:
 - surgeries for malignancy and infection
 - not recommended for routine use in lumbar spine surgery
 - not cost effective unless blood loss ≥ 500 cc
 - complications:
 - coagulopathy
 - altered composition of the transfused blood containing elevated fibrin split products and inflammatory cytokines (TNF- α and interleukins)
 - especially problematic in unwashed systems
 - can lead to increased wound drainage

- recommended to transfuse 1 unit of FFP for every 1,000 cc of volume of returned
- transient hemoglobinuria
- pulmonary complications
 - due to reperfusion of debris
- contamination
- cost

- Postoperative Management

- Allogenic blood transfusion
 - preoperative hemoglobin strongest risk factor for postoperative blood transfusion
 - below 13 g/dL more likely
 - other risk factors
 - female gender
 - increased age
 - larger patient size
 - longer procedures
 - lateral releases in total knee arthroplasty
 - 1 unit increased Hb by 1 g/dL
 - no absolute criteria for transfusion
 - transfusion should be considered for anyone with Hb <6 g/dL
 - transfusion should be considered for postoperative patients with Hb 7-8 g/dL
 - routine transfusion should be avoided for Hb > 8 g/dL
 - no increased mortality has been seen with this criteria, even in patients with cardiac history
 - initiate transfusion if patient is symptomatic
 - orthostatic hypotension
 - tachycardia unresponsive to fluids
 - Hb levels between 6 to 8 g/dL should be based on patient factors
 - expectation of continued blood loss
 - intravascular volume status
 - cardiovascular reserve
 - response to anemia
 - complications
 - increased risk of nosocomial infections
 - immunomodulatory effects

- increased SSI
 - increased UTIs
- viral transmission
 - hepatitis B - 1:205,000 unit donated
 - hepatitis C - 1:1.8 million units donated
 - human immunodeficiency virus - 1:1.9 million units donated
- transfusion-related acute lung injury (TRALI)
 - immunologically mediated damage to the lungs
 - can result in adult respiratory distress syndrome
- acute hemolytic reaction
 - potentially lethal complication
 - results from blood-type mismatch
 - rare complication
- Allogenic platlet transfusion
 - blood product most likely to be contaminated
 - stored at room temperature
 - infections in 10 cases per million units transfused
 - gram positive organisms most common
 - thrombocytopenia
 - platlet count below 5,000/mm³
 - give platlets to avoid spontaneous bleeding
 - platlet count below 50,000/mm³
 - give platlets before surgery
 - platley count above 100,000/mm³
 - no need to transfuse
- Postoperative iron supplementation
 - daily oral iron replacement mild acute blood loss anemia
- Drains
 - theoretically prevents surgical site hematomas
 - potential site for infection or neural compression
 - concern for increased post-operative blood
 - negates the tamponade effect by decreasing intrawound pressure
- Special Considerations
 - Jehovah's Witness (JW)
 - hold beliefs that blood transfusions are forbidden by the bible
 - some patients may still consent to a blood transfusion

- some patients may consider the use of cell saver as an alternative to allogenic blood transfusion
- use of colloids and coagulation factors are not forbidden and a matter of personal choice
- bovine-derived hemostatic agents are generally approved by JW
 - products derived from human plasma are a personal decision of JW
 - preoperative discussion about the use of the use of these agents

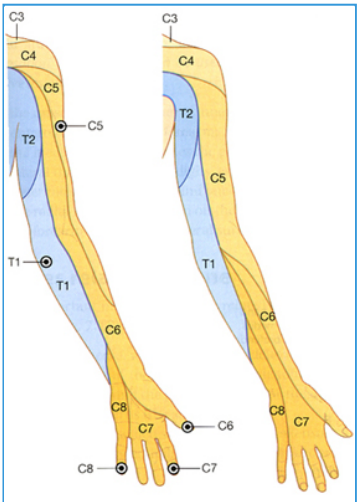
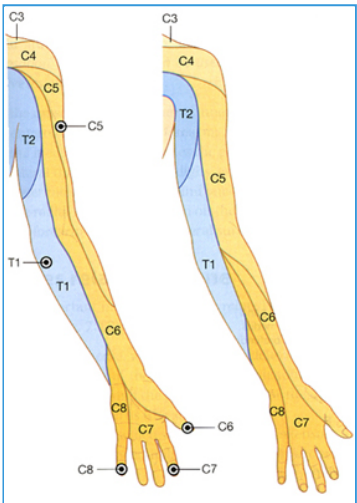
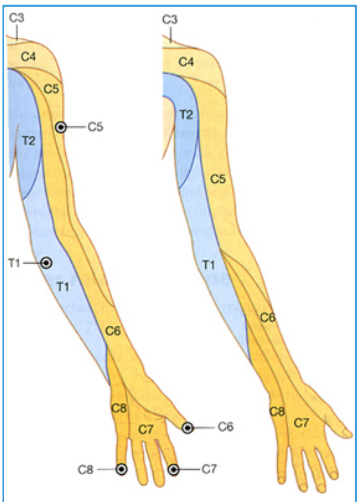
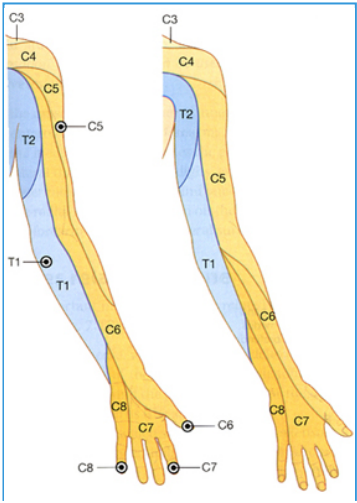
78- Biologics In Spine Surgery

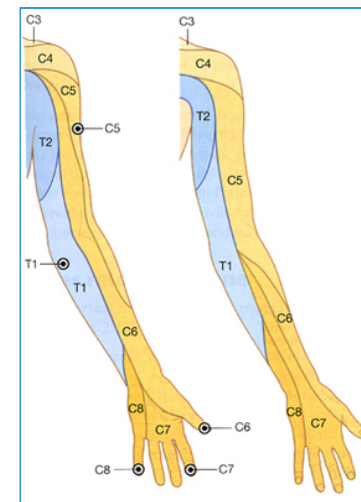
79- Neck And Upper Extremity Spine Exam

Images

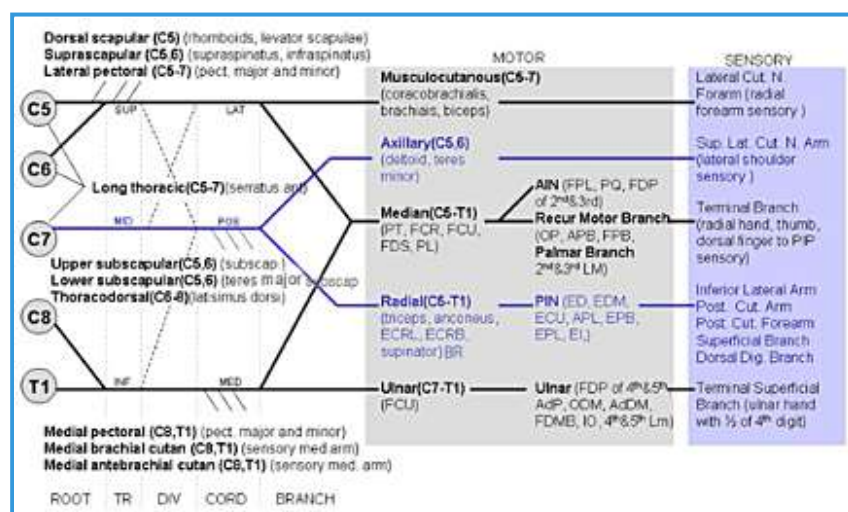
Muscle Grading System (ASIA)	
0	Total paralysis
1	Palpable or visible contraction
2	Active movement, full range of motion, gravity eliminated
3	Active movement, full range of motion, against gravity
4	Active movement, full range of motion, against gravity and provides some resistance
5	Active movement, 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

- Overview

■ Neck & Upper Extremity Spine Exam				
■ Root	■ <i>Primary Motion</i>	■ <i>Tested Muscles</i>	■ <i>Sensory</i>	■ <i>Reflex</i>
■ C4	■ Scapular Stabilization (Winging)	■ Upper portion of serratus anterior (significant variation in innervation)	■ Upper shoulder, over clavicle 	■ -
■ C5	■ Shoulder abduction ■ Elbow flexion (palm up)	■ Deltoid ■ Biceps	■ Lateral arm below deltoid 	■ Biceps
■ C6	■ Elbow flexion (thumb up) ■ Wrist extension	■ Brachioradialis ■ ECRL	■ Thumb and radial hand/forearm 	■ Brachioradialis
■ C7	■ Elbow extension ■ Wrist flexion	■ Triceps ■ FCR	■ Fingers 2, 3, 4	■ Triceps
■ C8	■ Finger flexion, hand grip, thumb extension	■ FDS	■ Finger 5 	■ -
■ T1	■ Finger abduction	■ Interossei muscles	■ Medial elbow	■ -

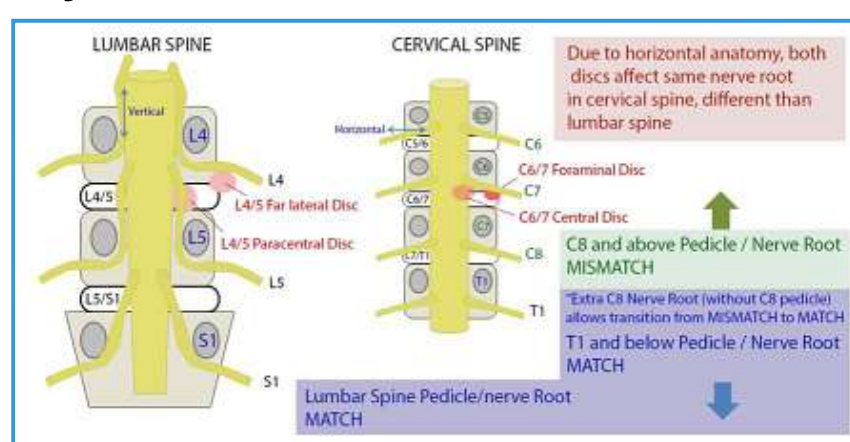


○ Brachial Plexus Illustrations



○ Nerve root anatomy

- key difference between cervical and lumbar spine is



- pedicle/nerve root mismatch
 - cervical spine C6 nerve root travels under C5 pedicle (mismatch)
 - lumbar spine L5 nerve root travels under L5 pedicle (match)
 - extra C8 nerve root (no C8 pedicle) allows transition
- horizontal (cervical) vs. vertical (lumbar) anatomy of nerve root
 - because of vertical anatomy of lumbar nerve root a paracentral and foraminal disc will affect different nerve roots

- because of horizontal anatomy of cervical nerve root a central and foraminal disc will affect the same nerve root

- Inspection, Palpation, ROM

- Inspection

- alignment in sagittal and coronal plane (e.g., kyphotic cervical spine)
 - prior surgical scars (e.g., prior ulnar nerve transposition or carpal tunnel surgery)
 - skin defects (e.g., cafe au lait spots associated with neurofibromatosis)
 - muscle atrophy (e.g., palsy will see decrease deltoid and biceps mass)

- Palpation

- palpate local tenderness on the spinal axis, asymmetric

- ROM

- document range of motion in flexion, extension, rotation, and bend
 - may give absolute degrees or relative to anatomic landmark (e.g, chin rotates to right shoulder)
 - normal range of motion of cervical spine
 - flexion: 50
 - extension: 60
 - rotation: 80
 - lateral bend: 45

- Motor Testing

- Grade key muscles groups from 0-5 using ASIA Grading System

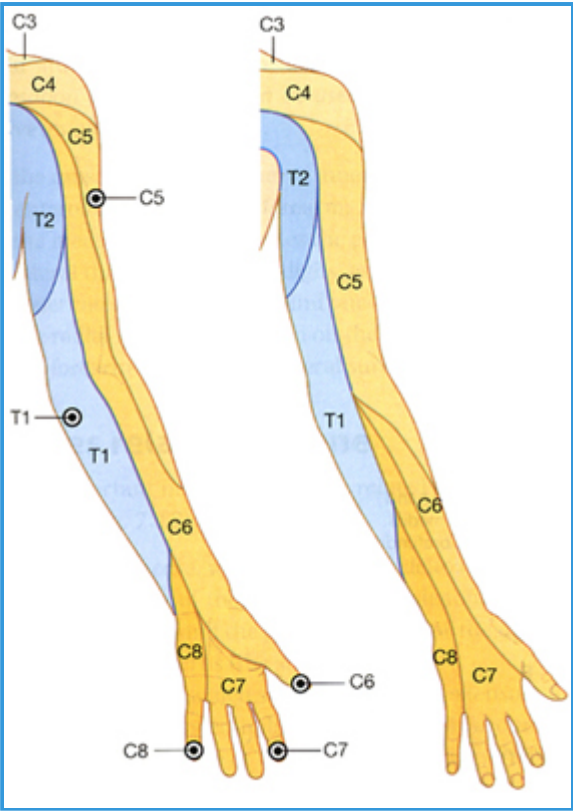
- include at least one muscle from each nerve root group (C5 to T1)
-

■ Motor Testing of Upper Extremity Muscles			
■ Primary Motion	■ Primary Muscle	■ Innervation	■ Nerve Root
■ Scapular stabilization	■ Serratus	■ Long thoracic n.	■ C4
■ Shoulder abduction	■ Deltoid	■ Axillary n.	■ C5
■ Shoulder internal rotation	■ Subscapularis	■ Subscapular n.	■ C5
■ Shoulder external rotation	■ Infraspinatous	■ Suprascapular n.	■ C5
■ Elbow flexion (palm up)	■ Biceps & Brachialis	■ Musculocutaneous n.	■ C5
■ Elbow flexion (thumb up)	■ Brachioradialis	■ Radial n.	■ C6
■ Wrist extension	■ ECRL	■ Radial n.	■ C6
■ Wrist supination	■ Supinator	■ PIN	■ C6
■ Elbow extension	■ Triceps	■ Radial n.	■ C7
■ Wrist flexion	■ FCR & PL	■ Median n.	■ C7
■ Wrist pronation	■ PT & PQ	■ Median n.	■ C7
■ MCP & PIP finger flexion	■ FDS	■ Median N.	■ C8
■ DIP finger flexion	■ FDP	■ Ulnar n. & AIN	■ C8
■ Thumb extension	■ EPL	■ PIN	■ C8
■ Finger abduction	■ Interossei	■ Ulnar n.	■ T1

•

Sensory Exam

- Grade sensory in C5 to T1 dermatomes



- score using ASIA Sensory Grading System

Sensory Grading System (ASIA)	
0	Absent
1	Impaired
2	Normal
NT	Not Testable

- score major sensory types in all patients

- pain (prick with sharp object such as paper clip, broken cue tip)
 - light touch (stroke lightly with finger)
- score minor sensory types for focused exam
 - vibration (focused exam)
 - temperature (focused exam)
 - two-point discrimination (focused exam)

- Provocative Tests

- Spurlings Test

- foraminal compression test that is specific, but not sensitive, in diagnosing acute radiculopathy.
 - it is performed by rotating head toward the affected side, extending the neck, and then applying an axial load (applying downward pressure on the head)
 - the test is considered positive if pain radiates into the ipsilateral arm when the test is performed for 30 seconds.

- Hoffman's Test

- a positive test is sensitive but not specific for cervical myelopathy
 - performed in one of two ways
 - hold and secure the middle phalanx of the long finger and then flick the distal phalanx into an extended position. Involuntary contraction of the thumb IP joint is a positive test.
 - hold and secure the distal phalanx of the long finger and then flick the distal phalanx into an extended position. Involuntary contraction of the thumb IP joint is a positive test.

- Lhermitte Sign

- a positive test is specific but not sensitive for cervical spinal cord compression and myelopathy
 - test is positive cervical flexion or extension leads to shocklike sensation radiating down spinal axis and into arms and/or legs

- Gait

- Antalgic gait

- caused by guarding for pain in affected extremity due to
 - hip and knee pathology
 - severe radicular symptoms

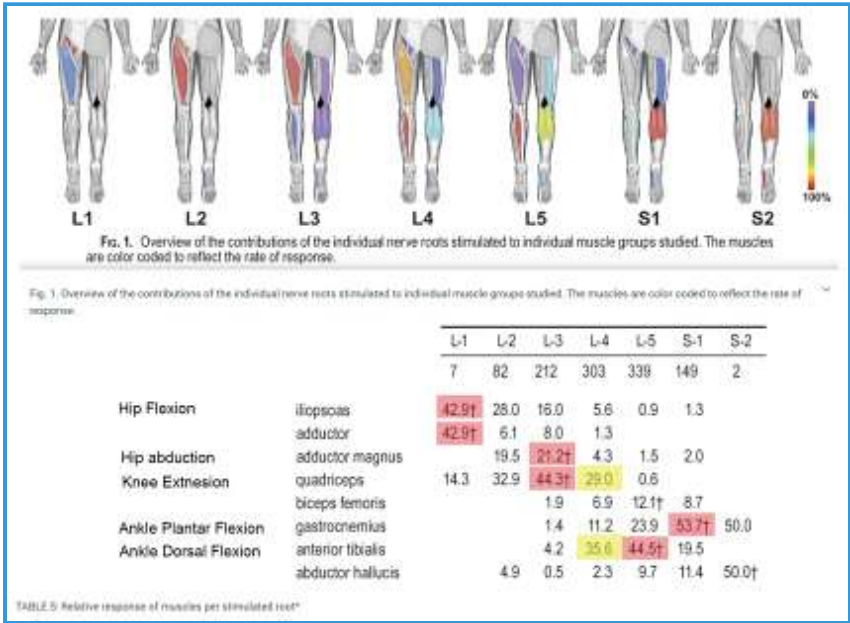
- Trendelenburg gait

- caused by painful arthritis of hip or gluteus medius weakness

- wide-based shuffling gait
 - due to neurologic disorder including myelopathy
- steppage or lateral swing gait
 - a method of gait compensation for a foot drop (weakness ankle dorsiflexion and toe extension)

80- Lower Extremity Spine And Neuro Exam

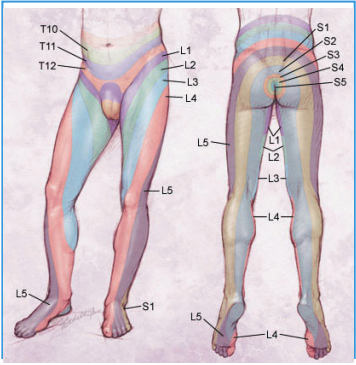
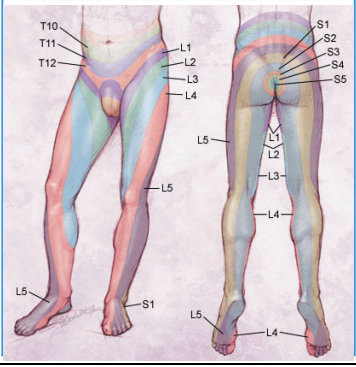
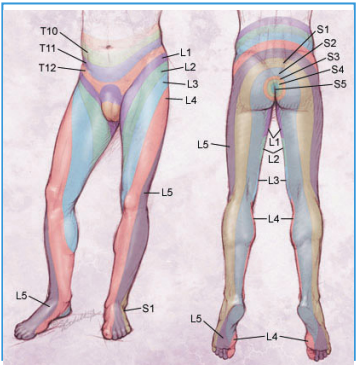
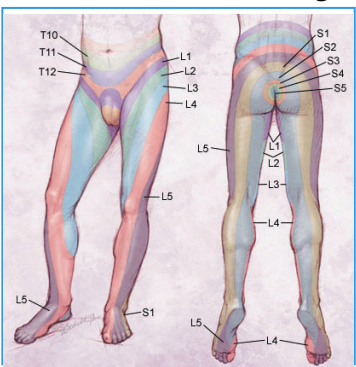
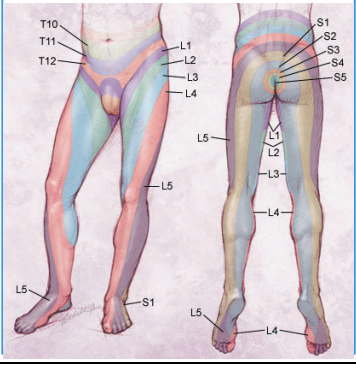
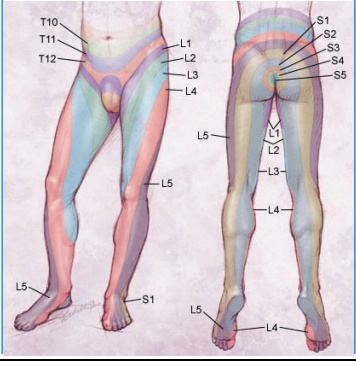
Images

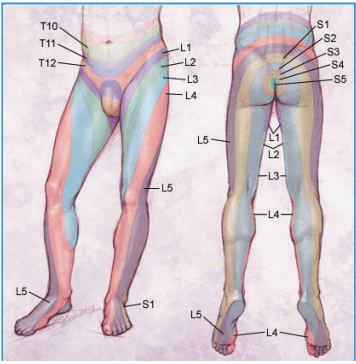
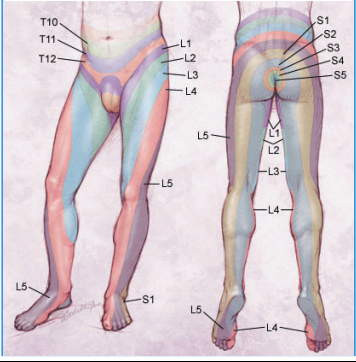


- Overview
 - Note: The table below is a simplification as muscles are often innervated by multiple nerve root
 - for example, ankle dorsiflexion usually has a contribution from both L4 and L5

TABLE 5: Relative response of muscles per stimulated root*														
Muscle	C-3	C-4	C-5	C-6	C-7	C-8	T-1	L-1	L-2	L-3	L-4	L-5	S-1	S-2
total	9	34	92	149	142	53	16	7	82	212	303	339	149	2
trapezius	44.4†	20.6	8.7	2.7										
deltoid	11.1	32.4	34.8†	16.8										
biceps	33.3	35.3†	25.0	32.9	2.8									
triceps			8.7	24.2	33.1†	5.7								
extensor digitorum communis			6.5	6.0	23.2†	18.9	12.5							
flexor carpi radialis			9.8	14.1	19.0†	9.4	18.8							
flexor carpi ulnaris					6.3	11.3†								
abductor pollicis brevis				0.7	5.6	22.6	50.0†							
abductor digiti minimi				1.3	1.4	18.9†	18.8							
iliopsoas								42.9†	28.0	16.0	5.6	0.9	1.3	
adductor								42.9†	6.1	8.0	1.3			
adductor magnus									19.5	21.2†	4.3	1.5	2.0	
quadriceps								14.3	32.9	44.3†	29.0	0.6		
biceps femoris										1.9	6.9	12.1†	8.7	
gastrocnemius										1.4	11.2	23.9	53.7†	50.0
anterior tibialis										4.2	35.6	44.5†	19.5	
abductor hallucis									4.9	0.5	2.3	9.7	11.4	50.0†
none	11.1	11.8	6.5	1.3	8.5	13.2			8.5	2.4	3.6	6.8	3.4	

* Values are percentages.
† Relative highest frequency response.

■ Lower Extremity Spine and Neuro Exam				
■ Nerve root	■ Primary Motion	■ Primary muscles	■ Sensory	■ Reflex
■ L1	■	■	■ Iliac crest and groin 	■ Cremasteric reflex (L1 and L2)
■ L2	■ Hip flexion and adduction	■ Iliopsoas (lumbar plexus, femoral n.) ■ Hip adductors (obturator n.)	■ Anterior and inner thigh 	■ Cremasteric reflex (L1 and L2)
■ L3	■ Knee extension (also L4)	■ Quadriceps (femoral n.)	■ Anterior thigh, medial thigh and medial knee 	■ -
■ L4	■ Ankle dorsiflexion (also L5)	■ Tibialis anterior (deep peroneal n.)	■ Lateral thigh, anterior knee, and medial leg 	■ Patellar
■ L5	■ Foot inversion ■ Toe dorsiflexion ■ Hip Extension ■ Hip abduction	■ Tibialis posterior (tibial n.) ■ EHL (DPN), EDL (DPN) ■ Hamstrings (tibial) & gluteus max (inf. gluteal n.) ■ Gluteus medius (sup. gluteal n.)	■ Lateral leg & dorsal foot 	■ -
■ S1	■ Foot plantar flexion ■ Foot eversion	■ ■ Gastroc-soleus (tibial n.) ■ Peroneals (SPN)	■ Posterior leg 	■ Achilles

■ S2	■ Toe plantarflexion	■ FHL (tibial n.), FDL (tibial)	■ Plantar foot	■ -
				
■ S3 & S4	■ Bowel & bladder function	■ Bladder	■ Perianal	■ -
				

•

History & Symptoms

○	■ Characteristic symptoms	
	■ Systemic symptoms (weight loss)	■ Tumor, infection
	■ Evaluation of localized axial pain	■ Tumor, infection
	■ Mechanical pain	■ Instability, discogenic pain
	■ Radicular pain	■ HNP
	■ Night pain	■ Tumor
	■ Referred pain	■ Peptic ulcer disease, cholecystiits, nephrolithiasis, PID, pancreatitis
	■ Concomitant pain	■ Hip & shoulder
	■ Psychogenic	■ Secondary gain

○

Inspection

- skin
 - looking for prior scars, cafe au lait spots, hairy patches in the lower lubmar spine

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Motor Exam

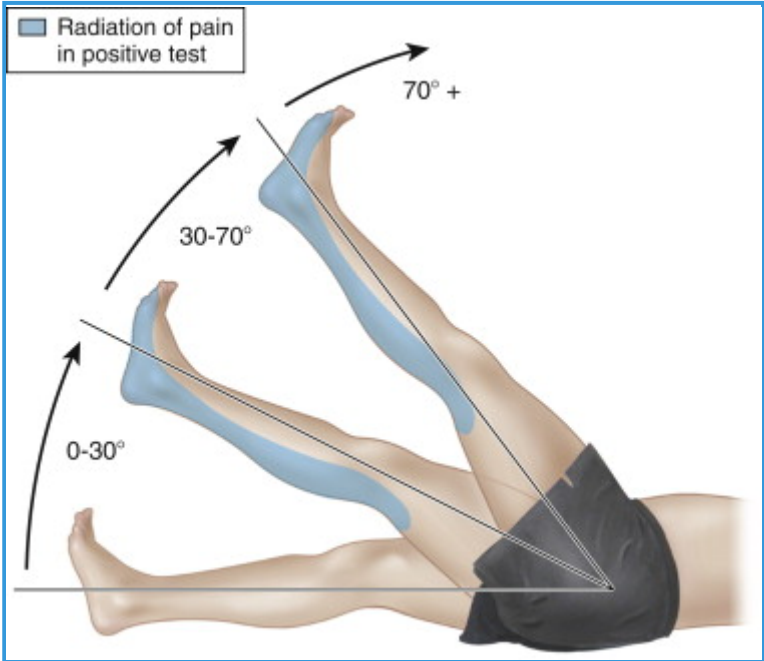
■ Muscle Grading System (ASIA)		
■ 0	■ Total paralysis	■
■ 1	■ Palpable or visible contraction	■
■ 2	■ Active movement, full range of motion, gravity eliminated	■
■ 3	■ Active movement, full range of motion, against gravity	■
■ 4	■ Active movement, full range of motion, against gravity and provides some 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.	■

• Sensory Exam

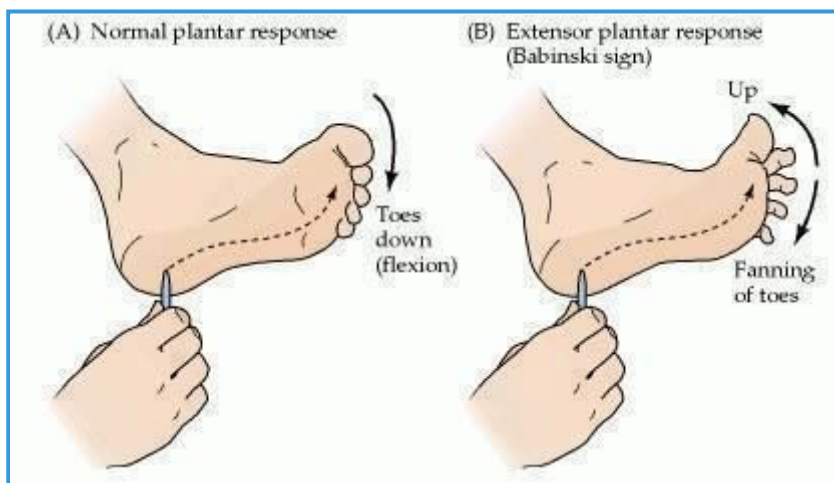
■ Sensory Grading System (ASIA)	
■ 0	■ Absent
■ 1	■ Impaired
■ 2	■ Normal
■ NT	■ Not Testable

• Specific Tests

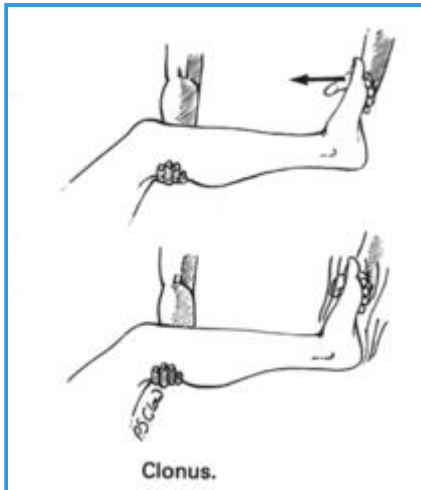
- Special tests
 - straight leg raise



- compression of lower lumbar nerve roots (L4-S1)
- important to distinguish from hamstring tightness
- considered positive if symptoms produced with leg raised to 40°
- crossed straight leg raise
 - performing straight leg raise in uninvolved leg produces symptoms in involved leg
- Babinski's test

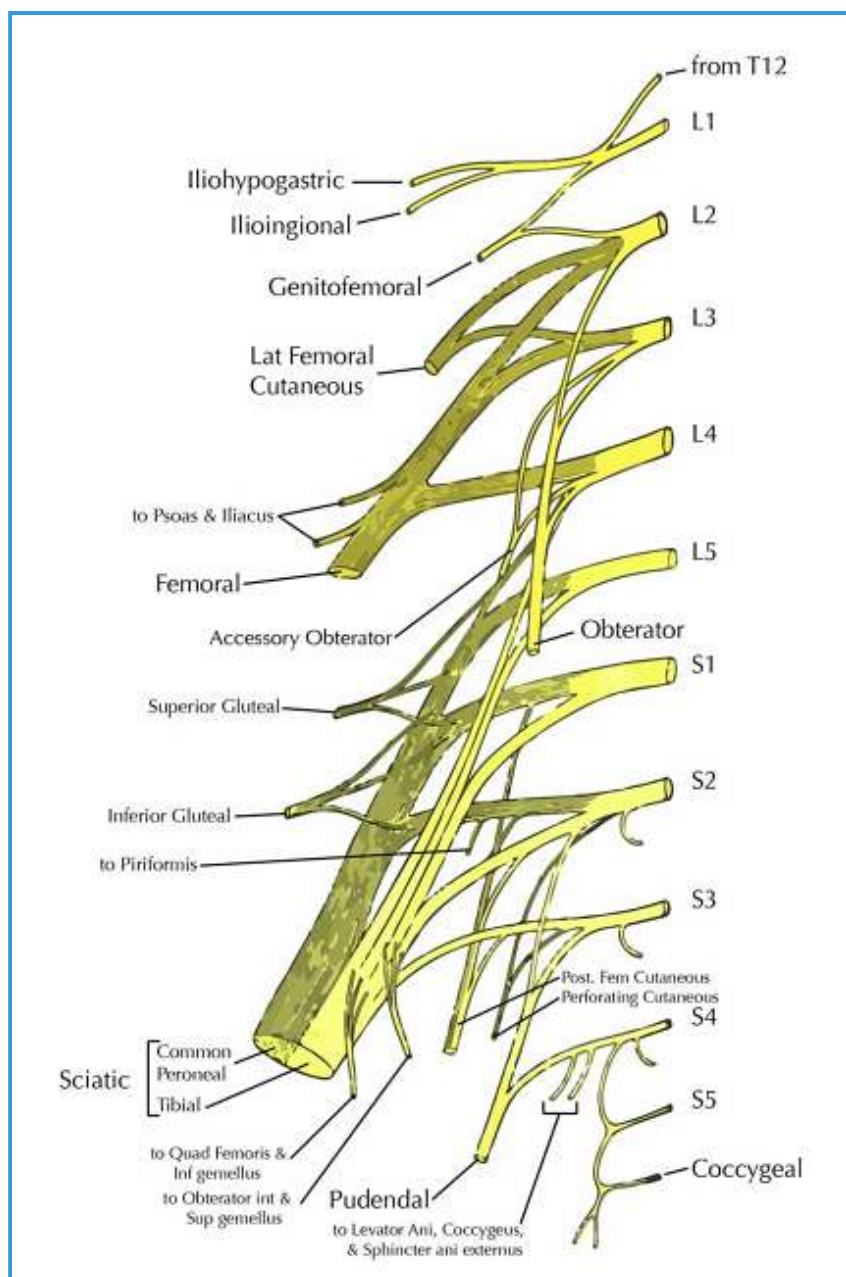


- positive findings suggests upper motor neuron lesion
- ankle clonus test

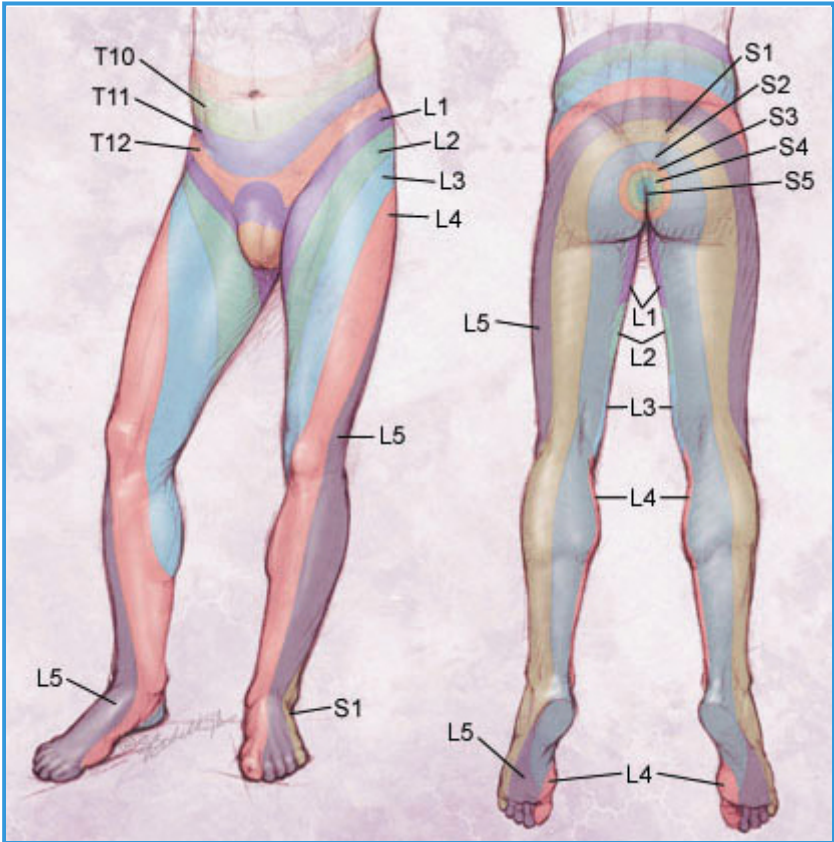


- associated with upper motor neuron lesion
- bulbocavernosus reflex
 - tests for the presence of spinal shock
 - positive reflex with anal sphincter contraction with squeezing of glans penis or clitoris
 - can alternatively tug on foley catheter to stimulate reflex

○ Lumbosacral plexus illustration



○ Sensory illustration



● Clinical Findings

■ Clinical Findings			
■ Symptoms	■ Neurologic etiology	■ Causes	
■ Paresthesias alone medial aspect of knee	■ Irritation of saphenous division of femoral nerve	■ Psoas abscess ■ Saphenous n. compression (surfing)	■ ■ 
■ A Trendelenburg gait	■ Injury to L5 nerve root	■ Paracentral L4/5 HNP	■
■ Numbness along lateral thigh	■ Meralgia paresthetica (lateral femoral cutaneous nerve palsy)	■ Compression of LFCN (patient positioning)	■
■ Foot drop	■ Common peroneal nerve palsy or sciatic nerve compression	■ Lateral knee compression ■ Hip dislocation	■
■ Quadriceps weakness	■ Femoral nerve palsy	■ Hyperflexed Pavlik harness ■ L3 and L4 nerve root compression	■

● Waddel Signs

- Waddell identified 5 exam findings that correlated with non-organic low back pain. The tests include

○

■ Waddell Signs		
■ <i>Finding</i>	■ Description	■
■ 1. Tenderness	■ a. Superficial - pain with light touch to skin ■ b. Deep - nonanatomic widespread deep pain	■
■ 2. Simulation	■ a. Pain with light axial compression on skull ■ b. Pain with light twisting of pelvis	■
■ 3. Distraction	■ No pain with distracted SLR	■
■ 4. Regional	■ a. Nonanatomic or inconsistent motor findings during entire exam ■ b. Nonanatomic or inconsistent sensory findings during entire exam	■
■ 5. Overreaction	■ Overreaction noted at any time during exam	■

