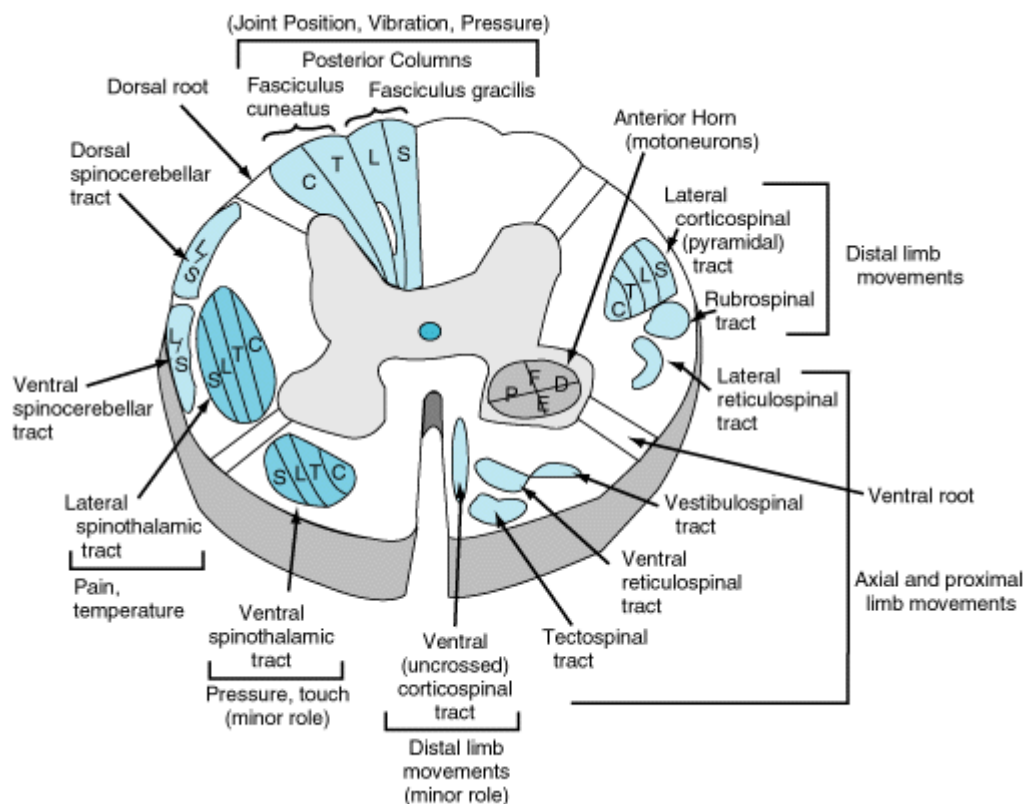


<b>SPINAL CORD COMPRESSION .....</b>	<b>4</b>
Cauda Equina, Conus Medullaris .....	6
Spinal Shock .....	7
Brown-Sequard syndrome .....	7
<b>SPINAL SYNDROMES .....</b>	<b>7</b>
Amyotrophic lateral sclerosis .....	9
Syringomyelia .....	10
Spinal muscular atrophy .....	10
Transverse Myelopathy .....	11
Multiple Sclerosis .....	11
Subacute combined degeneration of the cord .....	11
<b>SPINAL COMPLICATIONS .....</b>	<b>11</b>
<b>DEGENERATIVE .....</b>	<b>12</b>
SPONDYLOSIS .....	13
Cervical stenosis, Spondylotic Myelopathy .....	13
Lumbar Spondylosis, Stenosis .....	15
Diffuse idiopathic skeletal hyperostosis (s. DISH, Forestier disease) .....	16
Ossification of posterior longitudinal ligament (OPLL) .....	16
DEGENERATIVE DISC DISEASE .....	18
Disk herniation .....	19
Cervical .....	20
Lumbar .....	20
Recurrent .....	20
SPONDYLOLYSIS .....	20
SPONDYLOLISTHESIS .....	21
FACETOGENIC LUMBOSACRAL PAIN .....	23
EPIDURAL LIPOMATOSIS .....	23
LUMBAR ADHESIVE ARACHNOIDITIS .....	24
Etiology .....	24
Clinical Features .....	24
Diagnosis .....	24
Treatment .....	24
VENTRAL CORD HERNIATION .....	24
Clinically .....	25
Differential diagnosis .....	25
Treatment .....	25
SYNOVIAL CYST .....	25
<b>SCOLIOSIS .....</b>	<b>26</b>
Type 1 Scoliosis - Primary Degenerative (De Novo), s. “discogenic” .....	27
Type 2 (Progressive Idiopathic Scoliosis) .....	27
General surgery principles .....	28
Anterior Approaches .....	28
Posterior Approaches .....	28
Combined (Anterior-Posterior) Approaches .....	28
<b>VASCULAR .....</b>	<b>28</b>
<b>INFECTION .....</b>	<b>29</b>
<b>EPIDURAL INJECTIONS .....</b>	<b>29</b>
<b>SI JOINT .....</b>	<b>30</b>
Conservative Treatment .....	30
Surgical Treatment .....	31
<b>CERVICAL ARTHROPLASTY .....</b>	<b>32</b>
<b>CERVICAL SURGERY .....</b>	<b>33</b>
Wrong level surgery / Level localization .....	33
Prevention measures .....	33
Transitional anatomy .....	35

Adjacent segment disease.....	36
Proximal Junctional Kyphosis (PJK), Proximal Junctional Failure (PJF) .....	36
Allografts.....	37
Autografts .....	37
Cord compression.....	39
Carrot-stick fracture, ankylosing spondylitis .....	39
Osteoporotic spine .....	40
RA .....	40
PREOP OPTIMIZATION.....	41
Intraop .....	42
COMPLICATIONS .....	42
Esophageal injury.....	42
Post-op C5 palsy.....	43
Carotid injury .....	43
Vertebral Artery .....	44
Avoidance.....	44
Plan of action.....	44
Postop .....	47
Laryngeal Nerve injury .....	47
Superior laryngeal nerve .....	47
Inferior (recurrent) laryngeal nerve .....	47
Cardiac Arrest (intraop, prone) .....	49
Unable to ventilate in prone position .....	50
Ischemic optic neuropathy (ION).....	50
Infection .....	50
Osteodiscitis, Osteomyelitis .....	51
ACDF.....	51
CORPECTOMY .....	52
Cage.....	53
TRANSORAL ODONTOIDECTOMY.....	53
Contraindications.....	53
POSTERIOR CERVICAL SPINE.....	54
LAMINECTOMY .....	55
LAMINOPLASTY .....	55
PCF .....	56
POSTERIOR FORAMINOTOMY .....	57
OCCIPITOCERVICAL FUSION .....	58
Patient positioning.....	58
Cable.....	61
ODONTOID SCREW.....	62
<b>THORACOLUMBAR SURGERY.....</b>	<b>62</b>
BMP .....	62
DEFORMITY .....	63
Spinopelvic sagittal alignment .....	64
Scheuermann's Kyphosis .....	66
Scoliosis (Coronal Deformity) .....	67
Fusion extension.....	67
LUMBAR DISCECTOMY .....	67
Strategic Principles.....	68
Far Lateral Lumbar Discectomy .....	68
REDO .....	68
Complications.....	69
OSTEOTOMIES .....	69
FORAMINOTOMY .....	71
MIS .....	71

Lateral foraminotomy .....	71
PEDICLE SCREWS .....	72
TLIF .....	72
ALIF .....	73
LATERAL APPROACH INTERBODY FUSION .....	75
Corpectomy .....	77
THORACIC SURGERY .....	77
Thoracic spine approaches, Thoracic discectomy / corpectomy .....	77
CSF-pleural fistula .....	79
Thoracic pedicle screws .....	79
PERC STABILIZATION .....	79
MIDLF / CORTICAL SCREW .....	79
(SACRO)PELVIC FIXATION .....	80

**FLATAU law** – *topographic fiber lamination* – greater distance nerve fibers (of long tracts) run lengthwise in cord, more they tend to be situated toward its periphery.



	Pain is <b>exacerbated</b> by	Pain is <b>relieved</b> by
"Mechanical" back pain	movement	rest at recumbency
Inflammatory back pain	rest	stretching or activity

Local pain that **does not vary** with changes in position suggests **tumor, infection, fracture, or referred pain**

AMERICAN COLLEGE OF RADIOLOGY recommendation – do not obtain lumbar spine radiographs for acute low-back pain unless **fracture, malignancy, or infection** are suspected.

#### Choice of tests:

Motor deficits --> MR

Cancer or Infection:

known --> MR with contrast

suspected --> ESR, CRP, XR (if any positive → MR with contrast)

Risk of compression FX --> XR (if patient will need treatment - also MR)

- **normal dorsal root ganglia** enhance strongly with IV contrast (intradural roots do not!).

**Cervical spondylosis with primarily axial neck pain** (without radicular symptoms or myelopathy)  
surgery if meeting all criteria:

- 1) failed to respond to *extensive nonoperative treatment*.
  - 2) cleared *psychological testing*.
  - 3) **MRI** confirmation of spondylosis and no other causes.
  - 4) positive cervical **discography** (confirm a specific level as the pain source and, potentially, which levels to fuse) – only positive discs should be considered for surgical management, max. 1-2 discs.
- treatment of choice - **ACDF** (good results in appropriately chosen patients).

## SPINAL CORD COMPRESSION

On Boards – beware of **tandem compressive lesions** – ask for neuraxis MRI (“it is free on Boards”)

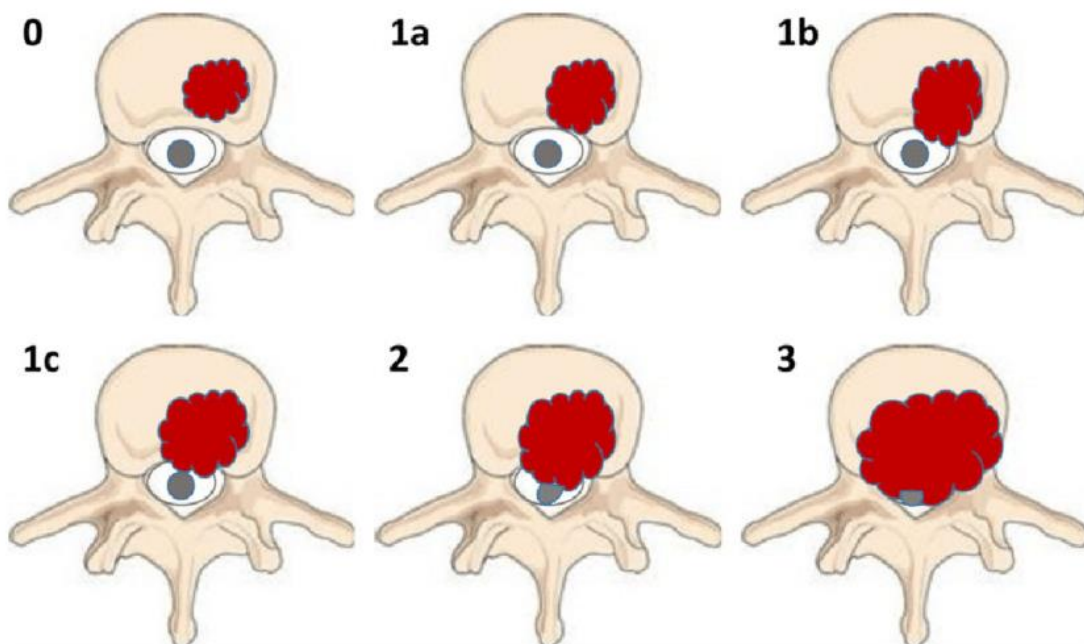
**Bilsky classification** - 6-point epidural spinal cord compression (ESCC) scoring system:

**Low grade** – no cord deformation

- (A) **Grade 0** - **bone-only** disease.
- (B) **Grade 1a** - epidural impingement, **without deformation of the thecal sac**.
- (C) **Grade 1b** - deformation of the thecal sac, **without spinal cord abutment**.
- (D) **Grade 1c** - deformation of the thecal sac with cord abutment, but **without cord compression**.

**High grade** – **cord compression**:

- (E) **Grade 2** - spinal cord compression, but with **CSF visible around the cord**.
- (F) **Grade 3** - spinal cord compression, **no CSF visible around the cord**.



**Extramedullary cord compression** - ascending loss of pain and temperature sensation + prominent *radicular pain* + early spastic weakness in **legs**

**Central cord syndrome** - descending loss of pain and temperature sensation

*Spinal cord compression is emergency!* (therapy will not reverse fixed paralysis of > 48 h duration)

Cord compression results in **venous congestion, edema, demyelination**. If compression is of short duration, effects are reversible; remyelination and recovery of function is possible. However, with prolonged compression, **secondary vascular injury** occurs with **infarction** of spinal cord - no meaningful recovery is possible.

- loss of **bowel / bladder function** is usually irreversible.

**Steroids** (**DEXAMETHASONE** 10-100 mg IV → 4-24 mg q6h or **METHYLPREDNISOLONE** in Bracken protocol) – always!

For **tumors**: (combined with high-dose steroids)

1. Emergency **radiotherapy**: 30 Gy in 10 fractions.
  - immediate salutary effect of radiotherapy may be seen in 24-48 h, at best.
2. If effective **chemotherapy** is available, it should be used with radiotherapy.

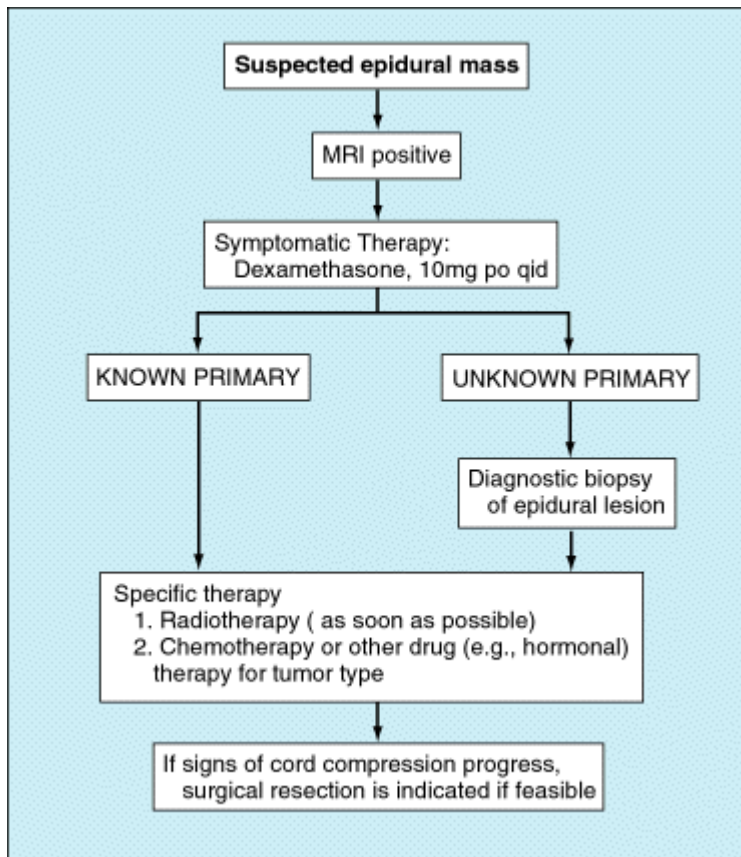
If cannot rule out **infection**, start **antibiotics**.

Indications for **surgical decompression**:

- 1) cord compression **worsens despite radiotherapy**.
  - 2) maximum tolerated dose of **radiotherapy** has been delivered **previously** to site.
  - 3) **bony compression** (e.g. vertebral fracture) contributes to cord compression.
- indiscriminate use of **laminectomy**\* in all patients → frequent surgical failures; **anterior approach** is now used for many cases of vertebral body lesions.

\*N.B. **laminectomy (removal of posterior elements) might be harmful** in **anterior** compression cases:

- 1) **does not remove tumor** - does not result in immediate decompression.
- 2) can cause **destabilization** because often only the posterior elements are intact and removal of these elements causes instability.



### CAUDA EQUINA, CONUS MEDULLARIS

Feature	Cauda Equina ( $\geq 2$ nerve roots)	Conus Medullaris
Pain	<i>Severe radicular pain</i> (sciatica) & low back pain	<i>Back pain</i> (less severe than radicular pain)
Sensory loss	Asymmetric <i>saddle anesthesia</i> * – all modalities (radicular sensory loss)	Bilateral <i>saddle anesthesia</i> * (usually restricted to perianal region) – all modalities (or touch preservation).
Motor deficits	Asymmetrical areflexic <i>para- / monoplegia</i>	<b>Absent!!!</b> (or mild distal leg paresis)
Evacuation disorder	<i>Late and mild</i> – hypotonic bladder ( <i>urinary retention</i> )	<i>Early</i> - atonic bladder ( <i>urinary retention with overflow incontinence</i> ), atonic anal sphincter ( <i>constipation with incontinence</i> )**
Impotence	±	+
Bulbocavernosus (S <sub>2-4</sub> ) & anal wink (S <sub>4-5</sub> ) reflexes	+	ABSENT

#### \*S3-5

**\*\*vs. lesions above sacral parasympathetic nucleus** – within several days of injury, automatic **spastic bladder with detrusor-sphincter dyssynergia** develops (bladder re-education should begin promptly!)

Cauda equina – LMN, leg weakness

Conus medullaris – UMN, no (significant) leg weakness

Red flags: saddle anesthesia, B/B/sexual dysfunction

Nerve roots in cauda equina:

- **poorly developed epineurium** - particularly susceptible to injury (in peripheral nerves well developed epineurium protects against compressive and tensile stresses).
- **relative hypovascularity** in proximal third of root (nutritional supply is supplemented with increased vascular permeability\* and diffusion from surrounding CSF).  
\*may result in edema compounding initial and sometimes seemingly slight injury.

N.B. in cauda equina syndrome, surgical decompression is recommended even with complete deficits - potential for recovery of peripheral nerves is great!

**Cauda equina injuries** (involving peripheral nerves rather than spinal cord) are surgically remediable for longer periods (up to 48 hour) than **conus medullaris injuries**

**SPINAL SHOCK**

- in humans it lasts for **minimum of 2 weeks** (if complications\* are present - it is much longer!)  
\*e.g. infection, malnutrition, anemia, bedsores

First reflexes to reappear: **sacral reflexes** (bulbocavernosus, anal wink)!!! – may return within 24 hours of injury!

Once spinal reflexes begin to reappear, their threshold steadily drops.

- various different stimuli may evoke **REFLEX SPASMS** (flexor or extensor) that involve many or all of paralyzed muscles;
  - *if cord section is incomplete*, spasms can be associated with particularly bothersome **pain bursts** (H: **BACLOFEN**).
  - repeated flexor spasms may occur for prolonged periods → **contractures of flexor muscles**.
- afferent stimuli irradiate from one spinal reflex center to another:
  - 1) **threshold of withdrawal reflex is especially low** (minor noxious stimuli → prolonged extremity withdrawal + marked flexion-extension patterns in other three limbs).
  - 2) **withdrawal reflex generalization** may cause **mass reflex** (bladder and rectum evacuation, sweating, piloerection, pallor, BP swings).

**BROWN-SEQUARD SYNDROME**

I. **Contralateral effects** – loss of pain-temperature sensation (tr. **spinothalamicus**).

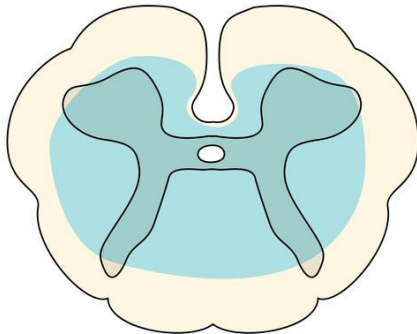
II. **Ipsilateral effects:**

- 1) **UMN paralysis** (tr. **corticospinalis lat.**);  
– jei aukštai kakle – hemidiafragmos paralyžius.
- 2) **loss of discriminative touch-proprioception** (**dorsal funiculus**)
- 3) **loss of sweating** (**descending autonomic fibers in ventral funiculus**)  
– jei aukštai kakle – Hornerio sindromas.
- 4) **SEGMENTAL** – **anesthesia / radicular pain** (**dorsal root**), **LMN paralysis** (**ventral horn**)

**SPINAL SYNDROMES**

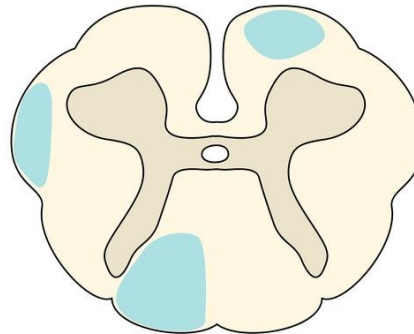
	Dorsal funiculi	Lateral funiculi (lateral pyramidal tract, UMN)	Anterior horn (LMN)	Anterolateral system	Intermediolateral column (central autonomic motoneuron)
<b>Subacute Combined Degeneration (vit.B<sub>12</sub> def.)</b>	+	+			
<b>ALS</b>		+	+		
<b>Spinal Muscular Atrophy (SMA), Progressive Bulbar Palsy</b>			+		
<b>Syringomyelia</b>	±	±	+	+ (decussating fibers)	±
<b>Tabes dorsalis</b>	+				
<b>Multiple sclerosis</b>	+	+		+	
<b>Poliomyelitis</b>			+		
<b>Shy-Drager syndrome</b>		±	±		+
<b>HIV vacuolar myelopathy</b>	+	+			

↑  
Anterior



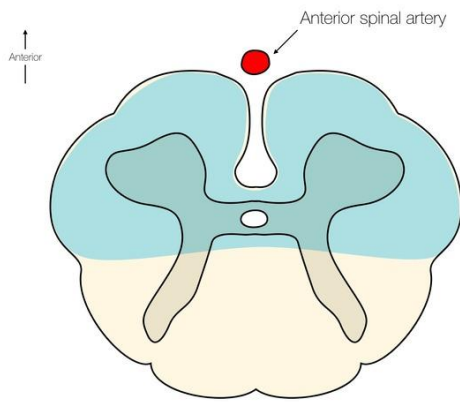
NMO

↑  
Anterior

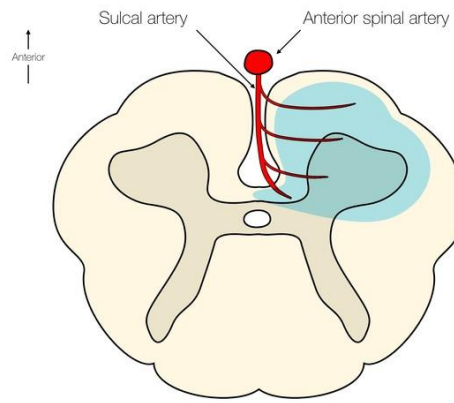


Multiple sclerosis

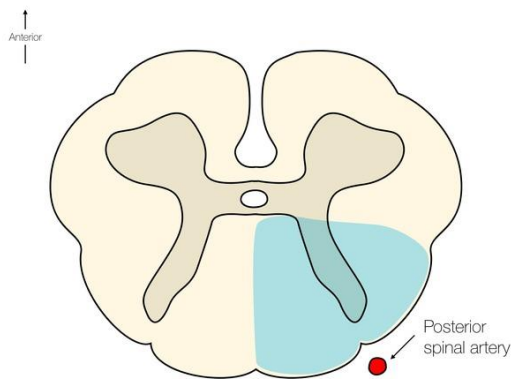




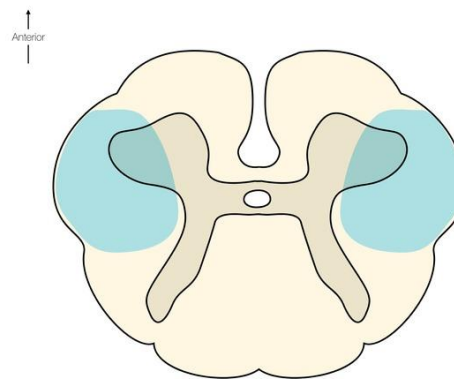
Anterior spinal artery infarction



Sulcal artery syndrome



Posterior spinal artery infarction



HTLV-1 associated myelopathy

### AMYOTROPHIC LATERAL SCLEROSIS

- **motoneurons of entire neuraxis (anterior horns + pyramidal tracts)** → **hyperreflexia & spasticity in weak, wasted, fasciculating limb** (hands and forearms – early)  
**no sensory loss! no pain! no cognitive dysfunction!**  
**(pseudo)bulbar palsy** + **preserved eyes** (no weakness of **eyelids** or **ocular muscles**)
- **painless WEAKNESS with fasciculations and muscle atrophy** – general symptom!
- fasciculations (e.g. in tongue!)
- course is progressive without remissions
  - eventually, all motoneurons are involved → **tracheostomized locked-in state**.
  - most die within 5 years (median survival: 3–4 yrs).
- **Riluzole** – the only drug shown to extend lifespan (although only 3 months; mortality rates are unaffected).
- 5% ALS patients still undergo cervical laminectomy!

No definitive test that can diagnose ALS! **Diagnosis primarily clinical!**

Tests necessary to confirm clinical ALS diagnosis:

- **CPK** (elevation may be present due to statins – trial of stopping!)
- **MRI** – normal or symmetric **high T2 signal within corticospinal tracts** (↑water content in myelin tracts undergoing Wallerian degeneration).
- **EDX:**
  - 1) **EMG** – **denervation including paraspinal muscles** (positive sharp waves, fibrillations)

- 2) **nerve conduction studies** – velocities normal, but lost H, F waves.
- **muscle biopsy** - groups of atrophic fibers, type grouping (reinnervation).
- **CFS** – normal

See N2 case >>

### SYRINGOMYELIA

(starting location - *base of posterior horn in cervical cord*) - chronic, slowly progressive **CENTRAL CORD syndrome** - painless hand ulcers, burns, and whitlows, striking early hand atrophy.

**Hydromyelia** – has epithelial lining (vs. syrinx)

**HYDROMYELIA** - *simple cystic expansion* of central canal of cord.

**SYRINX** - pathologic *tube-shaped cavity* in CNS parenchyma (outside central canal).

- fluid does not enhance – differential from enhancing fusiform intramedullary lesions (tumors, demyelinations)

Syrinx may expand into **brainstem** (syringobulbia) - into medulla oblongata or even into pons:

- **CN9-12** may be involved (**bulbar palsy**), usually asymmetrically.
- nuclear involvement of **CN5** → facial pain and thermal hypesthesia in *onion skin pattern*.

N.B. if syringomyelia occurs without *Chiari malformation* or *prior spinal cord injury* → *panspinal MRI with gadolinium* (to rule out intramedullary tumor).

### Treatment

- post-traumatic syrinx – try **lysis of arachnoid adhesions + duraplasty**.

### Shunts:

- syringopleural** – best in all outcome measures.
  - syringoperitoneal**
  - syringo-subarachnoid** (e.g. Heyer-Schulte-Pudenz system) - shunt of choice for cryptogenic syrinx; requires normal CSF flow in subarachnoid space, therefore cannot use in arachnoiditis or not decompressed Chiari malformation
- insert Silastic K or T-tube through small separate *paramedian hole in dura* – this allows to close midline durotomy watertight.
  - small T-tube diameter (5 FR) minimizes size of myelotomy.
  - **myelotomy**:
    - Rhoton suggests performing the myelotomy in the **dorsal root entry zone (DREZ)**, between the lateral and posterior columns (instead of midline as with a tumors) because this is consistently the thinnest part and there is usually already an upper extremity proprioceptive deficit from the syrinx.

### SPINAL MUSCULAR ATROPHY

– AR symmetrical progressive loss of **LMN** (midbrain ÷ spinal cord).

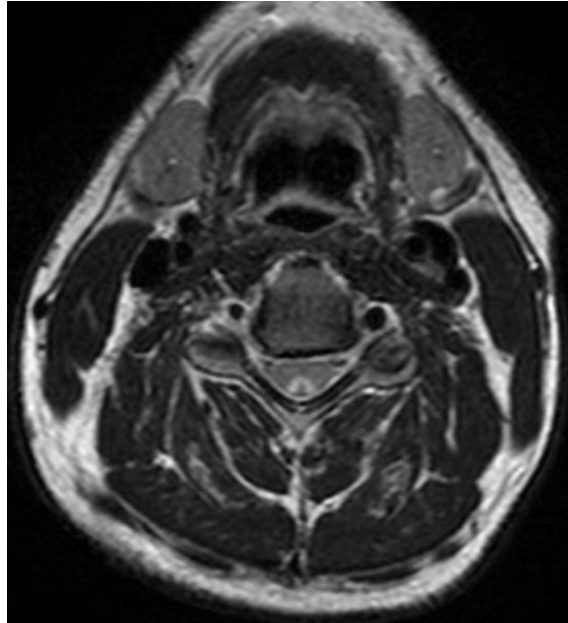
- UMN is not affected! (vs. in ALS)
- examples: **Werdnig-Hoffman** disease, **Kugelberg-Welander** disease
- diagnosis – DNA.

**TRANSVERSE MYELOPATHY**

&gt;&gt;

**MULTIPLE SCLEROSIS**

&gt;&gt;

**SUBACUTE COMBINED DEGENERATION OF THE CORD**

## SPINAL COMPLICATIONS

**AUTONOMIC** HYPERREFLEXIA + **SOMATIC** HYPERREFLEXIA (SPASTICITY)

**DVT Prophylaxis:**

- 1) *calf-compression devices* (for first two weeks)
- 2) *anticoagulation*: **ENOXAPARIN** (30 mg SC every 12 h) → **WARFARIN** (INR 2-3) for 3 months.  
Lovenox for 3 mos!

**Neurogenic Bladder:** Continue Foley and monitor I&O's → transition to intermittent catheterization (IC Q6h) if fluid output less than or around 2L daily. Keep IC volumes < 500cc. If voiding, check PVR/bladder scan and cath if > 150mL PVR. If needing any form of IV fluids, keep Foley in place.

**Neurogenic Bowel:** Docusate BID, Senna QHS, Bisacodyl supp daily + rectal digital stimulation. Can add MiraLax as necessary.

*Both bowel and bladder sphincter reflexes can be trained to provide reflex emptying if lesions spare lower motor neurons.*

**Respiratory Insufficiency:** Incentive spirometry, Mechanical in/exsufflation titrating to 40:40 or greater, chest PT. Trach.

N.B. in lesions above T<sub>10</sub>, there is no effective coughing!

**Spasticity prevention:** ROM and positioning. Baclofen, Tizanidine, Valium, Dantrolene PRN.

**Pressure Ulcer Risk:** Turn q2h, inspect skin daily.

**Hypotension:** abdominal binder, TED hose. If meds required, **MIDODRINE** (first-line) or **FLUDROCORTISONE** (Fluorinef).

**Depression:** Psychology consult or provide chaplain services as needed.

- *suicide rate* is 5 times higher than in general population

**Heterotopic ossification (HO) risk:** monitor for decreased ROM (e.g., of the hip, knee, shoulder, elbow) or for increased serum alk phos.

**Fevers:** Evaluate for common sources (UTI, PNA, wounds, DVT, HO).

GU tract is primary source of infection after cord trauma!

- prophylactic antibiotics are not indicated.

**Autonomic dysreflexia risk (Level T6 and above):** if acute HTN occurs with diaphoresis and headache, explore underlying noxious sources below the level of the injury, such as bladder distention, non-draining Foley, UTI, fecal impaction, pressure sore, tight clothes/splints, etc. and evaluate/treat.

- sensory inputs activate sympathetic neurons of intermediolateral nuclei in thoracic spinal cord → **massive reflex activation of sympathetic outflow below lesion** → **vasoconstriction** (below level of lesion), **tachycardia**, **systemic hypertension** (up to 300 mmHg!!!\*)  
\*may lead to life-threatening hypertensive encephalopathy, stroke, retinal hemorrhage!
- prophylaxis-treatment:
  - 1) removal of offending stimuli.
  - 2) BP can often be lowered by **tilting head upward**.
  - 3) **ganglionic blockers** (**MECAMYLAMINE**, 2.5-5 mg)
  - 4) short-acting centrally-acting **antihypertensives** (e.g. **CLONIDINE** prophylactically to reduce hypertension resulting from bladder stimulation).
- horizontal position for prolonged period results in sympathetic tone loss.

*in past*, **renal failure** was leading cause of death after spinal cord trauma.

*currently*, **pulmonary problems** (pneumonia, pulmonary emboli, sepsis) are single most common cause of morbidity and mortality after spinal cord trauma.

Major focus of rehabilitation:

- 1) bowel management
- 2) bladder management
- 3) transfer techniques

## DEGENERATIVE

- **cord damage** is sustained only when **sagittal diameter of cord is reduced by > 50%**.
  - *in thoracic region, far greater compression is tolerated* (because of reduced mobility of this part of spine) - cord becomes focally molded around calcified masses (which can occupy 60% of spinal canal) with no clinical abnormality.

**Intervertebral foramen** must be reduced < 30% of normal to cause root compression

- "vacuum phenomenon" - gas within apophyseal joint / intervertebral disc - pathognomonic for advanced degenerative process!

## SPONDYLOSIS

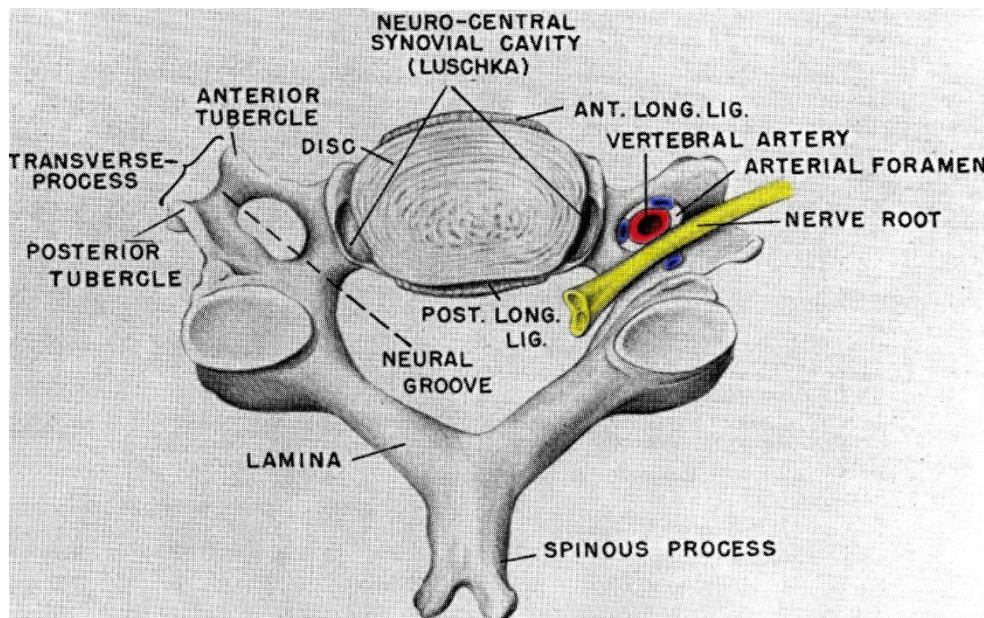
– *any degenerative* spinal lesion → spinal stenosis, lateral recess stenosis, intervertebral foramen stenosis → myelopathy, radiculopathy.

Spondylosis clinically  $\approx$  disc herniation with protracted course

**CERVICAL SPONDYLOSIS** → slowly progressive **spastic gait disorder**  $\pm$  sensory symptoms in hands in patient > 50 yrs

**LUMBAR SPONDYLOSIS** → **spinal stenosis** → **neurogenic intermittent claudication** - discomfort in buttock / thigh / leg on *walking* or *prolonged standing*, that resolves with *sitting*

- on sagittal imaging (MRI, CT), foramina appear as *comma-shaped, fat-filled spaces* just above disc level; roots exit via bulbous upper portion (just below pedicles) - early degeneration of disc and facet joints effaces only fat inferior to nerve roots.
- vertebral artery is anterior to nerve root:



Spondylotic changes increase with advancing age:

age 20-30 yrs – 5-10% have changes on radiographs

N.B. spondylosis can begin in persons as young as 20 years!

age 45 yrs – 50%

age 59 yrs – 85% men (70% women)

age 70 yrs – 97% men (93% women).

vs. disc herniations – highest incidence in 30-50 yrs.

## CERVICAL STENOSIS, SPONDYLOTIC MYELOPATHY

Slowly progressive **symptoms** (**spastic gait instability** + hand **numbness and loss of fine motor control** + **bladder dysfunction**) and **signs** (**hyperreflexia, weakness, alteration of proprioception**) in *patient* > 50 yrs = CERVICAL SPONDYLOTIC MYELOPATHY until proven otherwise.



Absence of jaw jerk ↑ helps to differentiate from general hyperreflexia and ALS

**sagittal** dimension:

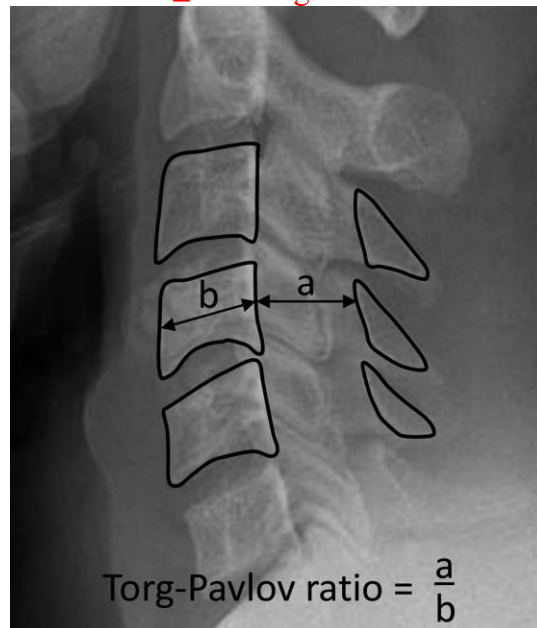
< 13 mm – *relative stenosis*

< 10 mm – *absolute stenosis* (absence of free CSF space - cord compression is probably present)

It is known that cervical cord AP diameter is 10 mm, add 1 mm of dura on each side and 1 mm of CSF – anything  $\leq 13$  mm is **stenosis** (present in 29% of population and most are asymptomatic; if canal is  $\leq 7$  mm, 50% chances the patient will have myelopathy in a lifetime)

**Torg-Pavlov ratio** (on lateral radiograph) = width of spinal canal / width of vertebral body:

ratio  $\leq 0.8$  = **significant cervical stenosis**



- vertebral body is measured from the midpoint of the anterior surface to the midpoint of the posterior surface.
- spinal canal is measured from the middle of the posterior vertebral body to the nearest point on the spinolaminar line.

Natural course of CSM for any given individual is variable, and a precise prognostication is not possible! Current view is that myelopathy **tends to progress**

**Nurick grades** of disability from cervical spondylosis:

Grade 0 - **root involvement**

Grade 1 - **myelopathy**

Grade 2 - slight **difficulty in walking**

Grade 3 - **unable to work full-time**

Grade 4 - walk only with **assistance or walker**

Grade 5 - **bedridden**

**Neck Disability Index (NDI)** – for mechanical neck pain ± radiculopathy

0-4 points (0–8%) no disability

5-14 points (10–28%) mild disability

15-24 points (30–48%) moderate disability

25-34 points (**50–64%**) **severe** disability

35-50 points (70–100%) complete disability

**Modified JAPANESE ORTHOPAEDIC ASSOCIATION functional score (mJOA)** – myelopathy severity:

- ≥ 15 – **mild**
- 12-14 – **moderate**
- < 12 – **severe**

- surgery is indicated for mJOA ≤ 12 (others closely watched for deterioration which may be ominous).
- surgery results:
  - 25-75% patients improve;
  - 5-50% patients worsen! (even adequately decompressed spinal cord may demonstrate progression of myelopathy although probably slower than natural history!)

## LUMBAR SPONDYLOSIS, STENOSIS

**PSEUDOC LAUDICATION (s. NEUROGENIC INTERMITTENT CLAUDICATION)** - unilateral or bilateral discomfort in buttock / thigh / leg

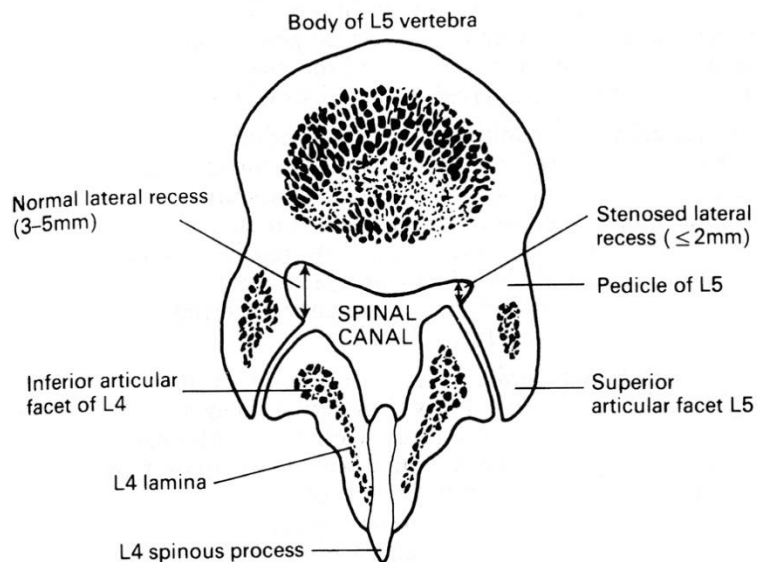
- discomfort is relieved within minutes by **lying down**, **sitting\***, or **flexing at waist\*** (N.B. pain may persist in recumbency until spine is flexed).
- discomfort persists if patient stops walking but does not flex spine\*\*.
- no loss of pulses\*\*, no trophic skin changes in feet\*\*.

\*vs. disc herniation pain

\*\*vs. vascular claudication – do not hesitate get **vascular study** (e.g. ABI)

On Boards, ask for gait characteristics!

N.B. normal lumbar **lateral recess is 3-5 mm**



**modified Oswestry Disability Index** – disability in ADL from low back pain.  
Range 0-100 (severe disability > 40)

## Spine patient outcomes research trial (SPORT)

- \$13.5 million study (13 US centers) of symptomatic lumbar spinal stenosis
- study shortcomings:
  - 1) patients were allowed to **decline randomization** and were then entered into **observational** cohort which may introduce bias into the groups

- 2) **crossovers were allowed** between patients randomized to surgery and those randomized to nonsurgical treatment (degrading the “intention to treat” analysis)
  - 3) **low long-term follow-up** (52% at 8 years).
  - 4) change in paradigm from analyzing **intention-to-treat** to **as-treated** analysis.
- results indicated a **strong benefit of surgery at 4-year follow-up** that appeared to diminish by 8 years.

N.B. **as-treated** analyses in **randomized group** showed that the **early benefit for surgery** out to 4 years converged over time, with **no significant treatment effect** of surgery seen **in years 6 to 8** for any of the primary outcomes! (vs. **observational group** showed a **stable advantage for surgery** in all outcomes between years 5 and 8)

### DIFFUSE IDIOPATHIC SKELETAL HYPEROSTOSIS (s. DISH, FORESTIER disease)

- flowing\* **ossification of cervical and thoracic ALL** → loss of ROM.  
N.B. no **SI joint** involvement! (although sacroiliac joint anterior bridging, posterior bridging, enthesal bridging may be present)
- **disc spaces** are preserved!

\*at least four contiguous vertebrae



Indication for surgery - dysphagia due to esophageal compression:

- a) not responding to dietary modifications + patient is **losing weight**
- b) recurrent episodes of choking or **(aspiration) pneumonia**

Preop evaluation:

- 1) speech therapy
- 2) barium swallow - **site of obstruction**
- 3) DVE (digital video esophagoscopy) - to rule out **intrinsic esophageal disease!**

Surgery - anterior removal of osteophytes with high-speed drill.

- no discectomy nor spine stabilization.
- counsel that **post-op may be worse** - need a (temporary) gastrostomy

### OSSIFICATION OF POSTERIOR LONGITUDINAL LIGAMENT (OPLL)



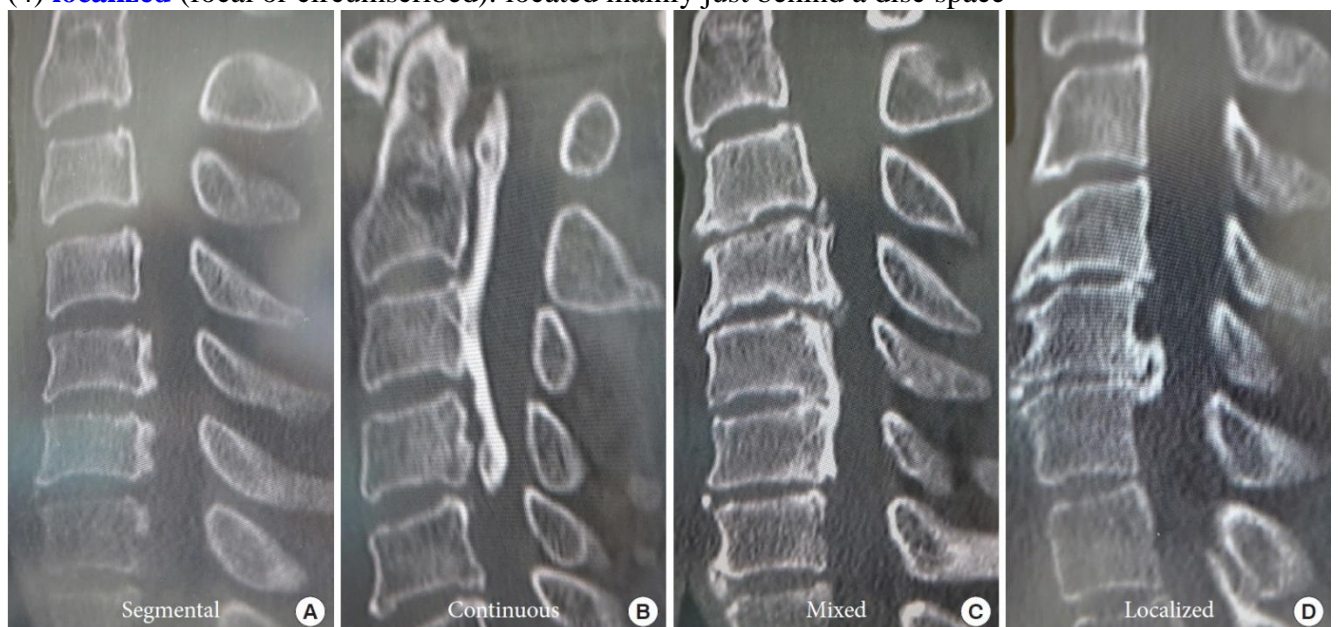


- average annual **growth rate** of 0.67 mm in AP direction and 4.1 mm longitudinally.
- **respiratory compromise** may result from ossification of costotransverse and costovertebral ligaments.

N.B. surgery is ineffective for Nurick grade 5

#### Japanese classification system for cervical OPLL:

- (1) **segmental**: separate lesions behind the vertebral bodies, i.e. **does not cross disc space**
- (2) **continuous**: a long lesion extending over several vertebral bodies
- (3) **mixed**: a combination of the continuous and segmental types
- (4) **localized** (focal or circumscribed): located mainly just behind a disc space



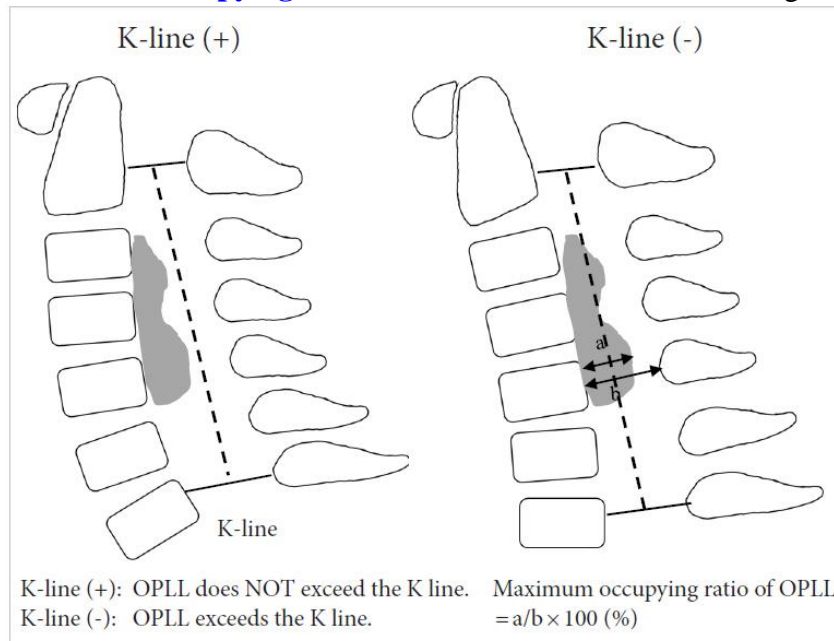
- risk of cord injury during intubation H: awake nasotracheal intubation.
- IONM
- surgical removal is often difficult – **may involve dura** (some even leave a thin layer of bone on dura); durotomy incidence 16-25%
- if OPLL extends at C2 and above, impossible to remove calcified ligament – use laminectomy up to occipital bone decompression.
- anterior approach is generally favored, although CLAM+PCF may be acceptable.

- C-collar at least for 3 months postop (halo-vest for > 2 level corpectomies).

### Radiological parameters

**C2–7 line (“K-line”)** - straight line connecting midpoints of spinal canal at C2 and C7 on a neutral cervical lateral radiograph.

**Maximum occupying ratio** of OPLL is calculated from a sagittal CT:



- in **K-line (-)**, posterior decompression surgery would be unable to achieve a satisfactory posterior shift of the spinal cord and thus satisfactory neurologic improvement.

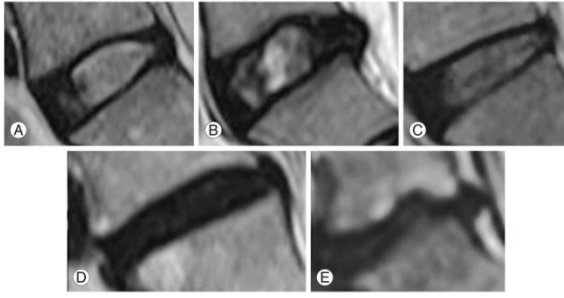
## DEGENERATIVE DISC DISEASE

**Disk DEGENERATION** (acceleration of aging effects)

### **Pfirrmann grades**

Grade	Structure	Distinction of nucleus and annulus	Signal intensity	Height of intervertebral disc
I	Homogenous, bright white	Clear	Hyperintense, isointense to cerebrospinal fluid	Normal
II	Inhomogenous with or without horizontal bands	Clear	Hyperintense, isointense to cerebrospinal fluid	Normal
III	Inhomogenous, grey	Unclear	Intermediate	Normal to slightly decreased
IV	Inhomogenous, grey to black	Lost	Intermediate to hypointense	Normal to moderately decreased
V	Inhomogenous, black	Lost	Hypointense	Collapsed disc space

<sup>a</sup> Adapted from Pfirrmann et al. [11], whereby grades IV and V represent “severe intervertebral disc degeneration”



### End-plate changes (Modic) – in stages:

- Type I - **edema**: ↓signal on T1-MRI, ↑signal on T2-MRI; differentiate from edema seen in infectious discitis/osteomyelitis (with infection, disc is abnormally bright on T2-MRI, whereas degenerated discs are dark).
- Type II - **end-plate infiltration by fat**; marrow is bright on T1 and T2; represents burned-out type I.
- Type III - **sclerosis of end-plate**: ↓signal on both T1 and T2.

N.B. only type 1 causes pain

Thoracic disc pathology – laminectomy is harmful (do not retract spinal cord!) – always choose lateral approaches!

**Selective nerve root block** may be *considered* if compressive lesions are identified at multiple levels on MRI / CT myelography to discern symptomatic level(s) (Grade of Recommendation: C).

## DISK HERNIATION

**POSTEROLATERAL HERNIATION** compresses *caudal root* (e.g. C<sub>6-7</sub> herniation affects C<sub>7</sub> root; C<sub>7-T<sub>1</sub></sub> herniation affects C<sub>8</sub> root, L<sub>4-5</sub> herniation affects L<sub>4</sub> root); most uncomfortable position is **sitting** (vs. in lumbar stenosis) pain is characteristically **RELIEVED** promptly when *patient lies down*

**CENTRAL (MIDLINE POSTERIOR) HERNIATION** → myelopathy, cauda equina syndrome.

- A. **BULGE** - **circumferential extension** of disc margin beyond vertebral body margins.
  - annulus normally may bulge diffusely little (< 2-3 mm) beyond vertebral margins, esp. in children.
- B. **HERNIATION** - **focal displacement** of disc material (nucleus pulposus and/or annulus) beyond margins of disc space; can occur in any direction (most clinically significant – posterolaterally).
  - a) **PROTRUSION (HARD DISC PROTRUSION, SPONDYLOSIS)** – hardened nucleus bulges beneath **attenuated annulus**; associated osteophytes add to mass effect;
  - b) **EXTRUSION (HERNIATION, SOFT DISC PROTRUSION, DISC RUPTURE)** – soft nucleus extrudes through **tear in annulus**;
- roots normally occupy ≈ 25-30% of space in intervertebral foramina (i.e. need > 70% foraminal stenosis)

**Nerve conduction studies** - usually normal (DRG not affected)

**EMG** – evidence of radiculopathy (**denervation** esp. in paraspinal muscles).

N.B. EMG is normal during first few days after herniation! Normal EMG does *not* rule out radiculopathy!

**EDX** can diagnose positive phenomena (pain).

**CERVICAL**

- A. Require **early operation** – muscles may rapidly irreversibly atrophy: **C<sub>5</sub>, C<sub>8</sub>**.
- B. Tolerate pressure for long periods – may respond to **conservative care**: **C<sub>6</sub>, C<sub>7</sub>**.

**LUMBAR**

- a) **passive straight-leg rising** s. **Lasègue sign** (for roots L<sub>5</sub> and S<sub>1</sub>);
- b) **femoral stretch test** (for root L<sub>4</sub>).
- pain is characteristically **RELIEVED** promptly when **patient lies down**\* (no matter how severe pain is when patient is erect!; vs. spinal tumor - pain is not relieved or even worsens!) on one side with hips and knees flexed.
- most uncomfortable position is **sitting** - causes increased intervertebral pressure!

Radiculopathy – exhaust conservative measures first!

Nerve root decompression principles:

True hernia → discectomy.

Annular bulge or prolapse → medial facetectomy (lateral recess decompression) without discectomy.

**RECURRENT**

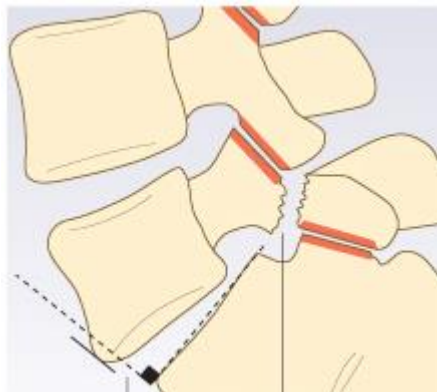
**IV gadolinium** differentiates **ENHANCING postoperative scar** (uniform enhancement) from **NONENHANCING recurrent / residual disc material** (margin enhancement).

First recurrence – redo discectomy

Presence of instability or second recurrence – add fusion

**SPONDYLOLYSIS**

(“vertebral loosening”) - bony cleft in **pars interarticularis**:



- may lead to **spondylolytic (s. isthmic) spondylolisthesis**.  
Spondy on XR → ask for oblique views (Scotty dog)

**“Stork test”** – ask adolescent to stand on one leg and hyperextend back; reproduction of pain is suggestive of spondylolysis:



**Congenital, stress fractures** - lesions with sclerotic borders are well-established with little chance of healing

- try **conservatives**: PT (relative rest from hyperextension), injections, oral pain medications (NSAIDs), ± nonrigid brace.
- indications for **fusion surgery**:
  - isthmic spondylolisthesis slips to **grades III and IV**
  - **pain does not respond** to conservative measures
  - **neurological symptoms** appear.

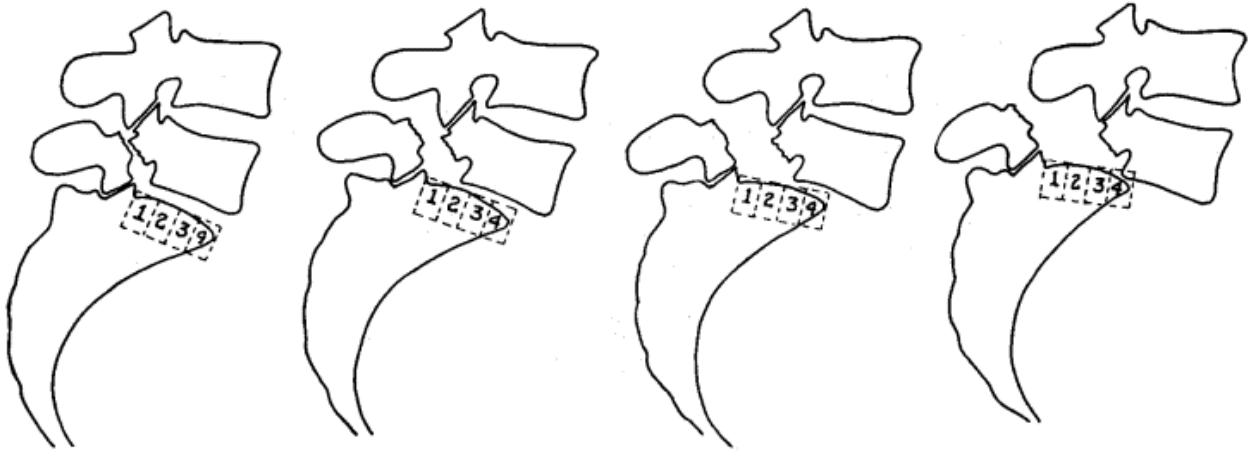
**Traumatic spondylolysis** – lesions with non-sclerotic edges / increased uptake on bone scan / high MRI T2 and STIR signal = active lesion with potential for healing in **rigid brace** (e.g. Boston brace for  $\geq 3$  months), then **PT** (kids may resume sports but if symptoms recur → stop).

See Case S3 >>

## SPONDYLOLISTHESIS

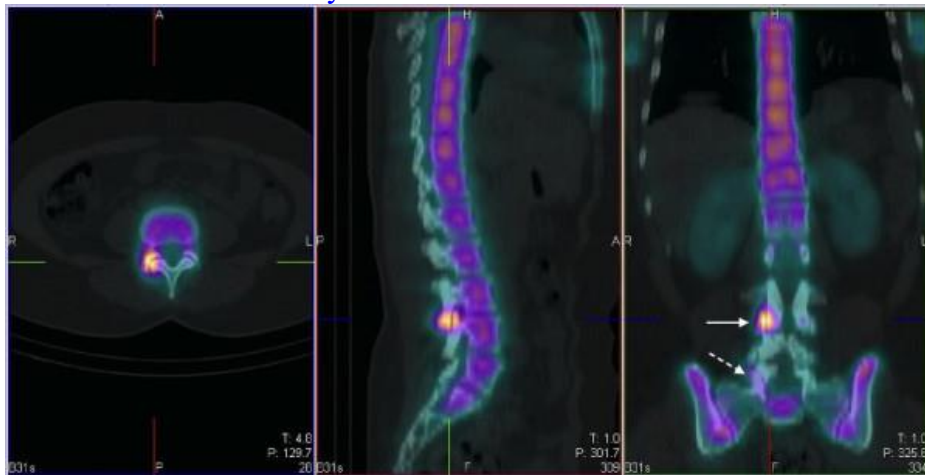


- **MEYERDING'S classification** - *degree* of lumbar spondylolisthesis – in lateral X-ray superior surface of sacrum is divided into four equal parts:



Indication for fusion – features showing (**predisposition for**) **instability**!

- 1) unstable\* on **dynamic imaging** (> 10 degrees of angulation or > 3-4 mm of relative motion)
  - $\geq 4$  mm translation is criterion used by USA insurance companies.
  - it can be determined by:
    - a. dynamic (flexion-extension) XR  
N.B. flex-ex radiography has low accuracy (measurement errors of up to 4 mm)
    - b. comparing upright standing XR with supine MRI  
N.B. every patient should get upright XR before simple decompression
- 2) **tall disk\***
- 3) **facets:**
  - a) **sagittally-oriented**
  - b) **facet-joint edema** - joints are likely to be unstable, even if they appear stable on dynamic imaging; **synovial cyst** – means instability (do dynamic XR!)
  - c) **back pain improved with facet blocks**
  - d) “hot” facets on SPECT study:



Spondylolisthesis should not be confused with “instability” - there are obvious differences between spondylolisthesis patients:

- a) **large disk\***, **bulky fluid-filled sagittally-oriented facets**, and **dynamic instability\*** → decompression with fusion.  
\*significant motion, large tall disc – strong indications to add **interbody graft** (if performing posterior fusion)

- b) **collapsed disk with fixed spondylolisthesis** – despite slip progression, a stable degenerative spondylolisthesis can be adequately treated with decompression alone, albeit with a 34%\* rate of revision surgery due to development of instability (vs. 14%\* or 22%\*\* if fusion was used)

\*Ghogawala Z et al. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. *N Engl J Med* 2016; 374: 1424-34.

\*\*Försth P et al. A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med* 2016; 374: 1413-23

N.B. results of reoperation may be worse than results of original surgery, and health care costs may be high, especially considering that most patients with lumbar stenosis are elderly!

**Swedish school** – decompress and do not fuse! If back pain gets worse, then do fusion!

N.B. every patient should get upright XR before simple decompression (not to miss instability)

- there is no clear evidence that radiologic instability is associated with pain and impaired function in the individual patient.
- **L4-5 spondylolisthesis** – some experts do *two-level fusion* L4-S1.

– *insufficient evidence* for or against the use of **spondylolisthesis reduction** with fusion: check if there is mobility, place interbody graft, then use cobalt-chromium rod and counter-lever technique.

NASS Clinical Guidelines for **Adult Isthmic** Lumbar Spondylolisthesis (2014):

*Insufficient evidence* for or against **surgical treatment** as compared to **medical/ interventional alone**. **360° fusion** is **recommended** to provide **higher radiographic fusion rates** compared to posterolateral fusion; *conflicting evidence* whether **360° fusion** provides better **clinical outcomes** than posterolateral fusion alone.

- if nerve root **compression** is **far lateral**, outside confines of spinal canal – simple decompression will not work – need **radical decompression (Gill procedure) plus fusion**

## FACETOGENIC LUMBOSACRAL PAIN

- lumbosacral facet loading – **Kemp test**: in seated or standing position - have patient **extend, lateroflex, and rotate** the spine (hold this position for 3 seconds) - local pain suggests a facet cause, while radiating pain into the leg is more suggestive of nerve root irritation
- due to the **poor correlation between history and physical exam**, **diagnostic blocks** (MBB - Medial Branch Blocks) are considered to be the mainstay in establishing a diagnosis - positive response is considered to be > 80% pain relief post-procedure.

N.B. **false positive results** have been documented to be as high as 25-40% in the lumbar spine; thus, it is recommended that **two diagnostic MBBs** are performed to confirm a diagnosis.

- if MBBs give positive response, proceed to therapeutic **RF ablation** of medial branches; alternative - **intra-articular steroid injections**.
- for refractory cases, surgical intervention may be considered (arthrodesis).

## EPIDURAL LIPOMATOSIS

- **steroid-induced fat deposition** in epidural space.

- earliest and commonest clinical feature - **low back pain** typically in thoracic spine (→→→ myelopathy, cauda equina syndrome, radiculopathy).
- diagnosis – **MRI**
- treatment - wide decompressive **laminectomy** and **debulking** of adipose tissue (+ weight loss in morbidly obese patient).

## LUMBAR ADHESIVE ARACHNOIDITIS

### ETIOLOGY

- **local tissue injury** → inflammatory response within subarachnoid space → **fibrotic process**.

### CLINICAL FEATURES

- **multifocal radiculopathy** with **neck / back pain** (due to nerve root adhesions).

### DIAGNOSIS

MRI - nerve roots *clumped together* centrally or *adhere to dura* peripherally, CSF loculations.

### TREATMENT

Practically, only option – **spinal dorsal column stimulator** for pain relief.

## VENTRAL CORD HERNIATION

- cord herniates through a defect in dura usually located anteriorly or anterolaterally.
- bone erosion anterior to dural defect may occasionally be seen.
- frequently associated with a **calcified disc fragment** (may have gradually eroded through dura).

Ventral cord herniation (on axial - **cord is rotated, anterior extradural CSF collection**) – cord plugs dural tear (from disc osteophyte?):



Dorsal scalpel sign:





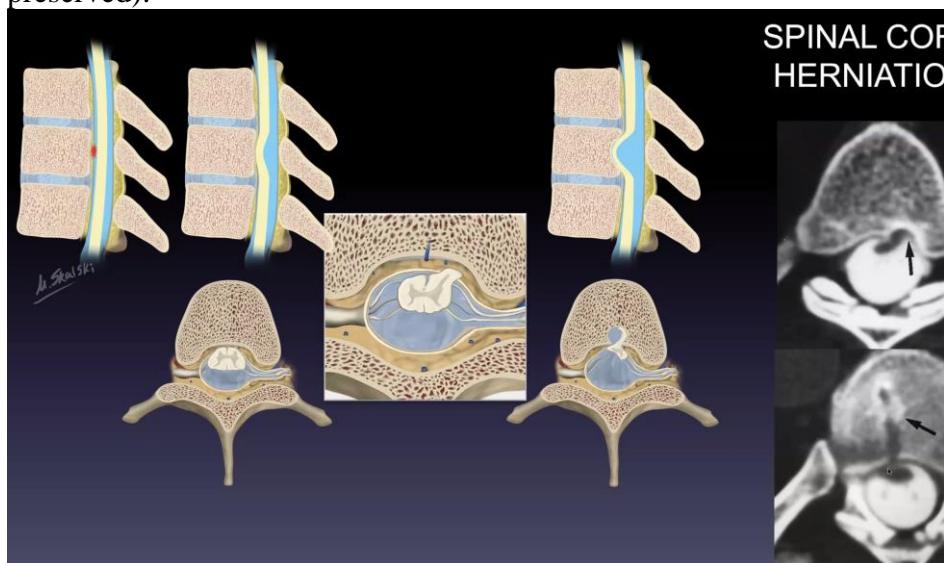
### CLINICALLY

- **incomplete Brown-Séquard syndrome** (with relative sparing of posterior columns).

### DIFFERENTIAL DIAGNOSIS

- **dorsal arachnoid cysts** (both result in increased subarachnoid space posterior to cord, and a ventral kinking of spinal cord)

Classically, there is **no CSF anterior to cord** (vs. in dorsal arachnoid cysts – some ventral CSF rim is preserved):



Contiguous **CSF pulsation artifact** on MRI can be seen with cord herniation, whereas arachnoid cyst tends to interrupt this.

### TREATMENT

- lateral or anterolateral approach: dural defect is widened → reduction of spinal cord herniation → sling of dural substitute slid anterior to the cord to prevent reherniation.

## SYNOVIAL CYST

**Synovial cyst** – means instability (do dynamic XR!)

Cyst can be adherent to dura!

# SCOLIOSIS

DEXTROSCOLIOSIS usually occurs in **thoracic spine**.

LEVOSCOLIOSIS common in **lumbar spine** (L&L).

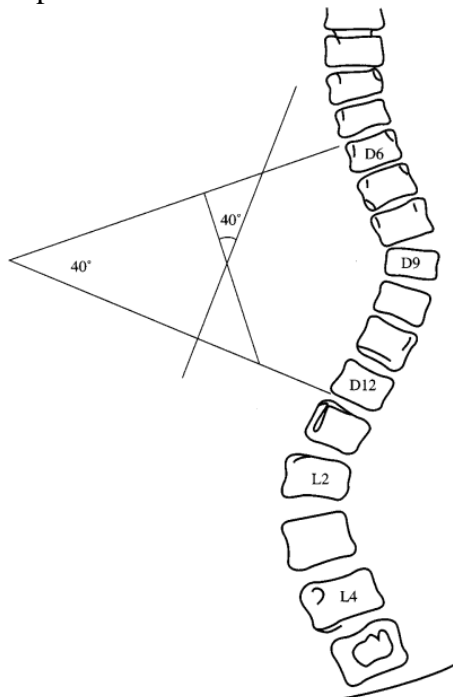
- rare occurrence in **thoracic** spine indicates higher probability that scoliosis may be secondary to a **spinal cord tumor** - order an MRI.

**Dextroscoliosis = tumor**

Rib hump (on forward flexion) is on apex side!

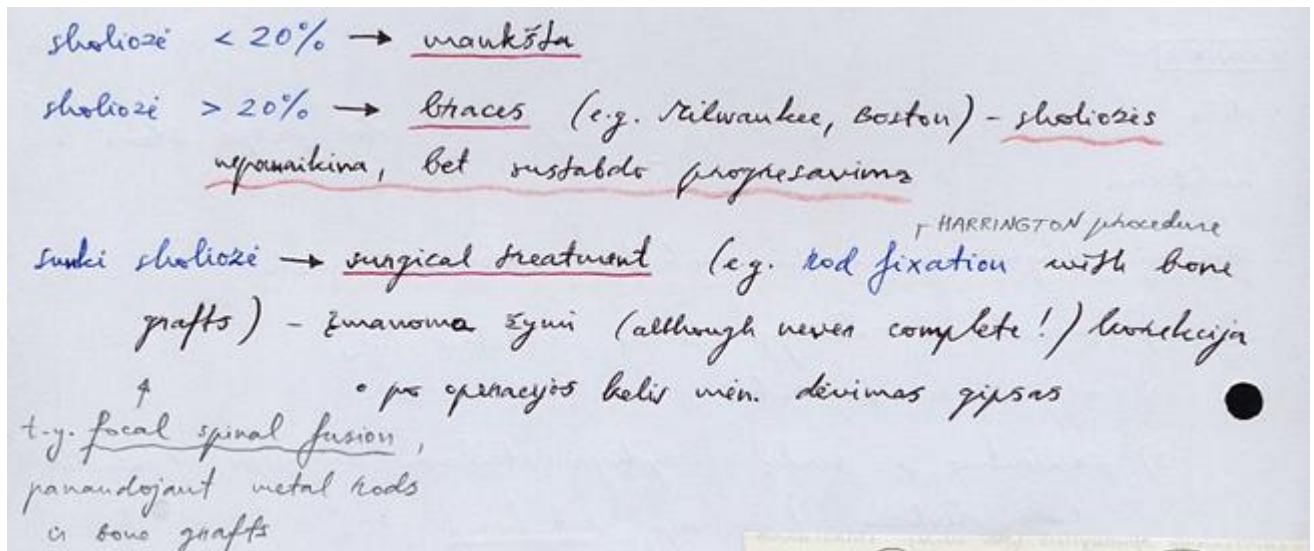
**Curve flexibility** – **primary (pathologic) curves** do not correct, **secondary (compensatory) curves** straighten

**Cobb angle** - angle made by intersection of two lines parallel to most cranial and caudal endplate of respective end vertebrae of curve:



**Lippmann-Cobb method** (on AP X-ray): “end vertebrae” are identified at the top and bottom of the scoliotic curve and are defined as the vertebrae with the **greatest angle relative to the horizontal plane**.

- **apex** (or apical vertebra) is the vertebra whose center is most laterally displaced from central line.
- **non-structural curve** can correct on side bending vs **structural curve** is not flexible.
- **major curve** is the largest structural curve; fractional curve is the curve below the major curve.
- **scoliosis = Cobb angle  $> 10^\circ$** ; angle  $< 10^\circ$  - spinal asymmetry.
  - example:  $60^\circ$  thoracic dextroscoliosis with apex at T8.
- 50 is degree at which surgery is normally indicated
- Cobb  $> 90^\circ \rightarrow$  cardiopulmonary insufficiency.



### TYPE 1 SCOLIOSIS - PRIMARY DEGENERATIVE (DE NOVO), S. "DISCOGENIC"

- curves develop **de novo** after skeletal maturity in previously straight spine.

Adult degenerative scoliosis: deformity with **Cobb angle**  $> 10^\circ$  in skeletally mature individual.

- tends to progress at  $3^\circ$  per year (range:  $1-6^\circ$ ).

### TYPE 2 (PROGRESSIVE IDIOPATHIC SCOLIOSIS)

- curves that **began before skeletal maturity** (may have been asymptomatic in children)

**BrAIST trial** – children 10-15 yrs with Cobb 20-40 degrees – early trial termination (bracing works! – 90% surgery avoidance if wore brace  $> 13$  hrs/d)

- risk factors for lumbar curve progression: Cobb angle  $\geq 30$ , significant apical rotation, lateral listhesis  $\geq 6$  mm, interest line through or below L4-5 disk space.

#### Four surgery indications

- (1) **cosmesis**
- (2) unrelieved **pain**
- (3) **neurological deficit**
- (4) progressive **deformity** (failure of bracing; Cobb angle  $> 20^\circ$  - most likely will progress without surgery)

progressive curves  $> 50^\circ$  in adults.

progressive curves  $> 40-45^\circ$  in growing children

N.B. in **muscular dystrophy**, pulmonary function begins to decline rapidly when patients become wheelchair users and can quickly reach level where surgery is impossible - surgery is often performed when curves reach only  $20-30^\circ$  but forced vital capacity is still  $> 40\%$ .

Cobb  $< 25 \rightarrow$  serial XR

Cobb  $25-45 \rightarrow$  PT, bracing in children

Cobb  $> 45-50 \rightarrow$  surgery (before pulmonary deterioration!)

## GENERAL SURGERY PRINCIPLES

- 1) restoration of lumbar lordosis
- 2) reestablishment of sagittal balance
- 3) avoiding termination of construct at thoracolumbar junction or at apex of thoracic kyphosis
- 4) all segments involved in curve should be fused
  - N.B. correct only primary curves (do not touch secondary compensatory curves)
- 5) areas of significant stenosis should be decompressed during surgical intervention and before correction of deformity.
- 6) preoperatively look:
  - i. **sagittal vertical alignment** (need long XR cassette – scoliosis film) – final goal (must be < 5 cm)
  - ii. **pelvic tilt** (SVA alone is not enough); normal  $13 \pm 6^\circ$  (i.e. goal of surgery is <  $20^\circ$ ); larger pelvic tilt (sagittal compensation) – larger PSO needed
  - iii. **T1 inclination** (T1-to-femoral head)
  - iv. lumbar lordosis must be within  $10^\circ$  of **pelvic incidence**

**intraoperative monitoring** (SSEP, MEP\*, EMG) should be used in every procedure; pedicle screw stimulation can also be used to assess for proper screw placement.

\***motor evoked potentials** are most sensitive for detecting cord injury resulting from correction of deformity.

N.B. for instrumentation, **Co-Cr (cobalt-chrome)** is used – stiffer (modulus of elasticity↑) than titanium; in other spinal surgeries **titanium** is used – better MRI compatibility!

- use **temporary rods** (one spine side while working on the other side)
- osteotomies can achieve  $5-45^\circ$  lordosis correction (Smith-Peterson – up to  $10^\circ$ )

## ANTERIOR APPROACHES

- ideal for younger adults (20-40 years) with flexible curves, healthy L5-S1 disk space, and no significant kyphotic deformity.

## POSTERIOR APPROACHES

- useful in older patients ( $\geq 40$  years) with flexible curves with or without pathology of L5-S1 disk.

- **degenerated L5-S1 disk** requires **fusion to sacrum**; high rates of pseudarthrosis (H: anterior interbody graft at L5-S1 to provide load-bearing interbody surface).

## COMBINED (ANTERIOR-POSTERIOR) APPROACHES

- for correction of **rigid curves**:

- anterior release is performed, followed by (staged or same-day) posterior segmental instrumentation and fusion.

N.B. most of correction of deformity, including vertebral body derotation and restoration of sagittal alignment, is achieved during posterior instrumentation and fusion.

## Surgical Strategies for Correction of Scoliotic Deformity in Adults

Approach	Patient age	Curve flexibility*	L5-S1 pathology	Correction of sagittal balance
Anterior only	< 40	Flexible	No	No
Posterior only	$\geq 40$	Flexible	Yes or no	Yes
Combined	Any	Rigid	Yes or no	Yes

\*unlike adolescents, in whom flexible curves are common, adult curves are generally stiff

## VASCULAR

- Spinal Ischemic Stroke** – apoplectic onset: back pain + transverse myelopathy (segmental at infarct level, long tracts below): a. spinalis ant. – anterior 2/3 (sparing posterior columns) – DWI-MRI.
- Hematomyelia (Spinal Cord Hematoma)** – apoplectic onset: back pain + transverse myelopathy.
- Spinal SAH** - back pain, meningismus, radicular pain, myelopathy
- Spinal epidural / subdural hemorrhage** - apoplectic onset: back pain + transverse myelopathy ± radicular pain, radiculopathy

## INFECTION

2015 IDSA Guidelines for the treatment of Native Vertebral Osteomyelitis in adults:

- **hold off on antibiotics** in a neurologically normal and hemodynamically stable patient until the diagnosis is established.
- **blood cultures x2**, ESR and CRP
  - fungal blood cultures if at risk for fungal infection
  - If blood cultures are negative → **IR biopsy**

Surgical intervention is indicated in:

- 1) recurrent/persistent **bacteremia**
  - 2) progressive **neurologic** deficits
  - 3) progressive spinal **deformity/instability** (with or without pain)
  - 4) **worsening pain** despite appropriate antimicrobial therapy
- just pain, including radicular pain (tends to get better with abx) are not surgical indications.
  - Pott's - highly aerobic bacteria - **discs are spared until later in course** – “skip” lesions.

## EPIDURAL INJECTIONS

### Transforaminal

- use spinal needle and bend distal end of it for easier steerability (so no need to pull needle back to readjust).
- start 8-10 cm off midline
- at **AP fluoro**, direct needle at the lateral edge of pars (towards the lower aspect of foramen); when hitting pars bone, switch to **lateral fluoro** - advance needle just below pars (i.e. to foramen level).
- inject steroid with local (patient may experience some muscle weakness served by that spinal nerve for several hours).

### Epidural

- level of injection – above pathology (e.g. L2-3 stenosis with severe arthropathy → inject at L1-2)
- outpatient procedure with **fluoroscopy**
- prone.
- 2 cc of **KENALOG** or **DEPOMEDROL** (80 mg) + 2 cc of saline.
  - **Dr. Graham** mixes with 1 mL of 1% preservative free **LIDOCAINE**.
- **AP fluoro** with Tuohy needle - aim needle tip (bevel towards head) just onto lower edge of the lamina. Insert Tuohy almost vertical under AP fluoro. Once on lamina, verify with fluoro needle position. Switch to **50-55 degree opposite oblique fluoro** - shows lamina profile very well - take stylet out and continue advancing Tuohy needle under lamina with **glass syringe** with saline attached. When lost resistance when tapping glass syringe, inject 1 cc of Omnipaque for epidurogram confirmation → inject steroid.

## SI JOINT

N.B. lumbar spine, hip, and SI joint pathology can mimic each other

- SI joint is a true diarthrodial joint:
- motion (primarily rotation) decreases with aging, and increases in pregnancy.
  - normal motion is approximately 2-4 mm in any direction, rotation < 4 degrees

LBP below L5

Pelvis/buttock pain

Hip/groin/thigh pain

Sitting problems – patient avoids sitting on affected side

Pain with position changes or transitional motions (i.e., sit to stand, supine to sit)

Single leg stance test may induce pain on supporting side.

Fortin finger test – patient points to PSIS area!

SI belt – stabilizes SI joint and pain improves (esp. when climbing stairs – can try in clinic to diagnose).

### Provocative Tests

In order of reliability:

1. Thigh thrust
2. Distraction
3. FABER - pain is posterior (vs. hip pathology – pain is anterior)
4. Gaenslen's
5. Compression

Need only **3 (out of 5) positive tests** to confirm SI pathology! → **PT!!!!**

Imaging - generally not helpful (except SPECT).

**SI joint disruption** - asymmetric SI joint widening

**Degenerative sacroiliitis** - sclerosis, osteophytes, subchondral cysts, or vacuum phenomenon

Differential - **Piriformis syndrome**:

**FAIR test** (maintain at least 10 seconds):

- lateral position with the tested hip on top.
- passively move **leg into flexion (90 degrees), adduction, and internal rotation**.
- examiner stabilizes the hip and applies downward pressure to the knee to internally rotate and adduct the hip - placing the piriformis on a stretch that compresses the sciatic nerve - positive test occurs when elicited **pain is posterior (sciatic/gluteal area) + sciatica**.
  - if pain in the anterior thigh - **femoral acetabular impingement**.

### Diagnostic Injection (True SI Arthrogram)

Indication – no response to PT for > 6 mos (PT helps in up to 60% of SI joint cases).

After injection

- ask patient to move around as in normal daily life.
- do again provocative testing – 30 mins to 2 hours after injection (MAC effect has worn off).
- positive if pain improves ≥ 50% (NASS requires ≥ 75%).

Caveat: SI joint is innervated by L5-S4 nerve roots.

N.B. **L5-S1 transforaminal injections** block L5 nerve root – **SI joint pain improves**

### **CONSERVATIVE TREATMENT**

1. **Medications**
2. **PT** (helps > 60% patients)



3. **SI belt** – stabilizes SI joint and pain improves
4. **Therapeutic SI joint injections** (with steroids) – usually 2-3; if patient responds, most likely will progress to surgical treatment.
5. **RF denervation** – temporary measure (causes temporary demyelination and pain recurs in 3-4 months) and denervates only posterior portion of SI joint.

## SURGICAL TREATMENT

### Indications

1. SI joint disruption (e.g. symptoms started during pregnancy and persisting postpartum for > 6 months)
2. Degenerative sacroiliitis

N.B. SI joint does not ankylose spontaneously!

N.B. **lumbar fusion** puts lots of stress on SI joint – joint degenerates faster

N.B. **SCS** is not a good option for SI pain.

### SI joint fusion

Better to stage **both sides 3 months apart** (patient is NWB\* with crutches on operated side; if bilateral – may need wheelchair postop)

\*3 weeks **partial weight bearing** (using crutches, normal foot progression – from heel to toe); experts say “weight bearing as tolerated, avoid stairs”

### Structures at risk

**L5 nerve** root runs in front of sacrum at proximity to SI joint (SI joint inflammation may mimic L5 sciatica!)

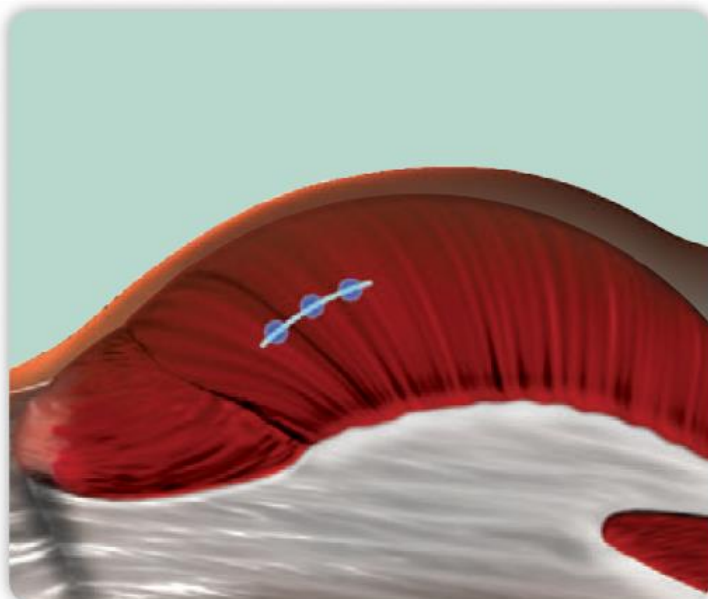
**Middle gluteal artery** is lower but may take aberrant course and may be injured.

**C-arm** – most experts use it (might be too obscure in obese patient – use O-arm instead).

### Robotic assistance

**O-arm** (iFuse Navigation Set plus Medtronic TeraTrackers)

- A. Lateral position
- B. Supine position
- C. **Prone position** – **only position for O-arm** – tracker goes into PSIS.



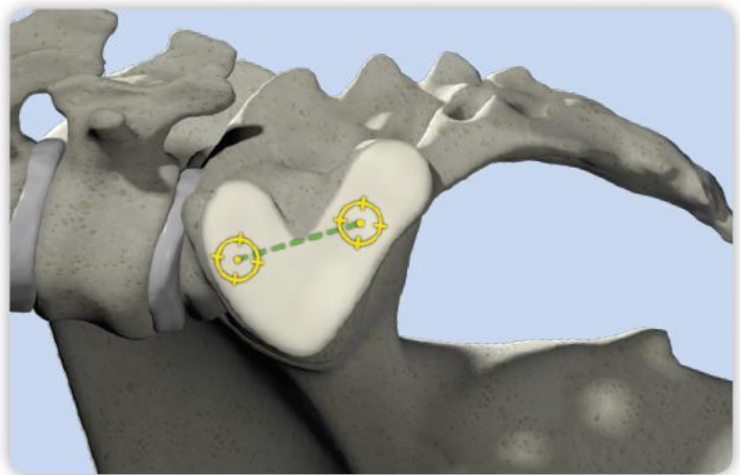
- The muscle fibers run perpendicular to the skin incision.
- Do not continue the skin incision through the muscle and fascia to the bone. Cutting muscle fibers may result in significant bleeding and/or muscle damage.
- Place Pin(s) through the fascia and seat them into the bone. The muscle may gently be spread in line with the muscle fibers to open the fascia and muscle tissue.

**1<sup>st</sup> pin** – aim **above S1 foramen** (1/2 of implant in sacrum)

**2<sup>nd</sup> pin** – aim **to S1 foramen** (be cautious not to penetrate into foramen, thus, **only 1/3 of implant in sacrum**)

N.B. due to shape of SI joint, start 2<sup>nd</sup> pin more anteriorly and aim dorsally!

**3<sup>rd</sup> pin** – aim **below S1 foramen** (1/2 of implant in sacrum)



**Figure 6.** The location of the first and second incision points representing the first and third implant locations, respectively, and the incision line connecting both implants. Note, the incision line should be approximately 3 cm.

**Note:** The synthetic lateral view may require adjustment to align the alar lines to match the orientation of the patient.

## **CERVICAL ARTHROPLASTY**

The right patient is < 50 yo with preserved disc height, normal facet joints and mobility

- FDA approved for 1 and 2 contiguous levels (C3-7) for Mobi-C, 1 level for all other designs.  
N.B. Mobi-C has **no nickel** – OK for patients with Ni allergy!
- skeletally mature patients (> 21 yo)
- failed at least 6 weeks of conservative treatment.
- **not approved to be combined with ACDF**
- **CI: instability** (translation > 3.0 mm, and/or > 11° angular difference to that of either adjacent level), severe **spondylosis / facet joint disease**
- **precaution: neck pain** alone
- not clear if **cord compression with cord T2 signal** is a contraindication (TDR may leave dynamic cord micro-traumatization unaddressed).
- **minimize soft tissue trauma** - limiting retraction ischemia, **minimal dissection of longus coli**, and **less electrocautery use**.
- **complete disc removal without burrs**, between unci, preserving bony endplate and annular rim.



Postop

- PT: isometric strengthening, active ROM typically at 2 weeks.
- restrict overhead activity, repetitive neck movements, and heavy lifting for 6 weeks.
- **dynamic XR** at 6 weeks.

**Heterotopic Ossification (HO)** is a potential complication associated with artificial cervical discs.

- prophylaxis:
  - 1) use **bone wax** after bone (osteophyte) removal
  - 2) postop **NSAID** - 200 mg/d **IBUPROFEN** for **6 weeks**
- 5-year results - reoperation rate was significantly lower with Mobi-C (4%) versus ACDF (16%).

## CERVICAL SURGERY

Surgery must address two **PATHOPHYSIOLOGIC COMPONENTS**:

**Static** – surgical decompression

**Dynamic** – surgical fusion

DECOMPRESS + FUSE

- when choosing approach, aim to create **AP canal diameter  $\geq 12$  mm**.

Fusion rates for 2-level anterior operations (i.e. 2 disc spaces) (**Class III**):

2-level ACDF with anterior plate = 1-level corpectomy with plate > 1-level corpectomy without plate\* > 2-level ACDF without plate

\* however, the graft extrusion rate is higher for corpectomy than ACDF

### Motion contribution

**Flexion-extension:** 50% at occiput-C1

**Rotation:** 50% at C1-2

**Lateral bend:** 90% at C3-7

### Techniques to increase lordosis via ACDF

Taller cages

Bend plate (more lordotic)

### WRONG LEVEL SURGERY / LEVEL LOCALIZATION

#### Risk factors:

1. Difficulty visualizing reference points
2. Unusual anatomy (e.g. rib counting in severe scoliosis)
3. Large body habitus
4. Failure to re-localize after exposure
5. Inconsistent counting methods

### PREVENTION MEASURES

#### Preop

- develop level counting plan preop - obtain **chest XR and CT preop** (esp. prior to thoracic surgery)! - carefully count number of thoracic and lumbar vertebrae - be aware of **aberrant anatomy**. see below >>

N.B. make sure MRI scout view shows all vertebrae!

N.B. count index level same way on preop MRI and intraop XR – either both from C2 down or both from sacrum up.

Ask interventional radiologist to place pedicle marker!!!!!!

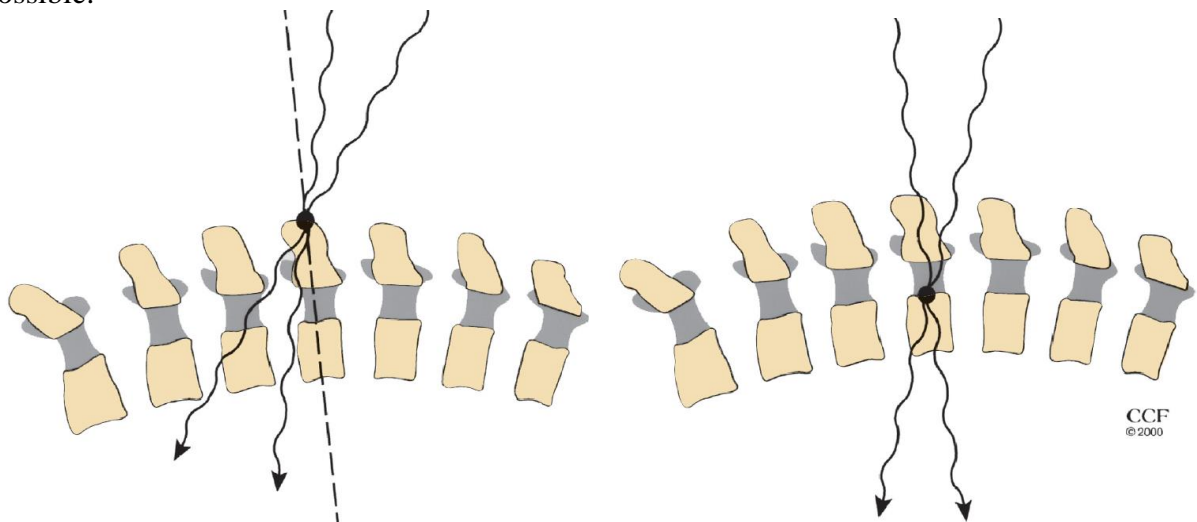
- outpatient preop **interventional radiologist**:
  - a) injects **methylene blue** (0.5 mL into spinous process).
  - b) places **metal marker** (**Guglielmi detachable coil**, **breast cancer surgery wire**, **screw\***) or **injects PMMA** as close to the index level pedicle as possible.

\*widely used in radiation oncology to localize tumors before SRS.

### Intraop

- **attending surgeon present in OR** for skin site marking – “hand-off” effect.
- **series of needles** are placed every few levels counting from sacrum in cephalad fashion in lateral views (or from first rib down).
- **attending surgeon scrubbed in** for vertebral marking – “hand-off” effect.
- intraoperative radiographs with **markers and retractors** positioned in place.
  - markers must be firmly and **immovably attached** to spine.
  - two forms of site marking required (and must not be mistaken for other objects), e.g. purple permanent marker and hemostat.
- radiographic **time-out** – do not proceed until two surgeons (at least one – attending; some sites require a second independent non-operating attending to assess – this may be ineffective policy, thus, shift is made towards radiologist verification) independently verbalize marked level (use open-ended questioning during spinal level verification).
  - send\* **localization XR to impartial radiologist** and do not proceed until radiologist calls into room to verbally discuss with attending (same as tumor frozen section result) – each OR should have posted on wall the number for radiology reading room that surgeon can call at their discretion to confirm vertebral level.

\*need for WiFi-enabled C-arm
- ideally, use **neuronavigation** (if there is radiographically-visible distinct bony pathology).
- avoid **parallax** with localization XR – by placing marker as close to pathology in sagittal plane as possible:



- if difficult to see on intraop XR – use **oblique views**, spin confirmatory **O-arm**
- if expected pathology is not found at the expected level, radiographs should continue to be performed with **different marking techniques** until the surgeon is satisfied operating at the appropriate level.
- reliably **mark identified level**
  - a) permanent marking **pen** - may be washed off with blood or irrigation.
  - b) **Bovie** marking - may be washed off with blood or irrigation.
  - c) small **bite** off the spinous process.
  - d) **suture** placed through spinous process.

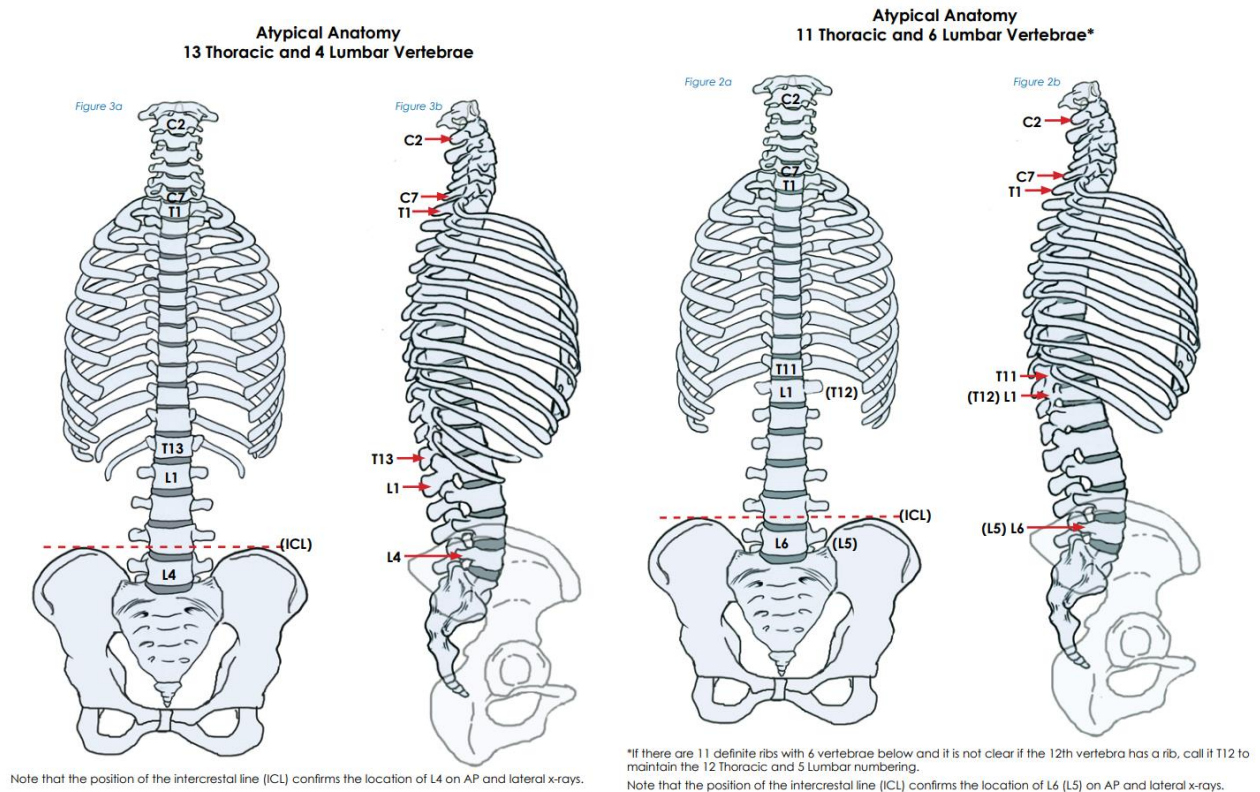
### TRANSITIONAL ANATOMY

There can be 4 (2.6) and 6 (8.2%) **lumbar vertebrae**.

*Intercostal line always bisects the lumbar vertebra above the last*

There can be 11 and 13 pairs of **ribs / thoracic vertebrae**:

N.B. lumbar and thoracic numbers are not related (i.e. one segment addition does not automatically compensate with another segment loss) but 11 thoracic + 4 lumbar vertebrae probably do not exist



### Cervical

- XR needle localization of disk level – **always insert double-bent spinal needle at the highest accessible level** (if lower – bulky patient's shoulders may obscure XR).
- **lateral radiograph** is obtained: count down from C1-2 complex; alternative – **anterior posterior radiograph** – localize 1<sup>st</sup> rib and count up, then verify with counting down from C2
- if **disc space is covered with osteophyte** (“patella”), do one XR, remove osteophytes with Leksell to see actual disc space – insert needle there and do second XR.
- if **shoulders very high** (pull shoulders down with wide tape) – use AP view or localize what you see on lateral view and count down under direct exposure.

### Thoracic

- **anterior posterior radiographs** are obtained - **ribs** are counted - frequently misleading!
- counting from T1 down is the most reliable method; alternative - counting up from T12.
  - anatomically numbered ribs articulate with disk space above correspondingly numbered vertebral body.
  - in the lowest segments of thoracic spine, rib articulations can be found below level of corresponding disk space.
- **large plate lateral radiograph** - **long cassettes** (that includes sacrum) instead of fluoroscopy can be used if necessary - careful placing an instrument under the lamina due to the narrow spinal canal

dimensions (safer, marker may be placed on the transverse process) - counting is performed from the sacrum

- if above fails, marker (Alice clamp) may be placed at the most rostral or caudal level (spinous or transverse process) that is exposed → lateral **cervical** or **lumbar** radiograph is obtained, which includes the occiput or sacrum, respectively → levels are counted to this marker → lateral **thoracic** radiograph is performed, and levels are counted from the prior marked level to pathology.

### Lumbar

- Alice clamp or sharp towel clip may be placed on **spinous process** along with a Penfield no. 4 or Woodson elevator **under the same lamina** - both directed perpendicular to the spine.
- **lateral radiograph** is obtained: count up from lumbosacral junction:
  - **most caudal normal disc space** is labeled as L5-S1.
  - **iliac crest** serves as a secondary internal landmark to identify L4.

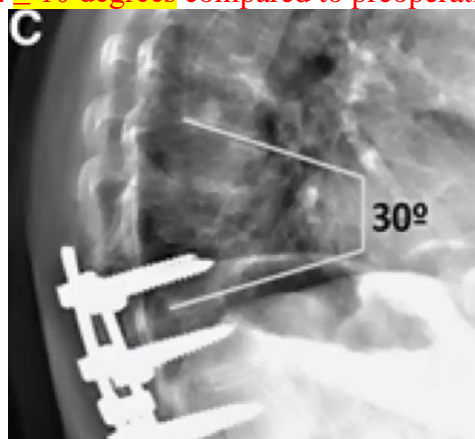
### ADJACENT SEGMENT DISEASE

- **after ACDF**, **3% / year** for the next 10 years (operation rate for symptomatic ASD after ACDF at **10 years is 5-20%**)
- **after L4-5 fusion**, **25% incidence** at 10-yr (requiring reoperation); rostral > caudal 8-fold
  - risk factors - **decompression of segments outside the fusion construct**, **female** gender (OR = 3.55); **older age** is associated with lower incidence (OR = 0.95).
  - **PI-LL mismatch > 10°** → 10-times higher risk of **adjacent segment disease**
- treatment:
  - a) board answer – **extend fusion** and do decompression.
  - b) alternative – **XLIF** and wait – many patient won't need posterior decompression as XLIF jacks up disk space and unbuckles nerve root compression.

### PROXIMAL JUNCTIONAL KYPHOSIS (PJK), PROXIMAL JUNCTIONAL FAILURE (PJF)

**PJK** – radiographic diagnosis (clinically “insignificant”):

sagittal Cobb angle between **inferior endplate of UIV** and **superior endplate of UIV+2** **≥ 10 degrees** compared to preoperative angle



**PJF** – clinical significance (pain, neurological symptoms, need for surgery):

**PJK + fracture** of UIV or UIV+1

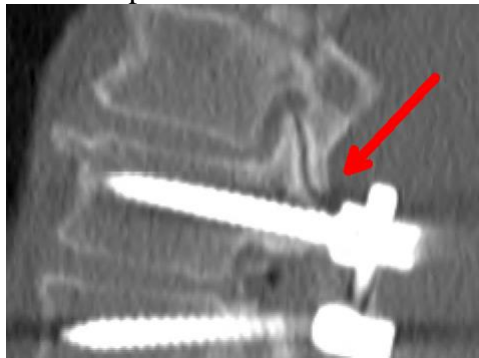
### Classification of PJK:

- Type 1 = disc and ligament failure
- Type 2 = bone fracture
- Type 3 = implant-bone interface failure.

Risk groups: age > 55, postmenopausal, osteoporosis (**HU value of < 104**), obesity, smoking, long-segment fusions, disruption of the posterior ligaments/facets, overcorrection or residual sagittal imbalance, extreme rod stiffness, combined front+back operations

No successful strategy exists to prevent it:

- A. Make **sagittal balance as neutral** as possible.  
N.B. **overcorrection** will definitely lead to PJK!
- B. Preserve **interspinous ligaments** (e.g. leaving top of lamina intact with attached lig. flavum).
- C. **Vertebral cement augmentation** at UIV+1 (may include UIV – will prevent screw pullout).
- D. Extend **noninstrumented fusion**.
- E. **Rib fixation** at UIV+1.
- F. **Sublaminar hooks** (instead of pedicle screws) for upper levels.
- G. **Sublaminar bands**
- H. **Transverse process hooks**
- I. **Spinous process augmentation** around UIV and UIV+1 with “Tethers” – Mersilene Tape.
- J. **“Soft landing”** - avoiding rod being proud (pre-loading) in **upper screws**.
- K. **Flexible rods** at the top.
- L. Upper screws should be placed not to violate the **facet joint above**:



- M. **TLSO brace** for 3 months – retrains brain to avoid anteroflexion.

### ALLOGRAFTS

- allografts act purely as **osteoconductive** material.
- allografts **lack osteogenesis** capacity because the marrow is absent! H: add patient's own marrow aspirate.
- allografts **lack osteoinduction** capacity! H: add BMP.

### AUTOGRAFTS

- gold standard - highest rates of fusion.

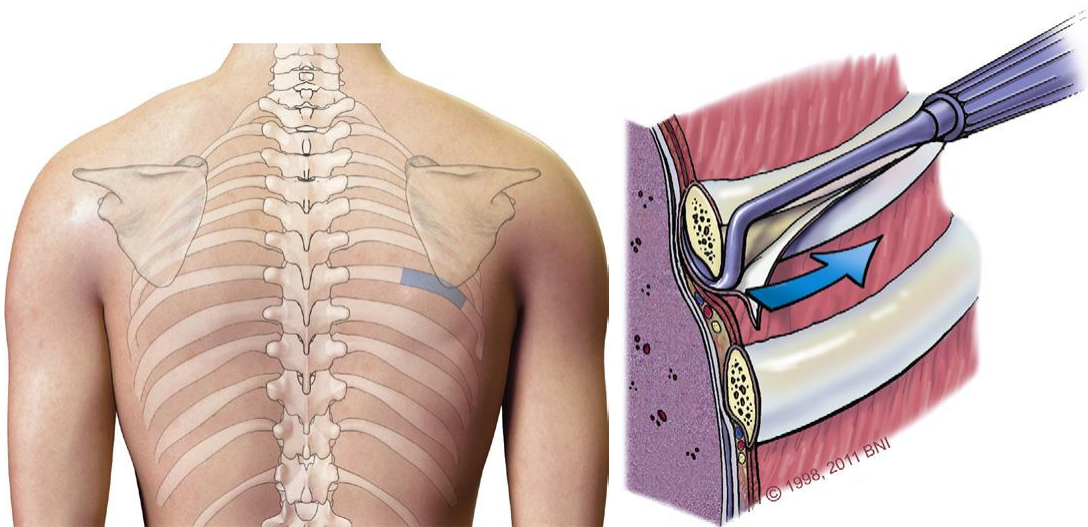
- have all three features:
  - 1) **osteogenesis** – native capacity to **form bone** by **osteoblasts** living in marrow under the influence of many factors such as bone morphogenetic protein (BMP).
  - 2) **osteoinduction** – capacity to **induce bone formation** by osteoblasts; **BMP** is osteoinducing agent.
  - 3) **osteoconduction** – physical property present in **structural composition** of bone graft that acts as a **scaffold for new bone to form**.
- disadvantages: pain, hematoma, cosmetic deformity, and infection at donor site.
- sites for harvesting:
  - 1) **local** – drilled osteophytes, uncovertebral joints, manubrium sterni, decompression bone (e.g. laminae - carefully separating all soft tissues and grinding it into a heavy paste)
  - 2) **iliac crest\*** - strongest structural support (stronger than rib)
  - 3) **posterior ribs\*** - somewhat flexible and can be contoured
  - 4) skull – for young kids



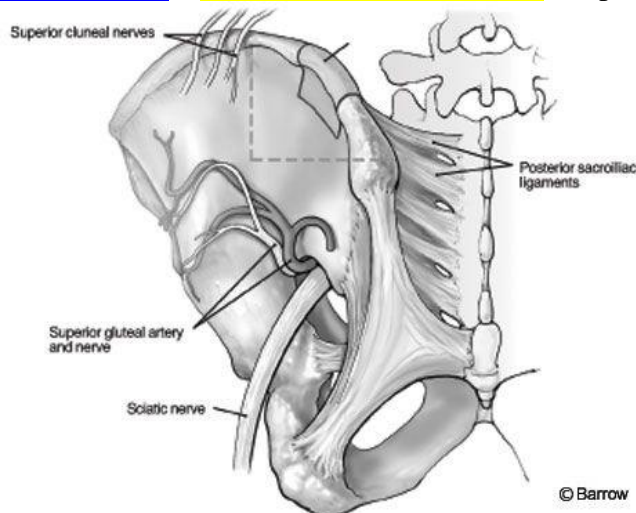
## 5) fibula

\*preferred sources of tricortical, bicortical, or cancellous chips; rate of arthrodesis for grafts from ribs or iliac crest is the same, but the rate of complications associated with harvesting a rib is lower.

**7th rib** - just caudal to scapula tip, just lateral to trapezius muscle border - **Doyen rib dissector, rib cutter:**



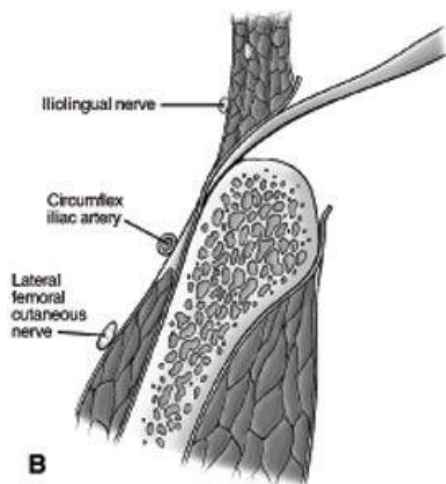
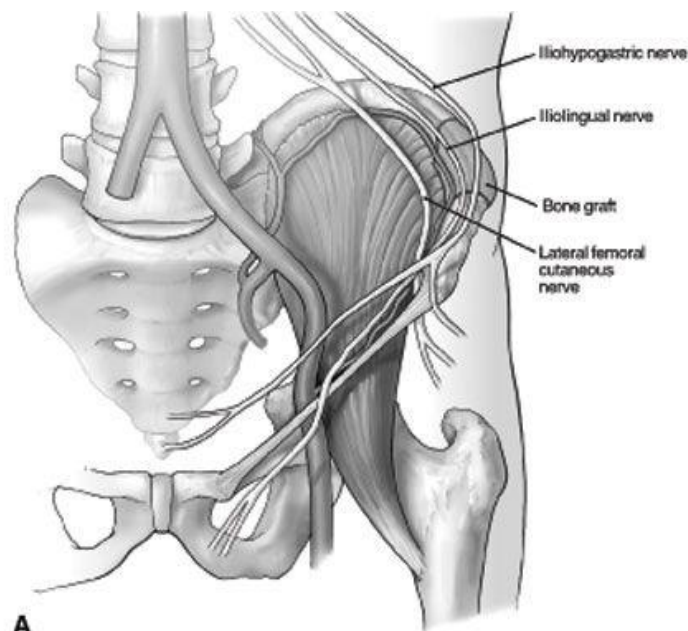
**Posterior iliac crest** – maximum 8 cm from PSIS - superior cluneal nerves



- injury to **superior gluteal artery** is reported; H: if vessel is identified, it should be ligated - usually not possible due to vessel retraction (then operative site should be packed → angiography suite for embolization; primary operation may be completed the following day).

**Anterior iliac crest** – 2-3 cm lateral to ASIS:

- to avoid avulsion/stress fracture (insertion of **sartorius muscle, rectus femoris muscle** and **inguinal ligament**)
- to avoid inadvertent damage to **lateral femoral cutaneous nerve** (may have anomalous course).



© Barrow

### Fibula harvesting

- straight lateral **incision** over the fibula - between peroneal and soleus muscles.
- midportion of the fibula should be adequate for use in the spine.
  - **proximal head of fibula** should be avoided to avoid peroneal nerve.
  - to preserve ankle stability, **lower 7 cm** should be preserved.
- when neither autographs nor cadaveric allograft can be used, **methyl methacrylate** is an option - immediate stabilizing method but **does not lead to bony fusion** (i.e. should be reserved for patients with a short life expectancy).

### **CORD COMPRESSION**

- 1) awake fiberoptic **intubation**
- 2) **position** patient awake (if in pins, scalp anesthesia)
- 3) **neuromonitoring** (prepositioning baseline and after positioning)
- 4) A-line - keep **MAP > 85**
- 5) prophylactic **steroids**

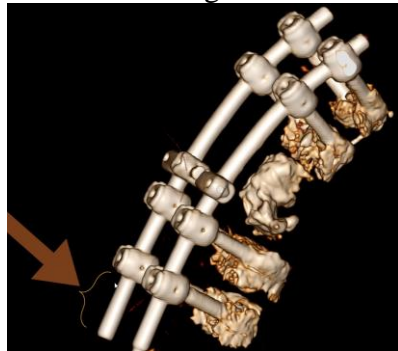
### **CARROT-STICK FRACTURE, ANKYLOSING SPONDYLITIS**

- **rheumatoid factor** is absent in the serum
- begins in SI joints (sine qua non of involvement) progressing rostrally.

- inflammatory morning back stiffness, progressive thoracic kyphotic deformity limits chest expansion.
- imaging: **osteoporotic** VBs, **calcified intervertebral discs** (sparing **nucleus pulposus**), **ossified ligaments** → square-appearing VBs with bridging syndesmophytes (“**bamboo spine**”).
- **Andersson lesion**: discovertebral lesion that results from previously missed fracture → mechanical stresses prevent from fusion → pseudarthrosis (erosive changes can mimic discitis on MRI)
- fragile rigid spine highly susceptible to **very unstable chalkstick** (3-column) **fracture** and SCI even after low energy trauma:
  - cervical → **long segment rigid PCF** C2-T2 fusion (consider 360 N.B. stand-alone **anterior** fusion → **50% failure rate**)
  - thoracic fracture – look at MRI
    - a) no ligamentous injury – brace
    - b) ligamentous injury – fusion (fixed-angle screws!!!, thicker rigid rods, PMMA augmentation to prevent screw pullout)
- very high (up to 30%) mortality.

### OSTEOPOROTIC SPINE

- **avoid hardware / avoid fusion**; if still needed:
  - use **more constrained** screws – less wobble, less loosening.
  - **do not tap!**
  - choose **PEEK** - more elastic than **titanium** - ↓risk of graft subsidence in osteopenic and osteoporotic patients; for rod choice – use **titanium** (vs. **cobalt-chrome**)
  - osteoporotic spines are predisposed to screw pull-out, wire cutout, and instrumentation-associated laminar fractures - **increasing points of fixation** (e.g. 360 – **anterior cage**, **multilevel** pedicle screws) may be necessary to offset poor bone quality.
- some experts suggest traditional pedicle screw technique replace with **MIDLF technique** due to the better cortical purchase.
- **rigid external orthotics** aid in maintaining stability while fusion occurs.
- **cement augmentation** (e.g. injection via cannulated screws); for pathologic fractures may use cement instead of metal cage into vertebral body defect:



### RA

Common involvement of C-spine (RA causes erosions in joints, loosening of ligament insertions)

- Anterior atlantoaxial subluxation** (most common manifestation of RA – may cause **sudden death**) – worsens with neck flexion – increased ADI; most important is PADI = posterior ADI (room for cord); indications for **C1-2 fusion**: **PADI ≤ 14 mm, ADI > 6-10 mm, symptomatic**
- Basilar impression** – needs **reduction with halo traction** (max 7 days) → **decompression** [C1, foramen magnum] and **occiput-C2 fusion**
  - N.B. if **unable to achieve reduction** (20% patients) – after fusion proceed with **transoral odontoidectomy** (patient must be able to open mouth > 25 mm to avoid splitting mandible for access)
- C1-2 pannus**: chronic inflammatory granulation tissue - often recedes after surgical fusion (TNF-α inhibitors expedite it)



### D. Subaxial subluxation

- indications for surgery: instability, myelopathy.
- preop 1 month “holiday” from gold medications (antimitotic → “zero” wound **healing**).
- rarely, **transoral approach** is used (if patient can open mouth to fit 2 fingers; if not – **endoscopic approach**).

N.B. keep in halo postop for 2-3 months

N.B. RA cervical pathology may cause VA or anterior spinal artery compression – do CTA preop!

- prognosis is very bad without surgery.  
Cervical instability is the most serious and **potentially lethal** manifestation of RA!

## PREOP OPTIMIZATION

- consider **prehabilitation** in high-risk patients
1. Cardiopulmonary consult, pulmonary function tests
  2. Diabetes control
  3. Malnutrition correction (serum testing, nutritionist consult for nutritional support)
  4. Obesity control (weight loss)
  5. Osteoporosis testing and treatment
  6. Anemia – Epogen, autologous blood donation, CellSaver, intraop TXA
  7. Smoking cessation
  8. Opioid use evaluation
  9. Immunomodulator use (risk of pseudoarthrosis – use **autograft**!)
  10. Assess frailty → TUG test → preoperative PT or “prehab”

**Timed Up and Go (TUG) test** – patient stands up from a sitting position, walks 10 feet, turns around, and walks back to chair, to sit down.

- perform the test as fast as possible; **≥18.4 sec (15-20 sec)** = frailty = **5-fold increased risk of high-grade complications**

CNS Systematic Review and Evidence-Based Guidelines for Perioperative Spine (2021)

**Grade B recommendation:** preoperative **HbA1c > 7.5 mg/dL** is associated with an increased risk of **reoperation** or **infection** after spine surgery.

**Insufficient evidence:** if **BMI** correlates with greater risk of **reoperation** or **infection** after spine surgery.

- number of studies demonstrating a correlation between a **BMI > 30** and **SSI**, particularly with **lumbar surgery**.

**SPORT** - surgery has a significantly greater benefit (over nonsurgical treatment) of degenerative spondylolisthesis in obese patients

**Grade B recommendation:** **Smoking** is associated with increased risk of **reoperation** (both for pseudoarthrosis and infection) in patients undergoing **spinal fusion**.

- **insufficient evidence** that **cessation of smoking** before surgery decreases risk.
  - nicotine-free for 6 wk before planned surgery - nicotine levels drawn on the morning of surgery - smoking is ground for the cancellation of elective cases.
  - **urine test** - positive cutoff:  
**Nicotine** 2 ng/mL  
**Cotinine** 5 ng/mL (< 100 ng/mL is used for surgery qualification)

**Grade B recommendation:** serum **albumin < 3.5 g/dL** or **prealbumin < 20 mg/dL** is associated with a higher rate of surgical site **infections** (SSIs), other **wound complications**, **nonunions**, hospital **readmissions**, and other **medical complications**.

- **multimodal nutrition management**

**Grade B recommendation:** one of tests - **DEXA scan** (**T-score  $\leq 2.5$** ), **CT** (**Hounsfield units < 97.9**), **serum vitamin D3 level (< 20 ng/mL)** - predicts increased risk of osteoporosis-related adverse events.

- **Grade B recommendation:** **treatment with TERIPARATIDE** (6 mos preop + 18 mos postop) increases **BMD**, induces earlier and more robust **fusion**, and may improve select patient **outcomes**.
- **Insufficient evidence** regarding preoperative treatment with **bisphosphonates alone**.

**Grade B recommendation:** any preoperative **opioid use** and **longer duration** of use are associated with chronic postoperative opioid use, higher **complications**, increased **length of stay**, higher **costs**, and **worse outcome\*** after spine surgery.

**Insufficient evidence\*\*** of efficacy of **opioid wean** before spine surgery.

**Refer to preop opioid weaning** - 29 MEA (morphine equianalgesic) mg/d = **oxycodone 10 mg TID**.

## INTRAOP

**Blood loss control** - intraoperative **Hb target  $\geq 10$  g/dL**.

- **FFP** is given after each 3 units of pRBC.
- **platelets** are given after every 5 units of pRBC for a goal 100 000/microliter.
- **cryoprecipitate** is administered for a goal concentration of fibrinogen > 100 mg/dL.
- **TXA** administration
- **CellSaver** ready.
- **pulse oximeter** on each big toe (for ALIF)
- preop blood **autodonation**

## COMPLICATIONS

### ESOPHAGEAL INJURY

– usually only big hole is visible; 60% cases present > 30 days after surgery (usually due to migrated hardware); mortality 20% if noticed within 24 hours of surgery (otherwise, mortality nearly 50%)

Risk of lethal mediastinitis!

- area of the esophagus most vulnerable to injury, known as **Killian's Triangle** - **anterior to C5-C6 disc** - posterior esophageal mucosa **lacks muscle protection** (only thin buccopharyngeal fascia separates the esophagus from retroesophageal space).
- dysphagia and odynophagia, followed by fever and cervical edema, unexplained tachycardia, wound drainage + WBC, ESR, CRP  
N.B. wound infection after ACDF is esophageal perforation until proven otherwise!
  - coughing up food = tracheo-esophageal fistula
  - classic triad of vomiting, chest pain, and subcutaneous emphysema (**Mackler's triad**) is seen in only 25% of cases.
- diagnosis:
  - 1) **for C1-5 - ENT eval with endoscopy**; **for below C5 - contrast esophagogram** (water soluble such as Gastrografin)
  - 2) **CT with contrast** (free air, abscess)
  - 3) if patient still has a drain – **swallow dye** (e.g. methylene blue) → watch if dye shows up in the drain.

N.B. imaging and endoscopy can have a false-negative rate of 10-46% - if there is high clinical suspicion, patient should be taken back to OR immediately for exploration, preferably with ENT.

- treatment:
  - a) **conservative management** - indicated in asymptomatic young patients with lesions smaller than 1 cm.
 

Small leaks + no esophageal obstruction may close spontaneously with good nutrition; for Boards – need operative exploration
  - b) **surgical treatment** – for infection, fistula, or pseudocyst:
    - *remove all anterior hardware* (replace with iliac autograft → staged posterior supplementation)
    - *primary repair by ENT over bougie* (in delayed-presentation cases, defect is larger – add reinforcement with pedicled muscle – rotate **SCM, sternohyoid, pectoralis major flap** or free omentum – work as a bolster between repair and cervical hardware, helps deliver abx).
    - *PEG + NPO*
    - *broad-spectrum abx*

#### By time of presentation

- A. **Noticed intraoperatively:** *primarily repair* with interrupted resorbable inverted sutures in a two layers; for anything more than super small injury, reinforce with *muscle flap* (layer between fresh suture line and bone graft - sternal head of sternocleidomastoid muscle reflected and sutured to contralateral paravertebral muscles), *drain* → *antibiotics* and *NG tube* → *esophagram* around day 7 - if normal oral feeding may be started.
- B. **Noticed postoperatively:** same as above but *wound may be left open* and consideration should be given to *remove spinal implants*

### POST-OP C5 PALSY

- new weakness (loss of strength by  $\geq 1$  grade) of **deltoid** and/or **biceps** **within 6 weeks of surgery** (most occur  $< 1$  week post-op).
- incidence:  $\approx 3-5\%$  of *extensive anterior or posterior decompression* (including laminoplasty).
- prevention: no effective preventative measures have been identified (in a series of 52 cases none had IONM changes during surgery).
- prognosis: chances of *spontaneous recovery* are generally good (most recover in 2 years) → expectant management: PT/OT to avoid contractures, perform EMG (serially) – if *no reinnervation* or developing *contractures*:
  - a) **nerve transfers** (work better in younger patients):
    - 1) spinal accessory nerve → suprascapular
    - 2) radial nerve (triceps branch) → axillary
    - 3) 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> intercostal nerves → musculocutaneous

OR

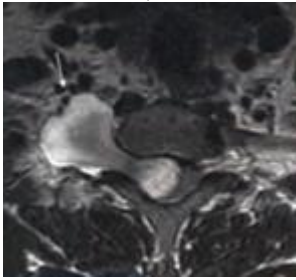
ulnar nerve (fascicle to flexor carpi ulnaris) (**Oberlin**) → musculocutaneous
  - b) **tendon transfers**
  - c) **joint fusion:** place arm in a more functional position than dangling limply at the side

### CAROTID INJURY

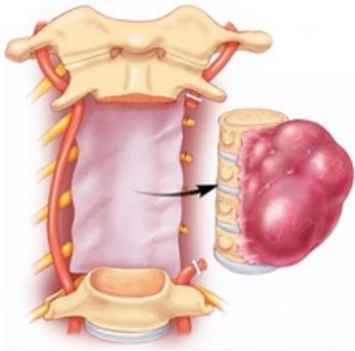
- controlled with direct pressure.
- carotid artery may be shunted or temporarily clamped while a primary or patch repair is performed.

## VERTEBRAL ARTERY

- 1) tumors with paraspinal extension (esp. **malignant** tumors – may leave thin cuff of tissue around VA)

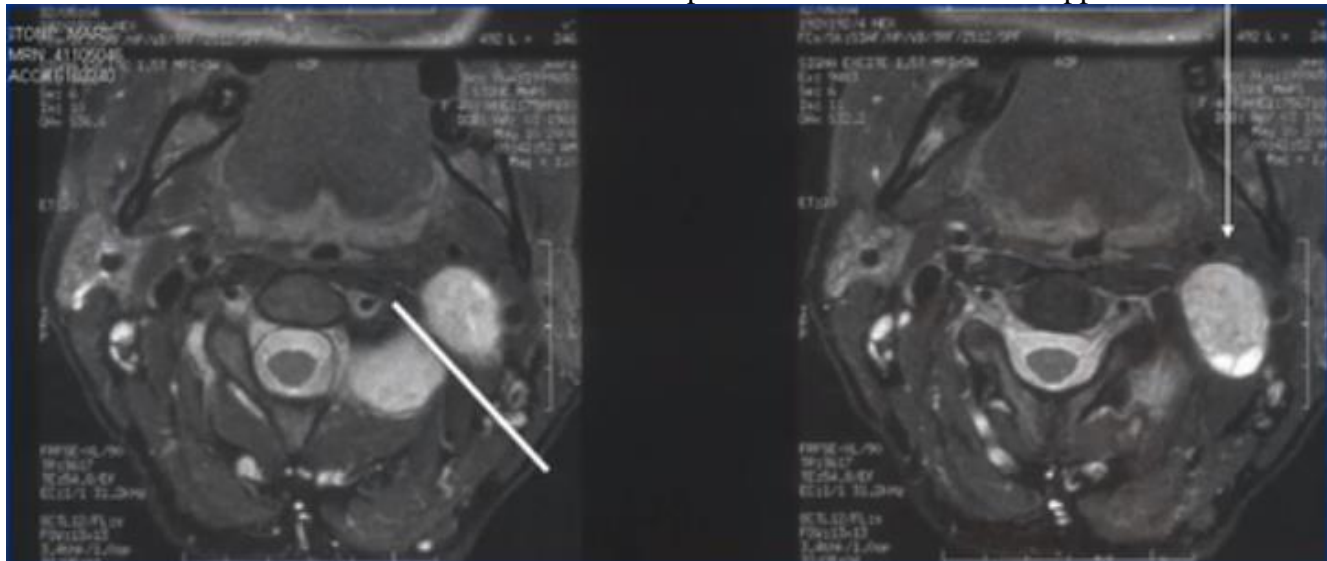


- 2) en bloc cervical resections:



**Tumor extends laterally to VA** along ansa cervicalis – approach in 2 stages

- transect tumor at the VA level - leave anterior tumor portion for anterior cervical approach:



## AVOIDANCE

- study MRI / CT carefully before surgery – see which VA is dominant, where VA is displaced
- consider VA occlusion test preop.
- intraop Doppler, microscope

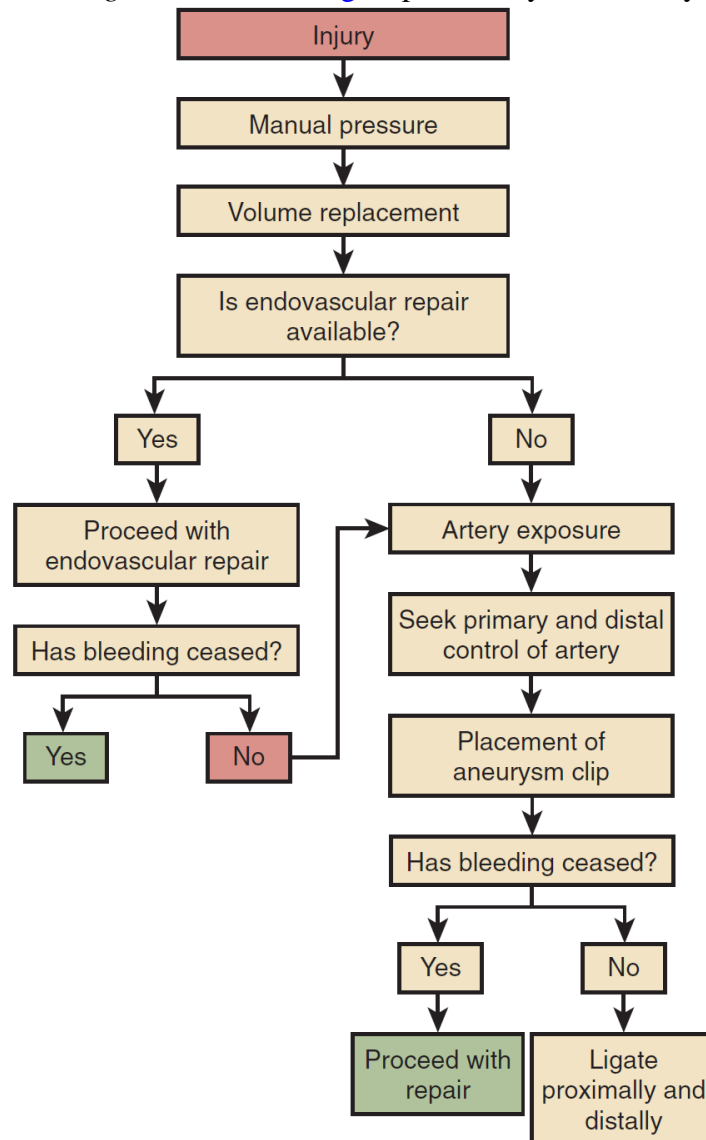
## PLAN OF ACTION

- (1) Achieve **control of hemorrhage**.
- (2) Prevent **acute central nervous system ischemia** (lateral medullary (Wallenberg) syndrome, quadriparesis)
  - **majority of patients do not get strokes** so calm down, on the other hand it **may be fatal**.
- (3) Prevent **postoperative complications** such as embolism and pseudoaneurysm

Bleeding control:

- **control bleeding with manual pressure and local hemostatic agents**: let it bleed and find out where exactly injury is, then control bleeding with cottonoid - keep suction tip over cottonoid over injured artery part (use larger pieces of hemostatic agents so it does not embolize).
- aggressive **fluid and blood resuscitation** communicated to the anesthesia team.
- let NIR team know.
- ensure **head is in a neutral position** (cervical extension and axial rotation can lead to occlusion of the contralateral vertebral artery).

If bleeding continues, aim for **endovascular repair**; if endovascular repair fails / unavailable → expose artery → **proximal and distal control** with temporary aneurysm clips – if bleeding stopped then **repair** artery, if bleeding continues then **ligate** proximally and distally

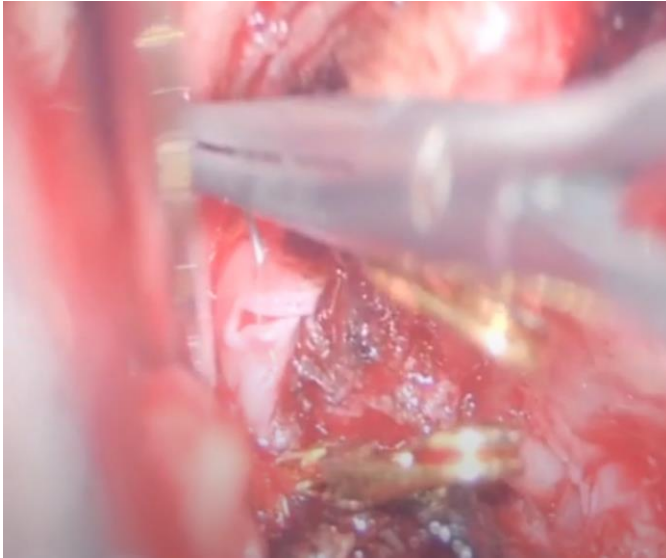
A. Tamponading

- patch of **Surgicel** - place over injury; ideally, may add muscle plug / Gelfoam over Surgicel.  
On Boards – if cord is exposed, protect cord during packing (pack laterally)
- if injury inside bone (e.g. pons/posterior) – place **bone wax**.
- if injury during screw placement, place **shorter screw** (do not want to see screw in the artery on postop CTA) to tamponade and **do not place screw on opposite side** (use alternative technique, e.g. sublamina wiring)
- keep working and do not check injury site; at the end, lift cottonoid off, may encase the whole area with **bioglue**.



**B. Repairing**

- if available, consider **endovascular covered stent** (→ dual antiplatelet).
- expose artery through foramen transversarium one level above and below injury with diamond drill bit.
- dissect with nerve hook proximally and distally → apply proximal and distal temporary aneurysm clips (or vessel loops).
- repair defect with interrupted 7-0 to 9-0 Prolene:

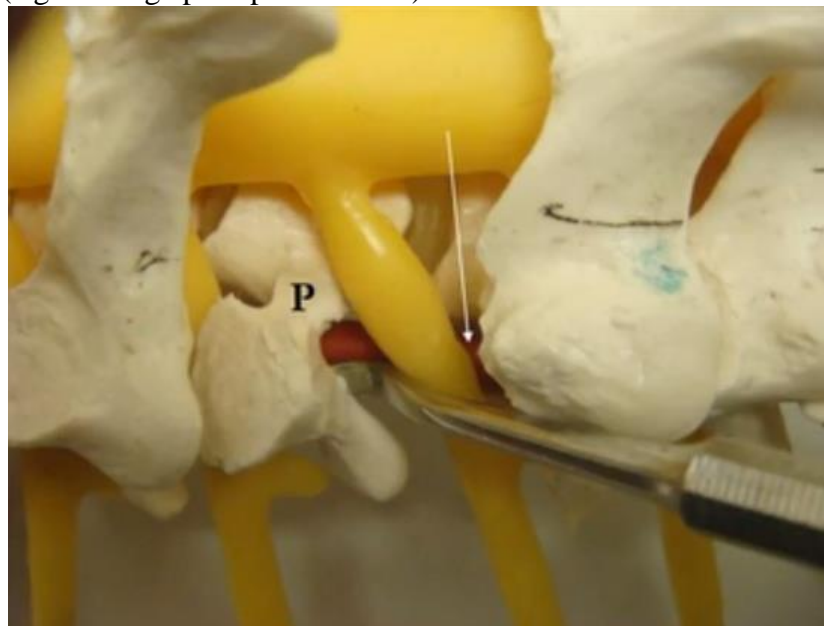


- prior to completion of the repair, temporary clips should be removed to prevent **air embolism** or the **propagation of other emboli**!

**C. Sacrifice** – ligation\* only if good retrograde flow (and monitoring shows no drop of signals)  
\*or endovascular coiling for pseudoaneurysm.

**D. Bypass** - if vessel cannot be repaired + poor retrograde flow.

Posterior localization (e.g. for large paraspinal lesions):



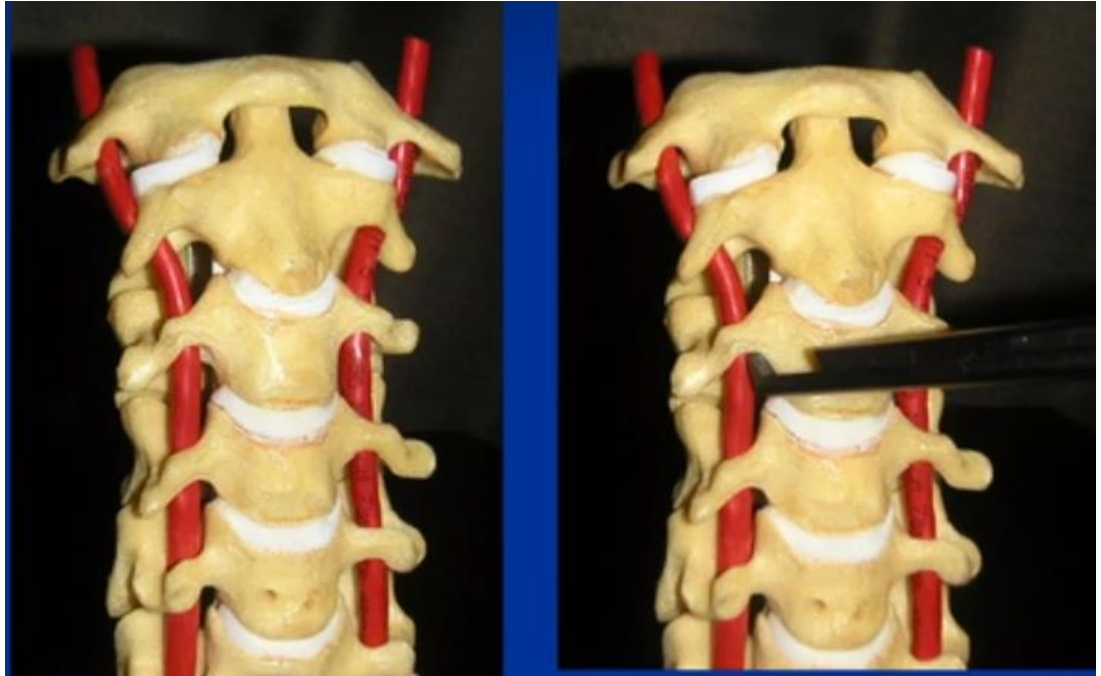
- full width foraminotomy → identify nerve and follow laterally (artery is anterior to nerve and more medial than most surgeons think – it is right at the lateral edge of vertebral body).
- resect pedicle (P) if needed.
- encounter robust venous plexus (easy hemostasis with injectable foam).



- for **V3 exposure at exit of C2 transverse foramen**, need to transect C2 nerve (**preganglionic cut** – to avoid neuropathic pain!!!) – VA is in front of ganglion.

Anterior localization (e.g. for spondylectomy lateral mobilization)

- mobilize **longus colli** up and down over many levels to mobilize muscle laterally (do not cut muscle transversely – risk of Horner's syndrome)
- go with curette laterally at upper level of vertebral body – to encounter transverse process.
- VA is directly under transverse process
- remove transverse process with Kerrison:



#### POSTOP

- go to **angiography** – VA open, occluded, dissection.
- start **ASPIRIN** at 6 hrs postop.
- **CTA** before patient discharge – look for: **pseudoaneurysm, AV fistula**

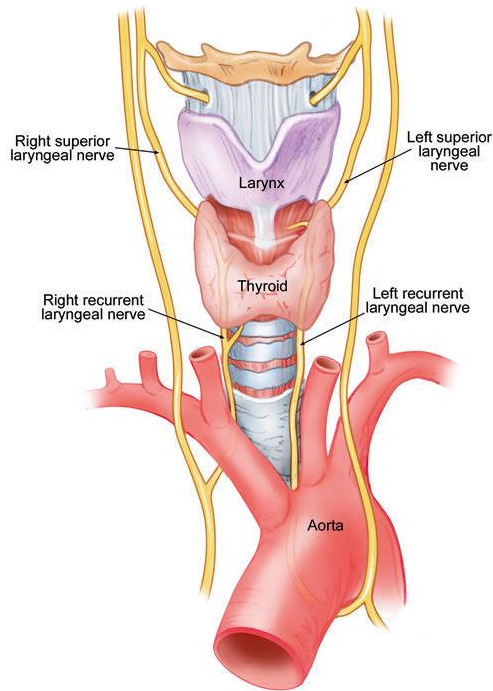
### LARYNGEAL NERVE injury

#### SUPERIOR LARYNGEAL NERVE

- innervates **cricothyroid muscle**.
- **superior thyroid artery**, encountered above C4, is an important anatomic landmark for the superior laryngeal nerve.
- damage to this nerve - **hoarseness, easy voice fatigue**.

#### INFERIOR (RECURRENT) LARYNGEAL NERVE

*n. laryngeus recurrent injury* due to traction ( $\approx 2.4-3\%$ ), esp. during reoperations;  
N.B. **minor hoarseness is common** (50%) after anterior cervical surgeries!



### Anatomy

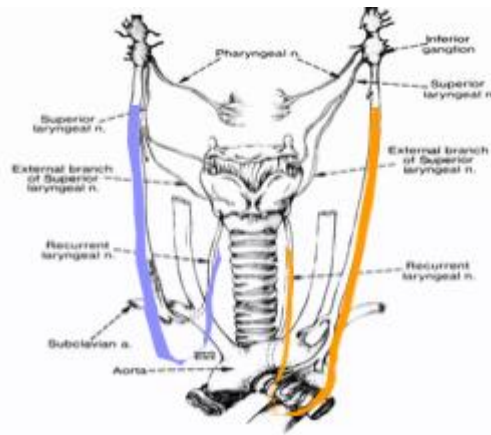
- on left side, RLN loops under the arch of the aorta and is protected in the left tracheoesophageal groove.
- on right side, however, RLN travels around the subclavian artery, **passing dorsomedially** to the side of the trachea and esophagus - vulnerable as it passes from subclavian artery to the right tracheoesophageal groove.
  - right **inferior thyroid artery** is an anatomic marker for the RLN (nerve usually enters the tracheoesophageal groove, the point at which the inferior thyroid artery enters the lower pole of the thyroid).
  - anatomic variant (< 1%) where right RLN is **nonrecurrent** - travels directly from vagus nerve and carotid sheath to the larynx; if nonrecurrent nerve is encountered, it may be identified with a nerve stimulator and laryngoscopic examination of the vocal cords; if it cannot be retracted safely, it is best to **abandon the procedure and use a left-sided approach!**

### Clinical

- hoarseness, vocal breathiness or fatigue, weak cough, dysphagia, or aspiration.

### Prophylaxis

- use nasogastric tube - allows easier identification of esophagus for protection, also allows localization of tracheoesophageal groove
- deflate ET cuff after placing retractor blades (decreased the rate of RLN temporary paralysis from 6.4% to 1.7% in one series)
- before performing **reoperation on opposite side**, preoperative direct laryngoscopy should be performed to identify existing occult vocal cord paralysis.
  - N.B. bilateral recurrent laryngeal nerve dysfunction will result in airway occlusion once patient is extubated!
- do not use Bovie below C6.
- in the past, left-sided approach was preferred (esp. for lower levels) due to more unpredictable and oblique course of right nerve; however, later anatomic studies have refuted this variation, and clinical studies have demonstrated that the **choice of operative side had no effect on the incidence of RLN palsy!**



### Diagnosis

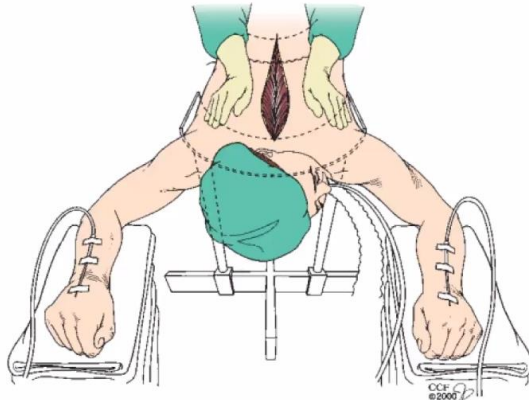
- many patients have some degree of voice change after ventral cervical operations, a thorough investigation is not required in most cases.
- persistent hoarseness → **laryngoscopic examination** (vocal cord fixed in paramedian position).

### Treatment

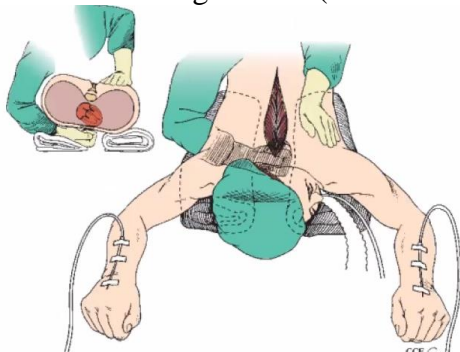
- **immediate treatment is not usually required** for a paralyzed vocal cord because, in most instances, the nerve has not been severed, and the condition will resolve with time.
- persistent hoarseness after several months can be treated with **injections** into vocal cord:
  - 1) **hemostatic gelatin (Gelfoam)** - temporary improvement and may be used as an interim measure pending spontaneous return of function.
  - 2) **Teflon** - permanent treatment if no recovery is expected.

## CARDIAC ARREST (INTRAOP, PRONE)

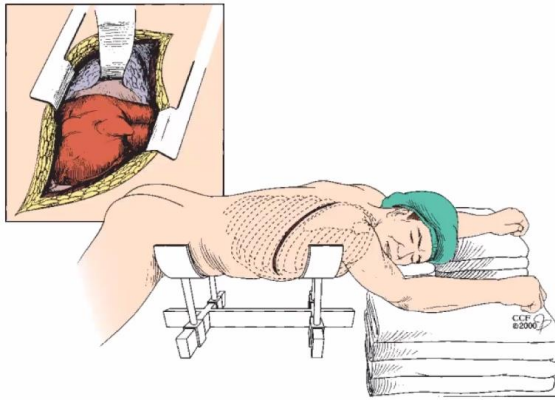
- cover widely with **large Ioban** → **roll supine**.
- when flipping the patient is not feasible – do chest compressions (chest support – sternal bar of Jackson table) – both hands over scapulae:



- if sternal support is not present, surgeon clenches fist and places it under chest over lower 3<sup>rd</sup> of sternum and massages chest (better if assistant does that):



- if unsuccessful – consider prone thoracotomy (cut between ribs) → cardiac massage:



### UNABLE TO VENTILATE IN PRONE POSITION

- never roll bed away after flipping prone until anesthesiologist confirms bilateral breath sounds.
- **Axis table** is the worst (consider **longitudinal gel rolls**).
- quickly close incision (e.g. cover widely with **large Ioban**) → **roll supine** on the bed

### ISCHEMIC OPTIC NEUROPATHY (ION)

**Spine surgery** remains one of the **largest sources of acute perioperative visual loss!**

- two forms:
  - a) anterior (AION) - optic disc
  - b) posterior (PION) (58-83%) - optic nerve.
- risk factors - higher blood loss, prone surgery, longer operative time, hypotension.
- bilateral (75%).
- **only 30% patients demonstrate improvement**
- management:
  - 1) urgent **ophthalmologic examination** - cause of vision loss.
  - 2) **test pupillary reflex** - absence implicates injury of the optic nerve or globe, while presence - cortical blindness from either stroke or posterior reversible encephalopathy syndrome (PRES).
- prophylaxis:
  - stage the surgery to reduce the duration.
  - avoiding prolonged periods of hypotension.
  - soft headrests or Mayfield.
  - regular eye checks.

### INFECTION

- if in doubt and skin is intact (infection vs hematoma vs seroma vs CSF) – do MRI w/wo, aspirate fluid for analysis.
- infection in the presence of hardware:
  - **stainless steel** (typically, old fusion hardware) - needs to be removed as it creates biofilm (vs. **titanium**)
  - **index surgery long time ago** (do CT to verify fusion) – remove hardware
  - fresh surgery:
    - a) Gr+ cocci – washout, leave hardware
    - b) **Gr- rods** – will likely need multiple washouts, even temporary hardware removal (keep patient on bed rest)
- **retention sutures** (esp. in obese patients).
- “Aquacel Ag” **dressing**.

- **antibiotics** for  $\geq 6$  weeks (ESR and CRP need to normalize).  
N.B. do not start perioperative antibiotics and do not irrigate with bacitracin **until cultures are sent!**  
- sometimes, if hardware present, needs lifelong suppression with **RIFAMPIN**.
- keep **drains** on suction until output = 0
- if infection recurs – consider **woundVAC** placement → delayed closure with plastic surgery.

### OSTEODISCITIS, OSTEOMYELITIS

Infection likes stability – consider fusion!

- **destroyed endplates** – place **large footprint TLIF** graft or 2-level **corpectomy** through lateral approach (may need vascular surgeon for approach due to chronic infection) → supplement with posterior fusion.

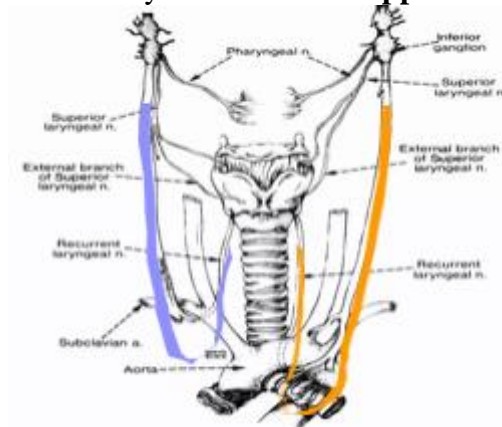
### ACDF

**BMP** is contraindicated in neck anteriorly!

Patients whose careers prohibit any **risk for voice alterations** may best be treated with **posterior** foraminotomies or laminectomies (**left-sided approach** has lower risk of recurrent laryngeal injury).

Hx of neck XRT – ask ENT help for approach!

- check **vocal cords** if going to operate on someone who had anterior neck surgery on opposite side; alternative – use **vocal cord EMG** (commercially available ET tube with mounted electrodes).
- some always use **left-sided approach** - lower chances of recurrent laryngeal nerve injury:



- **trauma cases**, try to use “carotid” skin incision (transverse incision may interfere with tracheostomy if patient will need one).
- hyoid bone – C3
- C4-5—top of thyroid cartilage.
- C5-6—bottom of thyroid cartilage.
- 3.5 mm **diameter**; larger for rescue screws; **screw length** (mostly **12-14 [women]** and **14-16 [men]** mm)
- variable screw allows load-sharing with interbody graft: **Wolff's law** - weight sharing helps stimulate fusion

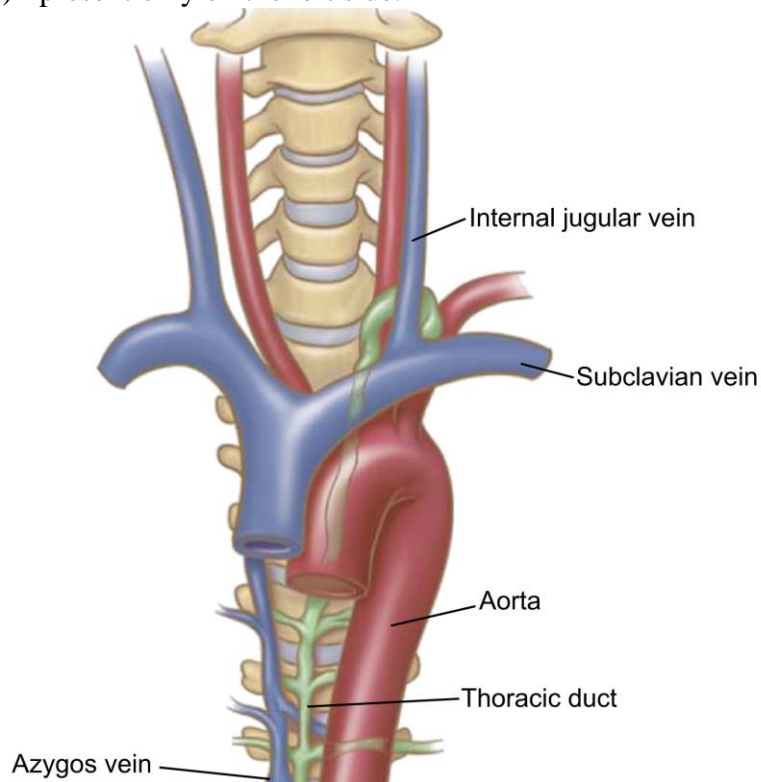
### Zero-profile

- may be implanted adjacent to prior fusion
- mechanically inferior to conventional plates (zero-P was invented when BMP was still used for ACDFs).

1) **esophageal injury**— see above



- 2) injury to **sympathetic chain** → Horner syndrome. H: do not dissect lateral to longus colli muscles and elevate muscle subperiosteally, do not overdistract.
- 3) **vertebral artery injury** – study MRI / CT carefully (VA medial to pedicle is a contraindication for anterior discectomy)
- 4) 2.6% have a **retropharyngeal carotid** - use opposite anterior side or a posterior approach.
- 5) **thoracic duct** (chylothorax) - present only on the left side.



#### Risk factors for pseudoarthrosis

1. Multilevel fusions
2. Steroid medication
3. Immunomodulator use
4. Noncompliance with postoperative immobilization
5. Allograft
6. Older age
7. Smoking

Diagnosis: dynamic XR, CT, SPECT (increased focal uptake)

Prophylaxis - External stimulator with Pulsed Electromagnetic Field

#### Treatment

- A) PCF (esp. for long-segment nonunions) – best solution
- B) ACDF with autografting

## CORPECTOMY

- if bone is good quality, no risk factors, then **2-level corpectomy** may not need **posterior stabilization** – but it is risky!!!; corpectomies > 2 levels need PCF.
- **aberrant vertebral artery**\* is relative contraindication.
  - \*i.e. aberrant VA passing medial to the pedicle precludes corpectomy at that level.
- width of corpectomy **should not exceed 15 mm** to avoid vascular injury (classically, distance between vertebral arteries is 20 mm) and allow lateral walls to help with bony fusion.
- average **interforaminal distance (VA) increases from C3 to C6** - wider decompression is safer at the more caudal levels - properly performed multilevel corpectomies usually result in a **trapezoidal-shaped decompression**.



- **chin on chest deformity** is CI (best treated with cervicothoracic fusion and T1 osteotomy)

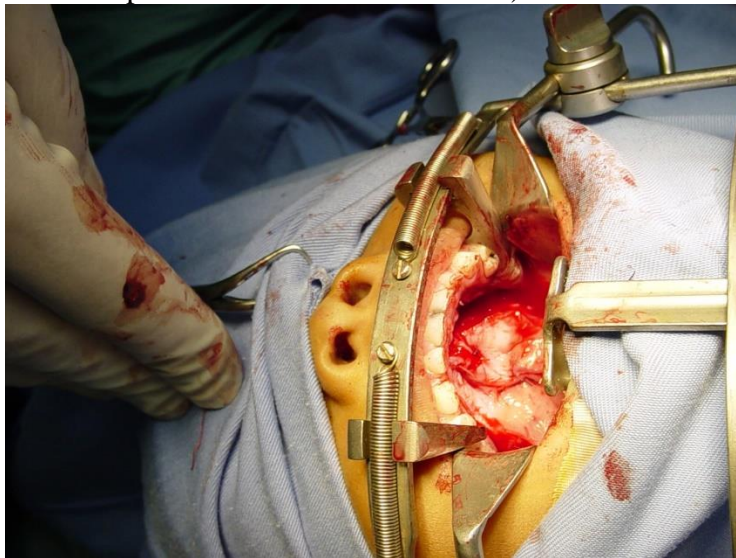
### CAGE

- A. **Titanium** mesh
- B. **Stackable PEEK** cage – gives more lordosis and is more elastic than titanium cage.
- C. **Methyl methacrylate** – as a preshaped block or inside Silastic tubing (e.g. thoracic drain) - used in oncology patients with a limited life expectancy (< 6-12 months) as this construct is less expensive, resists tumor destruction, and loses its compressive support after 1 year.
- D. **Expandable cage**
- E. **Bone** - better fusion but more frequent dislocation + donor site morbidity.

## TRANSORAL ODONTOIDECTOMY

**Very morbid operation** – check if posterior decompression is not better alternative (degenerative retrodental pannus involutes after stabilization)

- **epidural retrodental pannus causing cord compression** - first thought might be to decompress posteriorly (at least as first stage) – error! – cord gets even more deformed and patient deteriorates! H: always decompress from compressing side! vs use reduction first with halo traction
- add dorsal arthrodesis (e.g. occipito-C3 fusion)
- antibiotics should cover mouth flora (e.g. **CLINDAMYCIN**)
- **Dingman** retractor (release tongue pressure as often as you can – reduces tongue swelling but still typically need to keep intubated for 24 hrs or more)

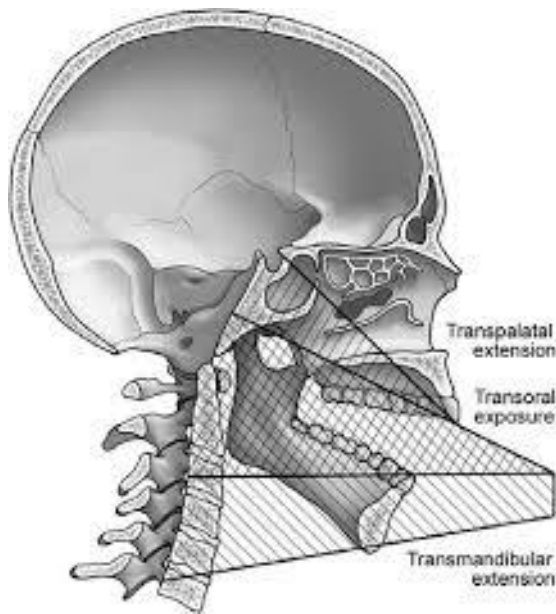


- advance Foley catheter through each nostril into oral cavity and then grab and secure tight both ends with hemostat – retracts soft palate
- linear vertical incision in pharyngeal mucosa.
- C1 ring is removed with high-speed bur (e.g. M8)
- odontoid is removed using combination of electric drills and hand tools; at lateral margin of exposure - avoid injury to hypoglossal nerves, vertebral arteries, and carotid arteries
- keep NPO for 7 days (to protect mucosa healing).

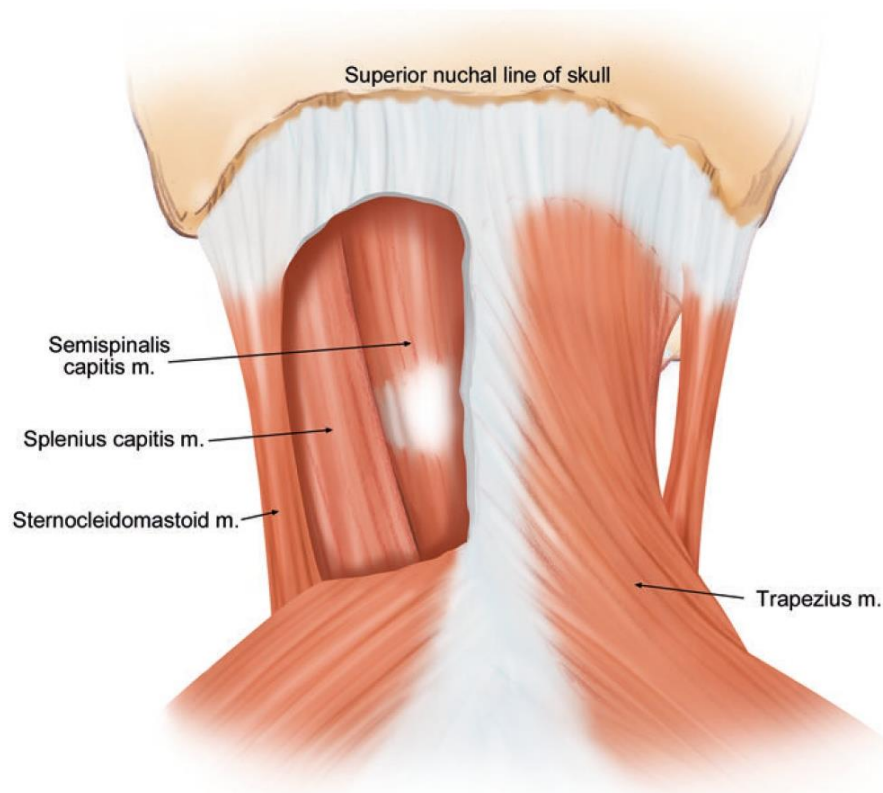
### CONTRAINDICATIONS

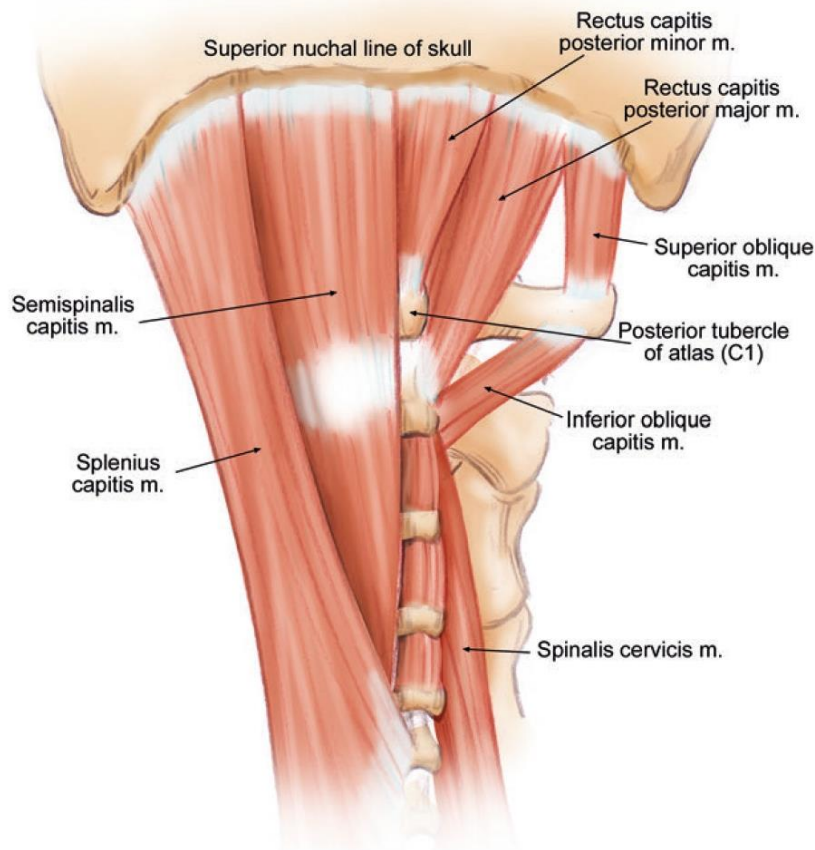
1. **Vascular aberrations** - "kissing carotids", single median vertebral artery
  2. **Intradural** lesions - better approached from a lateral approach
  3. **Low-riding hard palate** - requires a more extensive approach (e.g. palate split)
- hard palate dictates rostral access (superior border and extent of exposure and resection); if visualization is inadequate:

- a) soft palate split
- b) mandibular split - preoperative *tracheostomy*
- c) endonasal approach (independently or combined) for compression above hard palate



## POSTERIOR CERVICAL SPINE





- **suboccipital triangle** consists of inferior oblique muscle (inferiorly), the superior oblique (laterally), and the rectus major muscle (superiorly).
  - **suboccipital nerve** and **vertebral artery** pass through suboccipital triangle.

## LAMINECTOMY

- C3–6 laminectomy is often considered a “**standard**” laminectomy; “**extended**” laminectomy includes C7 and/or C2.
- CLAM is contraindicated in the kyphotic spine (loss of cervical lordosis)
- delayed formation of **postlaminectomy membranes** → recompression of the spinal cord dorsally.

To avoid significant destabilization of cervical spine (→ kyphosis):

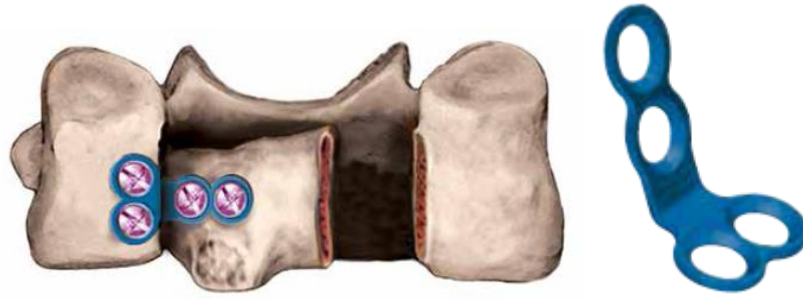
- do not remove **soft tissue overlying facet joints** (to preserve their blood supply)
- laminectomy only **as far lateral** as the extent of spinal canal, carefully preserving facet joints (use keyhole laminotomies where necessary)
- avoid removing a **total of one facet** at any given level.

## LAMINOPLASTY

– preserves posterior tension band but still 40% patients need fusion; more suitable for young patients with oncologic indications

N.B. to qualify for laminoplasty, *patient needs to have lordosis*

- **complete (bicortical) longitudinal troughs** are drilled on laminae on one side; if one **side has more stenosis or is more symptomatic**, this is the side on which we perform the opening.
- **partial depth (unicortical) V-shaped longitudinal troughs** are drilled on the laminae with a matchstick drill bit on the other side.
- laminae-spinous process complex is **hinged**.
  - sometimes must resect ligamentum flavum to open the door.
  - if **hinge side is fractured**, - **trough plate** can be placed across fracture line:



- laminae-spinous process complex is **fixed** in new position with OD plates laid on posterior surface of facets and lateral edge of laminae

Examples of grafts (optional):

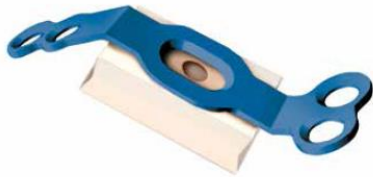


Figure 15a

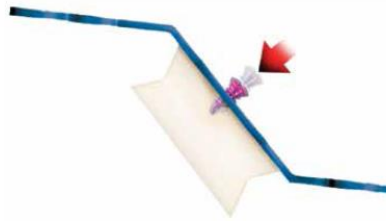


Figure 15b

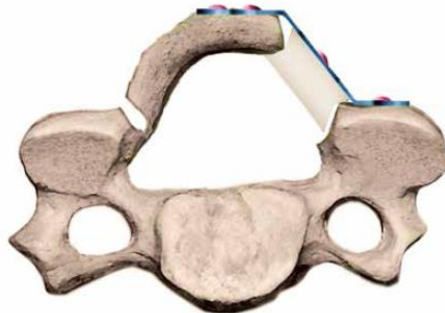


Figure 16

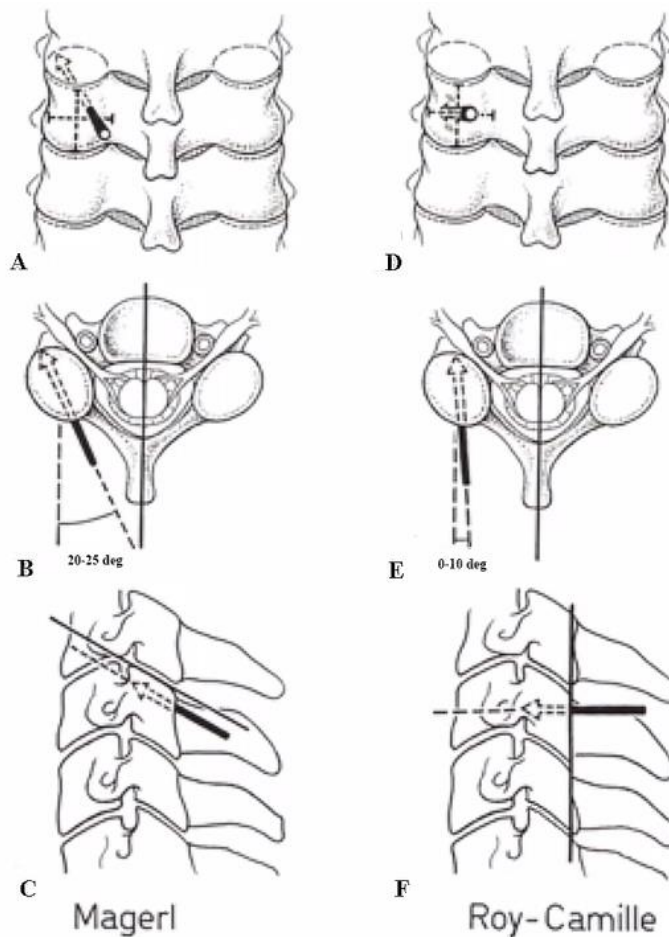
## PCF

Crossing cervicothoracic junction (CTJ) is recommended in smokers and osteoporosis (and others with increased risk of pseudoarthrosis); not recommended in frail patients

T1 may be the optimal end level when taking revision rate, procedure duration, and EBL into consideration

- largest lateral mass – C3; smallest – C7.
- **C7** lateral mass is rather small and at steep angle; options:
  - a) use C7 **pedicle screw** (screw head may or may not collide with C6 screw head so may need to skip C6)
  - b) C7 fixation is **skipped** to facilitate screw fixation into T1.
  - c) C7 lateral mass screw is placed using the “**down and out**” technique
- **screws** are 3.5 mm diameter, 14-16 mm length.
- **rods** are 3.0-3.5 mm diameter.
- starting points for the (a) Magerl and (b) Roy-Camille lateral mass screw:



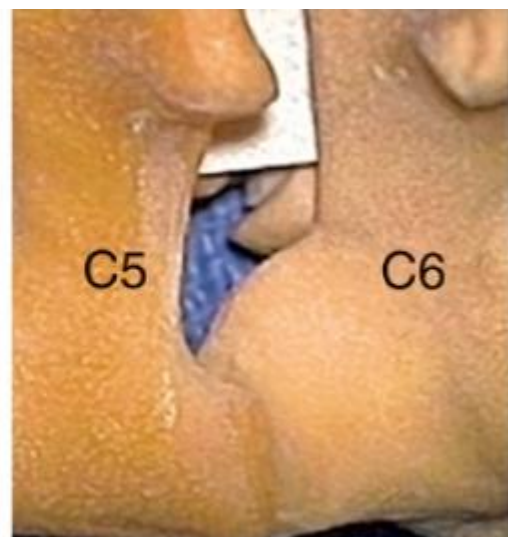
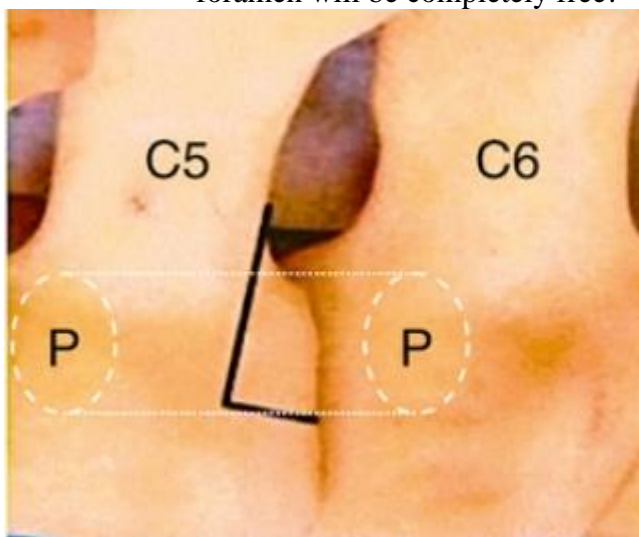


- if vertebral artery is encountered, place bone wax in hole → insert shorter salvage screw for tamponade, avoid placement of screws on contralateral side (alternative methods of fixation should be pursued if necessary, such as laminar screws).

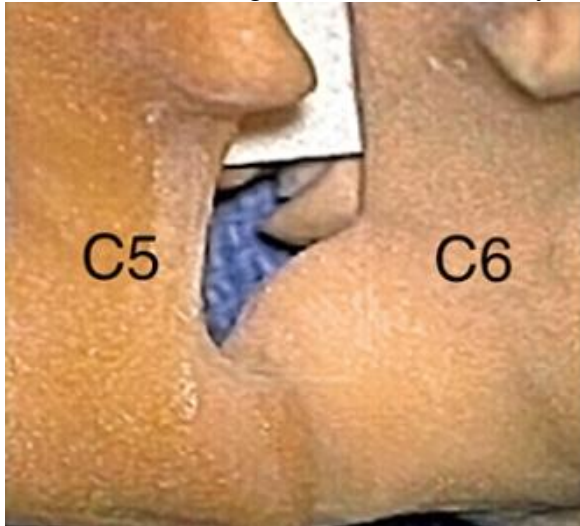
## POSTERIOR FORAMINOTOMY

- in personal observance, *high risk of nerve damage* – use **intraop free-running EMG**.
- maximum reverse Trendelenburg position (minimizes venous bleeding)
- **inferior articular process of superior vertebra is burred away in L-shaped resection** (resect 50% of distance between interlaminar V and lateral margin of facet – this is where lateral margin of pedicle is\*), leaving superior articular process of inferior vertebra:

\*foramen is bound by pedicles; if one performs decompression lateral to pedicle, foramen will be completely free!



- any bone that is overlying C6 pedicle is then removed with 1 mm Kerrison (careful – don't lever Kerrison heel against nerve root – may easily permanently damage it):



- resecting 50% of cervical facet does not typically require fusion or stabilization.

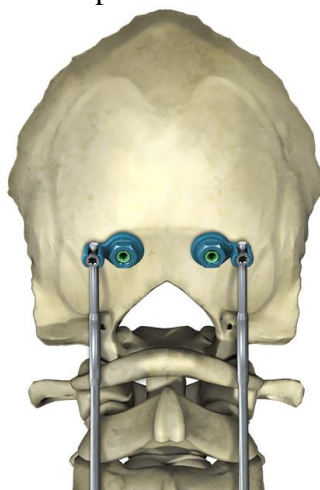
### Discectomy

- find nerve root axilla – reach for disc there; may need to bipolarize veins there.
- nerve root can be gently retracted superiorly and disc material removed with reverse angle curette.

## OCCIPITOCERVICAL FUSION

- instrumentations along junctions (occ-C, C-T) tend to break rods - some people place 3 or even 5 rods.
- always put crosslink at C1-2 level.
- if using **structural graft**, it should be fashioned so that there is solid contact with skull\*, C1, and C2 - by cutting an oblique angle into the graft and drilling a trough into the suboccipital bone into which graft is wedged.

\*for this reason some experts do not like occipital plates as they cover large area of skull that could be used for fusion; they rather use occipital buttons and iliac autograft:



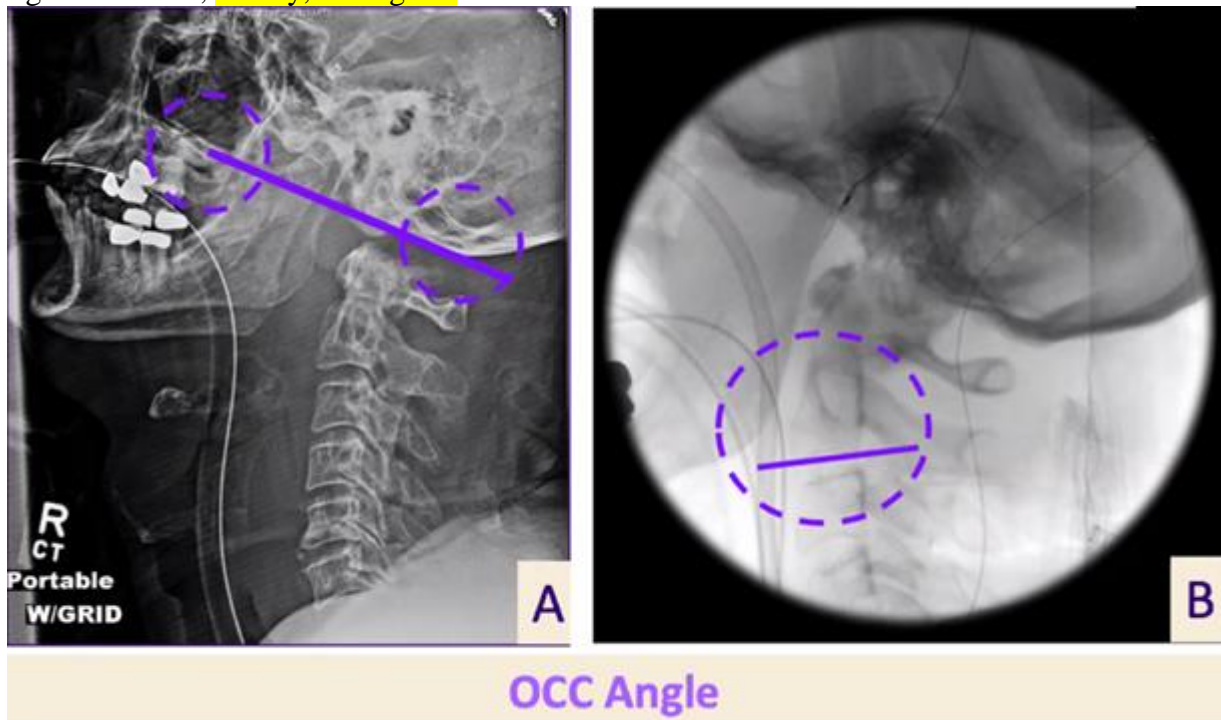
### PATIENT POSITIONING

N.B. take **lateral XR preop with patient standing in neutral position** – note the angle between C-spine and cranium – use same angle when positioned on the table; too much flexion – unable to swallow food!



## Occipito-cervical angle (OCCa) s. occipito-C2 angle (OC2A)

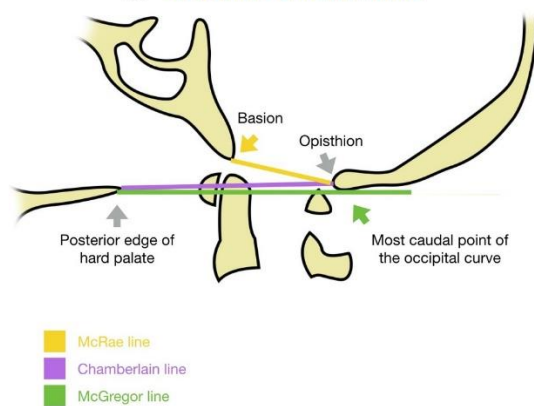
- gold standard; ideally, 14 degrees



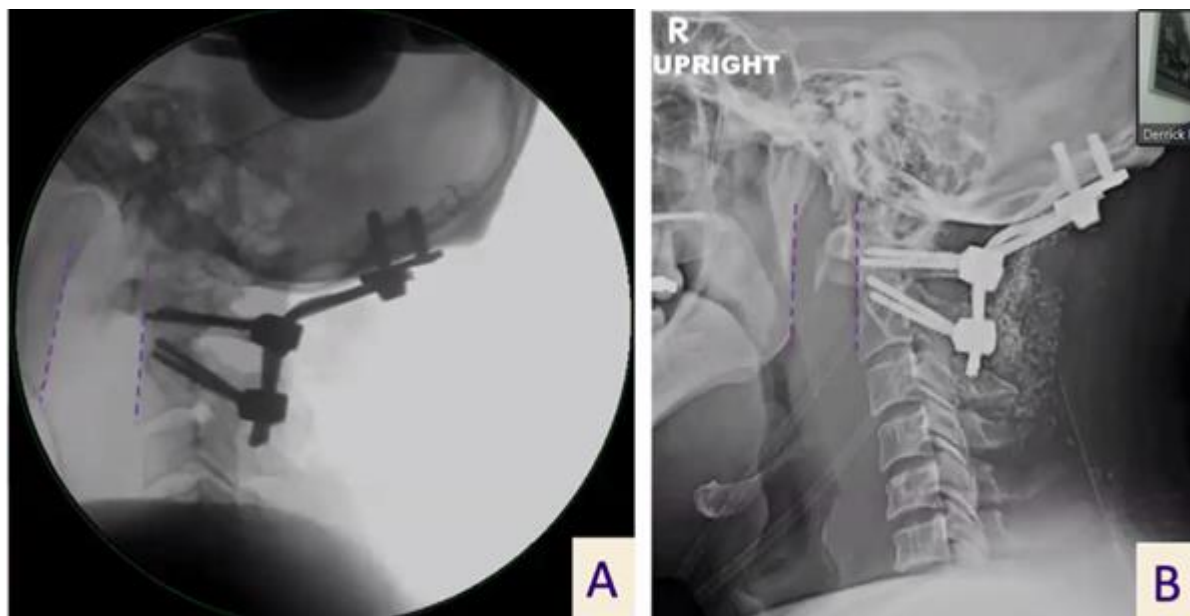
The OCC angle is measured between the McGregor line (A) and a line parallel to the inferior endplate of C2 (B).

## McRae line , McGregor line

& Chamberlain line



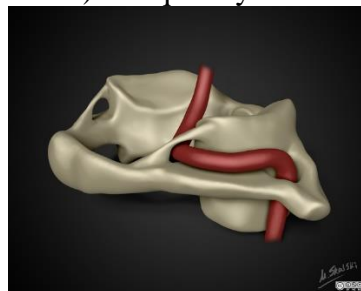
**C2-Mandible angle** – lines have to be almost parallel:



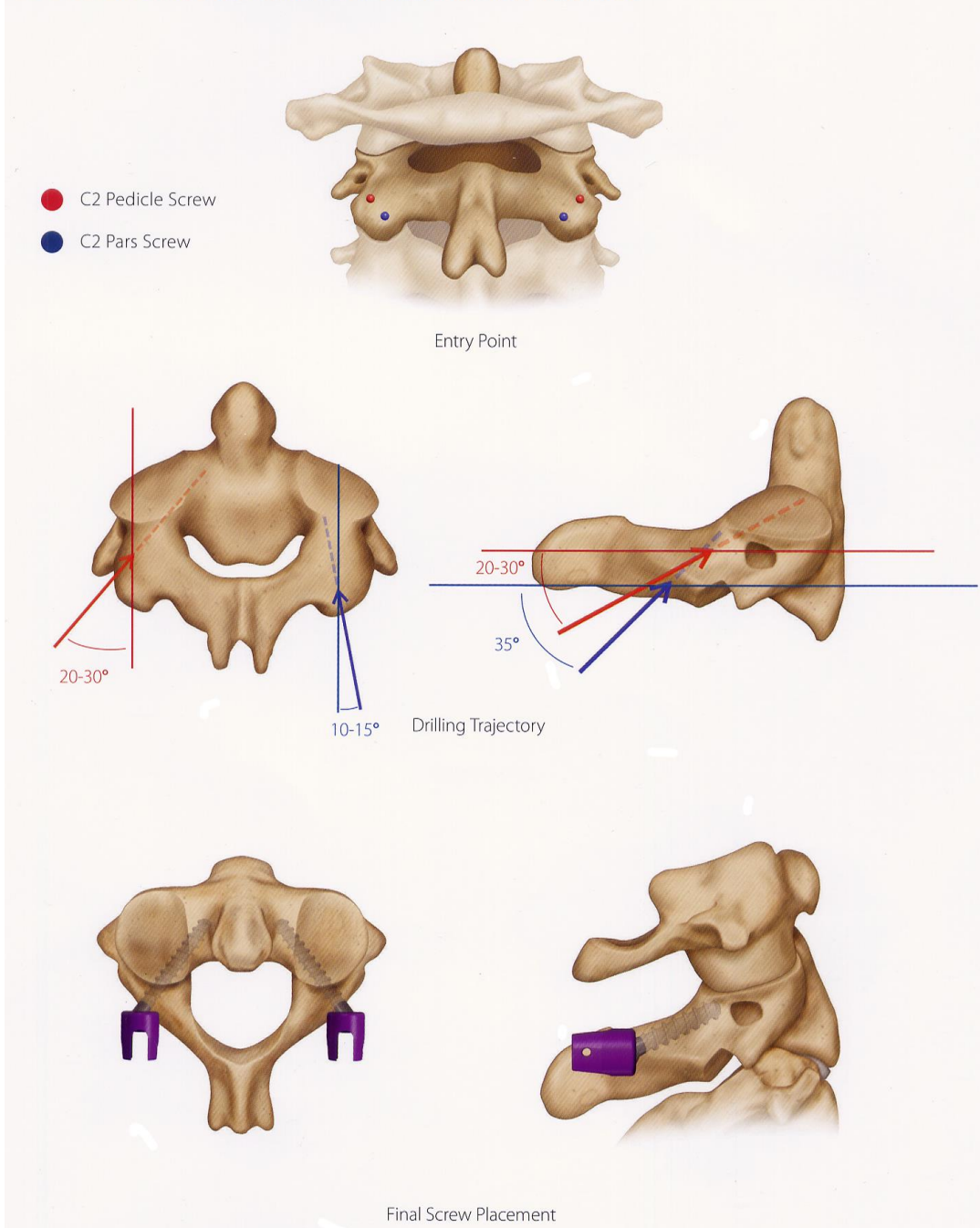
### C2-Mandible Angle

**Fig 2:** The C2 M angle is defined as the angle measured between a line parallel to the anterior C2-body/dens complex and a line parallel to the posterior mandible line of the mandibular ramus.

- to reduce risk of vertebral artery injury, **electrocautery is not used more than 15 mm lateral to midline** when performing subperiosteal dissection on C1.
  - retract C2 root with DRG caudally (if need to sacrifice\* → occipital anesthesia)  
\*cut preganglionically – avoid burning deafferentation pain
  - **trajectory:** drill bit should be angled slightly convergent (5-10° medial), directing tip of the drill bit toward the caudal half of the anterior tubercle of C1 (check CTA for kissing retropharyngeal ICA).
- N.B. C1 needs **bicortical purchase!** (vs. C2; although Nader recommends bicortical for C2 as well)
- **arcuate foramen** (**ponticulus posticus**) - frequently encountered normal variant of atlas:



## C2 Pedicle and Pars Interarticularis Screw Fixation



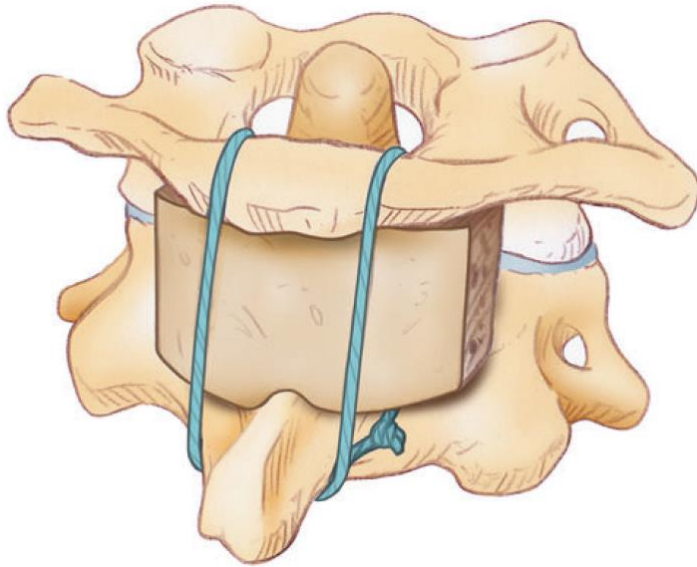
**N.B. always can place C2 pars screws but not always pedicle screws!**

### CABLE

Biomechanics – fixation is only semirigid - **does not counter rotatory or translatory movements** – rarely used stand-alone

- meticulous dissection of the dura mater from the lamina should prevent dural laceration
- rectangular graft is then harvested (dorsal rib) and trimmed to fit snugly between C1 dorsal arch and C2 lamina.
- braided titanium cables, e.g. Songer.
  - cable is tightened with the Tensioner-Crimper.

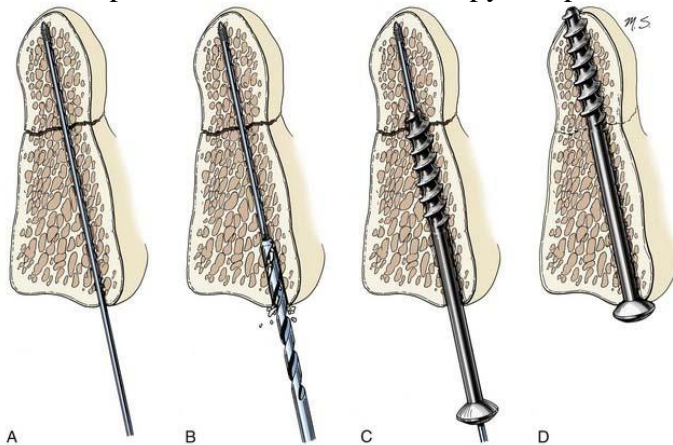
Dickman and Sonntag (1991)



## ODONTOID SCREW

### Contraindications

- fracture > 6 weeks old.
  - disrupted transverse ligament.
  - calcified\*apical ligament → aseptic necrosis.  
\*distal dens blood supply is coming through apical ligament
  - prominent chest (hard to achieve angle).
- incision at C5 level.
  - **biplane fluoroscopy**
  - place bite block to keep mouth open
  - drill off the superior anterior corner of C3 (also violates anterior part of C2-3 disk)
  - wire pin inserted under fluoroscopy is replaced by **lag screw** over it



## THORACOLUMBAR SURGERY

Ventral CSF leak – put DuraGen + lumbar drain (may try to repair in thoracic where root can be sacrificed)

## BMP

## Recombinant human bone morphogenetic protein (rhBMP) + absorbable bovine Type I collagen sponge carrier

approved in 2002 for use in anterior lumbar interbody fusion (ALIF) surgery with a proprietary titanium interbody cage

results in **equivalent or slightly higher rate of radiographic fusion** cf. traditional gold standard (autologous iliac crest bone graft)

**complications** (**hyperostosis** and inflammation, **de novo cancer** when used at doses above 40 mg)  
Indication

- fusion procedures in skeletally mature patients with DDD at **one level from L2-S1**, who may also have up to Grade I spondylolisthesis at the involved level.

On-label, it has to be used in combination with Interbody Fusion Device.

### Contraindications

- 1) active **infection** at operative site
- 2) active **malignancy** in the vicinity or patients undergoing treatment for a malignancy
- 3) **skeletally immature** patients
- 4) **pregnant** women
- 5) **allergy** to bovine Type I collagen

### Precautions

- safety and effectiveness in **cervical spine** has not been established:
  - a) **anterior cervical spine** - reports of increased **infection**, retropharyngeal **edema with dysphagia / airway compromise** ← FDA recommending **avoid BMP in anterior cervical spine**
  - b) **posterior cervical spine** [pseudo rates in reports 0-10%] – conflicting long-term efficacy, no early complications – use lower doses in C-spine!

## DEFORMITY

- look for **C2 and T1 slopes** (ideal difference < 32 degrees).
- if need osteotomy, select **T2** (no brachial plexus – can take T2 root, no vertebral artery).

Practically, every patient should be evaluated for sagittal imbalance before fusion (even single level) – **standing 36 inch lateral XR**:

- include **femoral heads** and **C7**
- hips and knees extended
- arms flexed at elbows and positioned at a 45° angle in front of the body with both hands resting on clavicles.

Sagittal imbalance can be classified into two types:

**Type 1** – **segmental** hyperlordotic or kyphotic segment (patient compensates for imbalance by hyperextension of segments above and below); **corrective osteotomy** is done at **involved segment**.

**Type 2** – imbalance **across significant segment of spine**; spine is flat, and there is segmental loss of kyphosis and lordosis (patient is unable to compensate); more amenable to **corrective osteotomy** - done at **lower spine** - greater lever arm correcting axis of view, there are fewer complications related to thoracic viscera and vascular structures, and correction is not hindered by ribs.

Two alternatives:

- a) **osteotomies**; best level is where normally lordosis should be – at L3, 4, 5.
- b) **ALIF** (for L5-S1 but heavily dependent on access surgeon), **LLIF** – may achieve impressive lordosis with large grafts (made PSO obsolete bloody procedure!)



N.B. **corpectomies** and **pedicles subtraction osteotomies** are usually avoided in long-segment cases to mitigate excessive blood loss (+ **multilevel posterior osteotomies** are often sufficient for deformity correction).

## 2/3 of lordosis L4-S1

- Normal Average Lordosis 61° (Range 55°- 65°)
- L4/5 Lordosis 16.8°
- L5/S1 Lordosis 32.4°



### Long posterior instrumentation:

Standard stop upper levels – either T10 or T4.

Standard stop lower levels – see Scheuermann's kyphosis

N.B. **extending to L4 or L5 may cause adjacent segment degenerative disc disease\*** (vs. minimal degeneration occurs with fusions ending more proximally)

\*if need to stop at L4 or L5 with longer construct, better extend to **pelvis** (+ always add L5-S1 interbody cage)

- for long fusions (thoracic-sacrum) always add L(4)5-S1 **interbodies!** (Dr. Lenke)

### **SPINOPELVIC SAGITTAL ALIGNMENT**

- sagittal imbalance → pain (muscles work inefficiently) + horizontal gaze trouble (tries to compensate with cervical hyperextension) ← affects social independence.

**Odontoid-hip axis** – most global evaluation of alignment.

### **Sagittal vertical axis (SVA)**

- vertical plumb line from midpoint of C7 vertebral body - distance between this line and the posterosuperior corner of S1.
- SVA is dynamic - patient can compensate with stance change!
- general aim for **positive SVA < 50 mm**

Age-related goals:

Age 50 yrs - SVA < 50 mm

Age 60 yrs - SVA < 60 mm

Age 70 yrs - SVA < 70 mm

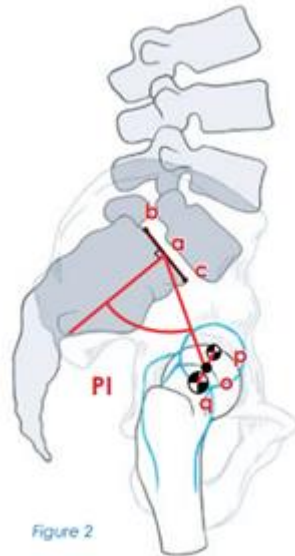
**Lumbar lordosis (LL)** - Cobb angle between superior endplate of L1 and S1.

Normal lumbar lordosis **55-65 degrees (Greenberg: 20-40 degrees)**

Normal thoracic kyphosis = LL x 0.75

**Pelvic incidence (PI)** - angle between **line perpendicular to S1 endplate at its midpoint** and **line connecting to midpoint of line connecting centers of femoral heads:**





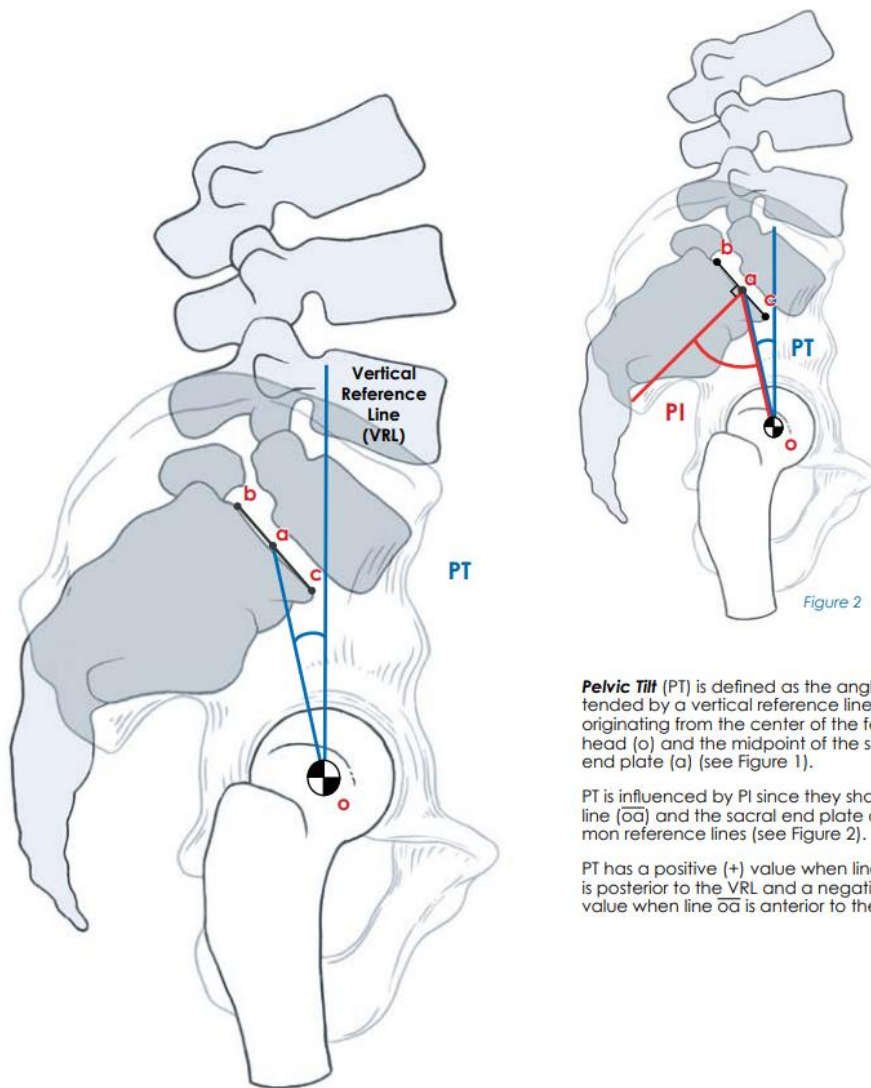
- it is indicator of innate reserve (patient cannot change it) – how much patient can compensate kyphotic tendency by pelvis retroversion (pelvis is like the first vertebra)
- when PI increases, more and more lordosis comes from upper lumbar spine (vs. usual L4-S1 level).
- smaller PI the better:  $PI-LL \text{ mismatch} > 10^\circ \rightarrow 10\text{-times higher risk of adjacent segment disease.}$

**Pelvic tilt (PT)** - angle between a vertical line through the midpoint of the centers of the femoral head and a line connecting to the midpoint of S1 endplate.

Patient can change PT: increasing PT (> 20-25 degrees) means patient is trying to compensate for lack of lordosis by retroverting pelvis! (PI is static – patient cannot change it; PT is position dependent)

Ideally, < 20 degrees

## Pelvic Tilt



**Pelvic Tilt (PT)** is defined as the angle subtended by a vertical reference line (VRL) originating from the center of the femoral head (o) and the midpoint of the sacral end plate (a) (see Figure 1).

PT is influenced by PI since they share the line (oa) and the sacral end plate as common reference lines (see Figure 2).

PT has a positive (+) value when line oa is posterior to the VRL and a negative (-) value when line oa is anterior to the VRL.

## SCHEUERMANN'S KYPHOSIS

- structural thoracic kyphosis - anterior wedging of  $\geq 5^\circ$  in at least 3 adjacent vertebral bodies (differentiate Scheuermann kyphosis from postural round-back deformity).
- "developmental" type of kyphosis - develops over time during periods of bone growth (such as puberty)
  - young patients may be treated with brace (Milwaukee, TLSO with cowhorns) worn at least 23 hrs/day for 1–2 years; it is not logical to brace a skeletally mature spine!
- surgery indicated: refractory pain, thoracic kyphosis  $> 70-80^\circ$

Posterior osteotomies + fusion:

Proximal fusion level (upper instrumented vertebra, UIV) - T2

Distal fusion level (lower instrumented vertebra, LIV)

- A. **Vertebra just below first lordotic disc (FLD)** – historical golden standard (→ shorter fusion than necessary)



B. **Sagittal stable vertebra (SSV)** – much lower (> 4-fold) distal junctional failure at the expense of incorporating additional motion segments in a typically young population.

SSV - most cranial vertebra touched by a vertical line from posterior superior corner of S1:



### SCOLIOSIS (CORONAL DEFORMITY)

- measure **coronal offset** with plumb line (**C7 spinous process tip – midsacrum**); normal < 4 cm
- coronal deformity is usually less functionally important than sagittal balance.

### FUSION EXTENSION

- never stop at thoracolumbar junction (ie. L1) – extend fusion to T10-11; next level – T4, then C2.
- to extend previous fusion – depends on status of **fusion below**:
  - a) **solid fusion** - use **rod-to-rod connectors** to attach to old rods.
  - b) **poor fusion** - **remove old rods** (± pedicle screws – if suspicion for being loose) and place longer rods.

See Case S5 >>

## LUMBAR DISCECTOMY

Clear indications for surgery:

- 1) **cauda equina** or **conus medullaris** syndrome → emergency surgery!
- 2) acute or progressive **myelopathy**
- 3) severe or progressive neurologic (esp. **motor**) deficits.

4) intractable *pain*.

Additional indication - *unsatisfactory response* within 4-12 weeks of conservative measures.

Large central disk herniation - *full laminectomy* is indicated.

- for morbidly obese patients use Taylor retractor.

General Trend: more **aggressive discectomy** – *less recurrences* but *more back pain*.

- irrigate disc space to remove inflammatory cytokines.
- anterior annulus is violated and *retroperitoneal vessel is injured* → *close back* while resuscitating and vascular surgeon prepares to repair vessel via LAPAROTOMY

Disk recurrence (*reoperation* for ≈ 15% of lumbar discs) → **MRI w/wo**:

Scar enhances consistently regardless of time since surgery.

Disc material does not enhance (or has peripheral enhancement) - lack of vascularity.

### STRATEGIC PRINCIPLES

1. The **natural history** of sciatica due to lumbar disc herniation: *the majority of patients improve significantly* within 8 weeks!
2. *Surgery provides a faster relief* from the acute attack than conservative management.
3. *No overall difference in the longer-term outcomes* between surgery and conservative.
4. *Risks of surgery need to be balanced* against the risks of conservative management – *no winner*:  
*Surgical risks* - 1 % risk of neurological damage.  
*Risks of conservative management* - have not been quantified.
5. Strong economic argument supporting *rationale for early surgical intervention* based on a *cost–benefit analysis*.

How urgent surgery must be? *Give bedrest and steroid trial!!!*

- decision to operate emergently is often based on fear of legal repercussions rather than on scientific evidence.
- ensure completeness of **diagnostic workup** prior to operation (diabetic plexopathy or epidural metastasis).

### Recovery of ankle dorsiflexion weakness

- patients treated with surgical decompression at various intervals [urgent (< 10 days), expeditious (< 30 days) and routine (> 30 days)].
- outcomes assessed at 24 months
- ankle dorsiflexion power at the long-term follow-up significantly correlated with preoperative ankle dorsiflexion power ( $p < 0.001$ ).
- level IV therapeutic evidence that *timing of surgery does not affect recovery of ankle dorsiflexion*.

*Mangialardi R et al. Lumbar disc herniation and cauda equina syndrome. Considerations on a pathology with different clinical manifestations. Chir Organi Mov. Jan-Mar 2002;87(1):35-42*

### FAR LATERAL LUMBAR DISCECTOMY

See p. Op220 >>

takes months for irritated DRG to recover!

**MIS durotomy (CFS leak)** – no need to attempt repair – after Tubular Retractor is removed, muscles collapse and seal the potential space.

### REDO

Increase laminotomy window

## COMPLICATIONS

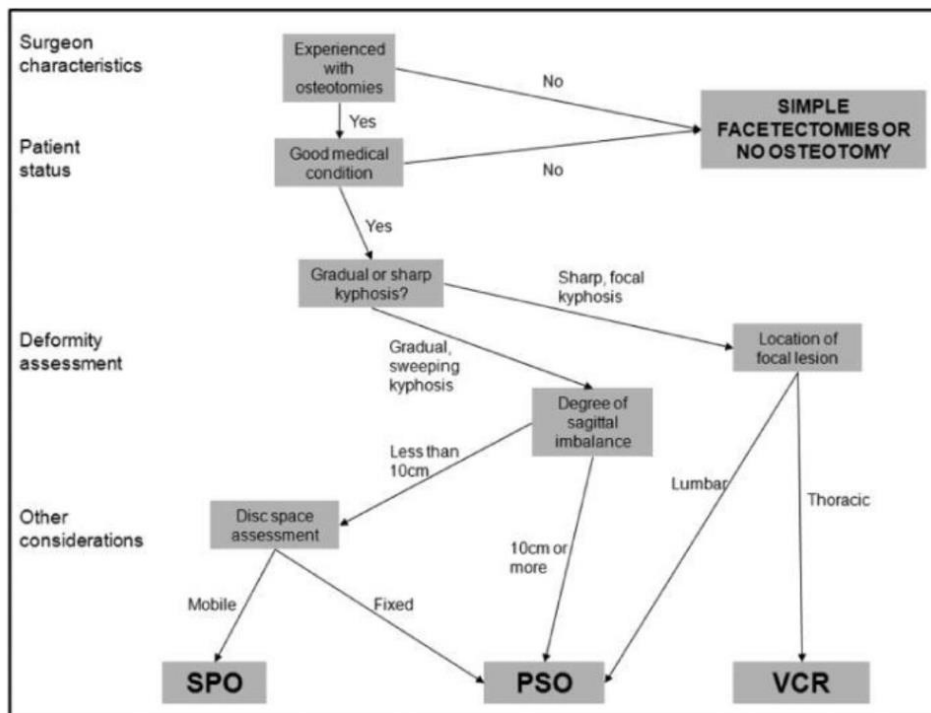
1. **Postoperative discitis** (fevers, severe localized pain, recurrent symptoms).
    - disc space is avascular and, as a result, less resistant to infection.
    - many patients experience **transient radiculopathy flare up at 2 weeks postop** (likely due to inflammation).
    - ESR↑, CRP↑, MRI w/wo, blood culture, CT-guided biopsy (if liquid pus obtained → surgical disk washout) → abx for 6 weeks + immobilization
  2. **Disk recurrence** (≈ 15% of lumbar discs).
  3. **Postoperative scar** (epidural granulations → mature fibrous tissue) - **extradural** reactive process; may cause recurrent symptoms.
    - lumbar epidural fibrosis (scar) is replacement of normal epidural fat with postoperative fibrotic tissue, which is capable of binding dura and nerve roots to surrounding structures anteriorly and posteriorly.

N.B. distinguish from **recurrent / residual disc material** (**MRI w contrast** is best – accuracy 96-100%) - firm indication for re-operation!!!

Scar enhances consistently regardless of time since surgery.  
Disc material does not enhance (or has peripheral enhancement) owing to its lack of vascularity.
1. **Durotomy** (risk ≈ 3-5%) – aim to repair primarily
  2. Very rarely, anterior annulus is violated and **retroperitoneal vessel is injured** (left common iliac artery crosses directly over L4-5 disc) → **close back** while vascular surgeon prepares to repair vessel via LAPAROTOMY (if patient is stable, may go to IR instead).

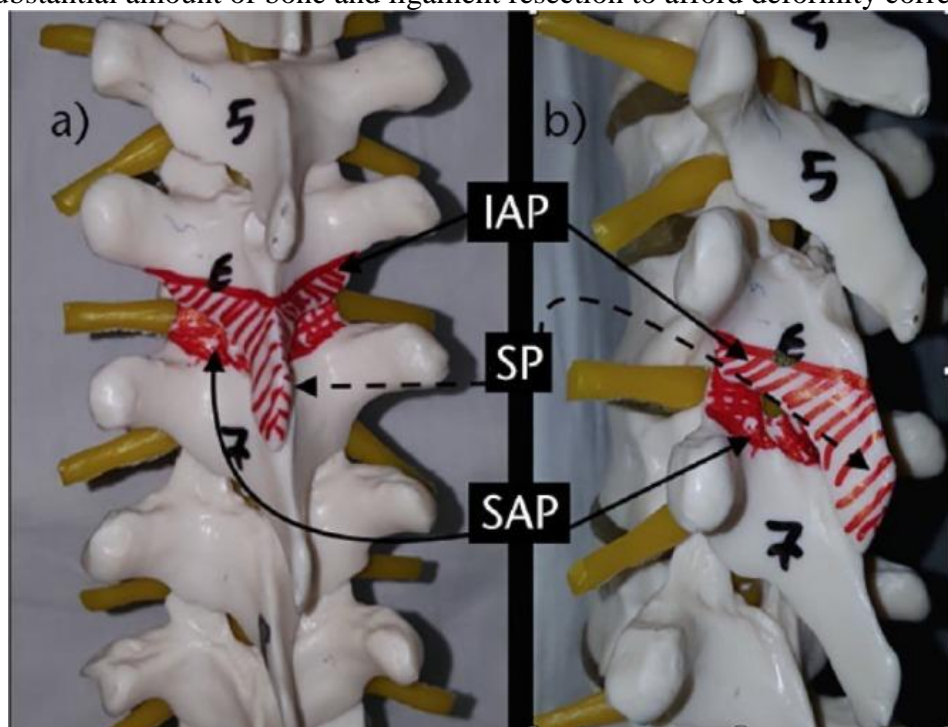
## OSTEOTOMIES



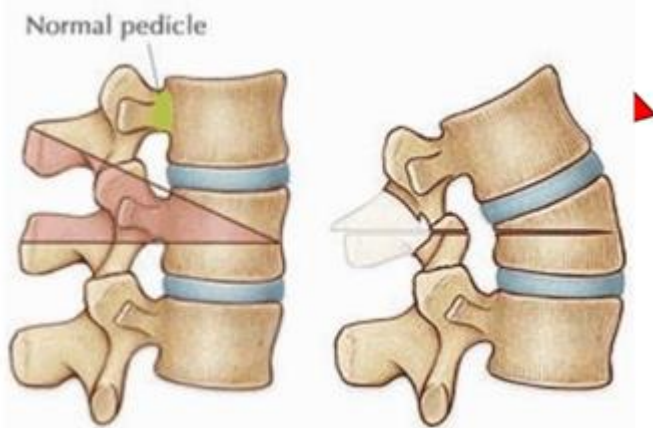
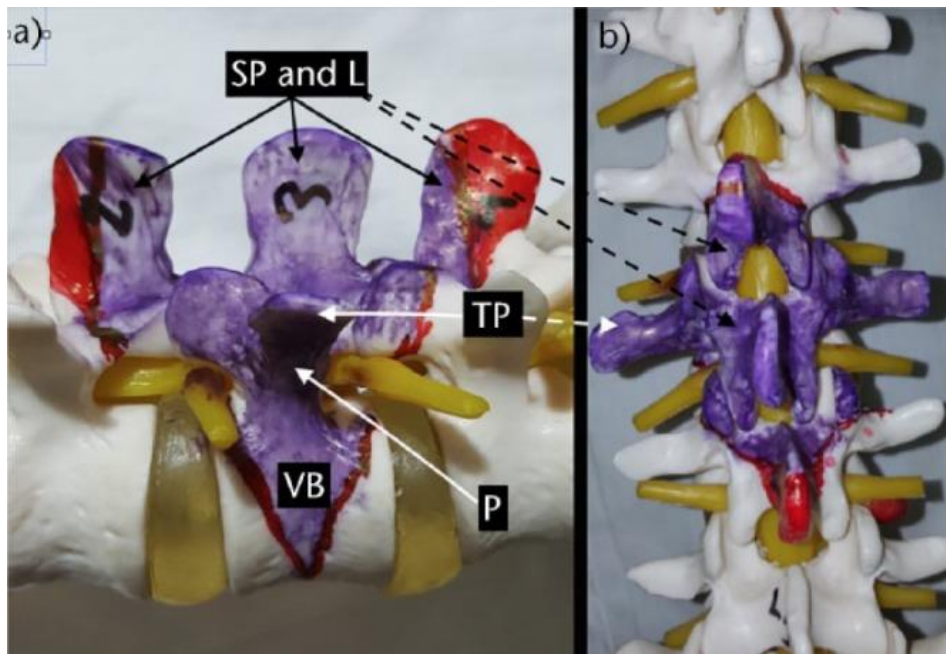


Osteotomies in the posterior-only treatment of complex adult spinal deformity: a comparative review. Dorward, IG, Lenke, LG, JNS Mar 2010

1. **Smith-Petersen osteotomy (SPO)** - posterior column osteotomy in which the **posterior ligaments** (supraspinous, intra-spinous ligaments and ligamentum flavum) **and the facet joints** (inferior facets of the upper vertebra + superior facets of the inferior vertebra).
  - correction is performed **through the disc space** - mobile anterior disc is essential.
  - amount of correction is 10° per segment.
  - in 1984, **Ponte** described a very similar technique in Scheuermann's kyphosis cases. **Ponte procedure** - resection of multiple facets along with the resection of spinous processes and involves substantial amount of bone and ligament resection to afford deformity correction



2. **Pedicle subtraction osteotomy (PSO)** - **posterior elements and pedicles** are removed.



- posterior spine is shortened using **anterior cortex as a hinge** (i.e. may be used in fused disc space).
- most useful if done at the apex of the deformity.
- single level osteotomy can produce 30-40° of correction.
- up to **2 liters of blood may be lost**
- traditionally done at L2-3 (below conus) but that is not where normal physiologic lordosis should be; best PSO at L4-5 levels

## FORAMINOTOMY

- safely can remove medial ½ of pars
- use 2 mm foraminal Kerrison and 45 degree curette to enlarge foramen; check with Woodson probe.

Alternatives – indirect decompression with LLIF or interspinous decompression (e.g. COFLEX)

## MIS

Baxano Io-FLEX – with laminotomy, directional stim + NIM-EMG

## LATERAL FORAMINOTOMY

- if stenosis is created by **lateral facet osteophyte** – expose lateral side of pars and top of lateral facet; dissect anteriorly; generous venous plexuses – bleed a lot but bipolarizing may irritate dorsal root ganglion (postop neuralgia).

- use drill, pituitary rongeur, 2 mm Kerrison.

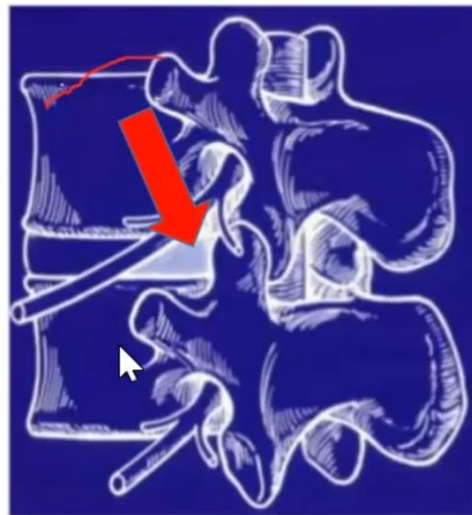
## PEDICLE SCREWS

- stimulate pedicle screws up to 30 mA (if cortical bone is intact, EMG response should occur at > 14 mA; threshold to suspect breach is 6 mA).
- cobalt-chromium – stiffer (use for spondylolisthesis, scoliosis reduction).

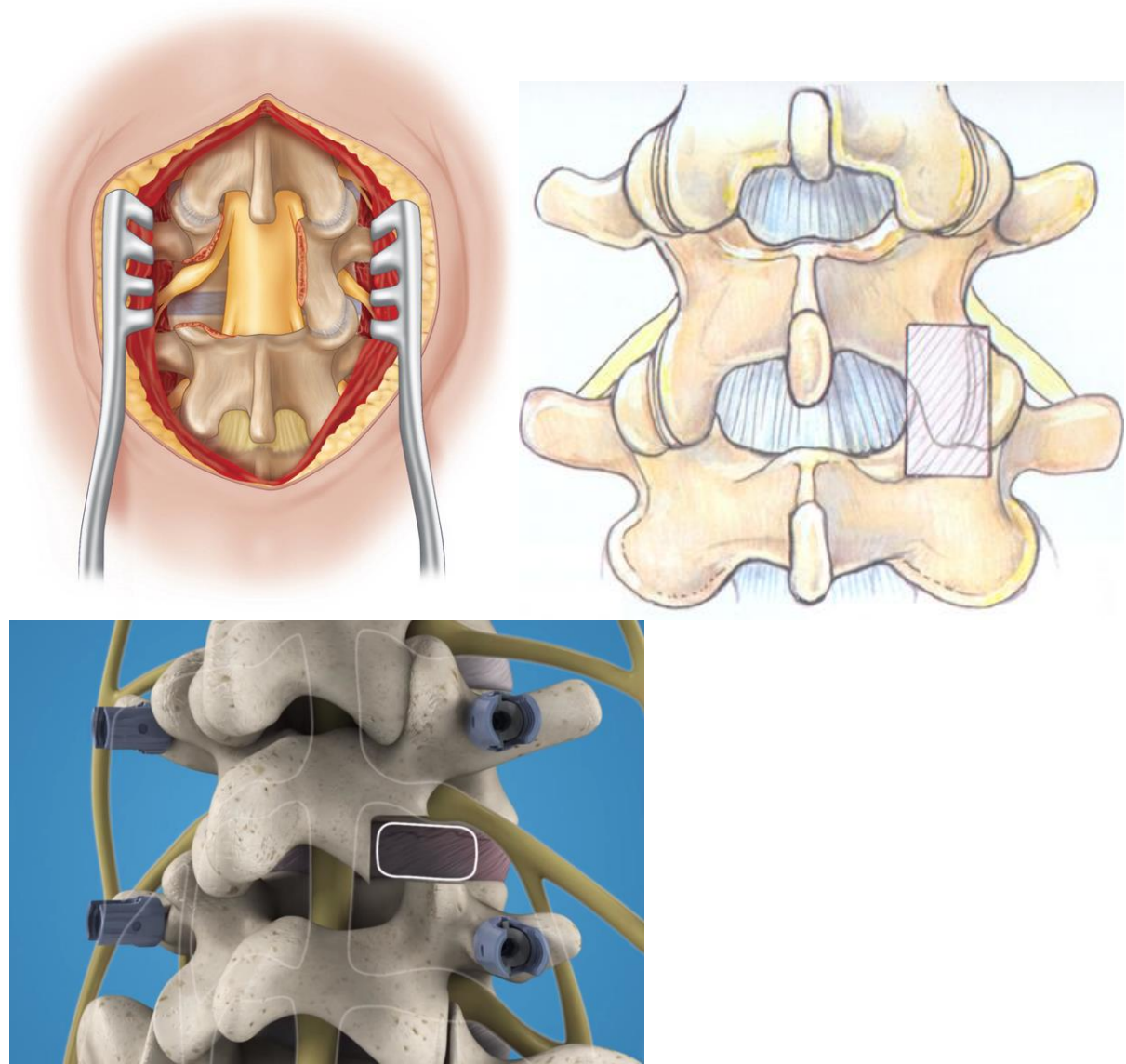
## TLIF

- it is alternative to PLIF for lesions at or above conus medullaris because retraction of thecal sac is not an option.
- not feasible at L5-S1 (iliac crests); H: PLIF or ALIF

# Kambins Triangle



- removal of *pars interarticularis*, lamina, ***inferior and superior articular processes***:



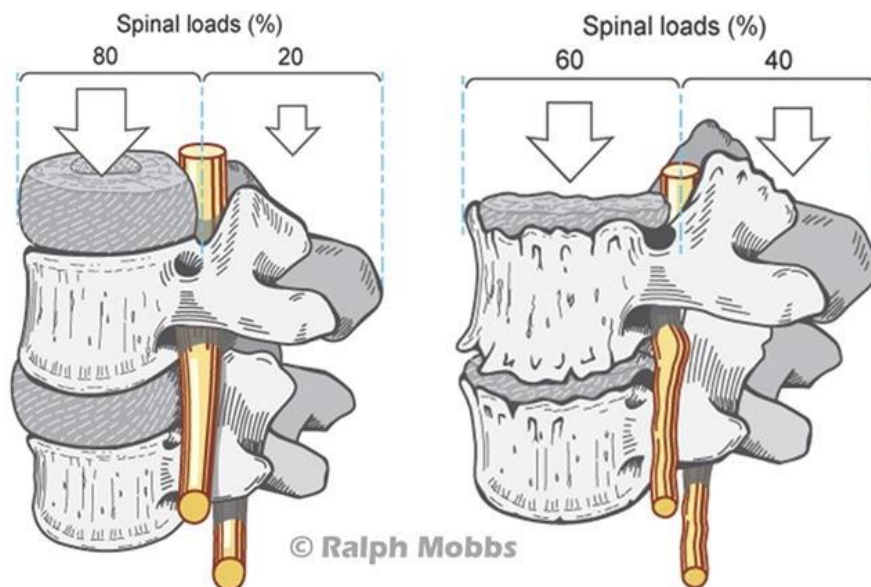
- goal is to place graft in **middle of disk space, as anterior as possible**
- do **on more symptomatic side** – if will damage root, it is already worse side; on the other hand, it is greater chance of helping that side by better distraction.
- TLIF is kyphosis inducing procedure (or at best – preserving status quo; best TLIF if bilateral with expandable cage, ALL release, and posterior compression).
- Smith-Peterson osteotomies or removal of Gill fragments = unroofing neural foramen + allows compression of screws / disk space.
- put some BMP inside graft and between grafts (anteromedially).

## ALIF

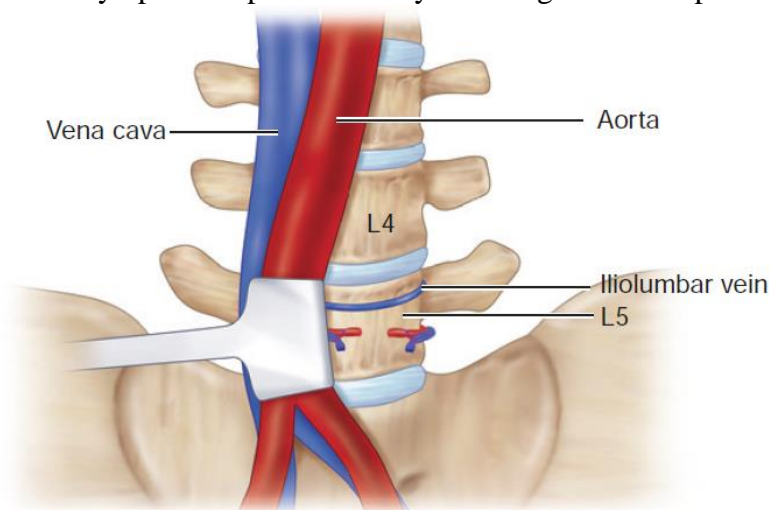
### Weight-bearing distribution

- in normal lumbar spine, anterior and middle columns support 80% of spinal load, and posterior column supports 20%
- with degenerative cascade, weight-bearing shifts to posterior column.
- ALIF, redistributes weight-bearing distribution to original ratio.





- a) **transperitoneal approach** - may be used to access L4-5 and L5-1.
- b) **muscle-sparing retroperitoneal approach** from left side (retraction of aorta is more safely performed) has become more popular - lower rates of postoperative ileus, ability to sweep sympathetic plexus bluntly to the right of disk space:



Pathology at **L4-S1 levels** (at higher levels – use LLIF).

- at **L5-S1**, mobilization of large vessels is usually unnecessary because approach can be taken through vascular bifurcation; **pubic symphysis** is access-limiting structure (explore imaging preop).
- at **L4-5 level**, iliolumbar vein enters common iliac - avulsion can lead to aggressive bleeding.
- **L3-4 disk** requires more significant mobilization and retraction of iliac vessels and aorta.
- **supplement posteriorly with screws**

#### Complications

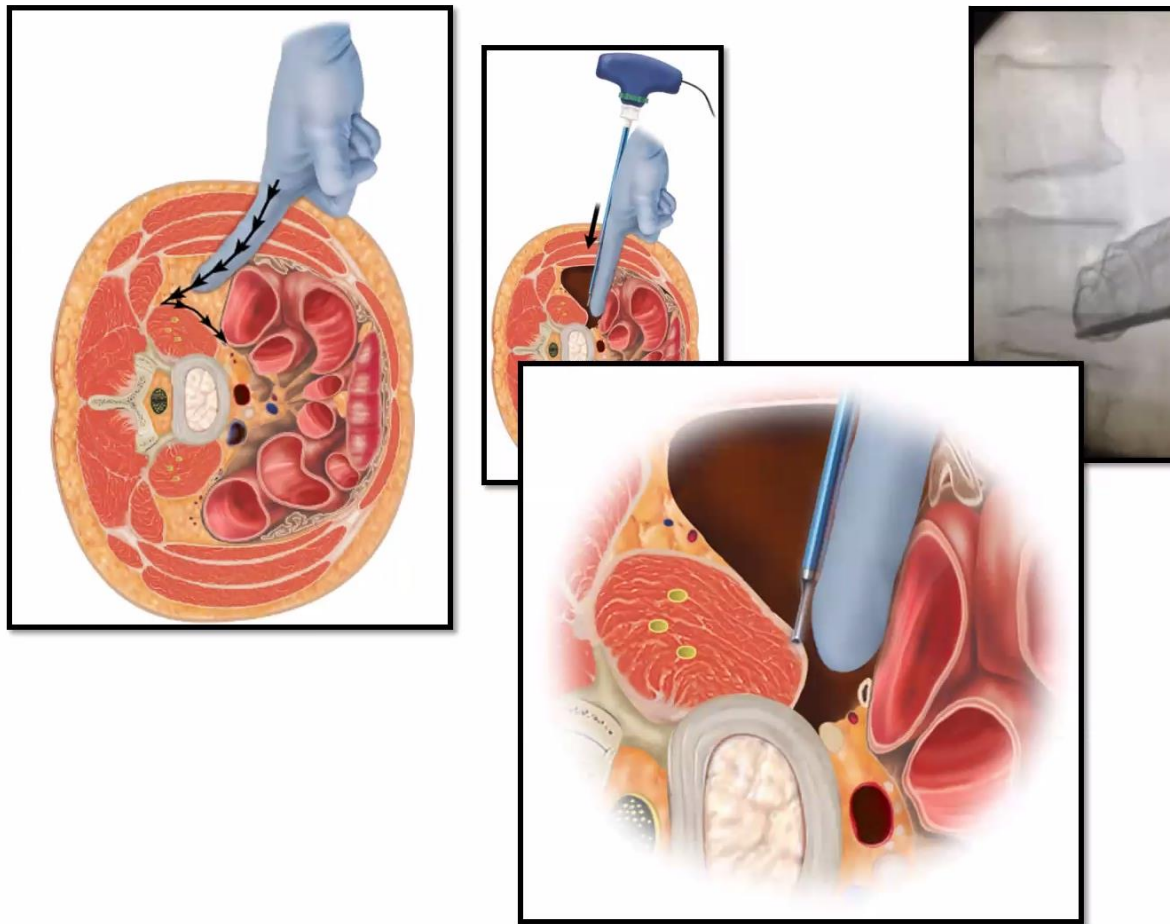
- 1) **implant migration** - observed in majority of patients
- 2) **retrograde ejaculation and sterility** (2-8%) - injury of superior hypogastric sympathetic nerve plexus (particularly at L4-S1); can be temporary or permanent  
H: avoid using **Bovie** (use bipolar!) around sympathetic chain; avoid **BMP** (role unclear); patient may **donate sperm preop** (if patient wants to try how retrograde ejaculation feels – start  $\alpha$ -blockers)
- 3) mobilization of sympathetic plexus → **lower extremity sympathetic dysfunction** - asymmetric feeling of “cold leg” or “warm leg.”
- 4) **blood loss, leg ischemia** – have **CellSaver** ready, **pulse oximeter** on each big toe



## LATERAL APPROACH INTERBODY FUSION

Pathology at **T12-L5 levels** (for levels L4-S1, ALIF may be better).

- above T12 need pleura retraction
  - at L5-S1 iliac crest is in the way.
  - consider **access surgeon** (general or vascular surgeon) - for mobilization of the great vessels and handling of the abdominal contents - shortens procedure duration and reduces blood loss.
  - ***always approach from left side*** regardless of scoliosis curve (right side – liver and vena cava)
  - Ureter courses on anterior surface of psoas - identification may be confirmed by **preoperative ureteral stenting** and by **Kelly's sign** - visible ureteral peristalsis following application of gentle pressure
  - if patient has ***one kidney and on the left***, ask for **urologist** for approach.
  - usually as **two stage procedure**:
    - first day** – **LIF** → bed rest with HOB up to 45 degrees until posterolateral fusion is done
    - second day** – **posterolateral fusion**
- A. **Anterior-to-psoas (ATP), e.g. OLIF (oblique lumbar interbody fusion)** – avoids psoas muscle – less potential for lumbar plexus injury.
- mandatory for L4-5 level (trans-psoas may cause severe femoral nerve injury and “high-riding” ilium is often in a way), optional for L3-4
- B. **Trans-psoas, e.g. DLIF, LLIF, XLIF** – acceptable for L1-3 levels (lumbosacral plexus is not well formed yet)
- for L1-2 need open thoracotomy approach to dissect diaphragmatic crus (along with rib resection)
  - **blunt dissection** (finger, Kelly clamp, Kittner, hand-held retractor blade [maybe with installed light source]) to split abdominal muscles – all three: **external oblique** (runs “put hands into pocket” direction), **internal oblique\***, **transversus abdominis** (may be inapparent)
    - \*anatomic dissection of the internal obliques limits exposure, rendering this approach most suitable for MIS
    - ideally, leave transversalis fascia intact but practically it gets entered and you follow in retroperitoneum
    - dissect with finger aiming towards transverse processes and feel psoas anterior to it.



- **three-adjustable-blade** Globus MARS **retractor** is fixed on FlexArm and then docked and attached to table.
- **directional stimulation probes** help checks 4 quadrants inside retractor to make sure no lumbosacral plexus nerves are trapped
- N.B. discectomy just to create channel for graft cage and no more.
- contralateral annulus is disrupted using **Cobb elevators** along each endplate
- N.B. **leave ALL intact to prevent graft migration** (some experts recommend to cut some ALL fibers – but only under direct vision to avoid vascular injury; reminder of ALL fibers will stretch naturally).
- N.B. do not damage ALL unless inducing lordosis - cut 50% of ALL fibers only under direct vision while protecting vessels with “ALL blade” anteriorly.
- center of graft is between 2/3 anterior and 1/3 posterior; however, more anterior is desirable if goal is to correct kyphosis
- graft – expandable Globus Elsa

### Plexus injury

- highest risk at **L3-5 levels**, thus, prefer to use OLIF there.
- monitor patients with directional stim probe + motor evoked potentials.
- **left hip flexion** reduces tension of the psoas muscle (and plexus inside it).
- avoid **breaking the table**
- **genitofemoral nerve** exits body of psoas medially near level of L3 and should be protected during lateral retraction of psoas muscle to avoid dysesthesia of the anterior thigh and inguinal region.
- evaluate position of plexus on preop MRI (“Mickey mouse ears”)

### Vessel injury

- LIF contraindicated - **calcification of great vessels**.

- check for major vessel position on preop MRI; **aortic bifurcation is usually at L4 level**, just above junction of the left and right common iliac veins

### CORPECTOMY

- a) **posterior**: place screws, laminectomy, place temporary rod, take pedicle (do not sacrifice any root!), do corpectomy
- b) **lateral**
- anterior thoracolumbar spinal cord receives collateral vascular supply, and surgical division of a single segmental lumbar artery at the level of the neural foramen is not known to cause spinal cord infarction. Routine preoperative angiography to evaluate the **artery of Adamkiewicz (RA)** is not indicated, nor should the occurrence of the RA in the surgical path warrant aborting an indicated thoracolumbar procedure (place temporary clip and watch neuromonitoring signals for change)
- **anterior and contralateral margins of the vertebral body** remain as barriers to the great vessels.
- closure - place rubber-rod catheter (e.g. pediatric Foley) inside pleural cavity → close soft tissues → put end of Foley into water basin → Valsalva → pull catheter and completely close incision.

## THORACIC SURGERY

- there can be 11-13 pairs of ribs (+ unrelated 4-6 lumbar vertebrae)  
Level on MRI is counted from C2 or from sacrum vs. intraop X-ray counting is done using ribs. Reconcile preop MRI level with plain films - to know the number of nonrib lumbar vertebrae + size of 12<sup>th</sup> rib.
- radicular arteries variably supply thoracic cord, and **watershed infarcts** can occur after root sacrifice. H:
  - 1) delineate with preoperative angiography location of **artery of Adamkiewicz** +/- tumor embolization
  - 2) if nerve root sacrifice is necessary, **temporary aneurysm clip** should be placed over root sleeve for 10-15 minutes – watch IONM before suture ligation

N.B. segmental vessels bleed a lot; maybe difficult to control, especially if injured on the contralateral side.

### THORACIC SPINE APPROACHES, THORACIC DISCECTOMY / CORPECTOMY

See p. Op220 >>

#### Summary

key issue (for selecting approach) - ability to visualize lesion without retraction on already deformed spinal cord (**paraplegia can occur from additional traction on already compromised spinal cord!!!**)

Adamkiewicz – comes from Left at T10-L2 – better to operate from R side (may check for Adamkiewicz with preop CTA/DSA, may place temporary clip on root before sacrifice and watch IONM)

- **simple laminectomy approach – high risk of paraplegia** (awareness started with Logue review in 1952):
  - a) if no discectomy - does not remove ventral compression
  - b) if discectomy is performed – requires cord retraction
- use **monitoring** (MEP, SSEP), **steroids**.
- **maintenance of blood pressure** (MAP > 85 mmHg) is crucial in severe cord compression!

- use **preop CT** – see if **disc calcified** – will be stuck to dura!
- for **unilateral** transpedicular approach to midthoracic spine, **no need to instrument** for stabilization (but may leave back pain); if bilateral – need to instrument.
- for cases that require bilateral transpedicular corpectomy, **contralateral screws and temporary rod** should be placed to stabilize spine during corpectomy and cage placement.
  - if **neuromonitoring signal changes** occur, **compression on temporary rod** may relieve tension on spinal cord that sometimes occurs as body settles after circumferential bony removal.

Costotransversectomy - can expose any thoracic level!  
Some experts use navigation!

#### Anterior access to Thoracic Spine:

**T1-2:** Anterior neck suprasternal approach with or without sternotomy.

in majority of patients, T3 vertebra is above suprasternal notch (eps. in patients with long necks)

**T3-4:** Anterior neck dissection with partial **median sternotomy** and anterolateral thoracotomy "trap door" technique.

alternative - posterior lateral extracavitary approach

**T5-10: thoracotomy:**

- Transthoracic open**
- Thoracoscopic** – less postop pain!
- Extra/Retro-pleural** – does not open pleural space – may not need chest tube!

Preferable side:

upper thoracic – right (avoids heart, aortic arch, subclavian and carotid arteries)

middle, lower thoracic – left (avoids inferior vena cava, liver)

**T11-L2: Combined thoracoabdominal** approach (requires partial takedown of diaphragm) - retropleural retrodiaphragmatic retroperitoneal approach or transpleural transdiaphragmatic retroperitoneal approach.

- verify that the proper rib is being resected by AP X-ray.
- Doyen elevator.
- **avoid injury to the segmental vessels, as well as the sympathetic chain** (but often necessary to ligate or clip intercostal vessels; some say sympathectomy may occur with little or no morbidity).
- if additional exposure of the neuroforamen is needed, **section intercostal nerve proximal to dorsal root ganglion**.
- parietal pleura is closed over a thoracostomy tube.

#### Approach selection for thoracic discectomy

By **nature and location of disc:**

- calcified (central) disk** - **anterior approach** (CT surgeon for approach with one lung ventilation)
- soft herniated discs, lateral calcified discs** – **posterolateral approach** (transpedicular ÷ transthoracic approach, best **costotransversectomy**) – semiblind procedure!

By **nature of indications:**

- severe, intractable **back pain** - surgery has a high failure rate!
- severe, intractable **radicular pain** - dorsolateral approach (radiculopathy alone is generally associated with a far lateral disc)
- (progressive / severe) myelopathy

N.B. nonsevere static myelopathy without functional impairment → treat nonoperatively

By **patient condition**: **high-medical-risk patients** - dorsolateral decompression (unless disc is midline, large, and densely calcified)

Verify adequacy of cord decompression:

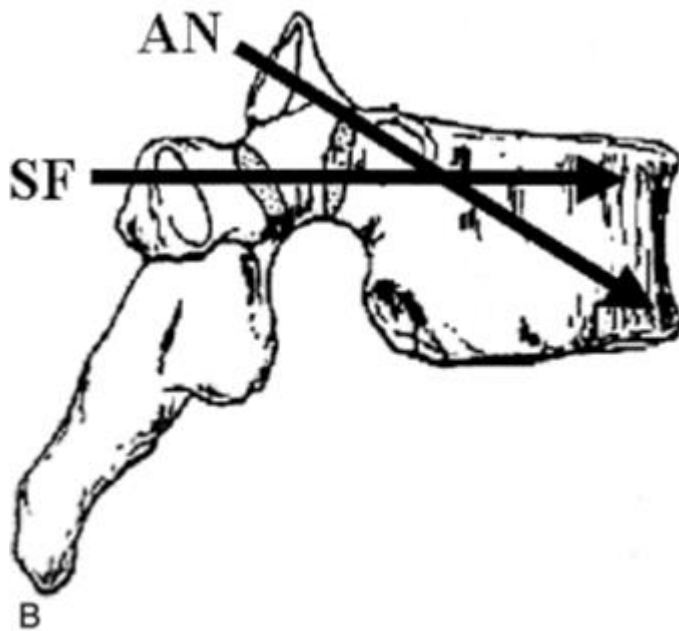
- 1) examine ventral spinal canal with a dental mirror, endoscopy
- 2) *contralateral pedicle should be palpated* with a blunt instrument
- 3) check with US
- 4) restoration of dural pulsations

### CSF-PLEURAL FISTULA

- may fill entire **hemi-chest** (hydrothorax) postop and cause **subdural hematoma**!
- treatment:
  - 1) *lumbar drain*
  - 2) reoperate for repair: primary repair, graft, use small pleura flap → *chest tube on water seal* [not on suction]

### THORACIC PEDICLE SCREWS

- a) **straight-forward trajectory** (paralleling the vertebral endplate) - 27% increase in **pullout strength**
- b) **anatomic trajectory** (directed along the true anatomic axis of the pedicle)



See Case S2 >>

## PERC STABILIZATION

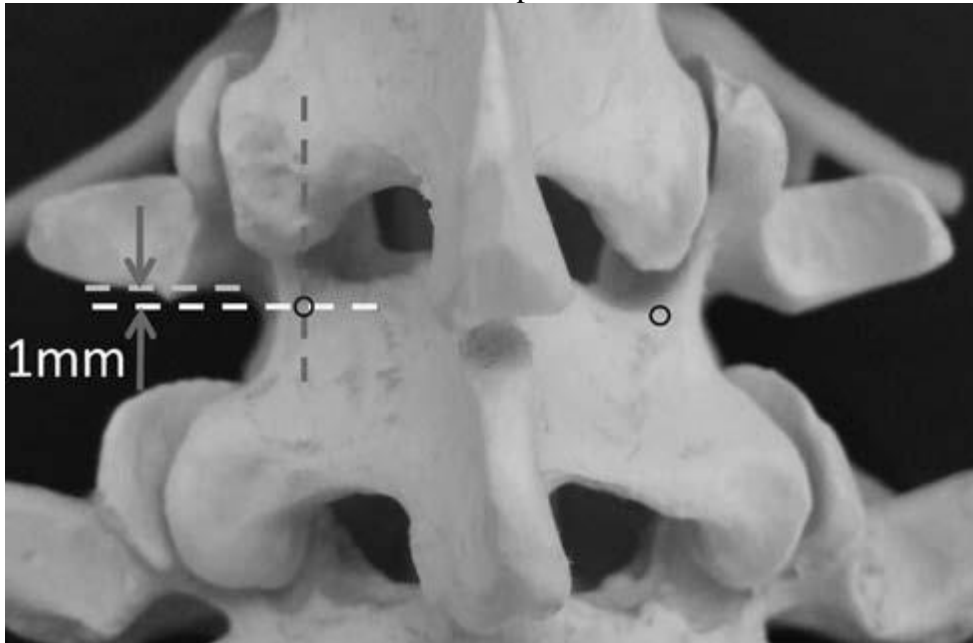
for bony trauma without need for decompression  
needs to be removed after healing

## MIDLF / CORTICAL SCREW

- indications:
  - 1) rescue when pedicle was destroyed
  - 2) adjacent level disease (may leave old hardware in untouched)

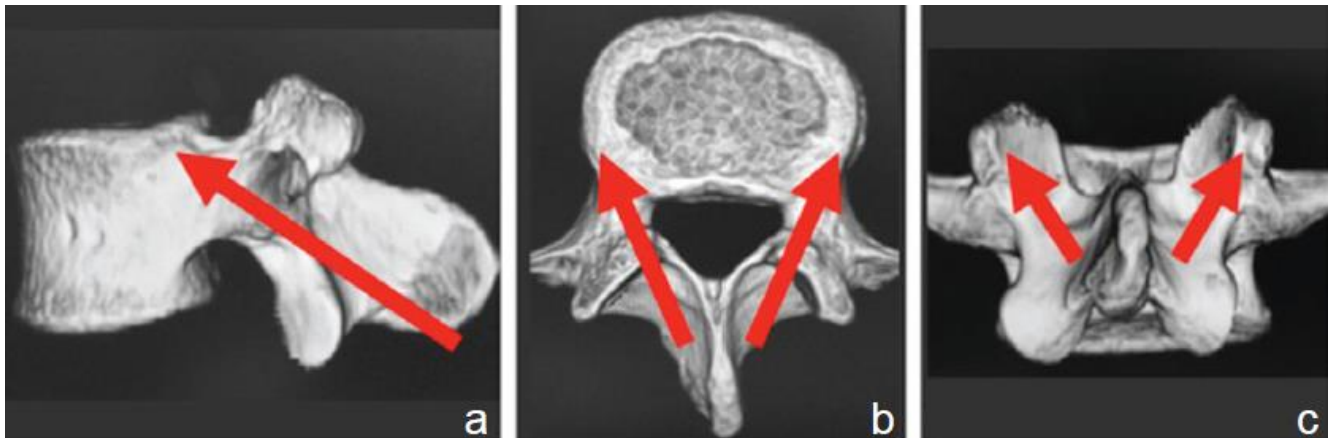


- 3) starting point - junction of center of superior articular process and 1 mm inferior to inferior border of transverse process:



N.B. best is to use AP fluoro or CT-based navigation – starting point is at 5 o'clock for L side (and 7 o'clock for R side)

**increased cortical bone contact:**



## (SACRO)PELVIC FIXATION

N.B. goal of iliac screws is to offload S1 screws!

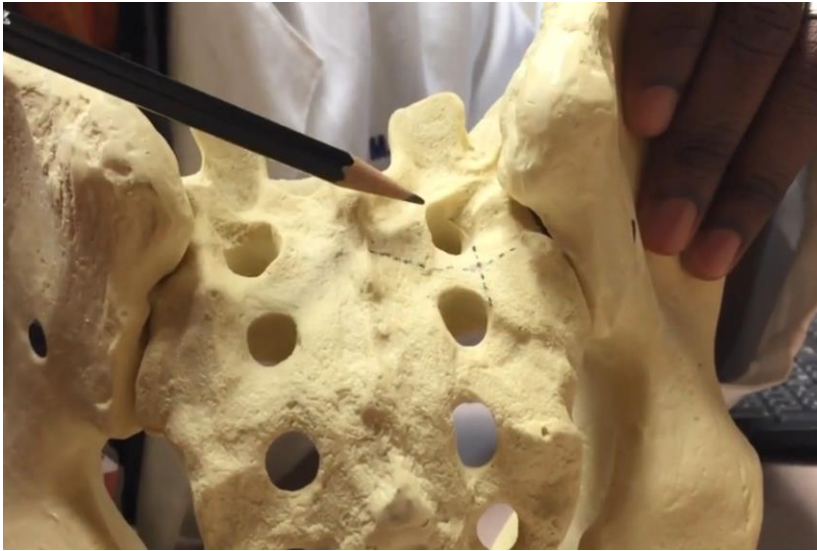
Indication - long fusion constructs (extending cranially to thoracolumbar junction or at least to L2)

- it is a prudent practice to consider sacropelvic fixation anytime instrumentation is extended into the sacrum.

### S2-alar-iliac (S2AI) screw

- biomechanically the best sacropelvic fixation method, 8.5 mm > 9 cm screw.

Starting point – lateral border, midway between S1 and S2 dorsal foramina (screw is placed in line with the S1 screw - obviates rod connectors):



Trajectory – crossing SI joint, just above greater sciatic notch, aiming at AIIS:

