ARABSPINE COURSE DIPLOMA



Module 4

Course Highlight Day-2

Deformity:

Normal Growth

Idiopathic Scoliosis

Degenerative Scoliosis

Neuromuscular Scoliosis

Sagittal Deformities

Spinal Malformations

Complications Related to:

Anterior and Posterior Approach:

Cervical Spine

Lumbar Spine

Thoracic Spine

Revision Procedures

NASS® ADVANCING GLOBAL SPINE CARE

ArabSpine

RCSI

DAY-2
(MODULE - 4)

ARABSPINE COURSE DIPLOMA
ASCD
الدبلوم العربي لجراحة العمود الفقري

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POSITION RELATED COMPLICATIONS

Ideal Surgical Position

Balance Surgical Comfort and Surgical Site Exposure Against the Risks Related to the Patient Position

Surgical Positions

- Prone
- Supine
- Kneeling
- Knee-Chest Position
- Knee-Elbow Position
- Lateral Decubitus
- Sitting/ Beach Chair



Positioning Complications

- Prolonged Table Based Retraction on Soft Tissues
- Abnormal Pressure on Extremity
- Abnormal Position of Extremity
- Skin Contact with Exposed Metal
- Pressure on Eyes
- Excessive Pressure on Mayfield Tongs





Complications

- Conjunctival and Tongue Swelling
- Ischemic Orbital Compartment Syndrome
- Nerve Palsies
- Thromboembolic Complications
- Pressure Sores
- Lower Extremity Compartment Syndrome
- Shoulder Dislocation/ Bursitis
- Upper Extremity Paresthesias



Risk Factors Resulting in Poor Positioning

- Emergency Procedures
- Surgeon and OR Staff Fatigue
- Unusual Patient Anatomy or Extremity Contractures
- Poor Communication
- Multiple Operations

Ischemic Optic Neuropathy

- Ischemia of Optic Nerve, Retina or Cerebral Cortex
- More Common with patients who have Closed-angle Glaucoma and Diabetes
- Increased Risk of Occurrence with Increased Eye Pressure, Acute Hypotension, Prolonged Surgery (>240 min) and Prolonged Hypoxia
- More Common with Prone and Knee/ Chest Position



Effect of Head Position on Intraocular Pressure During Lumbar Spine Surgery

- Randomized, Prospective Study
- Control Group Neutral Head Position and Experimental Group 10 degrees of Neck Extension
- Measured Intraocular Pressure, BP, pCO2 and Length of Surgery
- Significantly Lower IOP with Head Extension (4.53 vs 1.29 mm Hg)
- Increased Intraocular Pressure Results in Decreased Perfusion and Possible Ischemic Optic Neuropathy
- No Patients Incurred Perioperative Blindness

Emery,SE, JBJS, 2015

Lumbar Spine Positioning Complications

- Retrospective Study Review 3898 Articles
- Age, Operative Time, Type of Surgery, Surgical Position, Frame or Table Type.
- Complications Associated with Position, Time to Discovery of Complication and Long term Outcome
- Evidence-based Recommendations for Complication Avoidance

Shriver,MF, Neurosurg Focus, 2015

Recovery Room Evaluations

- Pressure Point Skin Examination
- Neurologic Examination in Recovery Room (1-2 hrs) and in Hospital Room (2-4 hrs)
- STAT Surgeon Notification
- STAT Diagnostic Study to Confirm Findings
  - -Compartment Pressure Evaluation
  - -Ultrasound Doppler Lower Extremity

Management of Positioning Complications

- Intraoperative Lower Extremity Sequential Compression Devices
- Compartment Syndrome Requires Diagnosis and Fasciotomy
- Paresis/Loss of Sensation Requires Neurologic Evaluation, Extremity Protection, Physical Therapy and Possibly Splinting
- Decubiti Require Monitoring and Alleviation of Pressure
- Postoperative Vision Loss Requires Evaluation, Resolve any Hypotension and Monitor Intraocular Pressure

Positioning Safety Checklist

- Should Precede the Time Out
- Needs to be Discussed and Agreed Upon by Surgeon, Anesthesiologist and Circulating Nurse
- Mandatory Educational Training for All OR Staff
- Checklist in OR is an Efficient, Time Saving Tool, Reliable and Increases Patient Safety

Summary

- Awareness and Avoidance
- Clear Communication and Collaboration Among Staff when Positioning
- Identify High Risk Patients and Make the Correct Positioning Adjustments
- Monitor All Intraoperative Physiologic Parameters Closely





BLOOD LOSS MANAGEMENT

Disclosures

Guyer (a) Alphatec; (b) Spinal Kinetics, Spinal Ventures, Mimedix; (c) DePuy-Synthes Spine, K2M, Flexuspine, Mimedix, Aescalup; Safe Orthopedics (d) DePuy-Synthes Spine, K2M, Paradigm Spine

Key: (a) royalties; (b) stock/options; (c) consulting/SAB; (d) Speaker/ faculty; (e) Research; (f) Fellowship and related research; (g) other

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I Hate Bleeding

- Stresses:
  - Me
  - Patient
  - Anesthesia team
  - Nurses





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1st Step of Blood Loss Management?

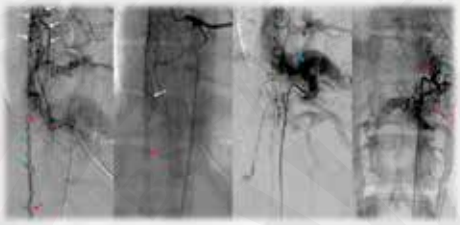
- Preop optimization
  - Hb/hematocrit
  - Stop anticoagulants (if safe)
  - Address deficiencies (vit K)
  - Aware of coagulapathies

PRE-ADMISSION TESTING

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1st Step of Blood Loss Management?

- Preop optimization for spine tumors
- Embolization



Thiex et al, Spine, 2013

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2nd Step: Intraop Management

- How to minimize blood loss?
  - MIS? Not everything
  - Open surgery: principles of minimizing blood loss

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Principles

- Achieve excellent hemostasis at each stage
- e.g. L4-5 Lami fusion

	Make it DRY	Make it DRY	Make it DRY
Exposure →	Decompression →	Decorticate/Screws →	End
• Levels confirmed • Retractors in • Direct visualization of TP • Laminae exposed	• Bipolar • Thrombin-soaked Gelfoam • Flo-seal	• Accept some bleeding (bone) • Screws stop bleeding from holes	•Irrigate •Close •Drain

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Tricks/Techniques to Minimize Blood Loss

- Hypotensive anesthesia (if safe)
- Paralytic
- Abdomen free
- Keep patient warm

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Tricks/Techniques to Minimize Blood Loss

- Hypotensive anesthesia (if safe)
- Paralytic
- Abdomen free
- Lumbar Approach, avoid interspinous, subperiosteal

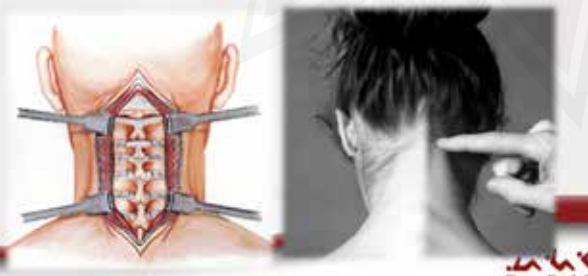


Moghimi et al, Eur Spine J, 2016

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Tricks/Techniques to Minimize Blood Loss

- Posterior cervical approach, ligamentum nuchae
- Avoid interspinous region (like lumbar)



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Where Can Bleeding Come from?

- Muscle
- Epidural
- Bone

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Where Can Bleeding Come from?

- Muscle

Electrocautery



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Where Can Bleeding Come from?

- Epidural

Bipolar Cautery





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Where Can Bleeding Come from?

- Muscle
- Epidural
- Bone

Bone Wax



Lami borders, spinous processes, any exposed bleeding surface (not on fusion surfaces though)

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Expected Uncontrolled Blood Loss

- Osteotomies
  - E.g. PSO
- Tumors
  - E.g. renal cell, myeloma



Sequence of events to consider….

Expose/ Instrument 1st → Tumor Removal 2nd → Bleeding continues until tumor is out (stop touching it!) → Cool irrigation (bleeding slows)

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Blood Replacement

- PRBC
- FFP
- K
- Avoid iatrogenic coagulopathy

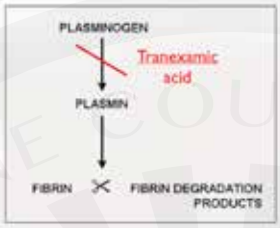




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"Other" Techniques/Agents

- TXA
  - IV
  - Topical (in wound)
  - Cheap, safe, effective





Contraindications:
hypercoaguable states/disorders

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"Other" Techniques/Agents

- Floseal (human-derived thrombin)
- Avitene (microfibrillar collagen)



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Blood Salvage

- "Cell Saver"
- Good if expect big blood loss
- Religious objection?(Jehovah's witness)
- Contraindication:
  - Tumor
  - infection



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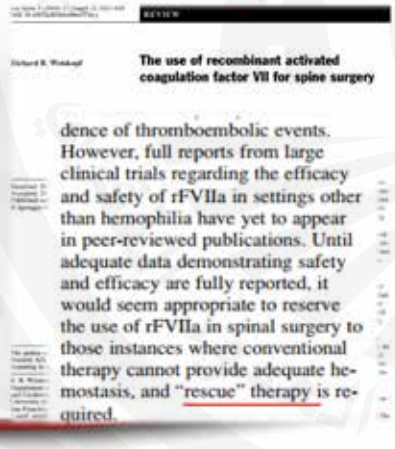
Emergency Maneuvers

- Factor VII(a), not for everyone



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"Rescue" Therapy, Last Resort



The use of recombinant activated coagulation factor VII for spine surgery

dence of thromboembolic events. However, full reports from large clinical trials regarding the efficacy and safety of rFVIIa in settings other than hemophilia have yet to appear in peer-reviewed publications. Until adequate data demonstrating safety and efficacy are fully reported, it would seem appropriate to reserve the use of rFVIIa in spinal surgery to those instances where conventional therapy cannot provide adequate hemostasis, and "rescue" therapy is required.

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Great Review



Tse, et al, JBJS Am, 2011

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THROMBO-EMBOLIC AVOIDANCE

Thromboembolic?

- DVT



- PE



Thromboembolic?

- DVT



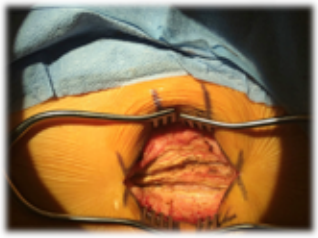
- PE

How big a problem?



Incidence varies

- "Low risk"—routine, elective spine surgery
  - w/o prophylaxis---unknown
  - w/ some prophylaxis: varied…
    - 1.3%, 15.5% to 60%
    - L > C (26.5% vs. 14.3%)



Incidence varies

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Why so much variation?

Incidence varies

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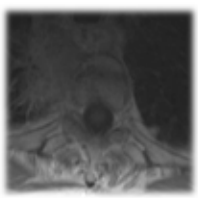
Why so much variation?

Detection/Screening:

Exam U/S Venography VQ scan

Incidence varies

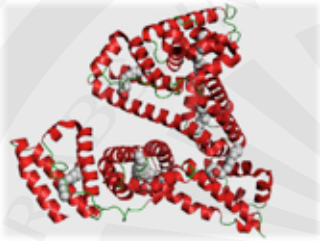
- "High Risk"—trauma, cancer
  - w/o prophylaxis:
    - Incidence difficult to estimate
  - Higher than elective
  - ↑↑ rate w/ SCI/neurologic deficit (Ploumis et al, JBJS, 2009)





Incidence varies

- "High Risk"—
  - Unique predictive factor
  - Serum Albumin ≤ 3.5 g/dL (Schoenfeld et al, Spine J 2013)



Routine Prophylaxis

- ALL patients (elective, non-elective, C, T, L)
  - SEQUENTIAL COMPRESSION DEVICES



Routine Prophylaxis

- ALL patients (elective, non-elective, C, T, L)
  - SEQUENTIAL COMPRESSION DEVICES

Grade B recommendation
(NASS Guideline)



Chemical Prophylaxis?

- Routine use?
  - Probably not for routine, elective
  - NASS: "may not be warranted as it is accompanied by a definable risk of serious wound and bleeding complications."



Chemical Prophylaxis?

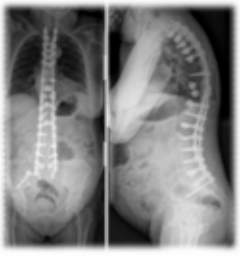
- Routine use?

Despite this, many US centers REQUIRE it for ortho: spine is lumped in



When indicated, how long for chemoprophylaxis?

- NASS guideline: Workgroup consensus
  - "...until patient is fully ambulatory is a reasonable practice."



OK for deformity
OK if can EVENTUALLY ambulate

When indicated, how long for chemoprophylaxis?

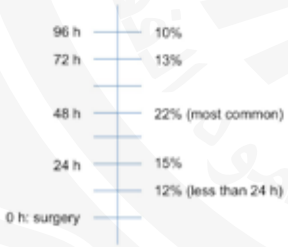
- NASS guideline: Workgroup consensus
  - "…until patient is fully ambulatory is a reasonable practice."



Not OK if no hope of ambulating
e.g. complete SCI

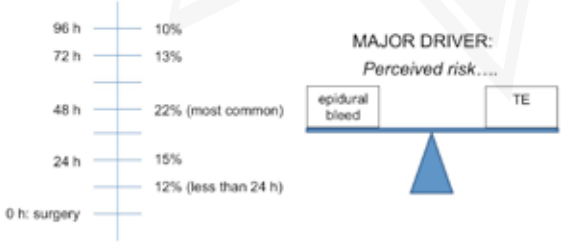
When is it safe to start chemoprophylaxis?

- Another unknown
  - NASS Guideline: can start day of
  - Boston Survey: wide range (for high-risk Pts)



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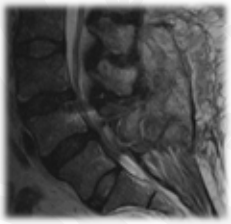
Does chemoprophylaxis ↑ risk for Epidural hematoma?

- Systematic review (Glotzbecker, Bono, et al, Spine, 2010)
- Estimated rates:
  - w/ chemoprophylaxis: 0-0.7%
  - w/o chemoprophylaxis: 0-1.0%

i.e. NO DIFFERENCE

Does chemoprophylaxis ↑ risk for Epidural hematoma?

- Systematic review (Glotzbecker, Bono, et al, Spine, 2010)
- Caveat:
  - THERAPEUTIC ANTICOAGULATION
  - Case reports of associated bleeds w/ neuro Δ



e.g. 62 year old woman, s/p lami-fusion, became SUPRTHERAPEUTIC (INR of 4) at rehab, then couldn't move legs

Ideal agent?

- Not great data for elective
- Most seem to work, even ASA
- Caveat: *unfractionated heparin less effective than LMWH in SCI pts*
- Our preference: LMWH
  - No blood draws
  - Reasonable efficacy



Special circumstances

- Bridge therapy
  - E.g. patient w/ past h/o of DVT/PE
  - Need to stop long-acting (e.g. warfarin, plavix) more than ½ life



  - "Bridge" w/ short-acting (e.g. LMWH)
  - Stop short-acting 12-24 h preop
  - Restart long-acting post-op

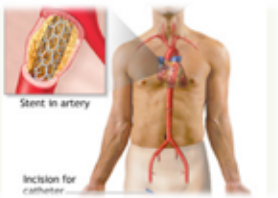
Special circumstances

- Tx of postop DVT or PE
  - Worst case scenario
  - Need to be therapeutic levels
  - Balance actual risk vs. benefit
    - E.g. DVT below knee---need to be txd?



Special circumstances

- Patients w/ stent
  - Fresh stent (<6 mos): postpone surgery (elective)
  - Stent > 6 mos—stay on ASA through surgery
    - Bleeding? Not much different intraop, ↑ in drain (postop)



APPROACH RELATED COMPLICATIONS: ANTERIOR CERVICAL POSTERIOR CERVICAL

Smith Robinson Approach

- Well tolerated

- Trans-platysma
- Medial to SCM, carotid sheath
- Prevertebral fascia
- Longus colli



From The Spine 6th edition

Intraoperative

- Esophageal injury (0.2-0.4%)
- Vertebral artery injury (0.3%)
- Dural tear (1-3.7%)
- Spinal cord injury (0.2-0.9%)
- Peripheral nerve injury or radiculopathy (0.2-3.2%)
- Sympathetic plexus (0.2-4%)

Esophageal Injury

- Incidence: 0.2-0.4%
- Mechanism: retractors, high speed drill, sharp instrument
- If missed, high mortality



- Appropriate retractor placement
- Hand held retractor to protect
- Meticulous dissection









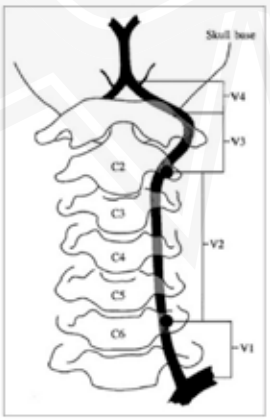




- Intraoperative
  - Indigo carmine
  - ENT, general, thoracic
  - G tube
  - Endoscopy
- Late management
  - Remove hardware, debride
  - Flap, GJ feeding, prolonged antibiotics
  - Posterior stabilization if necessary

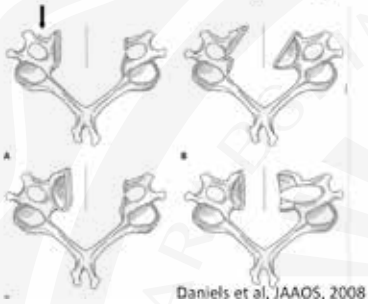
Vertebral Artery Injury

- Incidence: 0.3-0.5%
- Mechanism: drilling ~60%

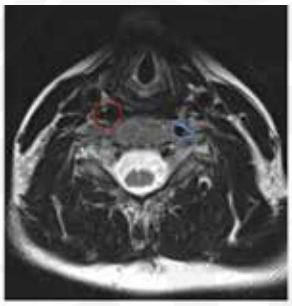


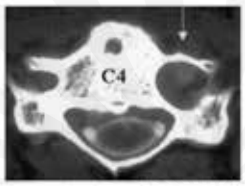
- Sequelae: AV fistula, pseudoaneurysm, late-onset hemorrhage, thrombosis, embolism, cerebral ischemia, death

- Loss of landmarks
- Wide trough
  - 5.5 mm from uncovertebral to VA
- Tortuous course (2.7%)



Daniels et al. JAAOS. 2008





Curylo et al, Spine, 2000

Management

- Adequate resuscitation
- Tamponade, hemostatic agent
- Direct exposure and repair or bypass
- Ligation, clipping: confirm retrograde flow
- Endovascular treatment (intra- or post-)
- Antiplatelet agent
- Angiography

Dural Tear

- Incidence 1-3.7% (higher in OPLL and revision)
- Fistula formation, secondary airway compromise
- Management: repair, fibrin glue, sealant, lumbar drain, head of bed >30 degrees

Spinal Cord Injury

- Incidence: 0.2-0.9%
- At risk: myelopathy, cervical kyphosis, myelomalacia, instability, ankylosed fracture
- MAP>80mmHg, MEP/SSEP, avoid excessive extension/distraction
- Evaluate graft and hardware
- Advanced imaging

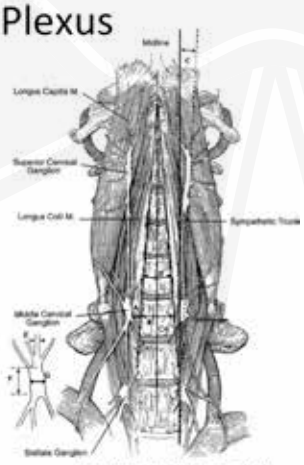
Peripheral Nerve Injury or Radiculoapthy

- Incidence 0.2-3.2%
- Usually indirect: traction, ulnar nerve pressure
- Advanced imaging to r/o neural compression
- Expectant management

Sympathetic Plexus

- Incidence: 0.2-4%
- Lower cervical levels
- Limit LC dissection
- Retractors underneath





Ebraheim et al, Spine, 2000

Immediate/Early Postoperative

- Airway compromise 2/2 edema or hematoma (1.7-6.0%)
- Epidural hematoma (0.2-1.9%)
- Radiculopathy (0.2-3.2%)

Edema

- Incidence: 1.7-6.0%
- Reintubation: 1.7-2.8%
- Risk factors: obesity, OSA, >5hrs, revision, asthma, 3+ levels, 4+units blood
- Limit surgical time, fluids
- Elevate bed



Hematoma

- Incidence: 0.2-1.9%
- Venous bleeding, unrecognized arterial bleeding
- Drain, hemostasis
- Bedside incision and drainage



Epidural Hematoma

- Incidence: 0.2-1.9%
- Arterial or epidural veins

- High suspicion with new neuro deficit
- CT or MRI if neurologically stable
- Urgent surgical re-exploration, removal of hardware and bone graft



Kim and Kuh, Korean J Spine, 2012

Intermediate to Long Term

- Dysphagia (28-57%)
- Dysphonia (2-30%)
- Bone graft extrusion (6-71%)
- Wound infection (0.2-1.6%)
- Pseudarthrosis (varies)

Dysphagia

- Incidence: 28-57%
- Esophageal denervation, post operative soft-tissue swelling, scar tissue, cervical immobilization, cervical hyperextension, plate prominence, hematoma formation

- Above C3: hypoglossal
- C3-4: SLN (sensory impairment)
- C2-5: pharyngeal plexus
- C5-T1: RLN (mild liquid dysphagia)

Dysphagia

- Previously underreported
- Majority improve with time

- Risk factors: longer duration of neck/arm pain, age>60yrs, female, 2+ levels, revision, thicker anterior plate
- Speech therapy evaluation
- Swallow therapy
- Possible feeding tube

Dysphonia

- Incidence: 2-30%
- RLN, vocal cord trauma or edema, reflux
- Persistent RLN 0.33-2.5%

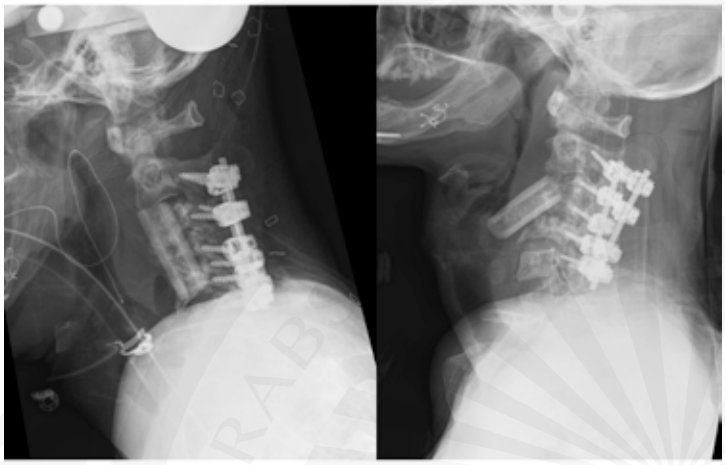
- Right versus left approach
- ET cuff



Bone Graft Extrusion

- Incidence: 6-71%
- 1-, 2-level okay with anterior plate
- 3-level should have simultaneous posterior instrumentation

- Meticulous carpentry



Wound Infection

- Incidence: 0.2-1.6%

- Irrigation and debridement
- Evaluate for esophageal injury
- Intravenous antibiotics

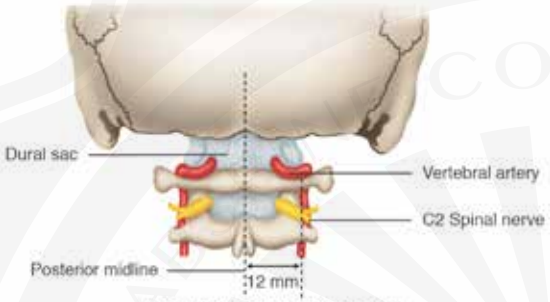
- Hardware removal, regrafting, posterior stabilization



Posterior Cervical



Approach to C1, C2



Medial-most edge of the vertebral artery groove on the outer cortex of the posterior ring

Posterior

- Infection (up to 18%)
- C5 palsy (1.4—18.4%)
- Vascular injury (0-8.2%)
- Durotomy (1%)
- Epidural hematoma (1.5%)
- Axial pain (up to 28%)

Infection

- Incidence: up to 18%
- ACS-NSQIP: 2.9%

- Risk factors: obesity, steroid, low albumin, Hct, plt; high ASA class, length of case, long hospital admission, collar

Sebastian et al, The Spine J, 2015

- Intrawound Vancomycin



Pahys et al, JBJS, 2013

C5 Palsy

- Incidence: 1.4-18.4%
- "Tethering effect"
- Risk factors: OPLL, laminectomy, neuroforaminal stenosis, excessive drift, male gender
- Majority resolve
- PT to prevent frozen shoulder



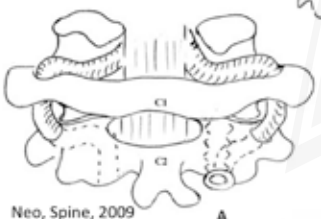
Vertebral Artery Injury

- Incidence: 0-8.2%
- V2: instrumentation
- V3: approach, instrumentation
- Low for subaxial lateral mass screws

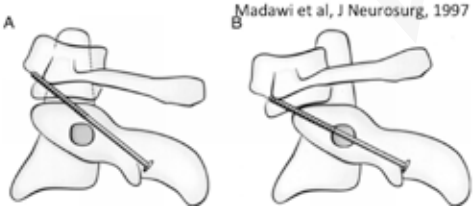




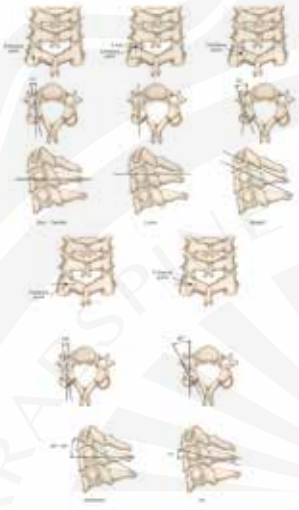
(A) Yamazaki et al, Spine, 2012 (B)



Neo, Spine, 2009



Madawi et al, J Neurosurg, 1997



Durotomy

- Incidence: 1%
- Risk factors: age, RA, OPLL, deformity, longer case, more levels, worse neurologic status, corpectomy, revision laminectomy
- Approach not risk factor

- Revision dural repair- suture, patch, sealant
- Lumbar Drain
- Bedrest

Epidural Hematoma

- Incidence: 0.22-1.5%
- Risk factors: comorbidities, post op NSAIDs, high alcohol consumption, multilevel, revision

- High index of suspicion
- Rapid surgical intervention

Axial Pain

- Pooled prevalance 28%
- Lami/fusion less than laminoplasty
- Preserve attachments to C2 and C7
- Minimize collar time



Key References

- Daniels AH, Riew KD, Yoo JU, Ching A, Birchard KR, Kranenburg AJ, Hart RA. Adverse Events Associated With Anterior Cervical Spine Surgery. J Am Acad Orthop Surg 2008.

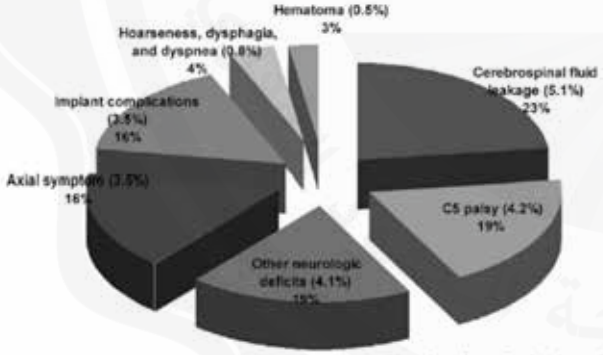
OPLL: SPECIFIC COMPLICATIONS

"You know, 97 percent of the time, if you come into a hospital, everything goes well. But three percent of the time, we have major complications."

Atul Gawande

Overview

No difference in rate of complications between anterior and posterior approach (24.3% vs 25.4%)

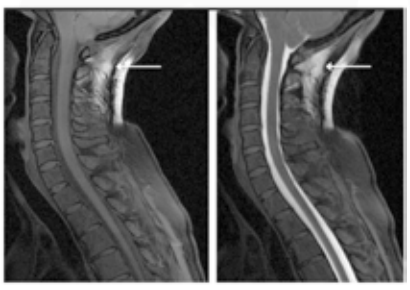


A systematic review of complications in cervical spine surgery for ossification of the posterior longitudinal ligament

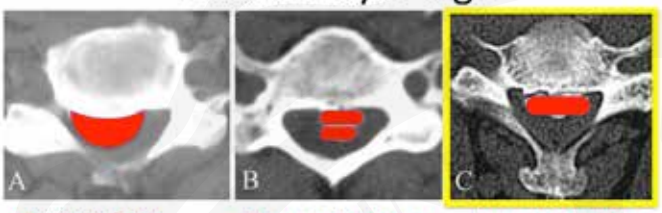
Hui Li, MD, PhD[a], Li-Yang Dai, MD, PhD[a,*]

CSF Leak

- Overall incidence: 5.1%
  - *Range in the literature: 1-23%*
- More common with ANTERIOR procedure
  - *11.9% with anterior*
  - *2.7% with posterior*
- Does not cause late sequelae if properly managed
- Double layer sign



Double Layer Sign



Crescent shape | Short-straight shape | Long-straight shape



CSF LEAK

Implications of different patterns of "double-layer sign" in cervical ossification of the posterior longitudinal ligament

Durotomy



- Leave layer of ossification (allow to float)
- When dura is deficient next to region of OPLL:
  - Autogenous muscle or fascial dural patches
  - Immediate lumbar subarachnoid shunting
  - Modified postoperative regimen (i.e. limit incentive spirometer; use antiemetics, etc)

Postoperative cerebrospinal-fluid fistula associated with erosion of the dura. Findings after anterior resection of ossification of the posterior longitudinal ligament in the cervical spine.

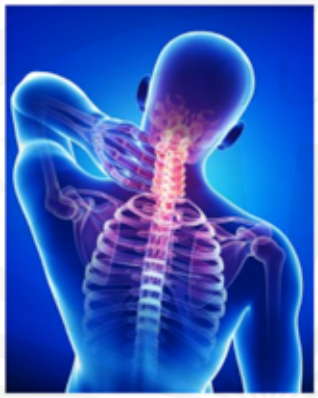
Neurologic deficit

- **Most common complication**
  - *Accounts for 38%!!!*
- **Overall incidence: 8.4%**
  - *Range in the literature: 1-21%*
- **C5 palsy: 4.2%**
- **More common with posterior procedure**
  - *16% with posterior; 5% with anterior*
- **20.6% failure of complete recovery**



Axial pain

- =neck pain or stiffness
- Overall incidence: 3.4%
  - –But 34.5% with posterior approach
- Does not typically require repeat surgery for symptoms



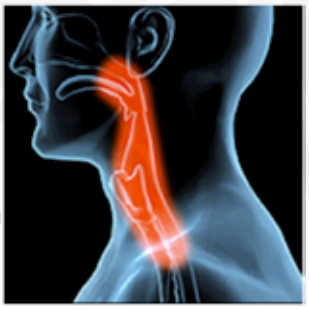
Implant complications

- = Bone graft/instrument dislodgement or failure
  - Nonunion (symptomatic or asymptomatic)
- Overall incidence: 3.5%
- Implant-related: most common after anterior corpectomy with anterior plate or interbody fusion
- Graft-related: extrusion or fracture most common with fibular graft



Hoarseness/Dysphagia

- Overall incidence: 0.3%
  - *Doubles with anterior approach: 0.68%*
- Hoarseness/dysphagia is usually transient (resolves in <2 months)



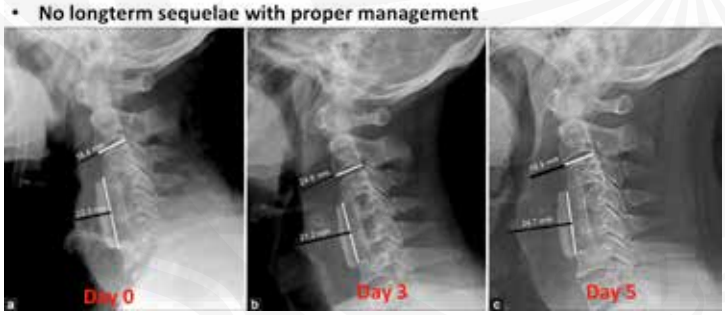
Dyspnea

- Overall incidence: 0.5%
- Most commonly due to retraction of larynx with anterior approach
- Beware of large hematoma / CSF leak causing symptoms



Hematoma

- Overall incidence: 0.5%
  - No difference in anterior/posterior approach
- May require emergency evacuation to prevent cervical spinal cord injury
- No longterm sequelae with proper management



Key References

- Li H, Dai LY. A systematic review of complications in cervical spine surgery for ossification of the posterior longitudinal ligament. Spine J 2011;11:1049-57.
- Smith MD, Bolesta MJ, Leventhal M, Bohlman HH. Postoperative cerebrospinal-fluid fistula associated with erosion of the dura. Findings after anterior resection of ossification of the posterior longitudinal lig- ament in the cervical spine. J Bone Joint Surg Am 1992;74:270–7.
- Yang H, Yang L, Chem D, et al. Implications of different patterns of "double-layer sign" in cervical ossification of the posterior longitudinal ligament. Eur Spine J 2015;8:1631-9.
- Tetreault L, Ibrahim A, Cote P, et al. A systematic review of clinical and surgical predictors of complications following surgery for degenerative cervical mylopathy. J Neurosurg Spine 2016;1:77-99.

THORACIC & LUMBAR: ANTERIOR APPROACH

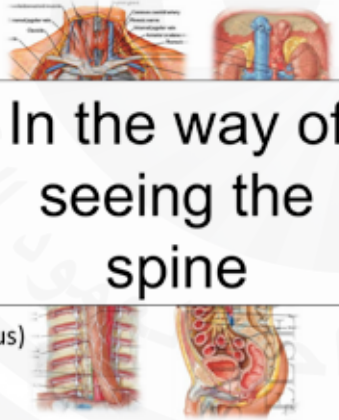
Anterior Approach to T and L Spine

- "Tiger Country"
  - Heart
  - Lungs
  - Major vessels
  - Lymphatics
  - Bowels
  - Kidneys/ureters
  - "other" nerves (plexus)



Anterior Approach to T and L Spine

- "Tiger Country"
  - Heart
  - Lungs
  - Major vessels
  - Lymphatics
  - Bowels
  - Kidneys/ureters
  - "other" nerves (plexus)



Our Job

- Expose spine
- Do our work
- Minimize collateral damage



Complications, Risks

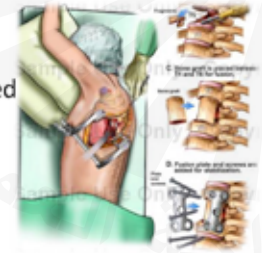
- Depend on precise approach
- Depends on the level of surgery





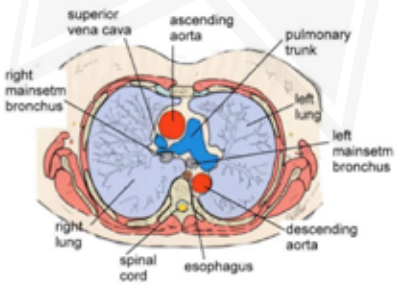
Anterior Thoracic Approach

- Workhorse: THORACOTOMY
  - Standard approach, up to T5 (T4?)
  - Modified approach (scapula mobilizing) up to CT jxn
  - Ribs resected, cut
  - Lung deflated
  - Heart/Great vessels protected



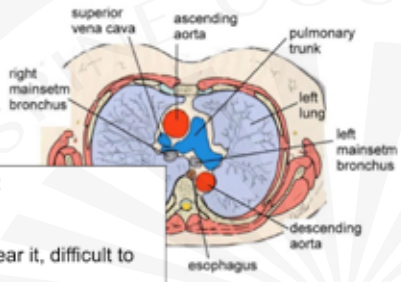
Thoracic: Vascular Complications

- Aorta (left)
  - Posterior to pulmonary vasculature
- Vena Cava (right)
  - More anterior



Thoracic: Vascular Complications

- Aorta (left)
  - Posterior to pulmonary vasculature
- Vena Cava (right)
  - More anterior



•Arteries---muscular, more robust
Easier to mobilize

•Vena Cava—thin walled, if you tear it, difficult to repair

Thoracic: Vascular Complications

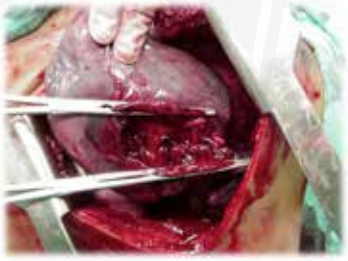
- In reality---Vena Cava not that big a problem
- Azygos Vein is!
  - Right side, must mobilize, ligate segmentals



Bleeding is brisk, can be life threatening…

Thoracic: Pulmonary Complications

- Intraop: Direct lung injury
  - Rare, must be repaired
  - Breach of sterility (secretions)



Thoracic: Pulmonary Complications

- More common issues
  - Pneumothorax
  - Hemothorax/Pleural effusions
  - Atelectasis
  - Pneumonia
  - Pleural adhesions





Thoracic: Pulmonary Complications

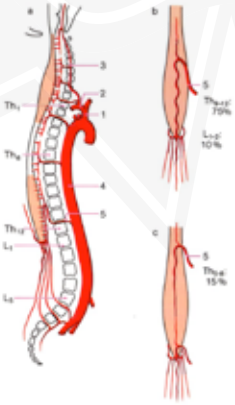
- More common issues
  - Pneumothorax
  - Hemothorax/Pleural effusions
  - Atelectasis
  - Pneumonia
  - Pleural adhesions

Chest tube management



Thoracic: Neurologic Comlications

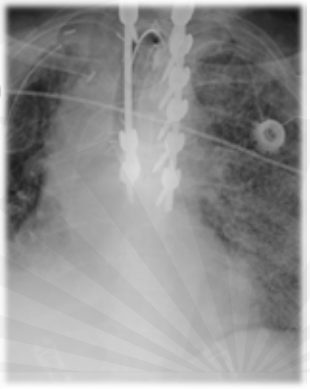
- (excluding direct cord injuries)
- Most common:
  - Intercostal neuralgia
  - 16 to 50%
- Vascular, ischemic SCI
  - Artery of Ademkiewicz
    - T10-L2
    - Preop arteriogram
    - Intra-op, temporary occlusion, MEP



Thoracic: Infections

- Fortunately rare
  - But when it happens, very bad
  - E.g. combined A/P approach for tumor, esophageal tear
  - Bronchopulmonary fistula





Thoracic: Lymphatic Complications

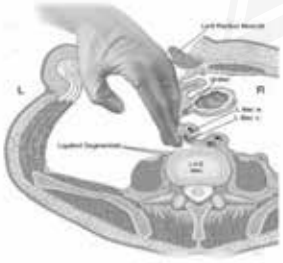
- Thoracic duct
  - Between aorta and azygos vein
  - Crosses from R to L @ T5
  - Injury can lead to chylothorax
  - Milky discharge
  - Tx: Chest tube until ↓s
  - Surgical repair, rarely needed
  - Nutritional supplementation



Anterior Lumbar Approaches

- Retroperitoneal
- Trans-peritoneal

Somewhat different issues





Lumbar: Vascular Complications

- Aorta/Vena Cava
- Iliac Vessels

Frank lacerations
Brisk bleeding
Smaller vessels, segmentals
Can be fatal



Lumbar: Vascular Complications

- Aorta/Vena Cava
- Iliac Vessels

L5-S1, minimal retraction
L4-5, at the bifurcation



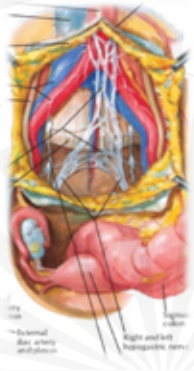
Lumbar: GI Complications

- Intestinal perforation
  - Rare, must repair, contamination risk
- Peritoneal tear
  - Repair, avoid intest hernia
- Postop ileus
  - Pretty common (6%)



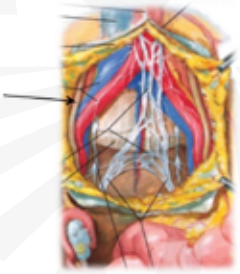
Lumbar: Neurologic Complications (Extraspinal)

- Sympathetic plexus
  - Vasodilation on affected side
  - "cold limb" normal
- Retrograde ejaculation
  - Superior hypogastric plexus
  - ↑er w/ trans vs retro (10% vs 2%)



Lumbar: Genitourologic complications

- Bladder (rare, trochars)
- Ureter
- Particularly w/ revision
- Stent preop (revision)
- Repair
  - End-to-end anastomosis



Lumbar: Wound complications

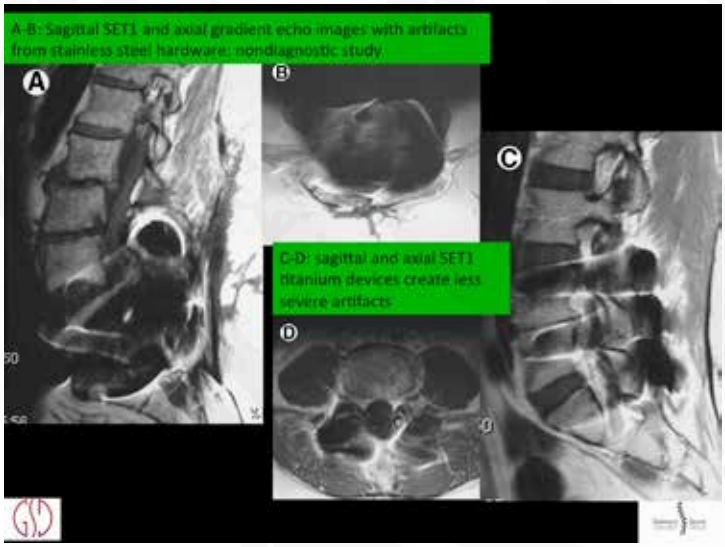
- Infection
  - Rare, usually superficial
  - Deep infection—poor prognosis
- Hernia
  - Surgical repair



IMAGING OF EARLY AND LATE COMPLICATIONS

Early postop complications

- Early complications may have a very quick onset and may be difficult to diagnose due to
  - presence of hardware
  - impaired clinical status
- Local spine surgery complications
- Other complications (embolism, retroperitoneal haemorrhage…)
- Have ready CT and MRI
- Metal artefact reduction strategy



Early Postoperative Complications

To evaluate for possible postoperative complications in the early phase, one needs to understand the typical appearance of the normal postoperative spine after successful back surgery

W. P. Sanders, E. Truumees



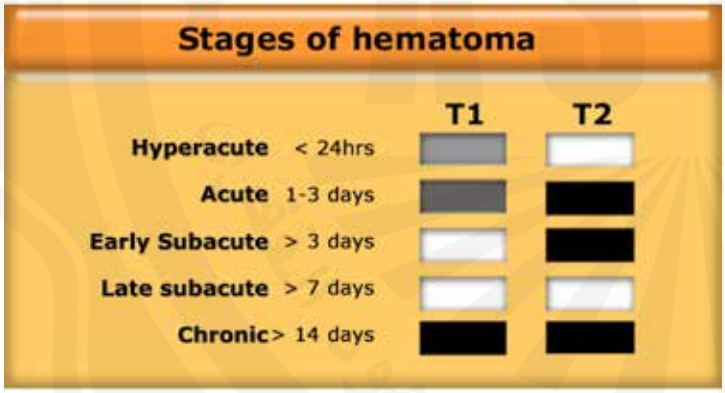


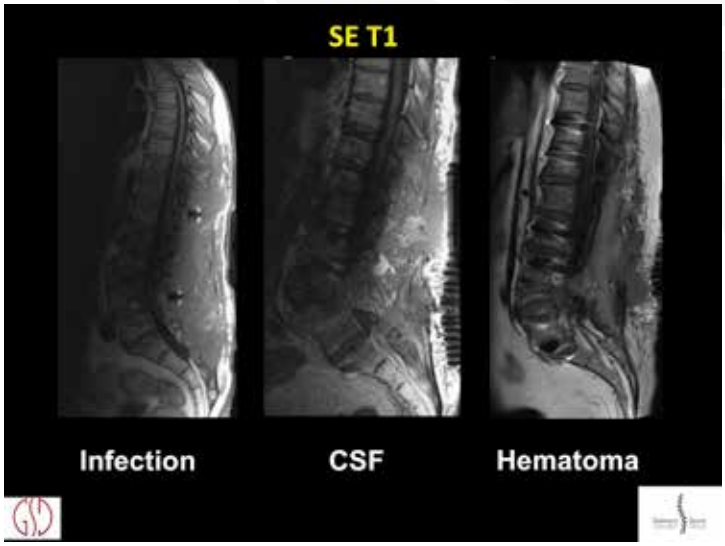
Early postop complications

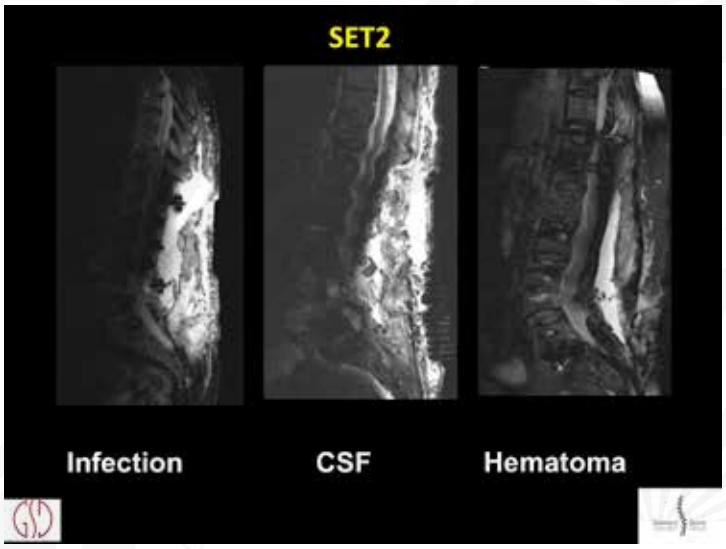
- Postoperative fluid collections
  - Seromas
  - CSF collections from dural leaks
  - Hematomas
  - Intraspinal hematomas
  - Postoperative abscess or subdural abscess
  - Texiloma
- Cord: direct or indirect lesions
- Misplaced instrumentation
  - direct lesions of anatomical structures dural sac, cord, vessels...

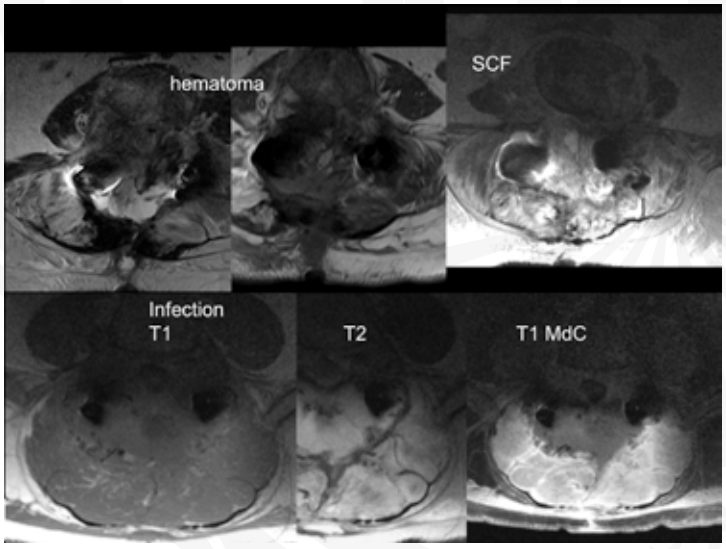
MR differential diagnosis findings

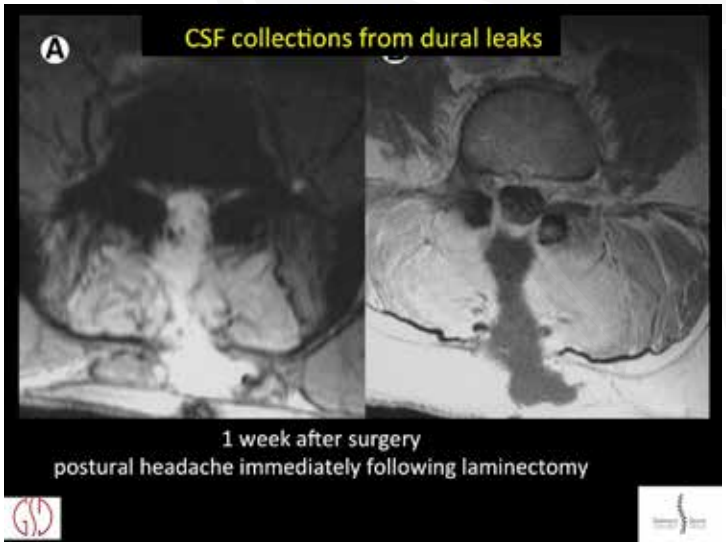
- **Hematoma**
  - Well defined borders
  - Intermediate signal intensity in T1, high in T2 and STIR
  - Hemosiderin spots
- **CSF**
  - poorly defined
  - Low signal in T1, high in STIR and T2
- **Abscess**
  - Well defined
  - Intermediate to low signal intensity in T1, high in STIR and T2
  - Wall enhancement with Gadolinium
  - Air bubbles

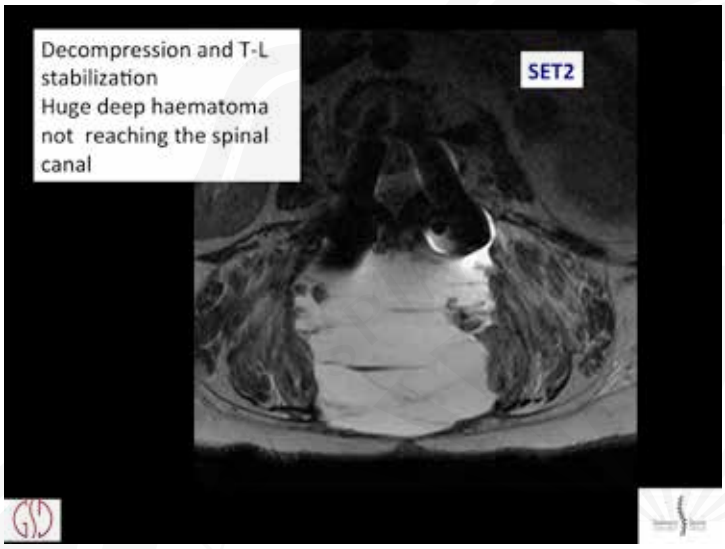




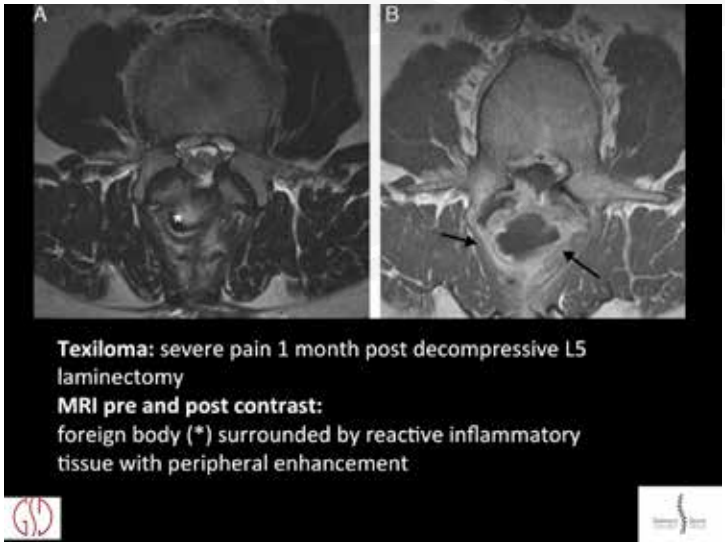

SET2
Infection
CSF
Hematoma

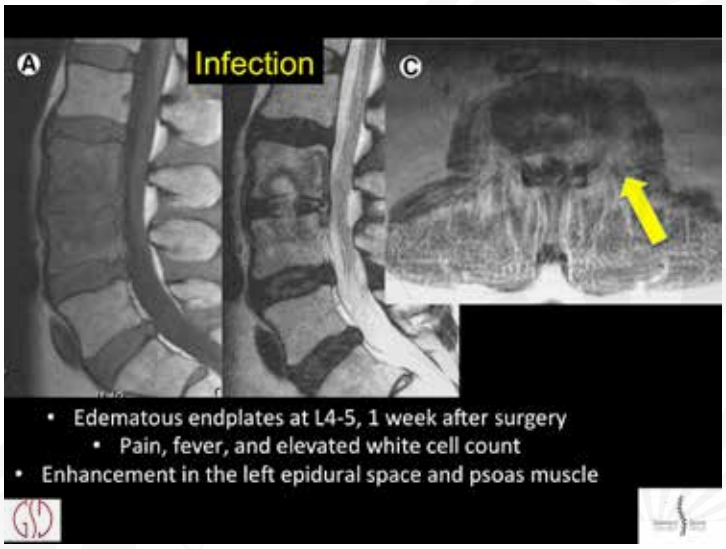

hematoma
SCF
Infection
T1
T2
T1 MdC

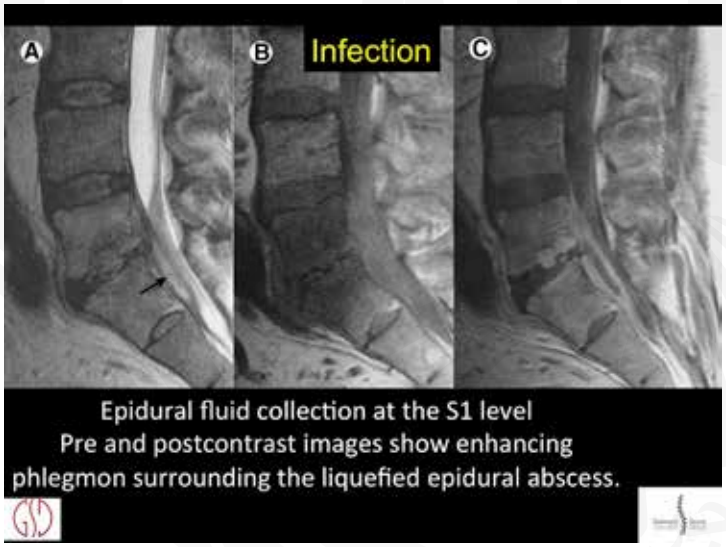

A
CSF collections from dural leaks
1 week after surgery
postural headache immediately following laminectomy


Decompression and T-L stabilization
Huge deep haematoma not reaching the spinal canal
SET2


SET2
SET1


A
B
Texiloma: severe pain 1 month post decompressive L5 laminectomy
MRI pre and post contrast:
foreign body (*) surrounded by reactive inflammatory tissue with peripheral enhancement


A
Infection
C
• Edematous endplates at L4-5, 1 week after surgery
• Pain, fever, and elevated white cell count
• Enhancement in the left epidural space and psoas muscle

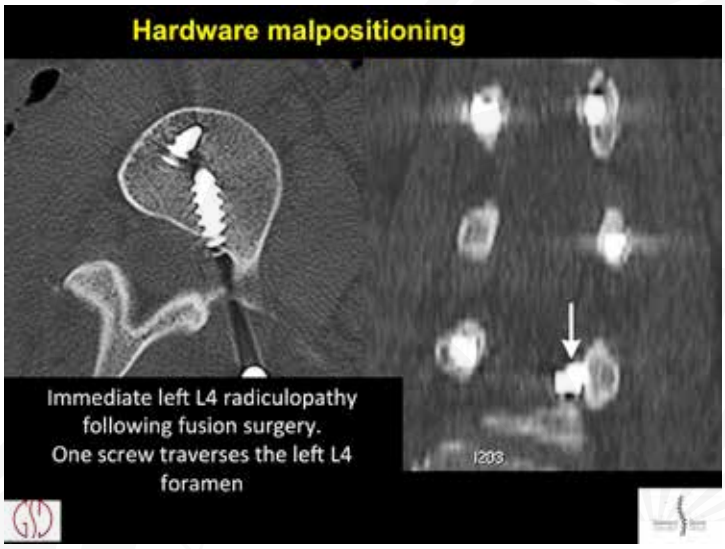

A
B
Infection
C
Epidural fluid collection at the S1 level
Pre and postcontrast images show enhancing
phlegmon surrounding the liquefied epidural abscess.

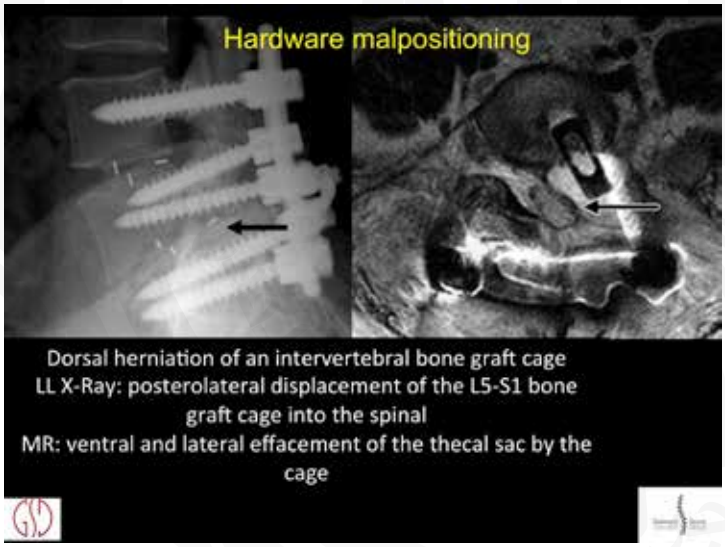

Postoperative diskitis and osteomyelitis.
postoperative
6-month

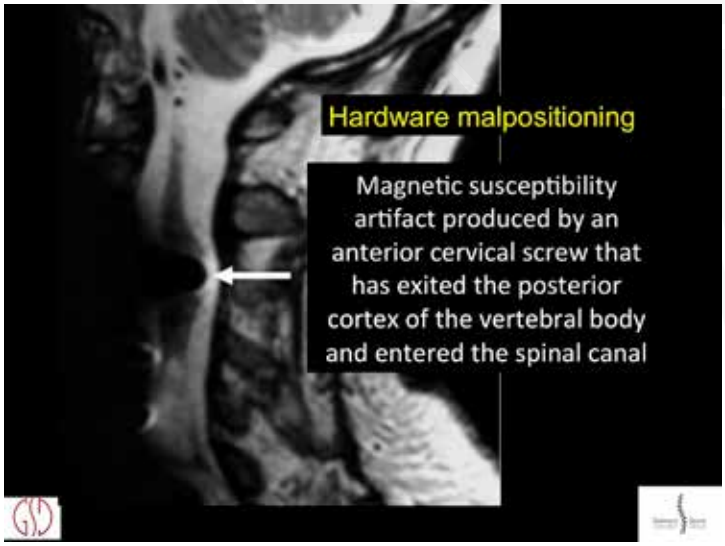

Osteomyelitis and thecal sac compression

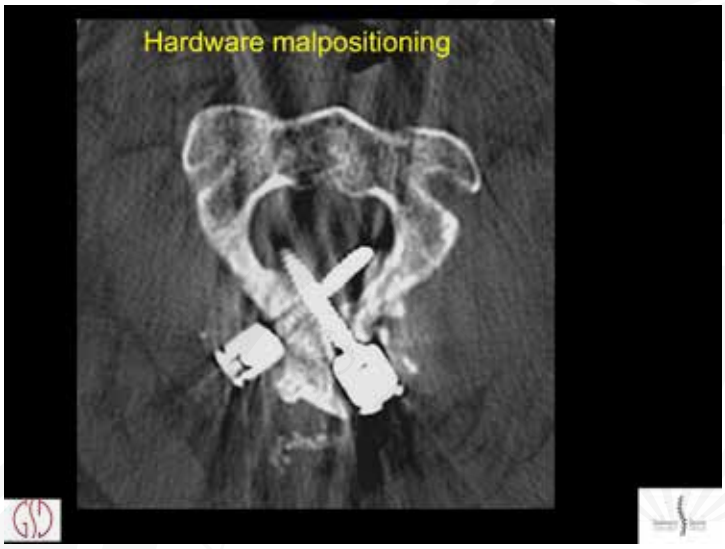

Infection and abscess formation
erosion around the base of proximal screw
Fluid collections

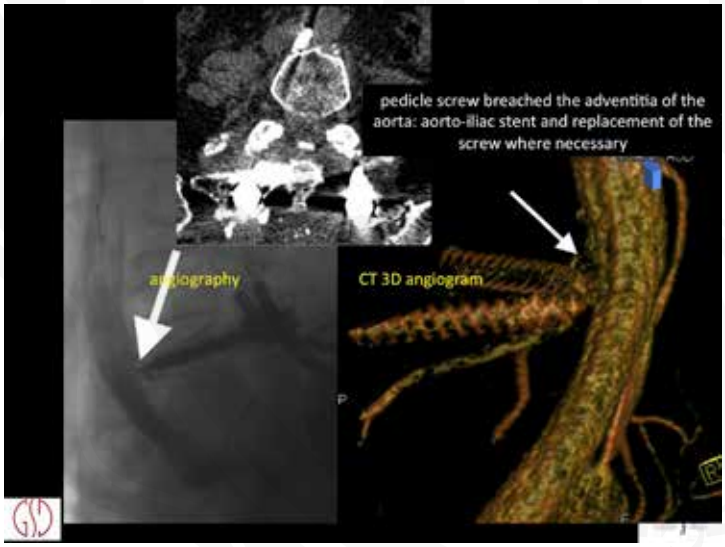

T2 FS focal areas of increased signal in posterior spine due to infection and abscess formation
Infection and abscess formation
T1 FS contrast enhancement in the margin of abscesses in the posterior spine with soft tissue inflammation.


Hardware malpositioning
Immediate left L4 radiculopathy following fusion surgery.
One screw traverses the left L4 foramen

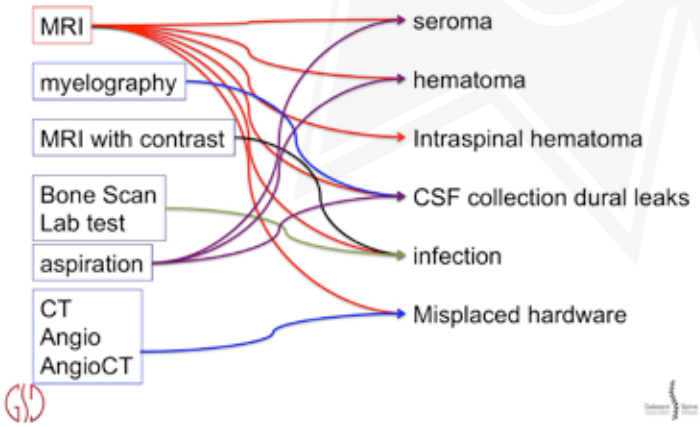

Hardware malpositioning
Dorsal herniation of an intervertebral bone graft cage
LL X-Ray: posterolateral displacement of the L5-S1 bone graft cage into the spinal
MR: ventral and lateral effacement of the thecal sac by the cage


Hardware malpositioning
Magnetic susceptibility artifact produced by an anterior cervical screw that has exited the posterior cortex of the vertebral body and entered the spinal canal





Early postop complications

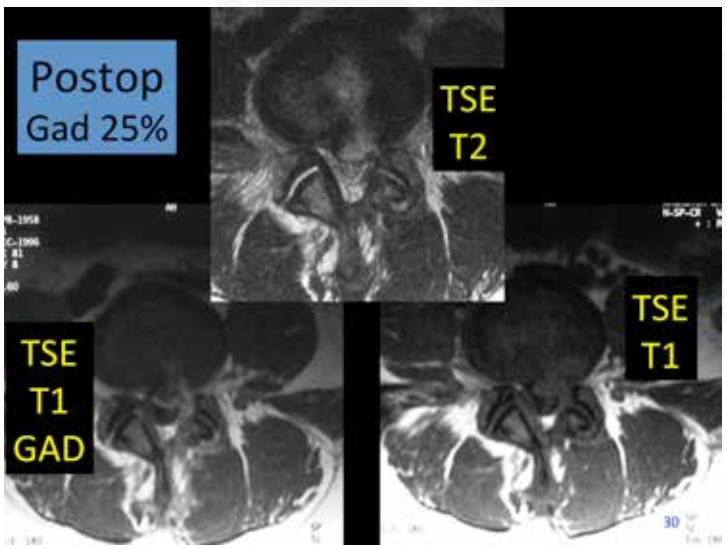


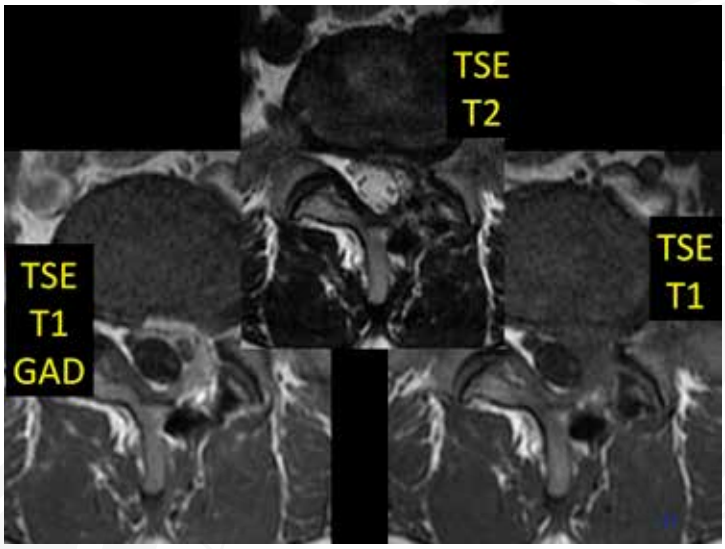
Late complications

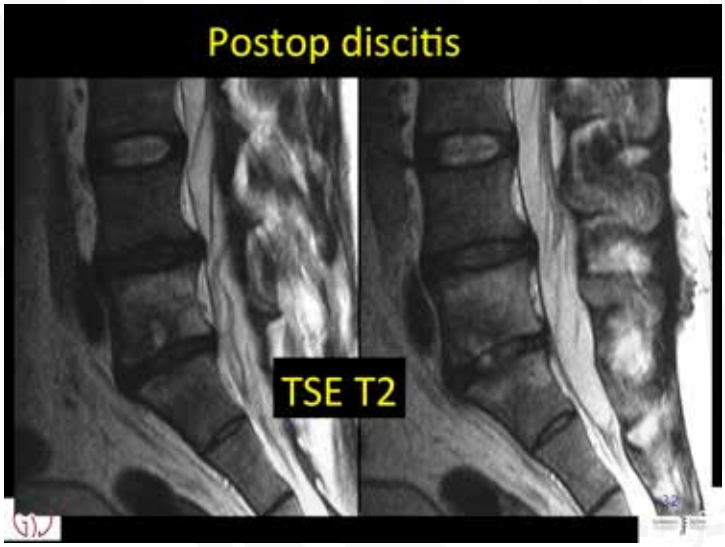
- Post surgery late complications
  - Delayed oesophagus perforation
  - Scar tissue
  - Arachnoiditis
  - Fluid in site of herniectomy
- Late complications due to non-union
  - Aseptic loosening
  - Hardware rupture
- Septic loosening
- Adjacent segment pathology

Gadolinium enhanced MRI

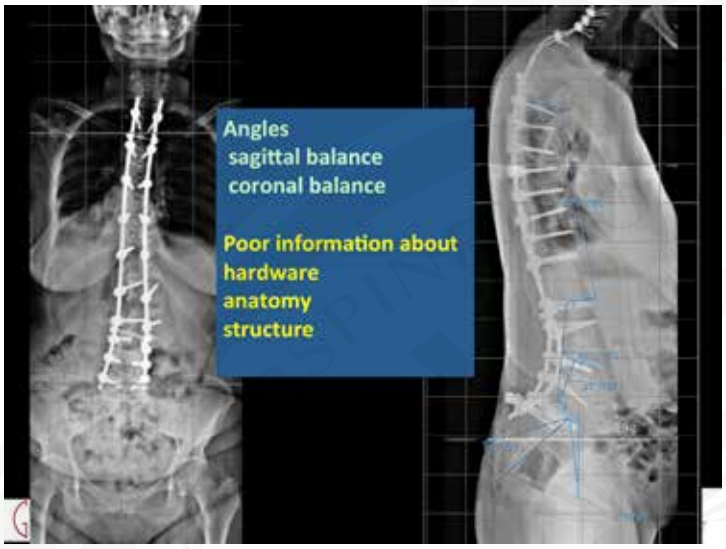
- A decision of the radiologist
- Expensive
- Contraindications
- Major and minor adverse reactions

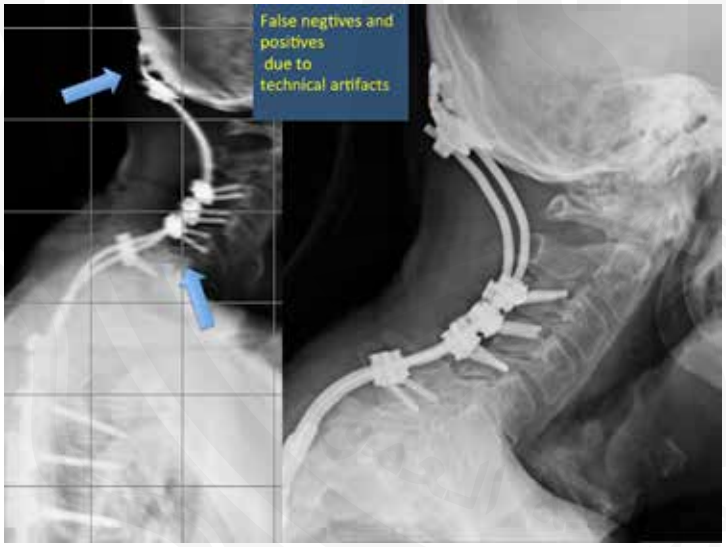



TSE
T2
TSE
T1
GAD
TSE
T1


Postop discitis
TSE T2


TSE T1+GAD





Early and late complication imaging

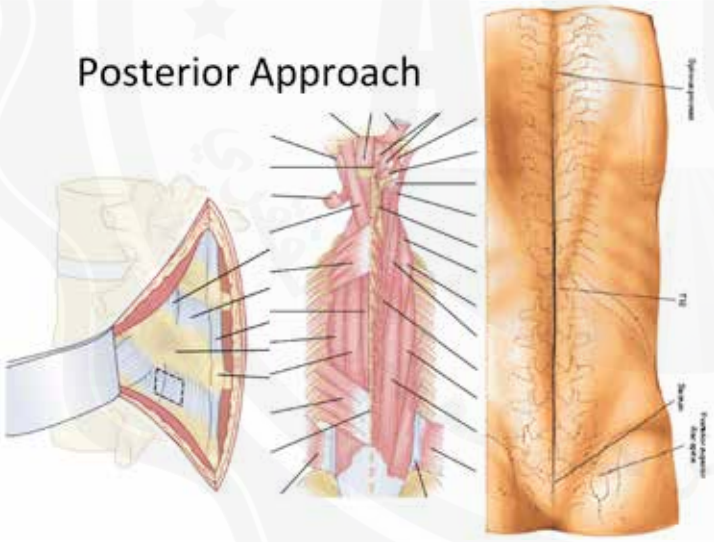
- Early and late complications may be difficult to diagnose due to
  - presence of hardware
  - impaired clinical status (early complications)
- Local spine surgery complications
- Other complications (embolism, retroperitoneal haemorrhage…)
- Have ready CT and MRI
- Metal CT and MRI artefact reduction strategy
- Share your concerns and any information with your radiologist the real add value is a deep cooperation among all of us

THORACIC & LUMBAR: POSTERIOR APPROACH

- You will have complications, unless you don't operate or are not truthful
- How you deal with complications separates an average from a great surgeon



Posterior Approach



Complications/Risks

- Depends on magnitude of surgery
- Depends on patient factors



Literature Varies

- SPORT (Prospective)
  - Discectomy 10.7%
  - Spondylolisthesis 30.8%
- Carreon et al (Elderly)
  - 79.5%
- Ikenaga et al (Deformity)
  - 48 complications in 67 patients
- Han et al (Circumferential vs Posterior)
  - 26.8% and 16.1%
- Deyo et al. 1.9x if fusing versus decompression

Extrinsic

- DVT/PE
- Positioning
  - Visual complications
  - Nerve/spinal cord injury
  - Skin complications
- Medical Complications

DVT/PE

- Elective surgery 2.2-4.2%
- Trauma (5.8%), SCI (80%), tumor are high risk

- SCDs, compression hose, early mobilization
- Consideration of chemoprophylaxis



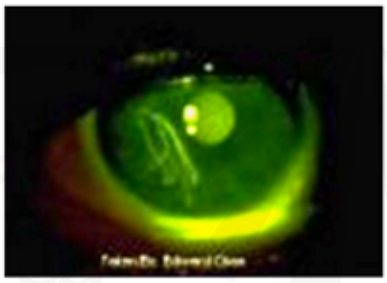


Visual Complications

- Perioperative blindness 0.05-1%
  - Corneal injury (abrasion)
  - Ischemic optic neuropathy
  - Retinal artery occlusion
  - Cortical blindness (stroke)
- Ischemia, direct pressure

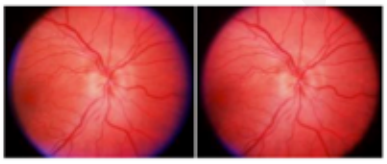
Corneal abrasion

- Most common
- Painful
- Topical antibiotics
- No anesthetics (delay healing)



Ischemic Optic Neuropathy

- Usually irreversible
- Blood loss >4L
- Hypotensive event or relative hypotension for extended period
- Long surgical time



Central Retinal Artery Occlusion

- Usually irreversible



- Direct or indirect pressure (increased intraocular pressure)
- Glaucoma??



Prevention

- Reverse Trendelenburg
- Avoid direct pressure (check constantly)
- Tape eyes or use protection
- Consider Mayfield tongs
- Maintain blood pressure
- Appropriate resuscitation
- Staging?

Quadraplegia

- Intubation, non-neutral positioning
- Elderly patients cervical spondylosis

- Additional chest padding
- Adjustable face rest
- Consider mayfield



Brachial Plexus

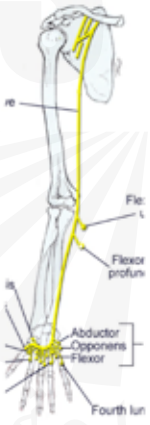
- Shoulder abducted >90 degrees
- Pain, motor/sensory deficits

- Majority improve, 3-6 months
- Neuromonitoring?



Peripheral Nerve

- Ulnar nerve most common:
  - Extended elbow
  - Pad medial epicondyle
  - Larger patients at risk
- Radial nerve:
  - If arm hanging at edge of table
  - Tape arms up, pad underneath arms
- Peroneal, LFCN



Medical Complication

- Cambell et al. Prospective Study
  - Strict definition of medical complication
  - 59.4%

  - Posterior: 49.3%
    - Minor 43.3%
    - Major 18.7%

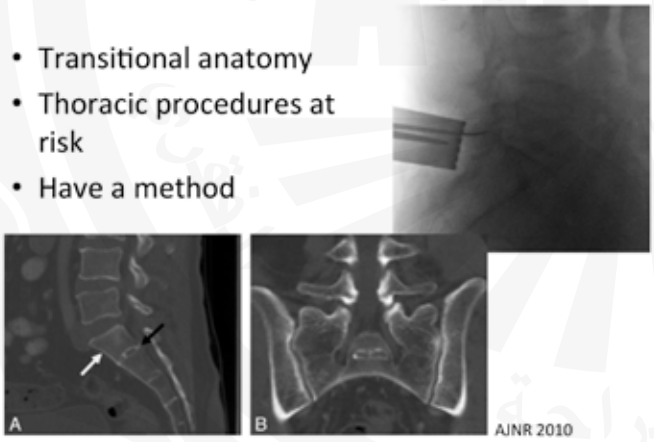
Complication	
Deep wound infection	Urinary tract infection
Hardware/graft malposition	Deep venous thrombosis
Myocardial infarction	Excessive blood loss requiring transfusion
Pulmonary embolism	Pneumothorax
Durotomy	Urinary retention
New weakness	Orthostatic hypotension
Sepsis	Durotomy
Splenic rupture	Thrombocytopenia
Wrong level surgery	Superficial wound infection
Death	Hyponatremia

Intrinsic

- Wrong level surgery
- Durotomy
- Nerve injury
- Implant related complication
- Blood loss anemia
- Vascular injury
- Epidural hematoma
- Infection

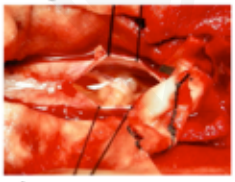
Wrong Level Surgery

- Transitional anatomy
- Thoracic procedures at risk
- Have a method



Durotomy

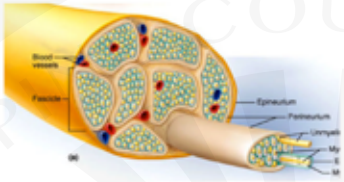
- Incidence ranges: 0.75-15.9%
  - Lowest in primary discectomy, highest in revision
- Dural scarring, dural thinning, large herniation
- Direct repair, sealants, grafts
- 1.8% may require repair



- SPORT- does not impact clinical outcome

Nerve Injury

- Direct: contusion, laceration, traction, compression, thermal
- Indirect: ischemia



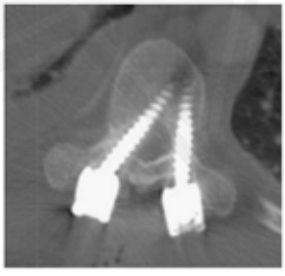
- Peripheral nerve: epineurium and perineurium
- Motor proceeds sensory recovery
- 7.7% deficit incidental durotomy versus 1.5%

Instrumentation Complication Know what can be injured

- Right
  - T4-5: superior intercostal vessels
  - T4-9: esophagus
  - T5-11: azygous vein
  - T11-12: IVC
  - T4-12: thoracic duct
- Left
  - T4-9: esophagus
  - T5-12: aorta
- Lateral
  - Lung, segmental, sympathetic chain

Screws

- Lumbar pedicle screw complication: 2.4%
  - 1% medial or inferior
  - 0.2% nerve root irritation
  - 0.2-5% removal/revision

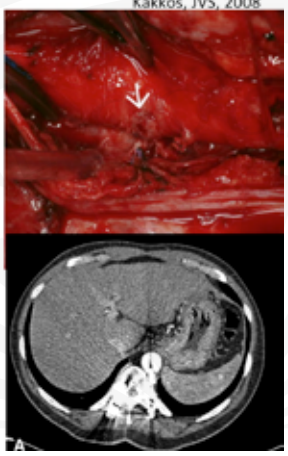


- Thoracic pedicle screws
  - 1.5% malpositioned (inferior and lateral most)

Vascular Complication

Kakkos, JVS, 2008

- Thoracic and lumbar midline surgery typically endangers no major vessels
- Scoliosis: rib resection, intercostal
- Segmental vessels
- Long pedicle instrumentation (left sided screws)
- Discectomy (L4-5 > L5-S1)

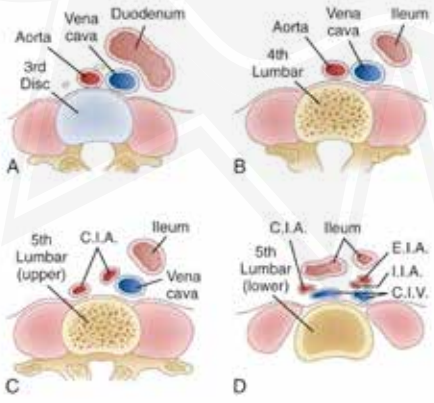


"Jeff Chandler" Syndrome

- 300+ cases of vascular injury from discectomy
- Pituitary or curette
- Hypovolemic shock
- False aneurysm
- AV Fistula
- 15-100% mortality



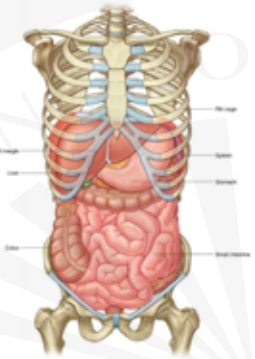
- Limit discectomy
- 2.5 – 4.5cm depth
- Angle matters
- Shevlin's test



From The Spine 6th ed

Visceral Injury???

- Urethral damage
- Small and large bowel perforation
- Damage of lumbar sympathetic chain
- Pancreas



Epidural Hematoma





Literature

Kou J, Fischgrund J, Biddinger A, et al. Risk factors for spinal epidural hematoma after spinal surgery. Spine 2002;27:1670–3.	Case control study 12 cases vs 404 controls Risk factors: multilevel procedures, preoperative coagulopathy Not risk factors: age, BMI, perioperative durotomy, post-operative drain

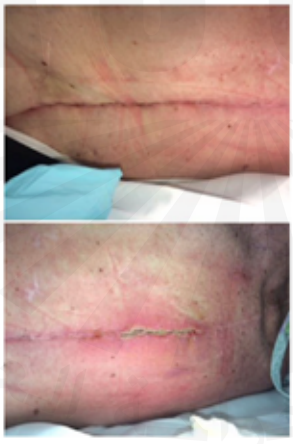
Glotzbecker MP, Bono CM,Wood KB, et al. Postoperative spinal epidural hematoma: a systematic review. Spine 2010;35:E413–20.	16 articles in literature Incidence in those who received DVT chemoprophylaxis: 0% to 0.7% All studies <1%

Literature

Aono H, Ohwada T, Hosono N, et al. Incidence of postoperative symptomatic epidural hematoma in spinal decompression surgery. J Neurosurg Spine 2011;15:202–5.	6356 spinal decompressions 0.41% incidence (26 cases) 0% (0 of 1568) in standard lumbar discectomy 0.50% (8 of 1614) in lumbar laminectomy 0.67% (8 of 1191) in posterior lumbar interbody fusion 4.46% (5 of 112) in thoracic laminectomy 0.44% (4 of 910) in cervical laminoplasty 0.21% (1 of 466) in cervical anterior spinal fusion Shorter the period to evacuation, better results of neurological recovery
Amiri AR, Fouyas IP, Cro S, Casey AT Postoperative spinal epidural hematoma: incidence, risk factors, onset, and management Spine J. 2013 Feb 13(2): 134-40	4568 cases, 0.22% symptomatic SEH Risk factors: EtOH >10 drinks, multilevel, previous spine surgery Symptoms began with median 2.7 hrs Surgery <6hrs improved 1 Frankel grade

Infection

- Instrumented fusion: 2.8-20%
- Modifiable: smoking, obesity, length of surgery, foley catheter, length of stay, malnutrition
- Nonmodifiable: RA, AIDS, steroid, malignancy



Late Complications

- Pseudarthrosis
- Adjacent segment degeneration
- Proximal junctional kyphosis

Key Reference

- Nasser R, Yadla S, Maltenfort MG, Harrop JS, Anderson G, Vaccaro AR, Sharan AD, Ratliff JK. Complications in Spine Surgery, J Neurosurg Spine, 2010.

XLIF / DLIF AND LATERAL TECHNIQUES

Indications for Lateral Access Surgery

- Degenerative disc and facet arthritis with neuroforaminal stenosis
- Degenerative scoliosis
- Degenerative spondylolisthesis
- Augmentation of posterior pedicle screw fusion
- MIS fusion to supplement posterior stabilization
- Pseudoarthrosis

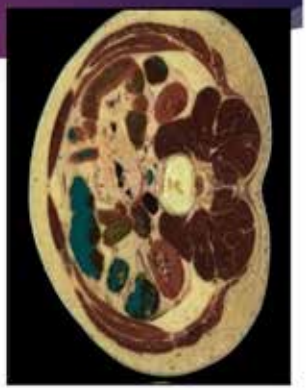
Coronal View of Lumbar Region

- Paravertebral position of Psoas Muscle
- Iliac Crest alignment with L4-5 Disc
- Inferior Pole of Kidney at L1-2
- External and Internal Oblique Muscles
- Retroperitoneal fat



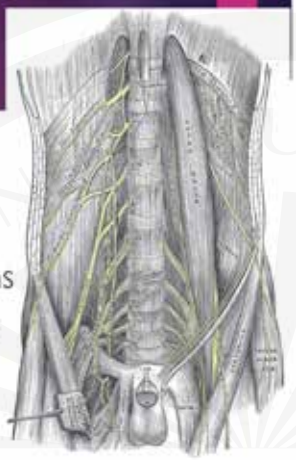
Axial View of Lumbar Region

- Psoas Muscles
- Great Vessels
- External and Internal Oblique Muscles
- Small Bowel
- Kidneys
- Retroperitoneal Fat



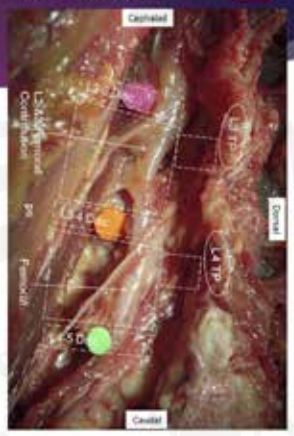
Anatomy at Risk

- Lumbar Nerve roots
- Aorta
- IVC
- Segmental Artery/Veins
- Osteoporotic Vertebra
- Small Bowel
- Kidney

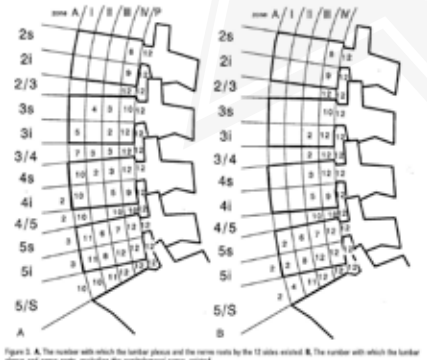


Visualization of Nerve Roots

- Note the Position of the Nerve Roots in the Posterior Aspect of the Disc Space



Nerve Root Location Diagram



Moro, et al

Nerve Roots at Risk

- Genitofemoral Nerve (L4-5)
- Femoral Nerve (L2-4)
- Lateral Femoral Cutaneous (L3-4)

*Ideal Starting Point for Guidewire is Slightly Anterior to Midline

Lateral Access Complications

- 27% Hip Flexor Strength Decrease
- 18% Upper Medial Thigh Numbness
- 10% Psoas Weakness (Often Partial Resolution)
- 5% Anterior Thigh Numbness
- 0.5% Thigh Pain

US Prospective Multicenter Study Neurovision

Post-op Surgical Complications

- Wound Hernia (0.2%)
- GI Ileus (1.4%)
- Cardiac MI vs Afib (0.6%)
- Vertebra Fracture (0.8%)
- Pneumonia, PE, Urinary Retention (Rare)

Rodgers.et al, SMISS, 2008

XLIF/DLIF Procedure

- Patient Positioning and Fluoroscopy Alignment
- Incision and Blunt Finger Retroperitoneal Dissection
- Guidewire Placement/ Neuromonitoring Check
- Dilators and Careful dissection down to Disc
- Adequate Discectomy
- Trial and Gentle Push through Opposite Side Annulus
- Implant Cage with Bone Graft/DBM/Biologic Sponge
- Confirm Position on Fluoroscopy

Positioning Effects on Anatomy

- Reverse Surgical Table to allow for easy C-Arm Fluoroscopy
- Stabilize patient in the lateral Decubitus Position
- Break Table in Reverse Jack Knife Position
- Do Not Over Distract Nerves
- Position Upper Extremities in a Nerve Safe Position



Fluoroscopic Alignment Important

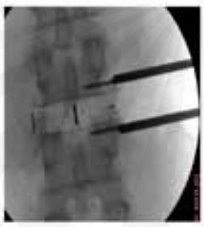
- Angle Fluoroscope According to the Operative Level
- Assure True A-P View
  - Adjust Table not Fluoroscope to get True AP View (Lateral Roll)
- Confirm Perpendicular Lateral View
  - Endplates and Pedicles Align
  - Adjust Table not Fluoroscope (Trendelenberg)

AP and Lateral Fluoroscopic View



Important Techniques to Decrease Morbidity

- Careful Dissection through Psoas Muscle
- Adequate disc removal
- Interbody Graft Resting on Bilateral Vertebra Cortex
- Left Sided Approach Beneficial
- No Oversizing of Graft with Osteoporotic Bone
- Monitor Pressure of Dialators and Retraction Blades



Neuromonitoring

- Stimulate Guidewire after docked on Vertebral Disc
- Decreased nerve Injury with Limited Wanding Through Psoas Muscle
- Bipolar Cautery Use Only
- One Neuromonitoring System Detects nerve Injury Impending if <10

Multiple Companies have Lateral Access Systems









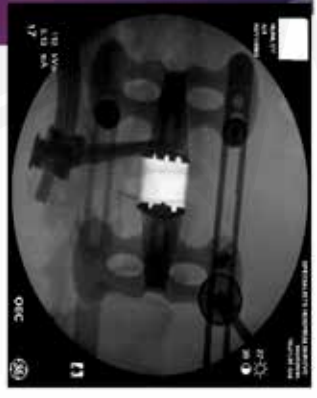
Retractor System

- Low Profile Allows for Easy Access
- Headlamp. Microscope or Fiberoptic Provides ideal Visualization
- Cranial, Caudal and Third Arm Soft Tissue Retraction
- Docking Pins will Allow for Better Visualization of the Disc Space



Fluoroscopic View through Retractor System





AP Intraoperative View

- Cranial /Caudal Blades Anchored to Vertebra
- Implant Introducer next to Lateral Vertebra
- Radiographic Markers Noted on Implant
- Spinous Process Midline/ Pedicles Symmetric



Neural Complications All Approaches

PLIF	1-6%
TLIF	4%
ALIF Minimal Access	1.5-6.5%
XLIF	1-3%

Referencing Six Level III Studies 2002-8

Structures at Risk Side Dependent

Left Side Approach		Right Side Approach	
L1-2	2.3%	L1-2	7.0%
L2-3	7.0%	L2-3	7.0%
L3-4	4.7%	L3-4	9.3%
L4-5	20.9%	L4-5	44.2%

Kepler, C. Eurospine, 2010

Patient

- 68 yo Female with Intractable Back Pain
- Failed Treatment with all Non-surgical Care
- 70% Axial Back Pain and 30% Radicular Pain
- Comorbidities of Diabetes, Hypertension, Gastritis
- No Significant Cardiac Disease
- No Prior Abdominal Surgery or Prior Lateral Access Surgery

68 yo Female with Degenerative Scoliosis



Summary

- Access to the Interbody Space from Direct Lateral Approach should be possible at L2-3, L3-4 and L4-5
- Post Surgical Morbidity/Complications can be Minimized with Meticulous Patient Positioning and Fluoroscopy Alignment
- Neuromonitoring and Careful Soft Tissue Dissection Will Decrease Neurologic Injuries
- Previous Abdominal Surgery or Lateral Access Surgery will Alter Normal Anatomy Secondary to Scar Formation

MIS COMPLICATIONS

Disclosures

- Royalties: Depuy-Synthes
- Consulting: Depuy-Synthes

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Minimally Invasive Spinal Surgery!!
=
Concept
≠
Incision size



Principles...

1. Localize incision
2. Tunneled or Inverted V-Shape exposure
3. Only expose necessary anatomy
4. Split rather than cut muscle fascicles
5. Spare tendon/ligament bone attachments
6. Spare nerve and blood supply to soft tissues
7. Use magnification/lighting for visualization

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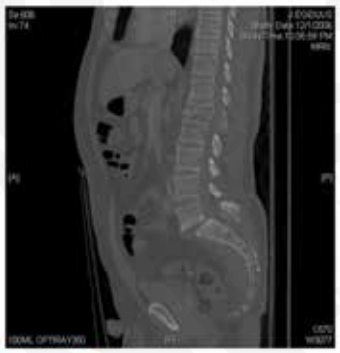
Advantages of Minimally Invasive Spinal Surgery

- Less initial trauma:
  - Less pain medications & earlier hospital discharge
- Less need for post-op rehab
- Better functional recovery
- Less collateral damage:
  - less Ilary surgeries
- Less hospital stay:
  - cost effective
- Faster return to work:
  - cost effective

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67 yo. Fall of a height. NV Intact
L1 Burst Fx & Traumatic L5-S1 isthmic spondy





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Minimally Invasive, Targeted treatment







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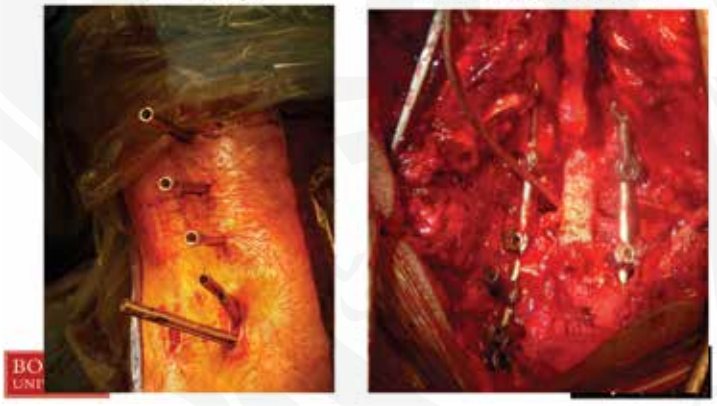
67 yo lady with severe Degenerative scoliosis.
CAD, HTN, NIDM, H/o Cardiac stents.



MIS vs Open

MIS Technique

Open/Standard approach



Very Attractive option



Great Sagittal Balance



Majors Questions to be answered

- Is MIS safe?
- Is MIS effective?
- Can it be applied to complex pathology?
- What is the cost of MIS vs Open?

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Patterns of MIS Complications

- Complications related to MIS technologies:
  - Instruments
  - Implants
- Complications related to MIS techniques
  - Inability to achieve the surgical tasks:
    - Decompression
    - Fusion
    - Spinal Alignment
  - Lack of adherence to surgical principles
- Marketing Driven Practices:
  - Conforming the indications to the technology and NOT the technology to the Pathology

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Stages of MIS Complications

- Prevention
- Recognition
- Management

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Radiation/Navigation Complications

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Radiation Exposure

- **Indirect Visualization → Radiation Use**
- Less clinically significant for patients than surgeon, assistants, OR staff

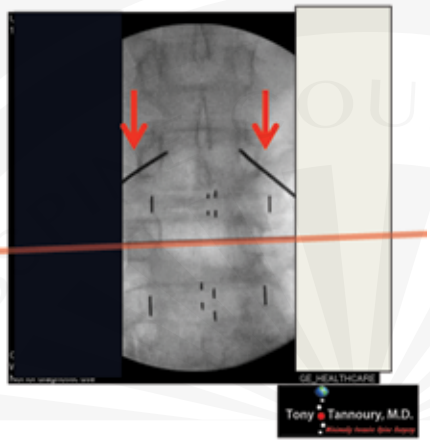


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Radiation Exposure reduction

- Skin Mapping
- Collimate
- Work Bilaterally
- Pulse Mode
- No Magnification
- Use tactile feedback



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Radiation Exposure

- C Arm Source Location



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Radiation/Navigation Summary

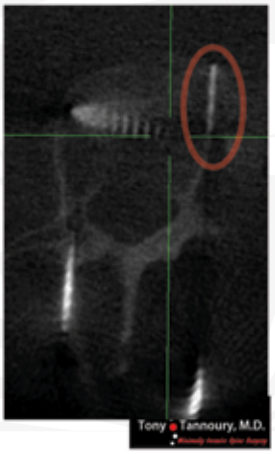
- Problem MIS ➔ Higher Radiation Dose
- Solutions:
  - Use Techniques to Minimize Fluoro Dose
  - Use Navigation
    - Verify Accuracy of Navigation Techniques

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Navigation Inaccuracy

- Instrument Deflection
  - Jamshidi Needles Bent
- Disturb Array
- Patient Motion (Breathing, Deformity Correction, Tapping Guidewires)



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Patient Radiation Exposure

- O-Arm High Resolution Run
- 400 Fluoro Shots
- 80% Adult CT Abdomen Pelvis

Protocol	Reference Level in mGy	O-arm STD 3D Medium		HD3D Medium	
Adult Head	75	13.90	19%	21.25	28%
Adult Abdomen	25	13.82	55%	20.13	80%
Pediatric Abdomen	20	13.82	70%	NA	NA

* *Data above taken from O-arm® System Dose Report by Frank Massey dated July 1, 2008*

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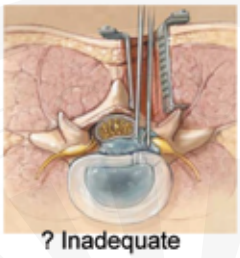
Decompression Complications

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Problem: Residual Leg Pain?

- Prospective, Randomized, Study
- Tubular diskectomy vs Conventional Microdiskectomy



? Inadequate Decompression

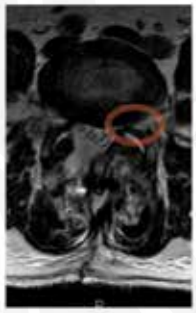
- Primary Outcome Measure:
  - No Difference
- Secondary Outcome Measure:
  - Higher Leg Pain in Tubular Diskectomy Patients

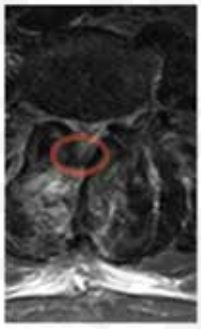
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Arts JAMA 2009

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Inadequate Decompression





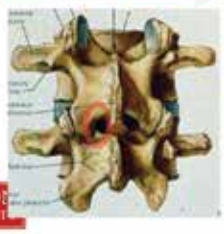
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Aggressive Decompression & Clinical Anatomy:

Spinal Process/Lamina/Working Tube Ration







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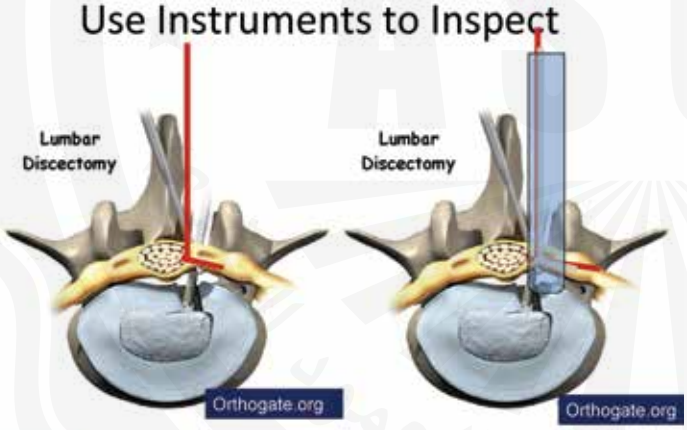
Excessive facet removal s/p L3-5 decompression, L4-5 MIS TLIF



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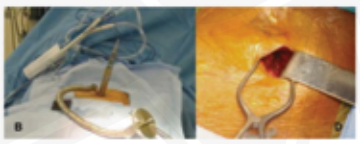
Use Instruments to Inspect



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Dural Tears



- Microdiskectomy
  - Dural tear 2.6% (MIS) vs 0%
    - Anderson Spine 2011
- Microdiskectomy
  - 9.2% MIS vs 7% open
- TLIF/PLIF
  - 1.9% MIS vs 0% open
  - Fourney Spine 2010

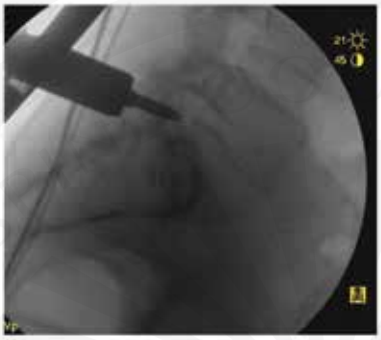
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Be careful with first, narrow dilators

- Be Careful When Attention Is Directed To Clamping Tubes To Table





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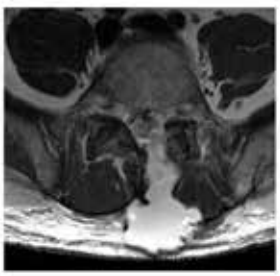
Dural Tears Not a Problem in MIS?

- Less Dead Space/Tissue Violation
- Muscle Forms Living Barrier
- "I have never seen Pseudomeningocele/ Wound Infection After Tubular Diskectomy"

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MIS Pseudomeningocele



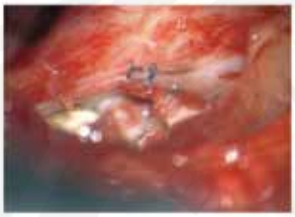


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Dural Repair Techniques

- Clips





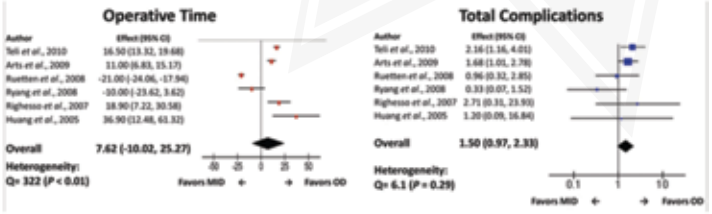
Ferroli Acta Neurochir 2008

Learning Curve

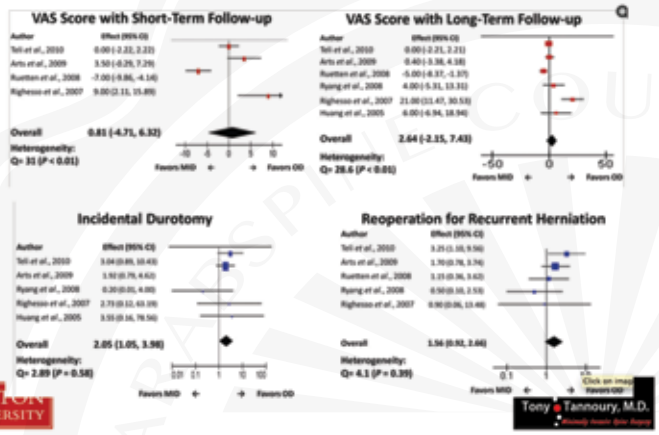
- Dural Tear
  - 6.8% of first 220 cases vs 3.6% of subsequent 653 cases (p>0.5)

(Wu Spine 2006)

Meta-analysis MIS discectomy vs Open, Bydon et al



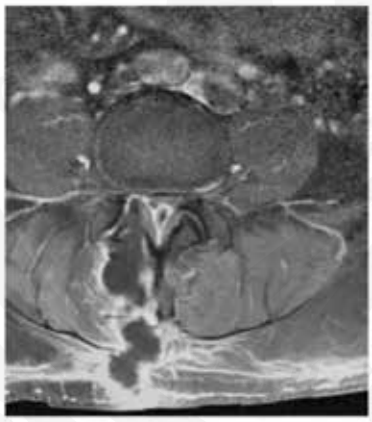
Meta-analysis MIS discectomy vs Open, Bydon et al



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Wound Infection



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Infection, SRS database

Spine (Phila Pa 1976). 2011 Apr 1;36(7):556-63. doi: 10.1097/BRS.0b013e3181ead061.

Rates of infection after spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee.

Smith JS[1], Shaffrey CI, Sansur CA, Berven SH, Fu KM, Broadstone PA, Chorma TJ, Goyan MJ, Noordeen HH, Knapp DR Jr, Hart RA, Donaldson WF 3rd, Polly DW Jr, Perra JH, Boachie-Adjei O; Scoliosis Research Society Morbidity and Mortality Committee.

Author information

Abstract

STUDY DESIGN: Retrospective review of a prospectively collected database.

OBJECTIVE: Our objective was to assess the rates of postoperative wound infection associated with spine surgery.

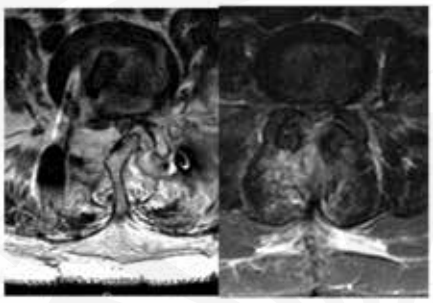
SUMMARY OF BACKGROUND DATA: Although wound infection after spine surgery remains a common source of morbidity, estimates of its rates of occurrence remain relatively limited. The Scoliosis Research Society prospectively collects morbidity and mortality data from its members, including the occurrence of wound infection.

METHODS: The Scoliosis Research Society morbidity and mortality database was queried for all reported spine surgery cases from 2004 to 2007. Cases were stratified based on factors including diagnosis, adult (≥ 21 years) versus pediatric (<21 years), primary versus revision, use of implants, and whether a minimally invasive approach was used. Superficial, deep, and total infection rates were calculated. RESULTS.: In total, 108,419 cases were identified, with an overall total infection rate of 2.1% (superficial = 0.8%, deep = 1.3%). Based on primary diagnosis, total postoperative wound infection rate for adults ranged from 1.4% for degenerative disease to 4.2% for kyphosis. Postoperative wound infection rates for pediatric patients ranged from 0.9% for degenerative disease to 5.4% for kyphosis. Rate of infection was further stratified based on subtype of degenerative disease, type of scoliosis, and type of kyphosis for both adult and pediatric patients. Factors associated with increased rate of infection included revision surgery ($P < 0.001$), performance of spinal fusion ($P < 0.001$), and use of implants ($P < 0.001$). Compared with a traditional open approach, use of a minimally invasive approach was associated with a lower rate of infection for lumbar discectomy (0.4% vs. 1.1%; $P < 0.001$) and for transforaminal lumbar interbody fusion (1.3% vs. 2.9%; $P = 0.005$).

CONCLUSION: Our data suggest that postsurgical infection, even among skilled spine surgeons, is an inherent potential complication. These data provide general benchmarks of infection rates as a basis for ongoing efforts to improve safety of care.

Epidural hematoma

- Less Bony Resection
- ➔ Less Room For Hematoma?



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Epidural Hematoma

- Epidural Hematoma
- After Laminoplasty

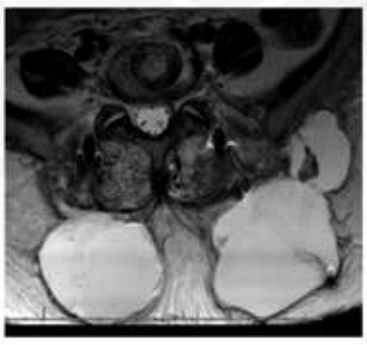


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MIS Wound Complications

Consider possible wound complications in all patients



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Summary Decompression Complications

- Carefully Inspect for Residual Pathology
  - Consider Extensive/Inadequate Removal
- Be very careful with tubular decompressions in the Upper Lumbar spine
- Respect/Repair Dural Tears
- Infection is much reduced but NOT impossible

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Fusion Complications

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MIS Instrumentation

- More Steps
- Unique Instruments vs Open
  - Jamshidi
  - Guidewires
- Less Visualization
  - Instrumentation Malposition

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Gearshift vs Jamshidi



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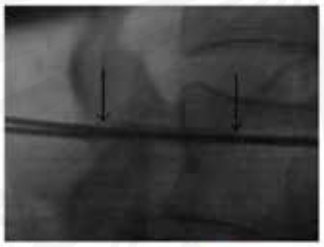
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Broken Jamshidi Needle

- Cervical Tap
- Threaded Into
- Broken Jamshidi

- Wang MY JNS 2011

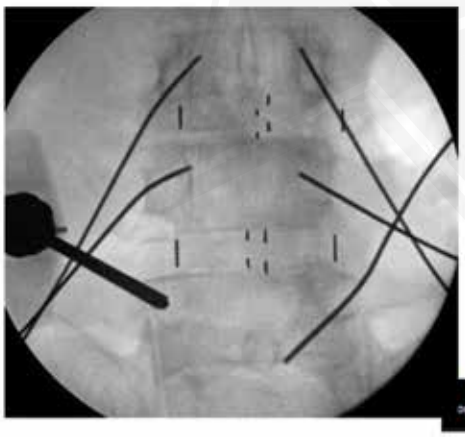




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Guidewires



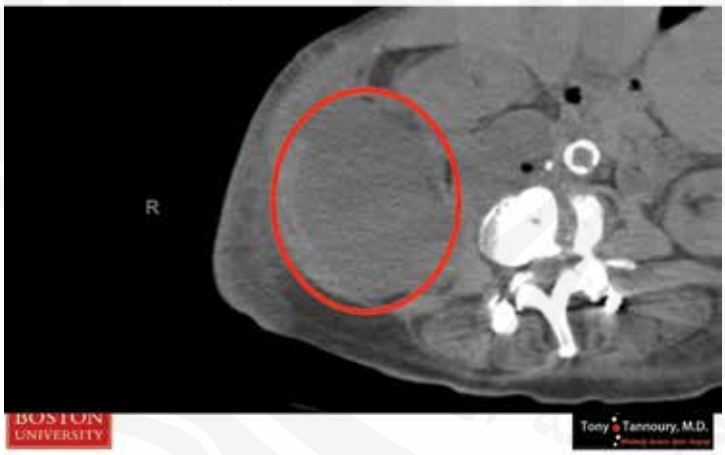
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Guidewires



Retro-peritoneal Hematoma

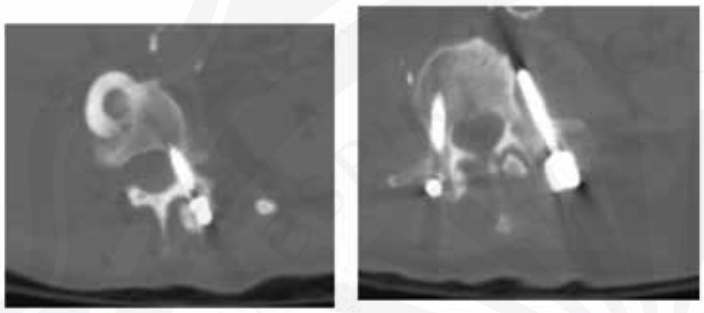


Abdominal Injury

- Urinoma



Misdirected Screws



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Misdirected Screws



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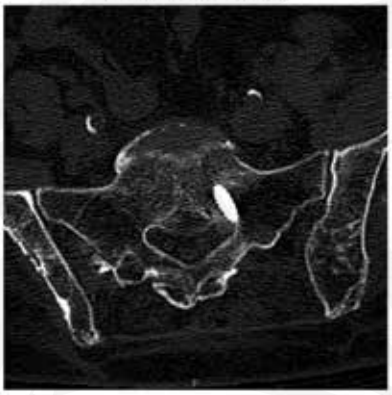
Misdirected Screws



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S1 breech



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Misdirected Screws

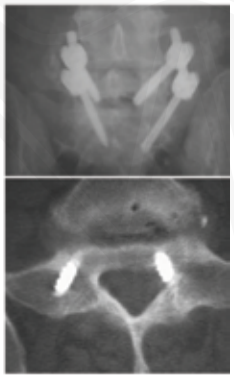
	Total Misdirected	Serious Misdirected Screws
Raley Spine 2011	9.7%	3.5%
Logroscino Eur Spine J 2011	7.5%	1.2%
Knox Spine J 2011		2.4%
Wang JNS Spine 2010	1.2%	0.4%

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Misdirected Screws

- Retrospective, n=409 screws
- 5 (1.2%) screws malpositioned
- 2 (0.4%) screws symptomatic
- All thresholds of breaches > 12mA



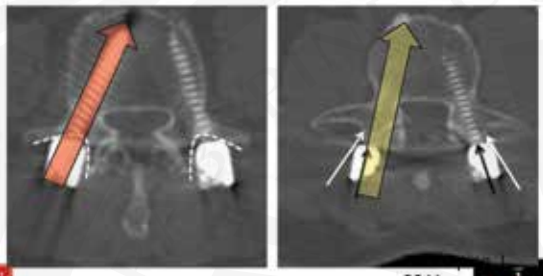
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Wang M,Tannoury T et al JNS Spine 2010

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Facet Violations

- Consider More Lateral Starting Point



2011

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Accuracy of Screw placement Open Vs MIS screws

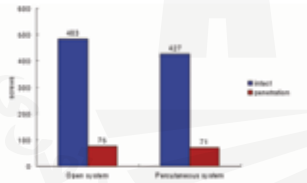


Fig. 1. Pedicle wall penetration rates with different instruments. The number of pedicle wall penetrations was 75 (13.4%) in the open pedicle screw fixation group and 71 (14.3%) in the percutaneous pedicle screw fixation group ($p = .701$).

Pedicle wall penetration rates according to severity

Degree of penetration	Open PF group	PPF group	Total
No penetration (% within the group)	483 (86.6%)	427 (85.7%)	910 (86.2%)
Minor (% within the group)	54 (9.7%)	53 (10.6%)	107 (10.1%)
Moderate (% within the group)	13 (2.3%)	13 (2.6%)	26 (2.5%)
Severe (% within the group)	8 (1.4%)	5 (1.1%)	13 (1.2%)
Total	558	498	1,056

PF, pedicle screw fixation; PPF, percutaneous pedicle screw fixation.

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H.S. Oh et al. / The Spine Journal 13 (2013)

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Revision Rate MIS vs Open

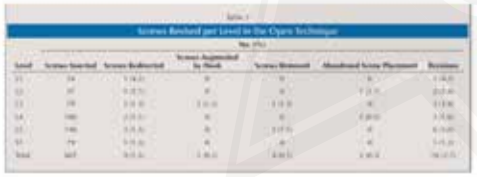


Table 3: Screws Revised per Level in the Open Technique



Table 4: Screws and K-wires Revised per Level in the Percutaneous Technique

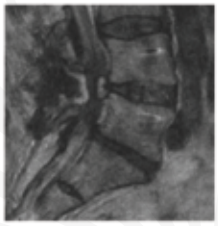
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Edward Ranver et al. Orthopedics. Feb Vol 38, Issue 2, 2015

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Bone Grafting

- BMP Radiculitis/ Perineural Cyst
  - Rihn CORR 2011
  - Mindea SA Spine 2009
  - Choudhry OJ, JNS Spi 2011
- Mannion RJ Spine J 2011
- Rihn Spine J 2009

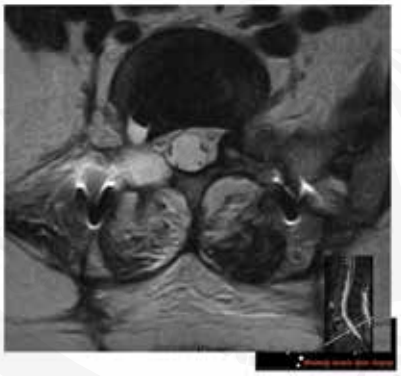


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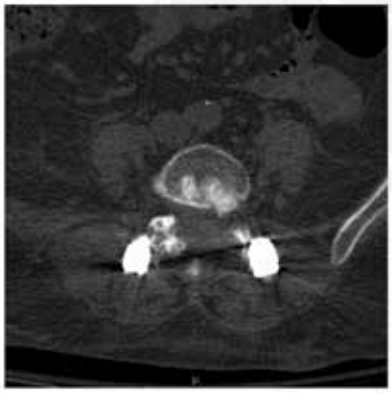
L4-S1 MIS TLIF

- Right S1 radiculopathy several weeks postop



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Bone graft s/p L4-5 MIS TLIF



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MIS Fusion Success: is it equal to the Standard (Open Surgery)?

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Fusion Rate

Minimal access versus open transforaminal lumbar interbody fusion: meta-analysis of fusion rates.

Wu RH[1], Fraser JF, Härtl R.

Author information

Abstract

STUDY DESIGN: A quantitative meta-analysis was conducted on published studies reporting fusion rates after open or minimally invasive/mini-open transforaminal lumbar interbody fusion (TLIF) procedures for single or multilevel degenerative disease including stenosis with spondylolisthesis and degenerative disc disease.

OBJECTIVES: The primary aim of this study was to establish benchmark fusion rates for open TLIF and minimally invasive TLIF (mTLIF) based on published studies. A secondary goal was to review complication rates for both approaches.

SUMMARY OF BACKGROUND DATA: Lumbar fusion for the treatment of degenerative disease has evolved from a purely posterior noninstrumented approach to a combination of anterior and/or posterior surgery with instrumentation. The increasingly popular transforaminal approach has advanced to incorporate minimally invasive spinal techniques. There currently exist no controlled comparisons between open TLIF and mTLIF.

METHODS: A Medline search was performed to identify studies reporting fusion rate on open TLIF or mTLIF with instrumentation. A database including patient demographic information, fusion rate, and complication rate was created. Fusion and complication rates were pooled according to whether TLIF was performed with open or minimally invasive technique. Publication bias was assessed with Egger's test, and adjustments were performed using Duval and Tweedie's Trim and Fill algorithm.

RESULTS: Twenty-three articles were identified that fit inclusion criteria. In each of the 23 studies, TLIF was performed with pedicle fixation and fusion was evaluated using radiograph or computed tomography scan at minimum 6-month follow-up. Overall, the studies included 1029 patients, 46.8% of which were female. The mean age of all patients was 49.7 (range, 38-64.9), and mean follow-up interval for assessment of fusion was 26.6 months (range, 6-48 months). The usage of recombinant bone morphologic protein was higher in the mTLIF group (50% vs. 12%). Mean fusion rate from 16 studies (716 patients) of open TLIF was 90.5%, whereas mean fusion rate from 8 studies (312 patients) of mTLIF was 94.8%. Complication rate was 13.8% and 7.5% for open and mTLIF, respectively.

CONCLUSION: Fusion rates for both open and mTLIF are relatively high and in similar ranges. Complication rates are also similar, with a trend toward mTLIF having a lower rate. This analysis provides clear benchmarks for fusion rates in open and mTLIF procedures for spine surgeons.

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Complication: Rabdo S/P Lateral + posterior precut.

J Neurosurg Spine. 2011 Jun;14(6):785-8. doi: 10.3171/2011.2.SPINE10369. Epub 2011 Mar 18.

Rhabdomyolysis and acute renal failure following minimally invasive spine surgery: report of 5 cases.

Dalwari S[1], Rifkin SI, Volcan IJ, Goodrich JA, Uribe JS.

Author information

Erratum in

J Neurosurg Spine. 2012 Jan;16(1):104.

Abstract

Minimally invasive spine surgery is increasingly used to treat various spinal pathologies with the goal of minimizing destruction of the surrounding tissues. Rhabdomyolysis (RM) is a rare but known complication of spine surgery, and acute renal failure (ARF) is in turn a potential complication of severe RM. The authors report the first known case series of RM and ARF following minimally invasive lateral spine surgery. The authors retrospectively reviewed data in all consecutive patients who underwent a minimally invasive lateral transpsoas approach for interbody fusion with the subsequent development of RM and ARF at 2 institutions between 2006 and 2009. Demographic variables, patient home medications, preoperative laboratory values, and anesthetic used during the procedure were reviewed. All patient data were recorded including the operative procedure, patient positioning, postoperative hospital course, operative time, blood loss, creatine phosphokinase (CPK), creatinine, duration of hospital stay, and complications. Five of 315 consecutive patients were identified with RM and ARF after undergoing minimally invasive lateral transpsoas spine surgery. There were 4 men and 1 woman with a mean age of 66 years (range 60-71 years). The mean body mass index was 31 kg/m2 and ranged from 25 to 40 kg/m2. Nineteen interbody levels had been fused, with a range of 3-6 levels per patient. The mean operative time was 420 minutes and ranged from 315 to 600 minutes. The CPK ranged from 5000 to 56,000 U/L, with a mean of 25,861 U/L. Two of the 5 patients required temporary hemodialysis, while 3 required only aggressive fluid resuscitation. The mean duration of the hospital stay was 12 days, with a range of 3-25 days. Rhabdomyolysis is a rare but known potential complication of spine surgery. The authors describe the first case series associated with the minimally invasive lateral approach. Surgeons must be aware of the possibility of postoperative RM and ARF, particularly in morbidly obese patients and in procedures associated with prolonged operative times.

Rhabdomyolysis/Acute Renal Failure

- 5 cases following MIS lumbar interbody fusion
- Dakwar JNS 2011
- 1-2 level procedures

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MIS vs Open complications 1-2 level TLIFs

Surg Technol Int. 2008;17:281-6.

Perioperative complications of minimally invasive surgery (MIS): comparison of MIS and open interbody fusion techniques.

Regan JJ, Patel N, Deutsch H, Herrog J, Sharan A, Vaccaro AR, Ratliff JK.

Author information

Abstract

The risk of perioperative complications while adopting minimally invasive spine surgery techniques may slow the acceptance of this technology. We assess the perioperative complication rate with minimally invasive single- and two-level interbody fusions and compare this incidence with a contemporaneous cohort of open single- and two-level open interbody fusions, with all procedures completed by a single surgeon in a single practice group. We compiled all open and MIS interbody fusion cases completed during the study period. Sofamor-Danek X-Tube and Stryker Luxor minimally invasive systems were used on all patients. Medical records were reviewed to assess any adverse events occurring in the perioperative period. Care was taken to include all medical and surgical adverse events and complications occurring within 30 days of surgery. Over the study period, 28 minimally invasive lumbar fusions were identified: 24 single- and 4 two-level cases. Both TLIF and PLIF techniques were used. This cohort was compared with a group of 19 single- and two-level open interbody fusion cases completed over the same period. The complication rate for the MIS cohort was 18%, with 7 complications occurring in 5 patients. In the open group, 8 complications occurred in 7 patients, an incidence of 37%. A standard distribution of complications occurred, and the difference between the two groups was not statistically significant. Limiting our analysis to severe complications yielded rates of 7% and 21% for the two groups, also not significantly divergent. Perioperative complications are not more common in well-selected MIS patients. Allowing for proper patient selection, MIS techniques have a favorable complication profile.

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Hybrid Anterior plus Posterior Fusion: Open vs MIS fixation

Comparison of open and minimally invasive techniques for posterior lumbar instrumentation and fusion after open anterior lumbar interbody fusion.

Author information

Abstract

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Complications and efficacy of MIS vs Open Rx of DDD

J Clin Neurosci. 2012 Jun;19(6):829-35. doi: 10.1016/j.jocn.2011.10.004. Epub 2012 Mar 28.

Minimally invasive surgery compared to open spinal fusion for the treatment of degenerative lumbar spine pathologies.

Mobbs RJ[1], Sivabalan P, Li J.

Author information

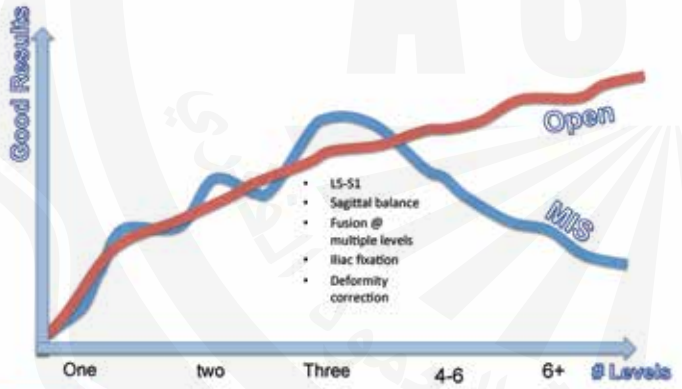
Abstract

This clinical study prospectively compares the results of open surgery to minimally invasive fusion for degenerative lumbar spine pathologies. Eighty-two patients were studied (41 minimally invasive surgery [MIS] spinal fusion, 41 open surgical equivalent) under a single surgeon (R. J. Mobbs). The two groups were compared using the Oswestry Disability Index, the Short Form-12 version 1, the Visual Analogue Scale score, the Patient Satisfaction Index, length of hospital stay, time to mobilise, postoperative medication and complications. The MIS cohort was found to have significantly less postoperative pain, and to have met the expectations of a significantly greater proportion of patients than conventional open surgery. The patients who underwent the MIS approach also had significantly shorter length of stay, time to mobilisation, lower opioid use and total complication rates. In our study MIS provided similar efficacy to the conventional open technique, and proved to be superior with regard to patient satisfaction, length of hospital stay, time to mobilise and complication rates.

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Learning Curve



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SPINE: MIS vs Open

- If MIS is good for small cases:
  - One or two level stenosis
  - One level fusion
  - Etc...
- MIS should be ideal for much larger cases:
  - Tumors
  - Deformities
  - Trauma
  - Patients with significant co-morbidities

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Promising techniques to address multiple levels: MIS Lateral

- Straight lateral surgery (XLIF, DLIF, Lateral Cougar etc...)
  - Lateral decubitus position
  - Incision at lateral border of erector spinae
  - Dilates through iliopsoas
    - "Finger assisted"
    - Neuromonitoring



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Direct Anterior: Hostile territory





Issues to resolve with the direct lateral option:

- The safety for the Lumbo-sacral plexus
- Ability to perform Proximal (L1-2, L2-3) and Distal (L4-5, L5-S1) levels
- Sagittal balance reconstruction
- Preservation of the end plates
  - Later cage subsidence
  - Recurrence of stenosis
- Ability to reconstruct the anterior spine
- Radiation use
- Availability and Cost of Neuro-monitoring

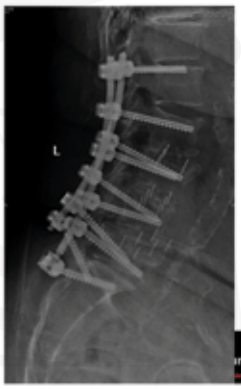
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Case Example: What went wrong?

- Breakage of endplates
- Loss of sagittal balance
- Did not address L5-S1
- Stopped at L1 & screws breaking into the endplate
- Loss of distal fixation

Direct lateral L2-L5 and Post L1-S1



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Next Challenges & Keys for Successful MIS surgery

- L5-S1
- Fusion @ multiple levels
- Iliac fixation
- Deformity correction
  - Sagittal Balance
  - Coronal Balance
  - Axial derotation

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The Value of L5-S1

- Sagittal correction:
  - 15-20°from L5-S1
  - For Each 10° SVL:80mm/
- Mechanical
  - Load sharing
- Biological
  - fusion



L5-S1: No interbody fusion



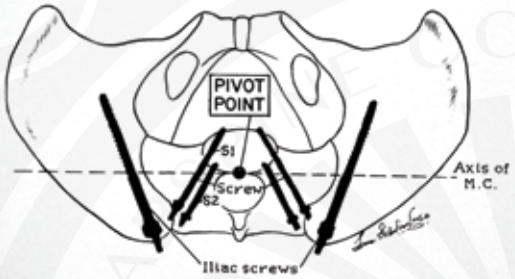
L5-S1: Insufficient interbody fusion

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Pelvic fixation?

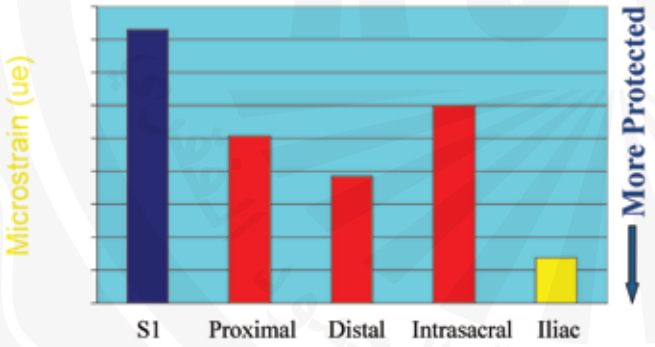
Is essential for long constructs but Sometimes omitted.



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S1 Screw Strain on Flex / Ext



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Lebwohl, Cunningham et al, Spine 2002 27:312-20

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Distal foundation incision: MIS Iliac, S1 & L5

Drawing the iliac and L5 Pedicle



Palpating the Crest/splitting the fascia



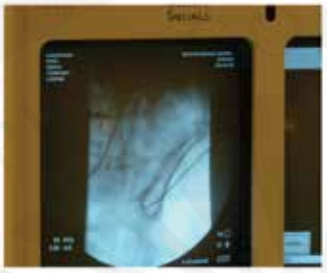


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Confirming safety: Tear Drop view





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Outlet view: Length of Screw





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Iliac Screw Placement





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My preferred approach:
Antero-lateral interbody fusion



- T12-L1, L1-2, L2-3, L3-4, L4-5, possibly L5-S1
- Split fibers of oblique and transversus muscles
- Retract anterior 10-15% of psoas
- be Very careful of the misleading Quadratus Lumborum muscle

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2 inch incision

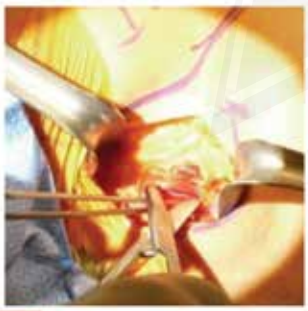


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Surgical Technique: Abdominal wall

External oblique fascia



Internal oblique



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Surgical Technique

Psoas belly

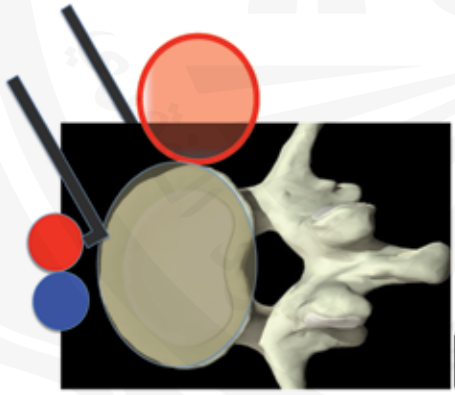
Psoas retracted laterally



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Anterior to the Psoas approach



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Advantage of Antero-lateral Approach

- Able to address T12-S1
- Protection and preservation of endplates
- Adequate anterior release
- Adequate interbody fusion
- Reliable direct and Indirect Anterior decompression

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84 yo lady, severe back and bilat leg pain



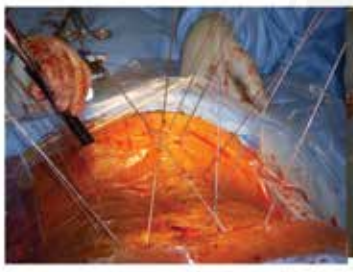


Post anterior stage





Intra-operative pictures



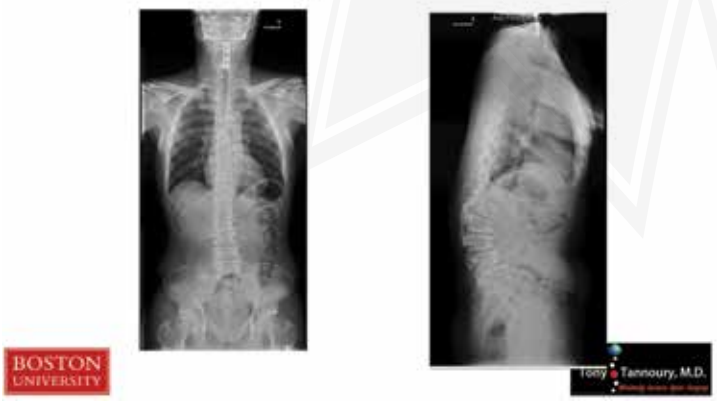




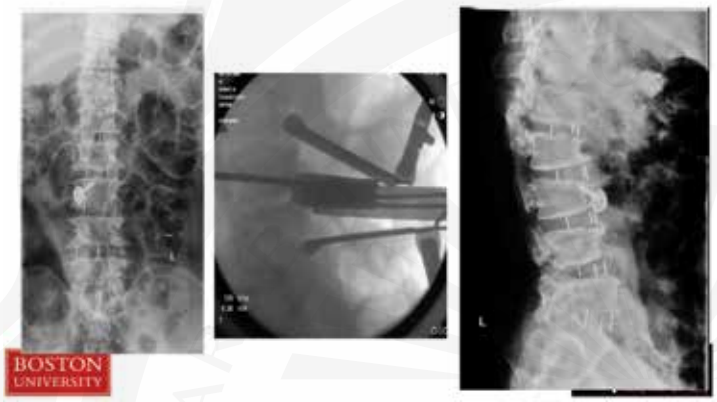
Lateral X-rays



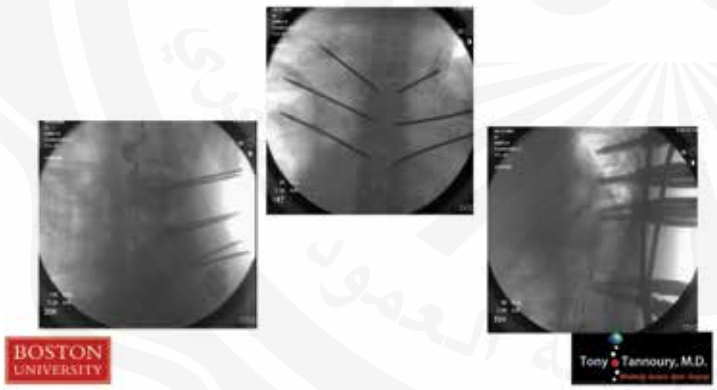
54 y.o. Post-L1-S1 Laminectomy kyphosis



T12-S1 ATP Fusion. stage 1

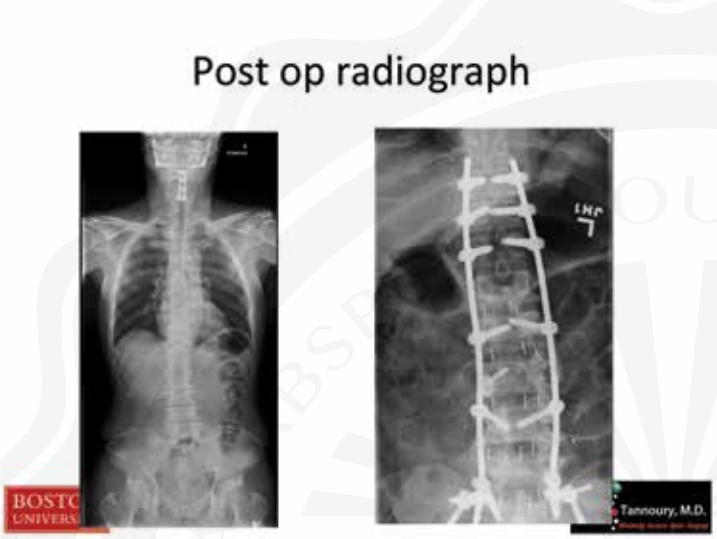


stage 2

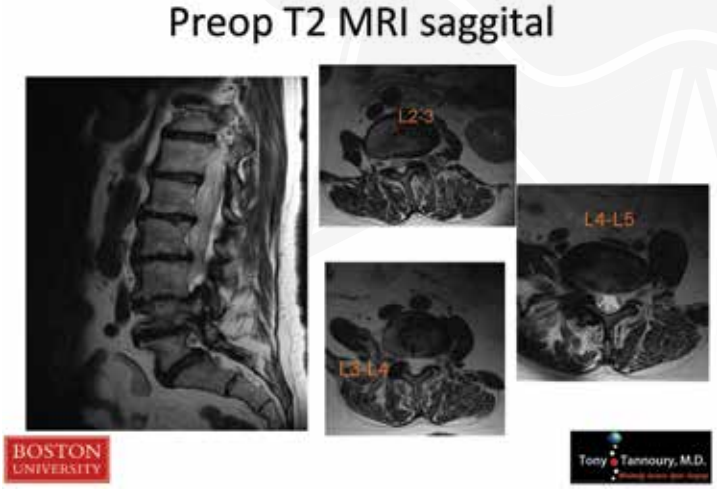


Post op radiograph




Post op radiograph
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54 Yo. Lady Cab driver


Preop T2 MRI saggital
L2-3
L4-L5
L3-L4
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T12-L5(Transitional) ATP fusion

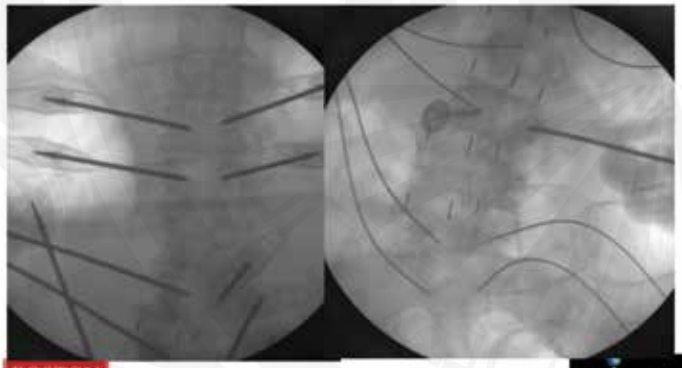




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Intraop imaging



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Derotation





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Derotation: Before & After



Lateral Views



Conclusion

- Carefully Plan Cases
  - Cosurgeon
- Minimize Time Wasting
- Adopt techniques that able to fully achieve the goals of the surgery
- Never compromize

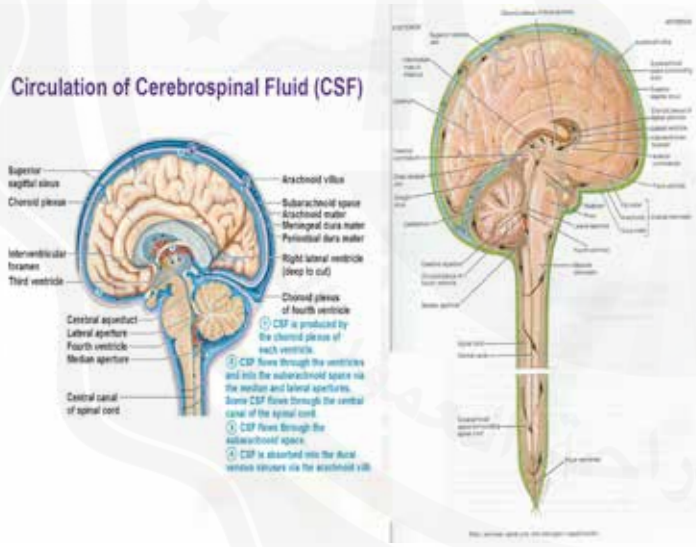
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CSF LEAK: MANAGEMENT

Introduction

- CSF leak may occur:
  - Post trauma
  - Post surgery
  - Idiopathic
- CSF leaks may be encountered intraoperatively or become apparent in the immediate or late postoperative period.
- They can be asymptomatic or present as persistent headaches, and have risks of developing meningitis, fistulas and pseudomeningoceles.
- Treatment strategies range from nonoperative to primary repair and diversion techniques.
- CSF leaks can lead to a significant mortality and morbidity if left untreated.



Cerebrospinal Fluid

Rate of formation:

- About 20-25 ml/hour
- 550 ml/day in adults. Turns over 3.7 times a day

Total quantity: 150 ml:

- 30-40 ml within the ventricles
- About 110-120 ml in the subarachnoid space [of which 75-80 ml in spinal part and 25-30 ml in the cranial part].

Cerebrospinal Fluid

- CSF is formed at a rate of about 550 milliliters each day,. About two thirds or more of this fluid originates as secretion from the choroid plexuses in the four ventricles, mainly in the two lateral ventricles.

- Additional small amount of fluid is secreted by the ependymal surfaces of all the ventricles and by the arachnoidal membranes

- Small quantity comes from the brain itself through the perivascular spaces that surround the blood vessels passing through the brain.

Cerebrospinal Fluid

Nature:

Colour	=	Clear, transparent fluid
Specific gravity	=	1.004-1.007
Reaction	=	Alkaline and does not coagulate
Cells	=	0-3/ cmm
Pressure	=	60-150 mm of H2O

The pressure of CSF is increased in standing, coughing, sneezing, crying, compression of internal Jugular vein (Queckenstedt's sign)

CSF Leak: Incidence and prevalence

- Incidental durotomy in spinal surgery has been reported with incidences varying between 0.5 – 18% depending on the type of surgery and region of the spine (Bosacco et al, Camissa et al).
- Hannallah et al, described a general rate of 1% in a series of 1,994 cervical spine surgeries (4.9% for anterior revision surgeries with corpectomy and 12.5% in patients with OPLL.
- Khan et al (series of 3,183 patients) reported a 7.6% incidence of dural tears in primary lumbar degenerative cases and a 15.9% incidence for revision cases.
- The incidence of unrecognized durotomy 0.28% (Cammisa et al).
- The prevalence of CSF leaks are higher in patients undergoing revision surgery followed by decompression surgeries.

Table 1
Incidence of dural tears according to surgical procedure.

	Patients	Total	Incidence (%)
Cervical anterior decompression	1	240	0.42
Cervical posterior decompression	1	14	7.1
Thoracic anterior decompression	2	24	8.3
Lumbar discectomy	8	312	2.6
Lumbar decompression (±) fusion without instrumentation	25	143	17
Thoracolumbar/lumbosacral decompression + fusion with poster lateral graft + instrumentation	11	529	2.1
Lumbar decompression + circumferential arthrodesis + instrumentation	2	32	6.3
Lumbar anterior procedure	1	32	3.1
Total	51	1326	

Table 2
Incidence of dural tears in different studies behind procedure.

Microscopic lumbar discectomy	4% Kotilainen et al.[37]; 1%: Wang et al.[38]; 7.1%: Stolke et al.[39]; 3.2% Sader et al.[11]; 3.5% Tafazal and Sell[17]
Lumbar Post discectomy dural tears	
Decompression for stenosis	3.1%: Cammisa et al.[3]; 1%: Wang et al.[38]; 8.5% Tafazal[17]
Decompression and fusion without instrumentation	1.8% Cammisa et al.[3]
Decompression and fusion with instrumentation	2.8% Cammisa et al.[3]
Revision spine surgery	8.1%: Cammisa et al.[3]; 17.4%: Stolke et al.[39]; 15.9% Khan et al.[28]
Revision discectomy	13.2% Tafazal and Sell[17]

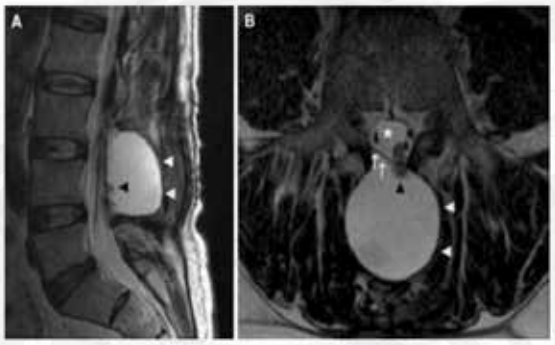
P. Guerin et al., Injury Journal 2011

Signs and symptoms

- Asymptomatic
- Postural headache
- Wound swelling
- CSF drainage from wound site
- Other symptoms:
  - nausea/vomiting, photophobia, dizziness, cranial nerve palsies, neck and axial pain, radiculopathy and/or myelopathy.
  - The symptoms have been postulated to be a result of intracranial hypotension leading to tension on the meninges and other intracranial structures or herniation of neural elements through dural tear.
- Signs and Symptoms of infection – meningitis

CSF Leak Complications

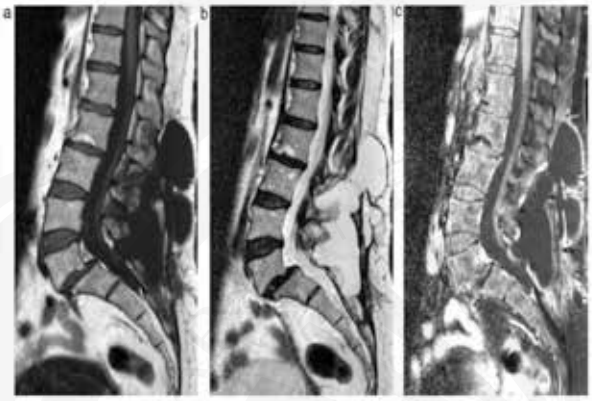
- Debilitating headache in upright position which may be associated with dizziness, tinnitus and visual impairment.
- Intracranial hypotension which may be complicated by the formation of subdural hygromas or hematomas.
- Subcutaneous CSF collection may impair wound healing and result in a CSF fistula with risk of wound infection, epidural abscess and meningitis.
- If fascia remains intact may result in a pseudomeningocele, which might act as a mass compressing nerve roots or the spinal cord.
- Neural element herniation with pain and neurologic deficit



Diagnosis

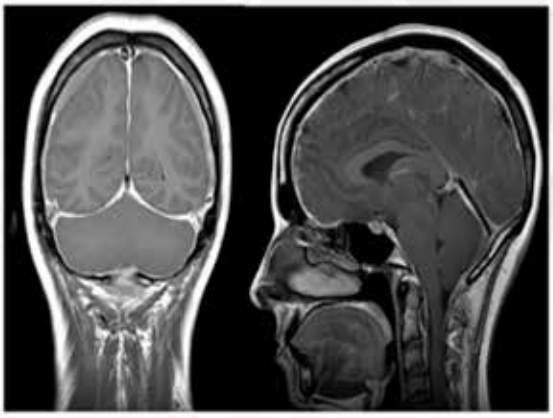
- Inspection of the wound – target or halo sign.
- Analysis of the fluid (B2-transferrin)
- MRI:
  - Delinate the location, extent and characteristic of the lesion.
  - gold standard to diagnose CSF leak but difficult to distinguish between CSF and seroma fluid.
  - Brain MRI
- CT-myelography and radionuclide myelography may be adjunctive imaging modalities.







Brain MRI findings in CSF Leak



Types of Dural Tears Encountered

1- Punctiform with Leak.
2- Punctiform with no leak.
3- Less than 1cm.
4- From 1-2cm.
5- Unsuturable anterolateral or anterior

Factors Leading To Dural Tears and CSF Leak

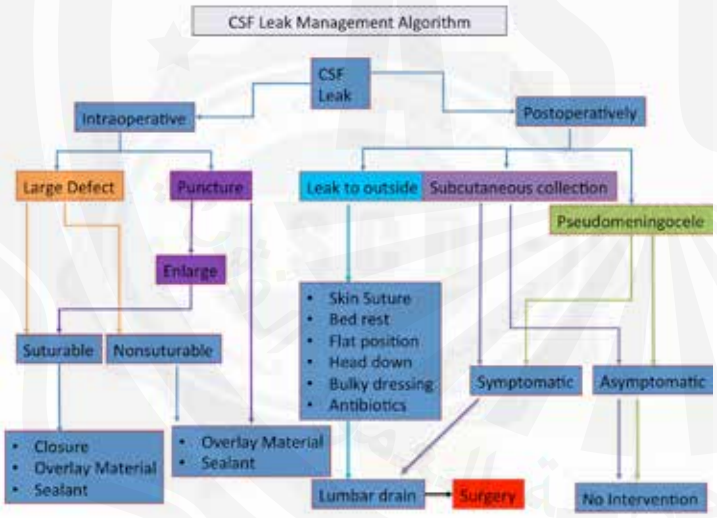
- Pathological conditions
  - Thinned dura (dural tears increase with old age due to decreased elastin)
  - Dural fibrosis
  - Prior surgery, adhesions and scars.
  - Spinal stenosis
  - Spina bifida
  - Ossification of ligaments
  - Bony spurs
  - Disc fragments
  - Synovial cysts has been associated with dural tears.
  - Post surgical site irradiation.

Factors Leading To Dural Tears and CSF Leak

- Surgical maneuvers:
  - Sharp instruments and high speed drill.
  - Excessive Dural traction and compression.
  - Failure to properly and adequately separate Dura from overlying ligaments.
  - Failure to appreciate anatomy and visualize the Dura.
  - Medial placement of pedicle screws or deep placement of anterior spinal fusion instruments can lead to dural injuries with late presentation of CSF leak.
  - Bony spurs not removed may lead to postoperative laceration.
  - Poor Dural closure after intradural exploration.
  - Resection of 3 or more vertebral bodies (spondylectomy).

Intraoperative measures to minimize dural tears

- Appreciate the anatomy, know where you are and obtain good exposure of the surgical field.
- Work layer by layer until dura can be visualized and ensure good separation of dura from overlying ligaments, lamina and adhesions using blunt instruments.
- Keep the ligamentum flavum for protection of the dura during bony removal with a LeKsell rogeur or high speed drill.
- If using the drill; it should be used in a medial to lateral fashion to reduce slippage and tear.
- Work from normal to abnormal (scar) anatomy (stick to bone).
- Ensure proper placement of screws, cages and various instrumentation.



Management of postoperative CSF leak

- Intraoperative Leak
- Postoperative Leak
- Postoperative collections
  - –Subcutaneous
  - –Pseudomeningocele

Management of intraoperative CSF leak

- Obtain a clear visualization of the defect, additional bone removal may be needed to appreciate the entire length of the defect.
- Ensure hemostasis and prevent blood from reaching into the defect.
- The need for expanding the defect by the surgeon?
- Gently push rootlets extruding from the defect inside with blunt instrument. Use cottonoid to keep the rootlets inside and act as protection to the rootlets.
- Some may put the patient in trendelenburg position to aid in relaxation of the thecal sac and dural edges.

Suturing the defect

- Suture material:
  - 5-0 or 6-0 synthetic braided or monofilament suture is recommended
  - Some surgeons prefer vicryl while others prolene.
- Suturing technique:
  - Running or interrupted watertight closure.
  - Interrupted sutures allows tension to be maintained on the suture line while in running stitch the tension on the suture line can be disrupted.
  - Advice: approximate with interrupted and then close with running sutures.
  - In thin friable dura that tear at suturing; one can tie the sutures over a pledget of muscle.
  - Water tight facial closure.
- Overlay materials:
  in case of large dural defect or where edges cannot be approximated, or for reinforcement of closure
  - Endogenous
  - Synthetic
  - Sealants
- Maneuvers to check closure.(Saline filling and valsalva maneuver).

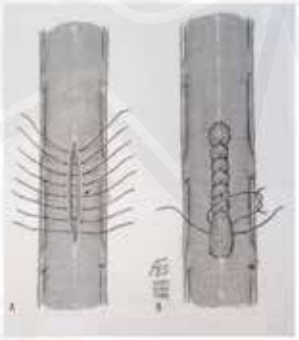
Primary Closure of defect using interrupted sutures



Closure of defect with patch using interrupted sutures



Closure of defect incorporating a pledget of muscle



'Parachute' technique for dural patch closure



Technique for repairing difficult to repair holes using midline durotomy



Application of fibrin glue to hold dural pach

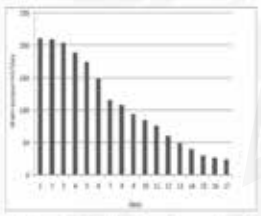




Wound Oversewing

Epidural patch (20cc blood)

Prolonged Subfascial Drainage



Managing The Cerebrospinal Fluid Leaks After Spinal Surgery By Prolonged Subfascial Drainage

Arif ÖSÜN1, Ali SAMANCIOĞLU1, Tayfun AYDIN2, Umut Ogün MUTLUCAN1, Murat KORKMAZ1, Ümit ÖZKAN1



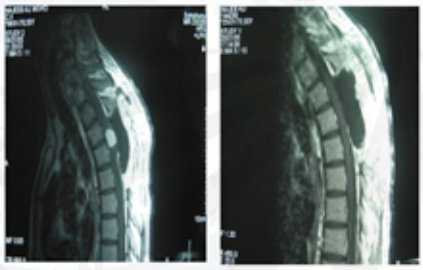


Postoperative Care

- Bed Rest
- Flat position tilt towards head.
- Bulky dressing.
- Antibiotics?
- Stockings and need for anticoagulants?
- Acetazolamide?

Management of postoperative CSF subcutaneous collection

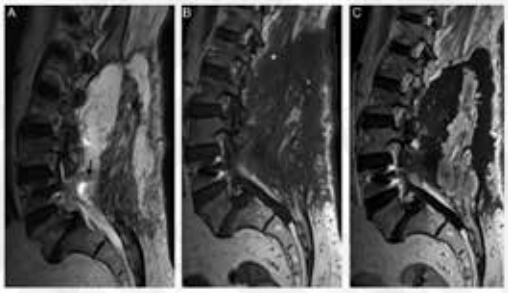
- Symptomatic vs Asymptomatic
- Conservative management trial
  - Bed rest, bulky dressing
  - Lumbar drain
- Surgical exploration and closure

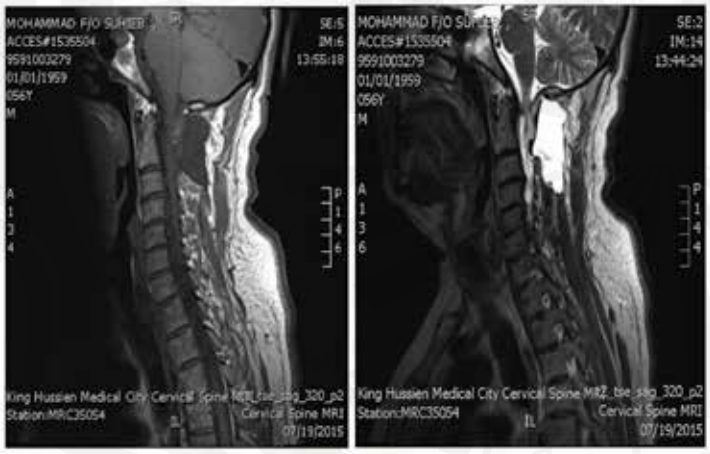


Management of pseudomeningocele

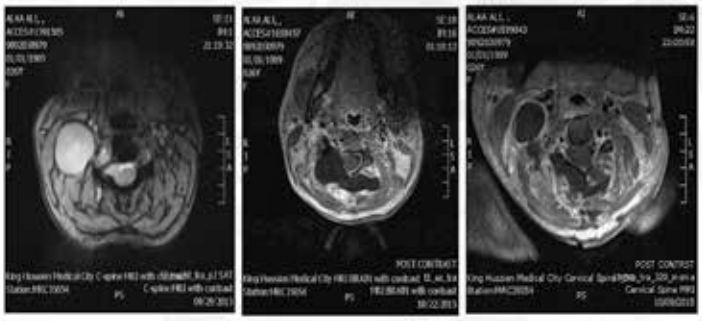
- Symptomatic presentation or asymptomatic imaging finding.
- Surgical exploration, drainage and closure (Obliteration of dead space).







Drainage of the Fluid Space



IATROGENIC NERVE AND SPINAL CORD INJURY MANAGEMENT OPTIONS



- Acknowledge my friend, and colleague
- James Harrop, MD, Thomas Jefferson University

We will review:

- Incidence
- Etiology
- Treatment/Prevention?
  - –Spinal cord perfusion
  - –Pharmacology
  - –Instrumentation



Literature Review

- Searches (1968-Present)
  - Medline/Pubmed
  - Scopus
  - Ovid
  - Cochrane review
- Reviewed >500 abstracts and articles
- Conclusion?
  - **Very limited data**

PubMed

Cochrane Library
Trusted evidence.
Informed decisions.
Better health.

Incidence

- Retrospective study (Flynn et al. Spine. 1982)
- 30,000 anterior cervical operations
  - 0.3% new postop deficit

Incidence

- Retrospective study (Bridwell et al, Spine, 1998)
- 1,090 spinal deformity surgeries
- Normal pre-op exams
- Found:
  - 0.38% (4/1090) major neuro deficits post-op
  - All four with deficit had:
    - AP surgery (P = 0.009)
    - Hyperkyphosis (P = 0.0006)
    - Unilateral convex segmental vessels ligation
  - 75% (3) purely vascular
    - 25% 1) Vascular and mechanical
- All showed marked improvement over time

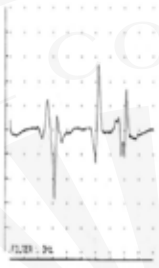
Incidence

- 162 deformity pts (Vitale et al, JBJS, 2010)
- Used SSEP/MEP monitoring
  - Alert criteria:
    - >10% in the latency of SSEP
    - >50% SSEP amplitude loss
    - >75% MEP Loss
  - 93%(151/162) successfully monitored



Incidence

- 162 deformity pts (Vitale et al, JBJS, 2010)
- Found:
- **8.0%** (12/151) new posto deficits
  - **17%** (2/12) were permanent deficits
- Etiology:
  - 66% (8/12) curve/deformity correction
  - 17% (2/12) hypotension
  - 1 direct cord trauma
  - 1 pedicle screw malposition
- w/ monitoring alerts…
  - ↑er rate of neurologic events ($p < 0.001$)
  - ↑er w/ cardiopulmonary comorbid ($p = 0.011$)

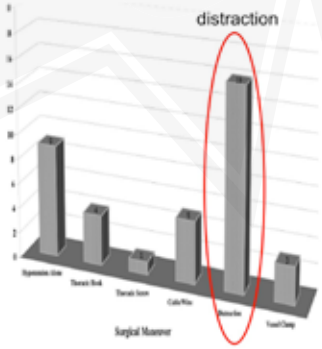


Incidence

- 4 y review, 1121 pts (834 F, 287 M) (Schwartz et al, JBJS, 2007)
- Intraop monitoring (SSEP/MEP)
  - AIS, mean age 14 yo
- Alert criteria:
  - Decrease amplitude (unilateral or bilateral)
  - >50% SSEP
  - >65% MEP
  - No latency criteria

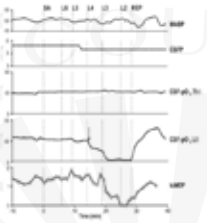
Incidence

- 4 y review, 1121 pts (834 F, 287 M) (Schwartz et al, JBJS, 2007)
- Found:
  - (0.8%) 9/1121 new deficits
  - 3.4% (38/1121) intraop alerts
    - 17 MEP and no SSEP change
    - SSEP lagged behind MEP (5min)
  - Surgical maneuver (26/38)
    - 35% (9/26) instrum-related
    - 9/9 new deficits
  - Blood vessel (12/38)
    - (9/38) Hypotension
      - All corrected elevating MAP
    - (3/8) Segmental vessel clamping
      - Left T12 segmental vessel



Etiology

- In vivo, pig study (Lips et al, Anesthesiology, 2005)
- Cord oxygenation
- *Methods:*
  - Myogenic tcMEPs
  - Continuous CSF PO2 via microcatheters
  - Graded lumbar SCI via sequential segmental arteries clamping
- Found:
  - CSF PO2 correlation to tcMEPs and SCI
  - New monitoring method?



Etiology

- 26 instrum-related alert (Schwartz et al, JBJS, 2007)
  - 9/26 (35%) new neuro deficit
    - 4 deep hook penetration
    - 2 sublaminar cable
    - 3 spinal distraction and/or derotation
- Type of deficit
  - 4 unilateral motor
  - 2 bilateral motor
  - 1 unilateral sensory
  - 1 bilateral sensory
  - 1 bilateral combined sensory/motor
- All neuro deficits resolved

Etiology

- 26 instrum-related alert (Schwartz et al, JBJS, 2007)
  - 9/26 (35%) new neuro deficit
    - 4 deep hook penetration

From this, developed alert algorithm

- Ty
  - –
  - 2 bilateral motor
  - 1 unilateral sensory
  - 1 bilateral sensory
  - 1 bilateral combined sensory/motor
- All neuro deficits resolved

Schwartz et al

- **Alert Algorithm:**
  - Surgical pause (mean 8.7 minutes)-technical?
  - Increase MAP
    - Alert MAP: 55 mm Hg (desired 65mmHg)
  - Applied correction reduced
  - Anchoring hardware removed
  - Steroid bolus – NASCIS II
  - Wake up test
- "Appropriate" response to the alert
  - 100% (9/9) Motor or sensory deficit resolved within 90 days



Etiology

- 1,445 total cases (Lee et al, Thomas Jefferson, Spine, 2006)
- 2 pts (0.1%) new postop neurologic deficit
  - Both corpectomies
- 267 (18.4%) neurophysiologic alert
  - 35% "Minor" alerts (i.e. sustained EMG activity)
  - 25% "Major" alerts

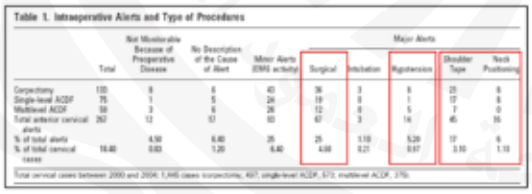


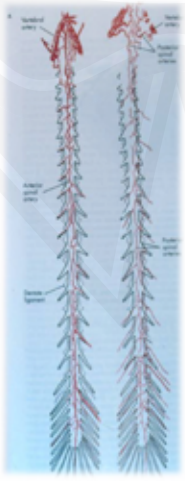
Table 1. Intraoperative Alerts and Type of Procedures

	Total	Not Monitorable Because of Preoperative Disease	No Description of the Cause of Alert	Minor Alerts (EMG activity)	Major Alerts				
					Surgical	Intubation	Hypotension	Shoulder Tape	Neck Positioning
Corpectomy	133	8	6	43	36	3	6	25	6
Single-level ACDF	75	1	5	24	19	0	1	17	8
Multilevel ACDF	58	3	6	26	12	0	5	7	0
Total anterior cervical alerts	267	12	17	93	67	3	14	45	16
% of total alerts		4.50	6.80	35	25	1.10	5.20	17	6
% of total cervical cases	18.40	0.83	1.20	6.40	4.60	0.21	0.97	3.10	1.10

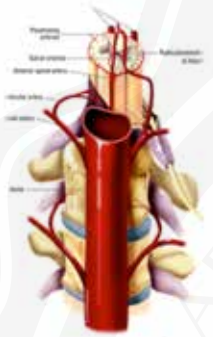
Total cervical cases between 2000 and 2004: 1,445 cases (corpectomy, 407; single-level ACDF, 672; multilevel ACDF, 376).

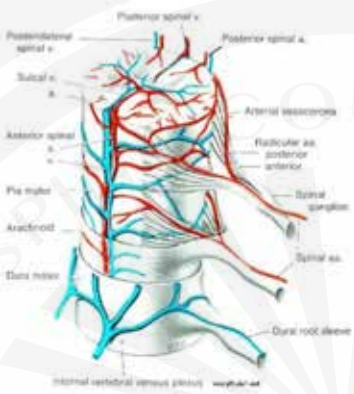
Etiology: Summary

- Most common causes of intraop neuro loss:
  - Patient positioning
  - Hypotension – Blood flow
  - Deformity correction
  - Instrumentation
  - Operative technique



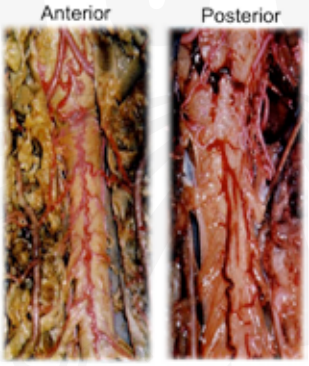
Etiology: Arterial Blood Supply





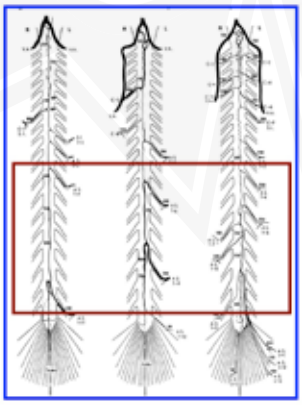
Blood Supply of the Spinal Cord

- Microdissection spine and spinal cord vessels, 35 cadavers (Dommisse, JBJS, 1974)
- **3 longitudinal arterial trunks**
  - Medulla oblongata to conus medullarus
  - 1 Ant.- over median sulcus
  - 2 posterolateral- post nerve rootlets
- Greatest: cerv and lumb enlargement



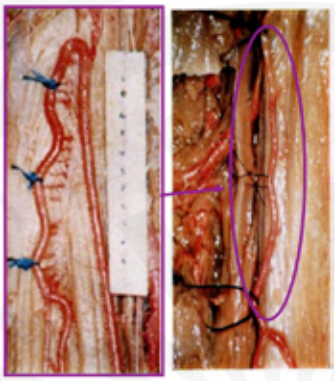
Blood Supply of the Spinal Cord

- (Dommisse, JBJS, 1974)
- Cervical medullary (radicular) feeders
  - 80% - Vertebral arteries
  - 20% - Deep cervical & sup. intercostal
- Thoracic and lumbar medullary feeders
  - Aortic segmental arteries



Thoracic Cord at Greatest Risk

- **Radicular** arteries reinforce the longitudinal arterial channels at various levels
  - 8 ant and 12 post feeders (Average)
  - Variability
    - 2-17 Anterior
      - [Kadyi(1889), Suh(1939), Woollam(1958)]
    - 6-25 Posterior
- Perforating arteries
  - Thoracic cord: too small



Cervical: all perforators

Thoracic : No perforators

Vascular Supply of the Spinal Cord

- Dog study, interrupted bilaterally segmental arteries (Fujimaki, et al, Spine, 2006)
  - Up to 7 levels ligated
  - Spinal cord blood flow
    - T12 by laser Doppler flowmetry
  - Neurologic function 15 dogs (5 Groups)
    - 10 hours after ligation
    - SC-evoked and motor-evoked potentials
    - Modified Tarlov grading



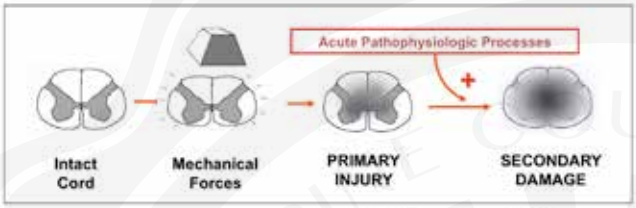
Vascular Supply of the Spinal Cord

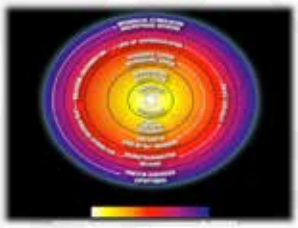
- Dog study, interrupted bilaterally segmental arteries (Fujimaki, et al, Spine, 2006)
  - Found:
    - Postoperative neurologic deficit:
      - 2/3 group 4
      - 3/3 group 5
    - CONCLUSION:

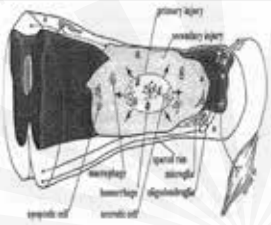
4 consecutive bilateral segmental artery ligation risks SCI

Group	Ligation	SC Blood Flow	Abn Evoke	Abn MEP
1	None	99.3%	No	No
2	3(T11-13)	80.7%	No	No
3	4(T10-13)	71.5%	No	No
4	5(T10-L1)	44.3%	2/3	1/3
5	7(T9-L2)	25.0%	3/3	3/3

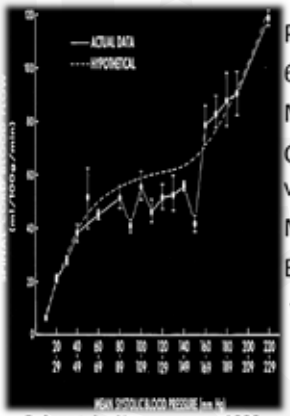
After the fact? Neuroprotection







Focus on the Secondary Injury: *PERFUSION*

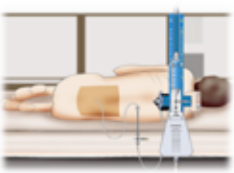


Rubenstein, Neurosurgery, 1990

- Prospective database (Vale, J Neurosurg, 1997)
- 64 SCI pts
- MAP > 85 mmHg
- Crystalloid, blood products, vasopressors
- Minimum: 7 days post-injury
- Better neurological recovery than historical control

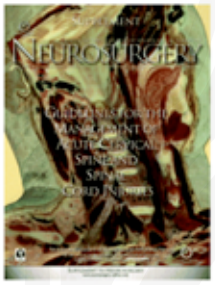
Non-spine surgery: Vascular

- Paraplegia following elective endovascular repair of an infrarenal AAA (Bajwa et al, Eur J Endovasc Surg, 2008)
- Lumbar drain immediately inserted
- Full neurological recovery





Steroids?



"Treatment with methylprednisolone for either 24 or 48 hours is recommended as an option… that should be undertaken only with the knowledge that the evidence suggesting harmful side effects is more consistent than any suggestion of clinical benefit."

AANS & CNS, March 2002

And…..**Stop steroid administration** of methylprednisone in patients whose neurologic injury resolved

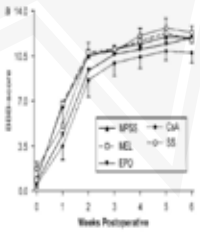
Steroids?



For intraop neuro deficit?
No data

Neuroprotection (in this setting) may not work

- 35 Rodents, T9 SCI mild intensity (Guizar et al, Spinal Cord Injury, 2008)
  - Erythropoietin
  - Melatonin
  - Cyclosporine-A
  - Methylprednisolone
- Motor function at 6 wks (BBB)
- Results:
  - No differences in:
  - locomotor performance
  - Spared cord tissue
- Conclusion:
  - **Neuroprotectant drugs used perioperatively did not reduce SCI.**



Problem: Instrumentation?

- When to Remove Pedicle Screw?
  - EMG threshold (<60%) in relation to others are suspect (Raynor et al, Spine, 2002)
- Pedicle screw past vertebral body midline on PA/AP radiograph = medial breach (Kim YJ et al: *Spine* 2005;30:2084-88)



Summary: What to Do?

- Checklist:
- Enhance spinal cord perfusion:
  - Increase MAP
  - Drainage of cerebrospinal fluid
  - Lidocaine, Papaverine?
- Decrease metabolic rate of ischemic neural tissues
  - Hypothermia
  - Barbiturates
  - Avoidance of hyperglycemia
  - Steroids?



AVOIDANCE OF INSTRUMENTATION FAILURE

Disclosure

DePuy Synthes Spine	Consultant Research Support Royalty

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Clinical presentation

Neurology	Mechanics
• Foraminal stenosis	• Deformity
• Lateral recess stenosis	• Loss of sagittal balance
	• Dynamic instability
	• Spondylolisthesis
	• Lateral Listhesis: Olisthesis

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Goals of Surgery

- **Relieve pain**
  - Neurogenic claudication
  - Radicular
- **Preserve stability of the spine during decompression**
- **When arthrodesis is performed**
  - Restore sagittal plane
  - Balance the spine

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Hardware complications

- **Mechanical**
  - Lack of clinical understanding
  - technical errors

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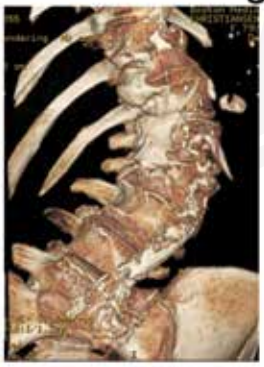
Critical Concepts to Understand:

- Mechanics of Aging Spine
- Spinal Reserves
- Biomechanical concepts:
  - Spine Biomechanics
  - Implants Mechanics

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Aging Spine Mechanics: the disc space is stronger than the vertebral body= STIFF SPINE





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Spinal reserves are exhausted

Disc above and below will survive long time

Adjacent DDD
High risk of ASD



Aging Spine: Spinal Reserves
2008, 81 YO lady, sever back and leg pain



3 yrs later, severe back & left leg pain: Just the Natural History



Biomechanical Concepts

- Loading patterns
- Metal modulus of Elasticity & failure
- Lever arm
- Bone physiology

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Spinal Implants

Spine

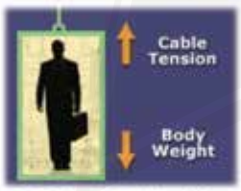
- Basic Function
- Anatomical Considerations
- Loads & Motion
- Bone Quality

Implant

- Bio-compatibility & Corrosion
- Durability & Strength
- Stress Shielding
- Motion vs. Fusion
- Profile
- Imaging

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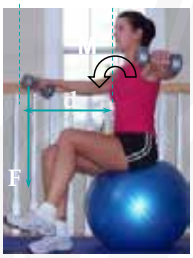
Forces & equilibrium



There are two types of equilibrium: STATIC, in which an object in equilibrium is at rest and DYNAMIC, in which the object in equilibrium is moving at a constant speed (uniform motion). The illustration above is an example of static equilibrium. In a stationary elevator, a person's weight is a downward directed force that is balanced by an upwardly directed force of the same magnitude in the elevator cable. The elevator will remain at rest until there is a change in cable tension.

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Moment (a.k.a torque)



- Moment is generated by a force that has a tendency of to rotate an object about an axis
- Moment of a force about a point is equal to the force times the perpendicular distance of its line of action from the axis point
- M = F * d
  = m (Kg)* g (m/s2)* d (m)
  = 1 kg * 9.81 m/s2* 0.75m = 7.3 Nm
- Clockwise moment is positive
- Counterclockwise moment is negative

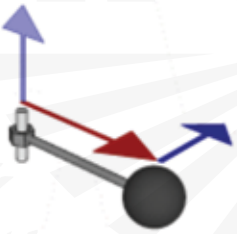
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Moment (a.k.a torque)

$\tau = r \times F$

$L = r \times p$

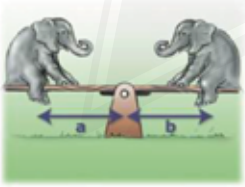


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Equilibrium (a.k.a balance)

Balanced see-saw



Sum of moments around fulcrum equals zero

(positive and negative moment of same amplitude)

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Equilibrium

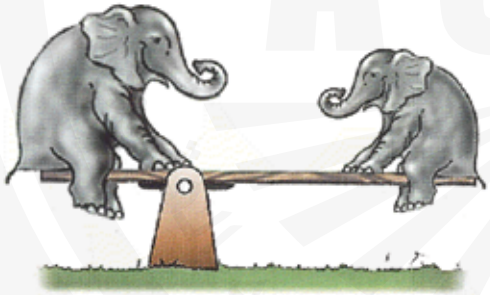


Unbalanced - Lever arms of equal weight but elephant weight unequal

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Equilibrium

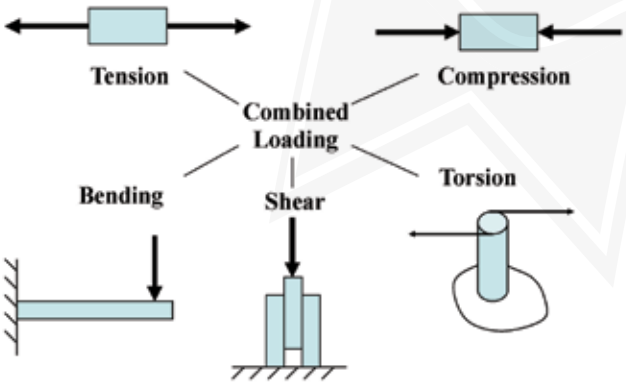


Balance – heavier weight of larger elephant counteracted by longer lever arm supporting smaller elephant

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Loading

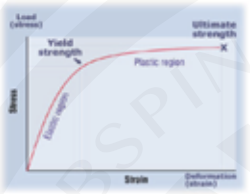


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Stress-Strain diagram

Classic engineering materials produce stress-strain graphs with two distinct regions. These regions correspond respectively to the **elastic** and **plastic** deformation of the test sample.



Move on to the next page for an explanation of these conditions...

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Stiffness versus strength

Strength is defined as the amount of load a material can resist without failing.

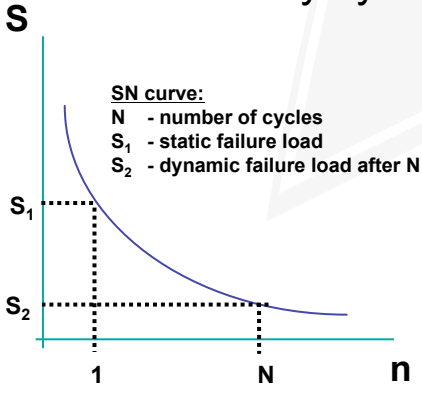


Stiffness on the other hand is defined as the measure of the resistance to elastic deformation when a load is applied.

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A safe static load can fail after many cycles





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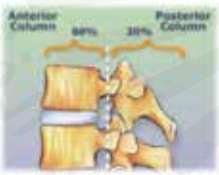
Spine Biomechanics

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Vertebral Column Theory - Loading

It is useful to discuss how the forces are distributed in the spine as this philosophy becomes essential when planning for spinal reconstruction.



In general, researchers say that roughly 80% of the compression (downward vertical force) passes through the anterior column and 20% passes through the posterior column.

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Vertebral Column Theory - Balance

Let us walk through a brief explanation of spine loading within a normal person standing quietly. (Use the **Click to Continue** button now.)

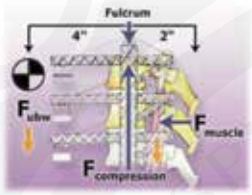


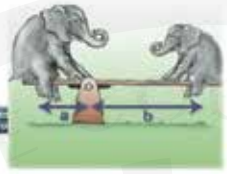


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Vertebral Column Theory - Balance





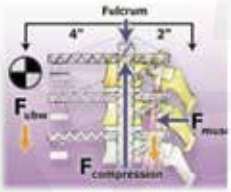
1. The compressive spine loading (F-compression) is roughly equivalent to the total of both the upper body weight (F-ubw) and the posterior back muscle force (F-muscle).
2. Similar to the unbalanced see-saw example, the posterior back muscles are located closer (2") to the anterior column than the center of the body (4").

For force equilibrium:

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Typical Loadings on spine



Activity	Load (N)
Supine in traction	100
Standing	700
Jumping	1100
Sit-up exercise with knees bent	1800
Lifting of 20 kg, back straight, knees bent	2100
Lifting of 20 kg, back bent, knees straight	3400

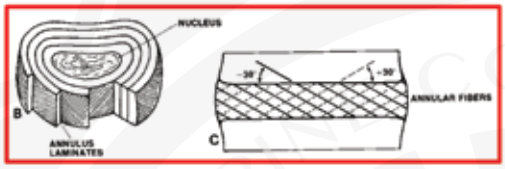
Bio-mechanics of Intervertebral Disc

- *Carry compressive load*
- *Allow and constrain vertebral motion*
- *Absorb shock to a certain extent*

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Disc Structure



- Annulus Fibrosus
- Nucleus Pulposus

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Planning for Spinal Instrumentation

- Must understand local and global mechanics
- Assess bone physiology
- Carefully consider pathology:
  - Short vs. long term fix
  - potential for bone remodeling
  - Spine stiffness
- Have full understanding of spinal implant role

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Bone Physiology: Wolf's law (1835-1902)



Bone remodelling:

-too much force → breaks
-not enough force → resorbs
-right amount of force → good bone remodelling

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Factors that surgeon can and should control

- Metal density: number of screws, cages etc… divided by the segment of instrumentation
- Metal Distribution: location of the screws or cages
- Optimize the biomechanical environment

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Factors that surgeon can and should control

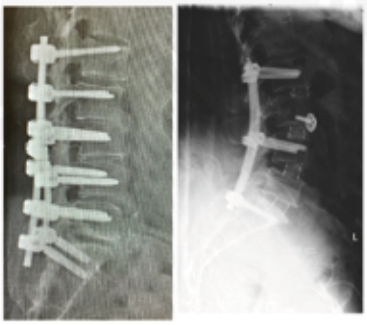
- Metal density: number of screws, cages etc… divided by the segment of instrumentation:
  - In Idiopathic scoliosis: density of 1.4/level or more is preferable.
  - Anterior column support relieves the stress on the posterior screws: Load sharing concept



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Factors that surgeon can and should control

- Metal density: number of screws, cages etc… divided by the segment of instrumentation:
  - Anterior column support relieves the stress on the posterior screws: Load sharing concept



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55/M with L1 compression Fx treated non-operatively X 6 wks, back pain, neuro intact



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Load Sharing



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MIS ANT + Post: Load Sharing



Factors that surgeon can and should control

- Metal Distribution: location of the screws or cages



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Inadequate screw distribution Distal T1 Failure

Screw Loosening



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Inadequate distribution at the deformity apex

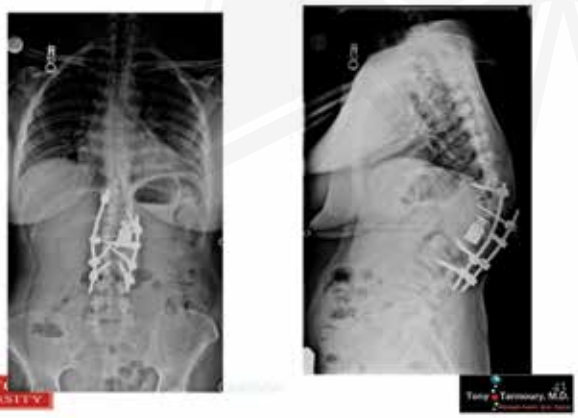


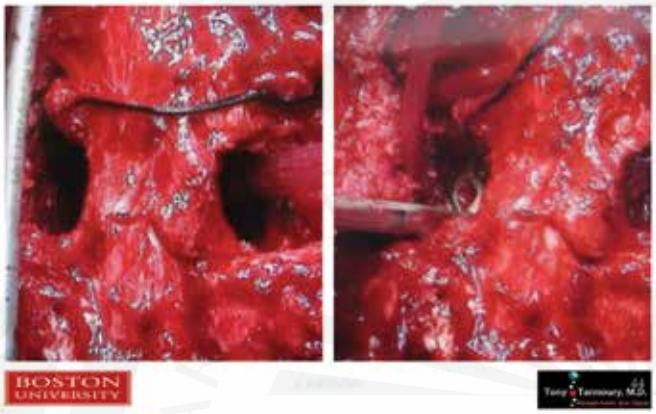
Post Traumatic Kyphosis: Inadequate screw distibution

- 28 YO Female, Desk job, now unable to work
- CC: Severe Back & Lt groin pain
  Bad posture
- PMH: Malabsorption, Osteopenia...



Inadequate screw distribution

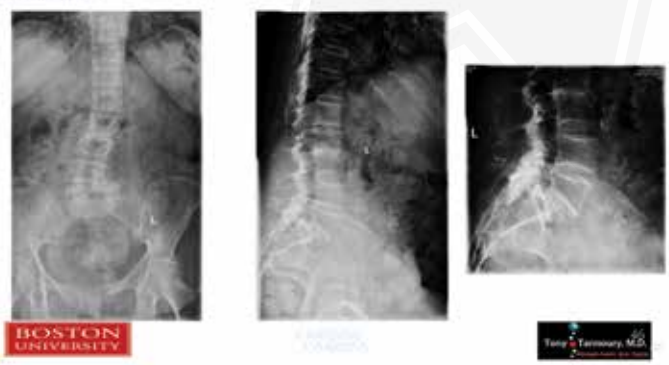






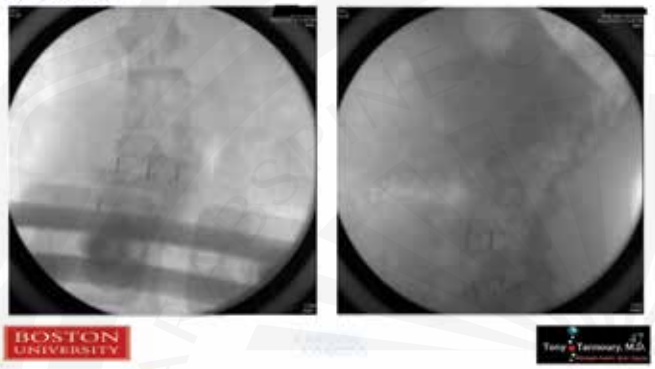
R.V. 72/F with severe back pain, degenerative scoliosis, spondylisthesis; heavy smoker

1-8-2008

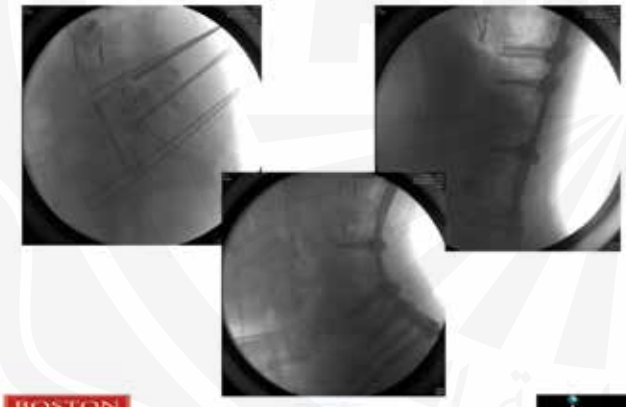


Stage 1: ALIF L1-S1

10-18-2010



Stage 2: PSIF T10 - ilium



Stage 2: PSIF T10 - ilium

10-19-2010



Hardware failure T10-T11 at 2 months post-op





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Revision PSIF T8-T12





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Planning for Spinal Instrumentation

- Must understand local and global mechanics
- Assess bone physiology
- Carefully consider pathology:
  - Short vs. long term fix
  - potential for bone remodeling
  - Spine stiffness
- Have full understanding of spinal implant role

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H&P

- 66 yo F
- progressively worsening back pain for 2-3 months
- COPD - on home O2 & chronic steroids
- Severe osteoporosis dt steroid use
- Neuro-intact except for diffuse 4+ weakness all over b/l lower extremities
- Multiple compression Fx
- T6,7 kyphoplasty 3 months ago

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MRI (before vertebroplasty)





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CT (after vertebroplasty)



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MRI (after vertebroplasty)



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Implant Role

- Get the patient out of bed.
- Lower the perioperative complications: very high risk patient.
- Stiffen the spine.

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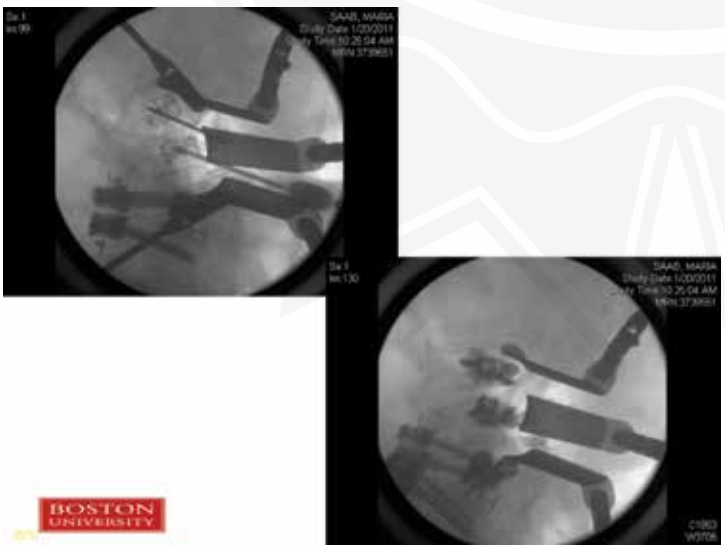
T3-S1 internal fixation with limited fusion



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2 Weeks Post Op X-rays
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Adjacent Segment Disease
with previous hardware: VERY COMMON
PROBLEM


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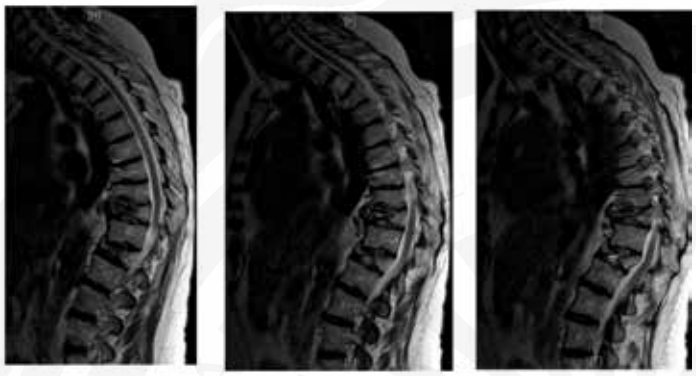


H&P (C.M.)

- 71 yo F
- Mid & Lower thoracic back pain
- Some associated radicular pain along waist
- Arched back, unable to stand straight
- No balance difficulties or B/B symptoms
- Neuro-intact
- 1.5 yrs ago, kyphoplasty at T10, T12

71 yo, Multiple compression Fx s/p two kypho. Severe back pain. Normal Neurology





Strategy

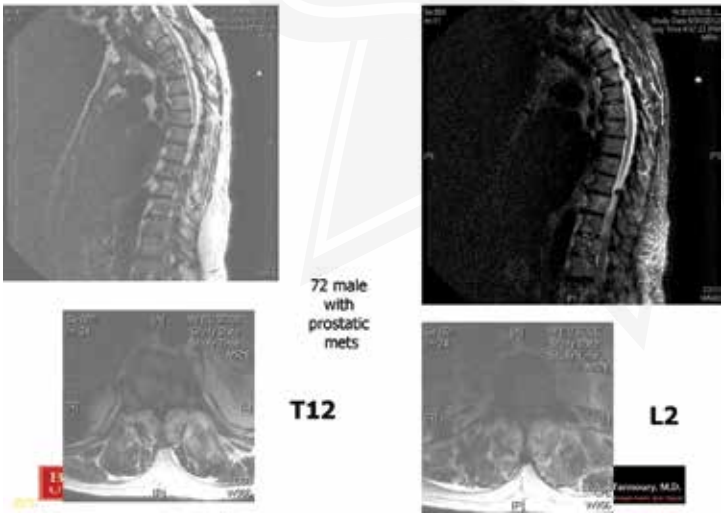
- Osteoporotic bone:
  - Multiple points of fixation
  - Cement augmentation
  - Thoracic spine: posterior only
- Simultaneous reduction of both rods
- Manual reduction

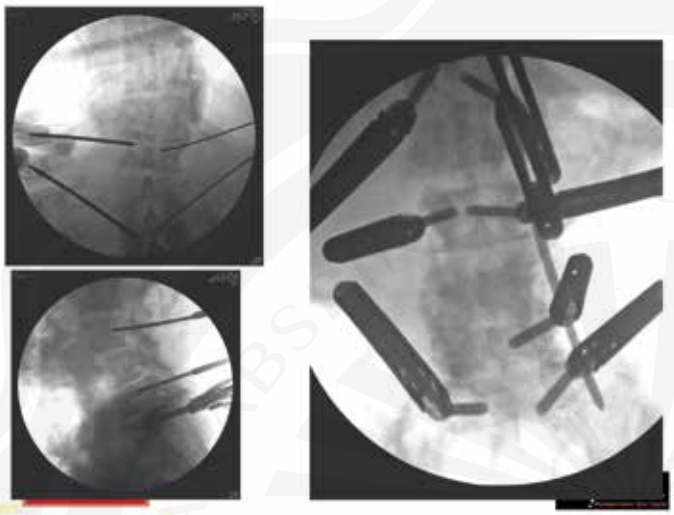
T6-L3




Before and After

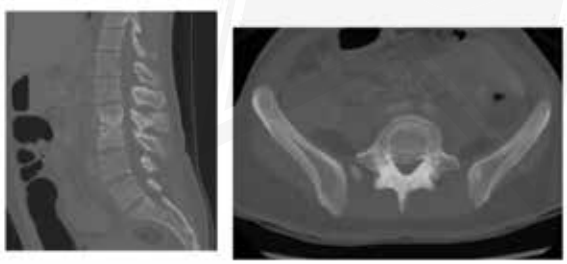

63 YO Prostate CA.
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72 male with prostatic mets
T12
L2





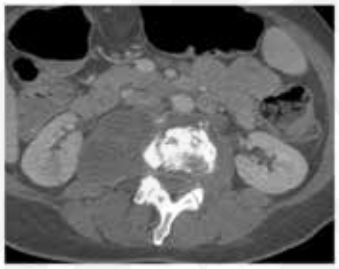
Infections
Non Fusion Concept
25 yo lady. Severe back and right leg pain
and weakness







CT Scan



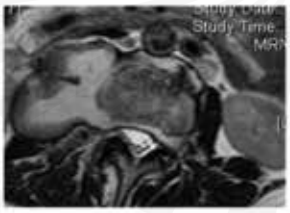


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MRI





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Rx Option

- Bracing
- Fusion
- Approach
- levels

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-L2-3 debridement

-Put the implant out of the zone of infection

-Implant Role: Temporary In-fixation





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6 weeks post op.



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4 months post op





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No Fusion, we saved the patient two levels





Spinal Reserves

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82

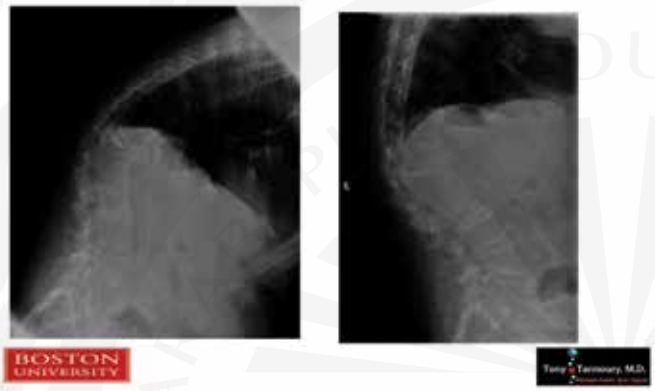
67/M with lymphoma metastatic to spine, s/p chemotherapy, in remission, back pain with bilateral proximal lower extremity weakness





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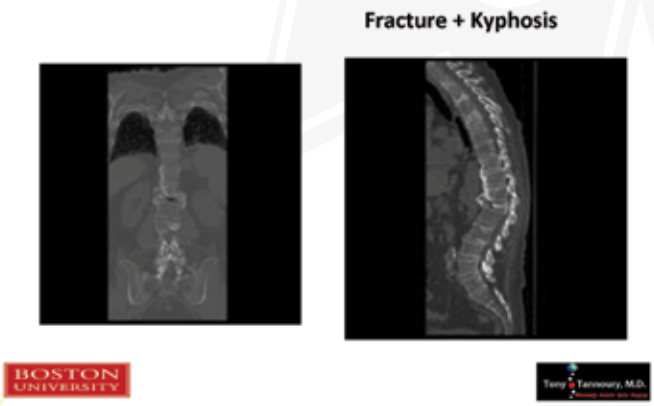
X-rays



MRI



Fx at the base of Auto-Ankylosis



Thoracotomy for L1 Corpectomy and T12-L1 interbody fusion; L2-L5 ALIF via anterolateral approach

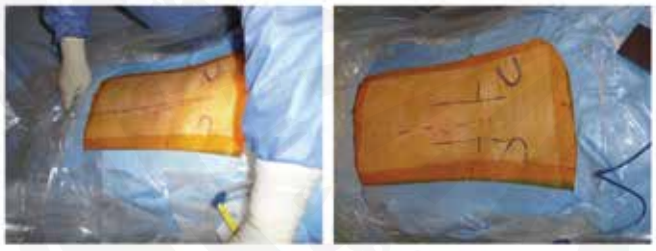
Stage 1: Anterior



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Stage 2: PSIF with bone cement



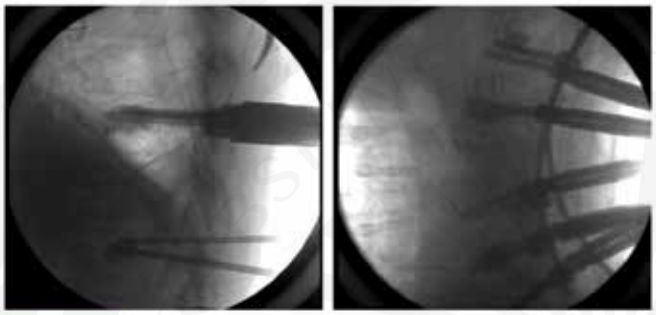
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Conclusion

- **Osteoporotic bone:**
  - Multiple points of fixation
  - Thoracic spine: posterior only
- **Load Sharing**
- **Adequate balanced spine restauration**
- **Biomechanics, Biomechanics, Biomechanics**

ADJACENT SEGMENT DISEASE

Introduction

- Lumbar interbody fusion has long been used to effectively treat painful disc degeneration after failure of non-operative intervention
- However, it carries the potential problems of pseudarthrosis and accelerated degeneration of the adjacent segment(s)

Texas Back Institute

SPINE • VOLUME 9 • NUMBER 6 • 1984

Lumbosacral Spinal Fusion
A Biomechanical Study

CASEY K. LEE, MD,* and NOSHIR A. LANGRANA, PhD†

- First study addressing possible ASD
- Biomechanical study
- Found fusion increased stress at adjacent segments

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SPINE • VOLUME 13 • NUMBER 3 • 1988

Accelerated Degeneration of the Segment Adjacent to a Lumbar Fusion

CASEY K. LEE, MD

- Clinical study of 18 with new symptoms at adjacent segment mean of 8.3 yrs after fusion
  - 16 facet degeneration
  - 8 stenosis
  - 5 disc degeneration
  - 1 degen spondy
  - 1 spondylolysis acquisita

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SPINE Volume 20, Number 5, pp 526–531
©1995, J. B. Lippincott Company

Intradiscal Pressure Measurements Above an Instrumented Fusion

A Cadaveric Study

Susan L. Weinhoffer, MS,* Richard D. Guyer, MD,* Morley Herbert, PhD,† and Steven L. Griffith, PhD*

- Lumbar spines tested intact, w pedicles screws/ rods at 1 and 2 levels
- Disc pressure measured using transducers at adjacent segments while spines moved through flexion
- Pressured increased with fixation, and more so with 2 levels instrumented

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ASD: Natural History (Genetic) or Biomechanical (Environment)?? Literature Review

- Biomechanically fusions increase intradiscal pressure, facet loading, and hypermobility above and beyond natural history
- Radiographic 5.2%- 100% at 36-360 mo f/u
- Symptomatic 5.2-18.5% at 44.8-164 mo f/u (higher with pedicle screws, 12.2-18.5%)
- Risk factors = pedicle screws, facet joint violation, sagittal mal-alignment, and fusion length

Park et al., Spine 2004

Texas Back Institute

5-yrs after 360 Fusion



Zigler, et al, J Neurosurg Spine, 2012

Texas Back Institute

Eur Spine J (2016) 25:1550–1557
DOI 10.1007/s00586-016-4469-5

ORIGINAL ARTICLE

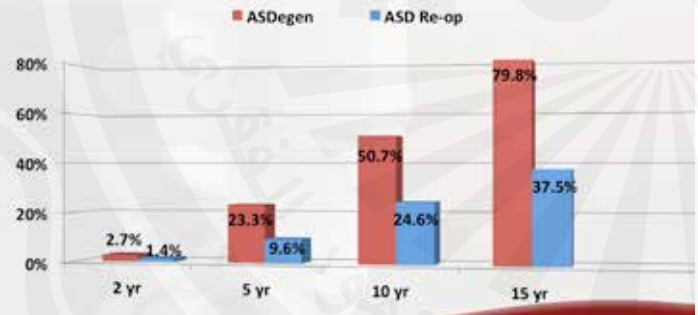
Adjacent segment degeneration and revision surgery after circumferential lumbar fusion: outcomes throughout 15 years of follow-up

José I. Maruenda[1] · Carlos Barrios[2] · Felipe Garibo[3] · Borja Maruenda[4]

- 73 pts with 360 fusion at 1-3 levels
- Re-op for ASD increased significantly with number of levels fused and older age

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ASD after Fusion



Maruenda et al, Eur Spine J, 2016

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Risk Factors for Post-fusion ASD

- 1250 consecutive instrumented PLF pts
- Radiographic risk factors for symptomatic ASD were increased sagittal balance, loss of lordosis, and adjacent disc space collapse
- BMI, pre-op adjacent disc degeneration on MRI and disc bulge were significance in predicting likelihood of clinical ASD

Ghasemi, Clin Neurol Neurosurg, 2016

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Lumbar TDR Rationale

- Lumbar TDR was designed to:
  - Reduce pain arising from disc degeneration
  - Maintain motion of the operated segment
    - By maintaining motion, reduce incidence of adjacent segment degeneration

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Biomechanics: TDR vs. Fusion

- Cadaveric study comparing 1 vs. 2 level TDR vs. fusion
- 1 level TDR had no effect on adjacent segments, 2-level TDR did transfer stress to levels nearest implants
- 1 and 2-level fusion transferred stresses to all other lumbar segments

Panjabi et al, Spine, 2007

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Disc and Facet Pressures in TDR, Discectomy, and Fusion

- Cadaveric biomechanical study
- TDR: Adjacent-level disc pressures and facet force pressures similar to intact
- Discectomy: Disc pressures increased compared with intact and TDR
- Fusion: Disc pressures and facet force pressure increased compared with intact and TDR

Gao et al, J Neurosurg Spine, 2011

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ELSEVIER

The Spine Journal 6 (2006) 242–247

THE SPINE JOURNAL

Range of motion and adjacent level degeneration after lumbar total disc replacement

Russel C. Huang, MD[a,*], Patrick Tropiano, MD[b], Thierry Marnay, MD[c], Federico P. Girardi, MD[a], Moe R. Lim, MD[a], Frank P. Cammisa, Jr., MD[a]

- 42 patients 8.7 yr follow-up
- Pts with ≥5° at TDR level had significant lower rate of ASD: 0% vs. 34%
  - Results suggest motion has preventive potential for ASD

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See the corresponding editorial in this issue, pp 503–503.

J Neurosurg Spine 17:604–611, 2012

Five-year adjacent-level degenerative changes in patients with single-level disease treated using lumbar total disc replacement with ProDisc-L versus circumferential fusion

Clinical article

Jack E. Zigler, M.D.,[1] Jamison Glenn, M.D.,[2] and Rick B. Delamarter, M.D.[3]

- 123 TDR; 43 fusion
- Radiographs evaluated by independent radiologist

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ASD: TDR vs. Fusion

- Δ ASD observed at 5 years in:
  - 28.6% of fusion patients
  - 9.2% of TDR patients



> 3 : 1 Difference

P<0.01

Zigler et al, J Neurosurg Spine, 2012

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Results in Patients with No Pre-op ASD

- New findings of ASD at 5 years found in:
  - 23.8% of fusion patients
  - 6.7% of TDR patients



> 3 : 1 Difference

P<0.01

Zigler et al, J Neurosurg Spine, 2012

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5-year Adjacent Segment

- Among pts with normal adjacent segments pre-op, significantly more (p<0.01) TDR pts had no change in these levels at 5 yrs:
  - TDR: 90.8%
  - Fusion: 71.4%
- Adjacent segment re-op (p>0.50):
  - TDR: 1.9%
  - Fusion 4.0%

Zigler, et al, J Neurosurg Spine, 2012

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5-yr Follow-up of activL FDA IDE Patients: Analysis of ASD

- 14 sites
- Pre- and 5-yr post-op radiographs available for:
  - 135 in investigational group
  - 63 in control group
- All treated for single-level symptomatic DDD non-responsive to non-op care

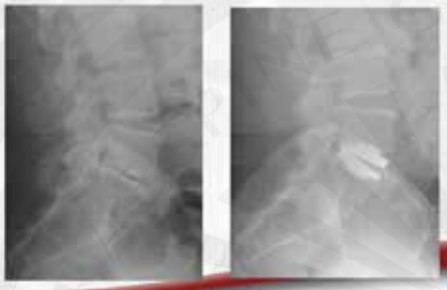


activL FDA IDE trial data

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ASD Example

- Change from Grade 1 to Grade 2 at superior adjacent segment at 5 yr follow-up in a 51 yr old male



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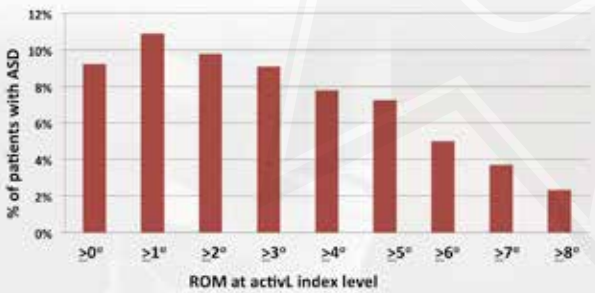
Results

- When compared to pre-op images, ASD was found at 5 yr follow-up in:
  - 8.8% of investigational group
  - 19.0% of control group
    - p<0.05

activL FDA IDE trial data

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ASD and ROM of TDR Level

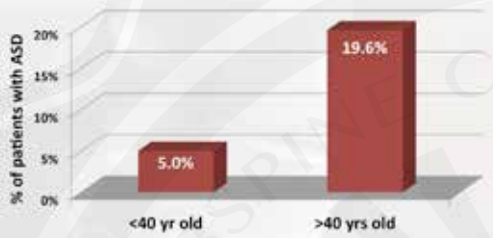


For each additional degree of motion at the TDR level, there was a decline in the rate of ASD

activL FDA IDE trial data

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ASD and Age



ASD significantly greater in older patient subset, p<0.01
(data combined for investigational and control groups)

activL FDA IDE trial data

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Lumbar Adjacent Segment Degeneration and Disease After Arthrodesis and Total Disc Arthroplasty

James S. Harrop, MD,* Jim A. Youssef, MD,† Mitch Maltenfort, PhD,* Peggy Vorwald, BS,† Pascal Jabbour, MD,* Christopher M. Bono, MD,‡ Neil Goldfarb, BS,§ Alexander R. Vaccaro, MD,* and Alan S. Hilibrand*

- Reviewed 27 Class I and II fusion and TDR studies
  - 314/926 fusion pts developed AgDD = 34%
  - 31/313 TDR pts developed AgDD = 9%
    - p<0.0001

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Eur Spine J (2016) 25:1522–1532
DOI 10.1007/s00586-016-4415-6

REVIEW ARTICLE

Adjacent segment degeneration after lumbar spinal fusion compared with motion-preservation procedures: a meta-analysis

Aixing Pan[1] · Yong Hai[1] · Jincai Yang[1] · Lijin Zhou[1] · Xiaolong Chen[1] · Hui Guo[1]

- 15 studies, 1474 patients
- TDR had significantly lower rates of ASdegen, ASDis, and re-op for ASDis compared with fusion
  - ASDengen: 18.6% vs. 37.5%
  - ASDis: 5.1% vs. 14.4%
  - Re-op for ASDis: 1.1% vs. 7.7%

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ASD: TDR vs. Rehab

- Randomized trial, 2 yr follow-up
- ASD evaluated by MRI
- No difference in ASD between the 2 groups
  - TDR group had greater facet joint changes at the index level

Hellum et al, Spine, 2012

Texas Back Institute

Pre-op Condition of Adjacent Segment and Post-TDR ASD

- Reviewed pre-op imaging of pts who had re-op for ASD post-TDR
- Adjacent segment pre-TDR:
  - 38.8% were normal
  - 38.8% moderately diseased
  - 22.2% had severe degeneration

Rainey et al, Int J Spine Surg, 2012

Texas Back Institute

Pre-op Condition of Adjacent Segment and Post-TDR ASD

- No level had a different grading at time of re-op compared with pre-TDR
- Conclusions: By carefully assessing degenerative changes at adjacent segment pre-TDR may further reduce rate of re-op for ASD in TDR pts

Rainey et al, Int J Spine Surg, 2012

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Discussion

- Biomechanical studies:
  - Consistent data supporting that fusion increases stresses in adjacent segment discs and facet joints
  - Indicate that TDR results in lower, if any, additional stresses to adjacent segments

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Discussion

- Clinical studies:
  - Not all are consistent
  - Variations in definitions of ASD
  - In general, ASD and re-op for ASD rates significantly lower for TDR vs. fusion
  - TDR is a viable treatment for ASD

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Discussion

- ASD rate declined with increasing ROM at the TDR level
  - Possibly suggesting protective effect of motion
- Higher rate of ASD among older patients may suggest that some changes in adjacent level discs may be attributable to aging process

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Discussion

- In general, the literature suggests that TDR has a protective effect in reducing ASD vs. fusion in the treatment of painful lumbar disc degeneration

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Treatment for ASD

- Traditionally, ASD treated by extending fusing the now painful level next to prior fusion
  - Does this set up the next level to become painful later?
- Currently, have the option to treat ASD with TDR

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Treatment for ASD

- To treat ASD with TDR, the pt must be a TDR candidate in general and particular attention must be paid to the facets at the level to be treated

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TDR Used to Treat ASD

- Potential benefit: Reduce risk of future ASD at additional level(s)
- Creates procedure similar to hybrid TDR/ fusion

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J Neurosurg Spine 4:91–97, 2006

Treatment of symptomatic adjacent-segment degeneration after lumbar fusion with total disc arthroplasty by using the ProDisc prosthesis: a prospective study with 2-year minimum follow up

Rudolf Bertagnoli, M.D., James J. Yue, M.D., Andrea Fenk-Mayer, M.D., Jonathan Errulkar, M.D., and John W. Emerson, Ph.D.

- 18 pts, mean interval between prior fusion and TDR 4.5 yrs (median 3 yrs, range 6–216 mo)
- Significant improvement in VAS, ODI, and satisfaction from 3 mo throughout 24 mo follow-up, no re-ops post TDR

Texas Back Institute

TDR to Treat Post-fusion ASD

- Pts should be screened carefully for facet joint impingement/degeneration, hardware-induced pain, and/or pseudo at prior fusion level(s) before undergoing TDR at adjacent level

Bertagnoli, et al, J Neurosurg Spine, 2006

Texas Back Institute

TDR to Treat Post-fusion ASD



Bertagnoli, et al, J Neurosurg Spine, 2006

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TDR to Treat Post-fusion ASD

- 27 pts, time from PLF to TDR at adjacent segment was mean of 33 mo (range 18-56 mo)
- Post TDR at adjacent segment, the mean:
  - Pain score decreased from 9.1 to 3.2
  - ODI decreased from 50.2 to 21.7
- Change in pelvic tilt post-TDR was independent predictor of better clinical outcome

Hähnle, et al, Int J Spine Surg, 2007

Texas Back Institute

COMPLICATIONS IN DEFORMITY SURGERY

SCHÖN KLINIK

Non fatal complication rates of scoliosis

SRS morbidity and mortality data
Stable around 9-10% for the years 2004, 2005, 2006
-infection: 2-3%
-neurological deficits: 1%

-idiopathic adolescent scoliosis: 0.2-0.4%
-degenerative scoliosis doubles neurological risk
-congenital scoliosis allmost triples neurological risk

SRS M&M data

John E. Lonstein (SRS 1992): „Primum non nocere". („First do not harm")

Schön Klinik. Messbar. Spürbar. Besser.

SCHÖN KLINIK

SRS- data base of 19360 pediatric scoliosis patients

Complication rate: 10,2%.

Overall complication rates differed significantly between idiopathic (6,3%), congenital (10,6%) and neuromuscular 17,9%) cases.

This was also the case for neurological complications with congenital (2%), neuromuscular (1,1%), idiopathic (0,8%).

The mortality rate was 0,3% for congenital and neuromuscular scoliosis and 0,02% for idiopathic scoliosis patients.

Revision surgery and osteotomies significantly increased the neurological complication rates.

Reames et al. (2011)

Schön Klinik. Messbar. Spürbar. Besser.

SCHÖN KLINIK

Complication rates of adult idiopathic scoliosis: 13.4%.

-Significant risk factors: osteotomies, revision procedures and combined anterior/posterior approaches.

- Scoliosis type and age: unimportant factors.

Sansur et al. (2011)

Schön Klinik. Messbar. Spürbar. Besser.

SCHÖN KLINIK

Hooks are out !!!!

Only a „rescue tool“

-longer fusion levels compared to screws

-less correction compared to screws

-more loss of correction over time



Schön Klinik. Messbar. Spürbar. Besser.

SCHÖN KLINIK

Accuracy of pedicle screw placement in the pediatric spine exceeded the rate reported in adults.

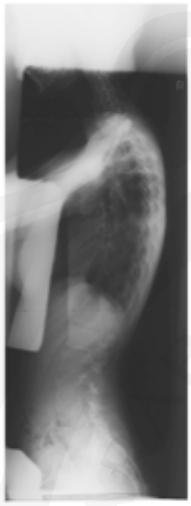
Ledonio GT, et al.: Pediatric pedicle screws: comparative effectiveness and safety. J. Bone Joint Surg (Am) 2011;93:1227-1234

Schön Klinik. Messbar. Spürbar. Besser.

14- year old female with idiopathic left lumbar scoliosis (Lenke 5CN)









Risk of neurological complications
- related to implant (screw positioning)
- related to osteotomies
- related to correction (spinal cord lengthening)

- 3-D malformation
- Intravertebral deformity
- Concave pedicles smaller
  – *Liljenqvist et al.*, Spine 2000







Basic Screw Test (Neurovision)

- A test to confirm that the pedicle screw is within the confines of the pedicle
  - Pedicle bone acts as an insulator for the screw
  - Stim current is sent down the screw
  - **Intact pedicles require more stimulation to elicit a nerve response**
  - **Breached pedicles require less stimulation to elicit a nerve response**



Schön Klinik. Messbar. Spürbar. Besser.

Screw Test Results

- An intact pedicle requires more stimulation to elicit a nerve response
- A breached pedicle requires less stimulation to elicit a nerve response

Numeric Reading*	Color Code	Interpretation
11mA or Greater	Green	Unlikely Breach
7-10mA	Yellow	Possible Breach
6mA or Less	Red	Likely Breach



Schön Klinik. Messbar. Spürbar. Besser.

NeuroVision® Value

Spinal Cord Monitoring

- MEPs
  - Protection of the motor pathways
- SSEPs
  - Protection of the sensory pathways





Schön Klinik. Messbar. Spürbar. Besser.

Osteotomies (neurological risks)

- Smith Peterson / Ponte: 5%
- Pedicle Subtraction: 10%
- PVCR: 15-25%

Smith-Peterson Osteotomy (SPO)

Multiple SPO's

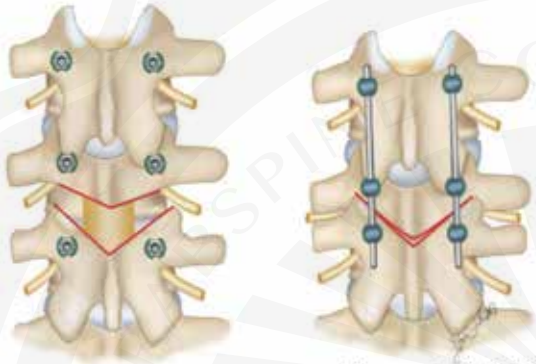




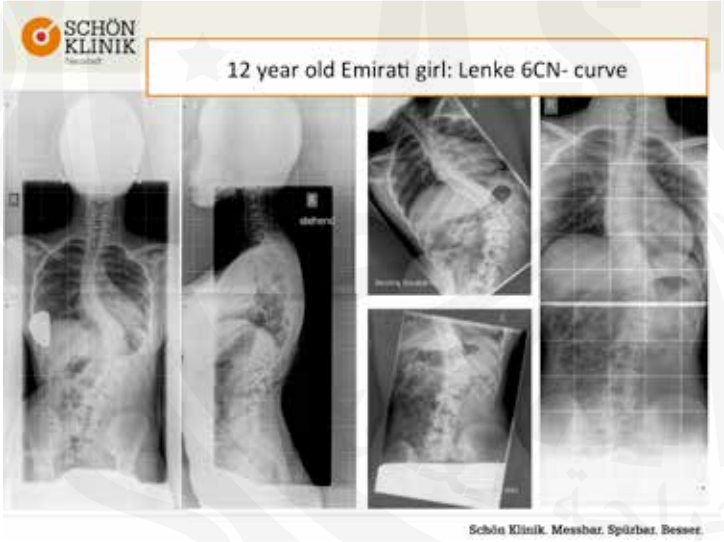


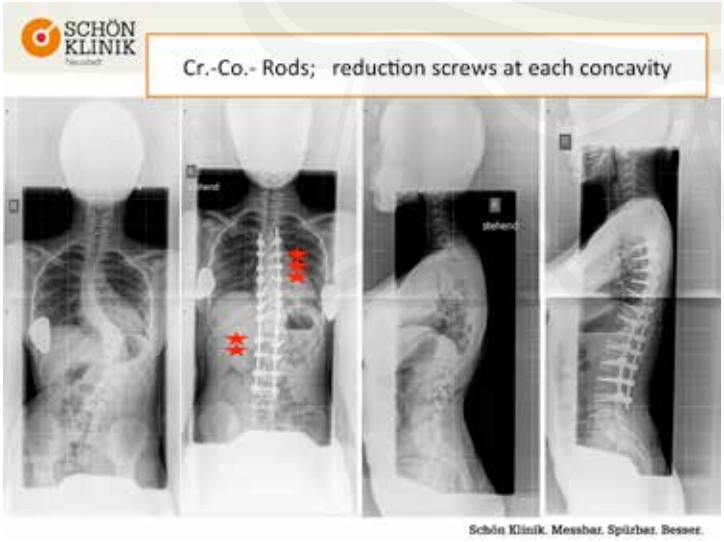
(multiple SPO's)

SPO: before and after closure

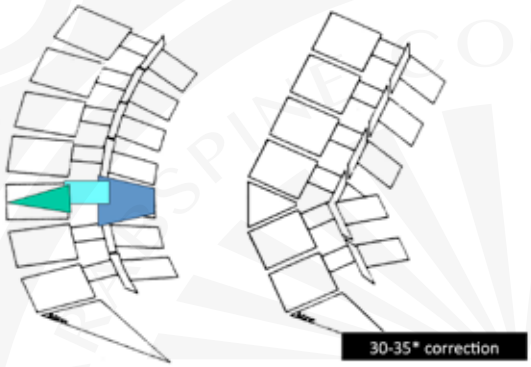


Alanay et al. ESJ 2012





Pedikel Subtraction Osteotomy (PSO)



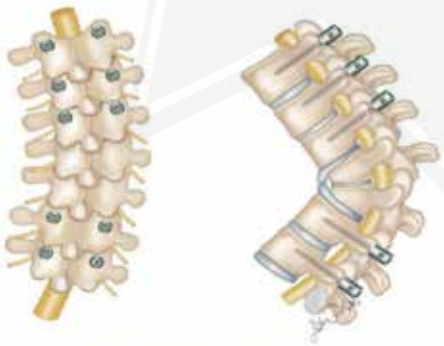
PSO: excellent for correction of rigid kyphosis (kyphoscoliosis)



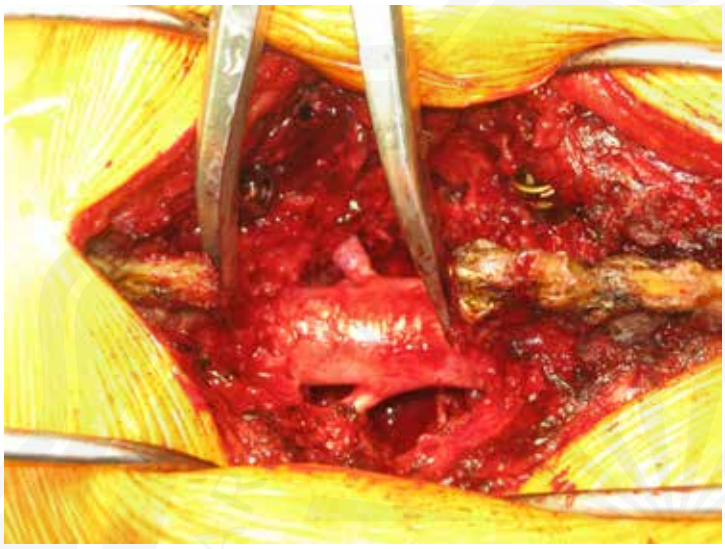
Alanay et al. ESJ 2012

Alternative to combined release and staged surgery with halo traction between procedures

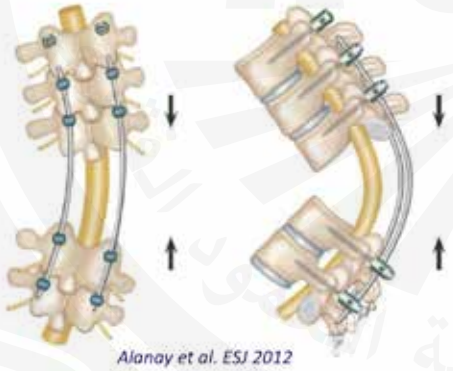
PVCR – surgical technique



Alanay et al. ESJ 2012

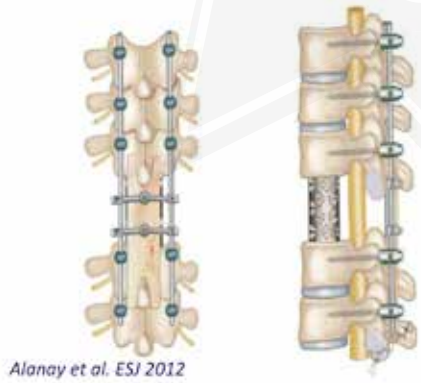


PVCR – surgical technique



Alanay et al. ESJ 2012

PVCR – surgical technique



Alanay et al. ESJ 2012

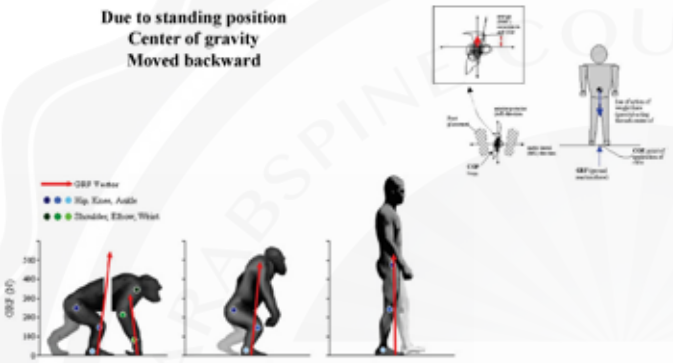
SAGITTAL IMBALANCE: PRINCIPLES IN REVISION

Patient safety

Dubai 2016

Standing position

Due to standing position
Center of gravity
Moved backward



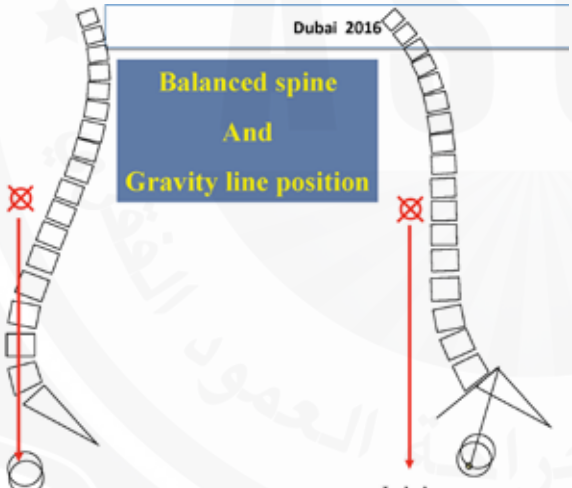
2/Tet

Module V Spinal balance – Imbalance Le Huec

Patient safety

Dubai 2016

Balanced spine
And
Gravity line position



Good balance
Gravity line through femoral head

Imbalance
Gravity line in front of femoral head

3/Tet

Module V Spinal balance – Imbalance Le Huec

Patient safety

Dubai 2016



Full spine in standing position
AP and Lateral
Is requested

Digitilyzed X rays
C2 – Femoral head

If possible
Full Body image
With EOS low dose system



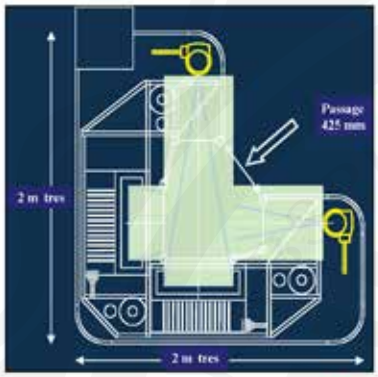
4/Tet

Module V Spinal balance – Imbalance Le Huec

Patient safety

Dubai 2016

EOS DEVICE



BIOSPACE

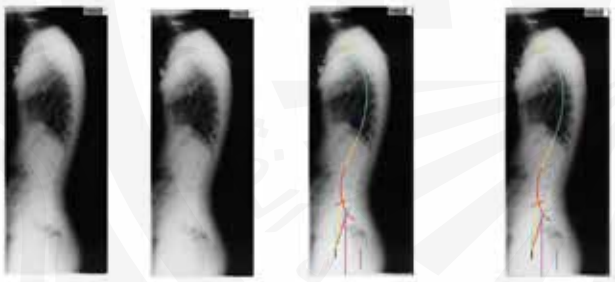


Module V Spinal balance – imbalance Le Huec

Patient safety

Dubai 2016

LATERAL VIEW: FULL SPINE IN STANDING POSITION



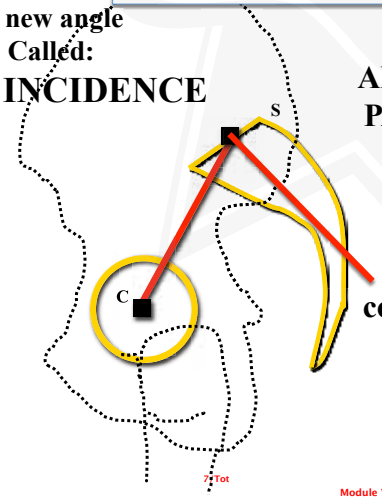
Module V Spinal balance – imbalance Le Huec

Patient safety

Dubai 2016

This new angle is Called:

PELVIC INCIDENCE



IT IS AN ANATOMICAL PARAMETER OF THE PELVIS

Which is constant for all your life

Module V Spinal balance – imbalance Le Huec

Patient safety

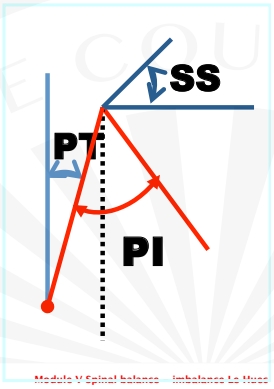
Dubai 2016

3 ANGLES

- PELVIC INCIDENCE = constant shape parameter

- PELVIC TILT (PT) and SACRAL SLOPE (SS) are variable positional parameters

PI = PT+SS



Average PI angle
is between 50 and 55°

8/Tot

Module V Spinal balance – imbalance Le Huec

Dubai 2016



3 %

12 %

18 %

27 %

40 %

Typical spatial organization of lumbar lordosis

→ 2/3 of the lumbar lordosis located in the lower lumbar spine segment L4-S1

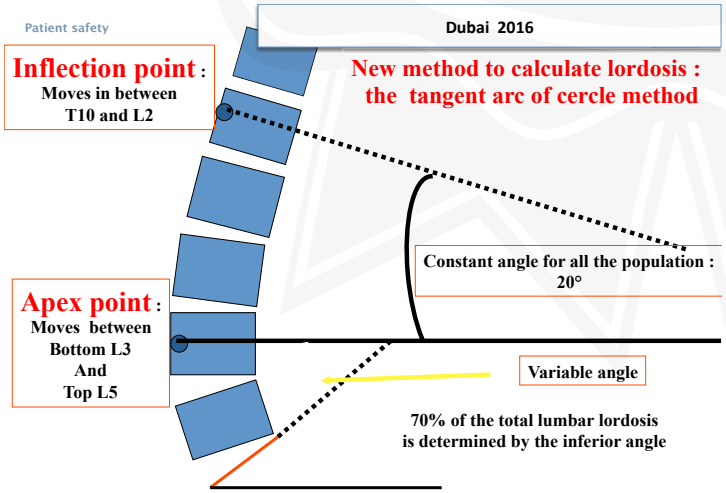
Module V Spinal balance – imbalance Le Huec

Patient safety

Dubai 2016

Inflection point :
Moves in between
T10 and L2

New method to calculate lordosis :
the tangent arc of cercle method



Constant angle for all the population :
20°

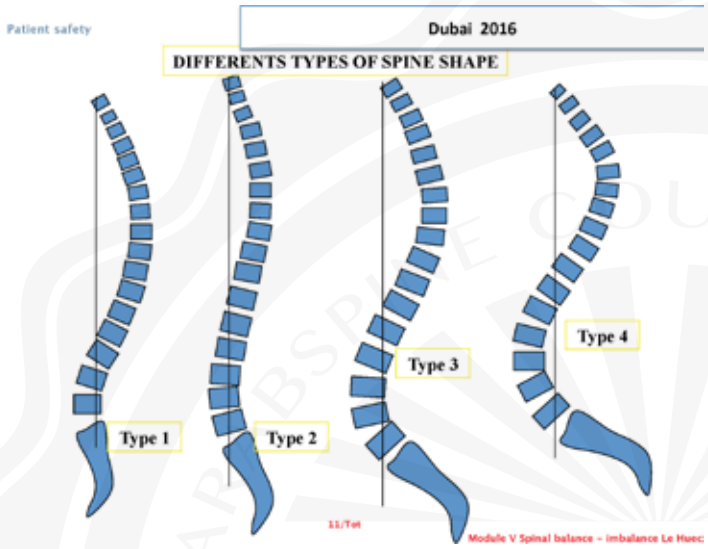
Apex point :
Moves between
Bottom L3
And
Top L5

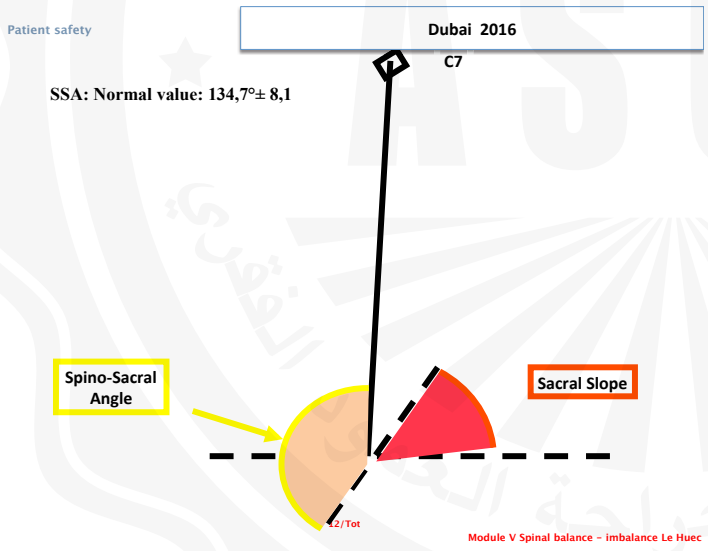
Variable angle

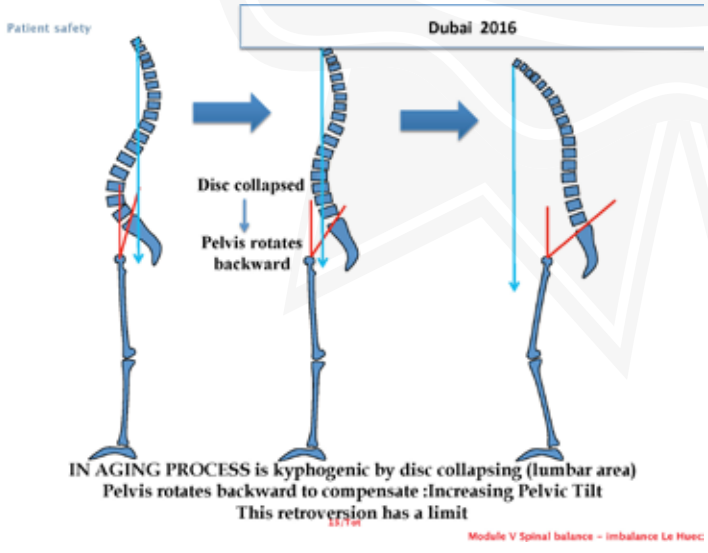
70% of the total lumbar lordosis
is determined by the inferior angle

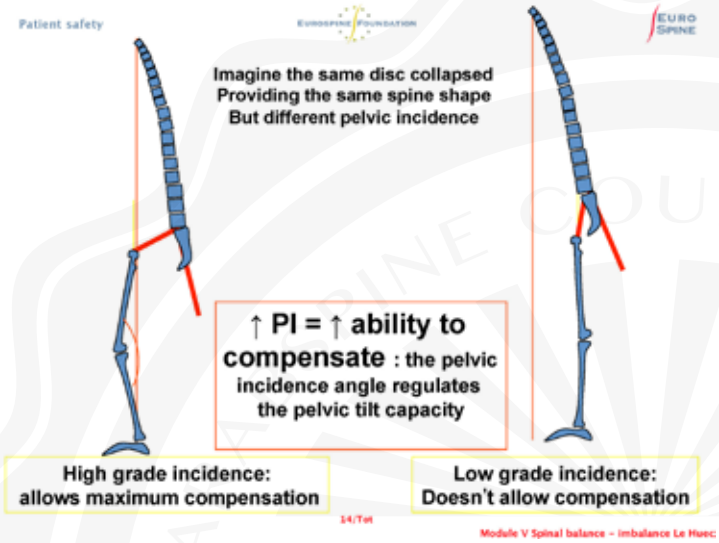
10/Tot

Module V Spinal balance – imbalance Le Huec

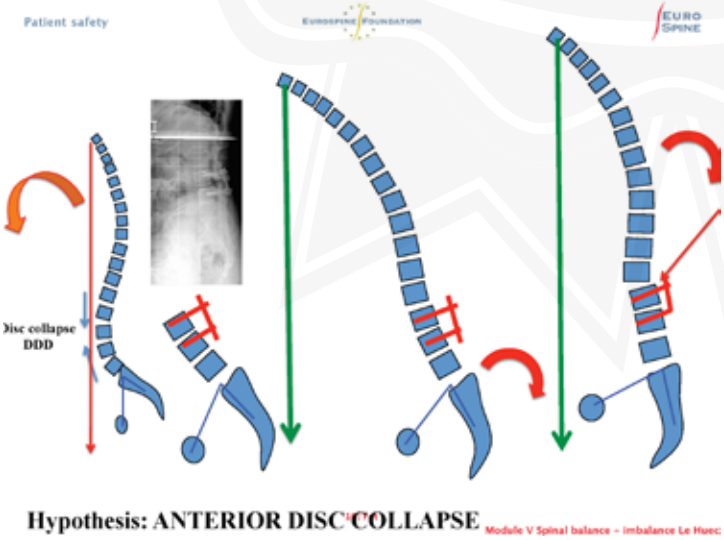

Patient safety
Dubai 2016
DIFFERENTS TYPES OF SPINE SHAPE
Type 1
Type 2
Type 3
Type 4
11/Tot
Module V Spinal balance – imbalance Le Huec

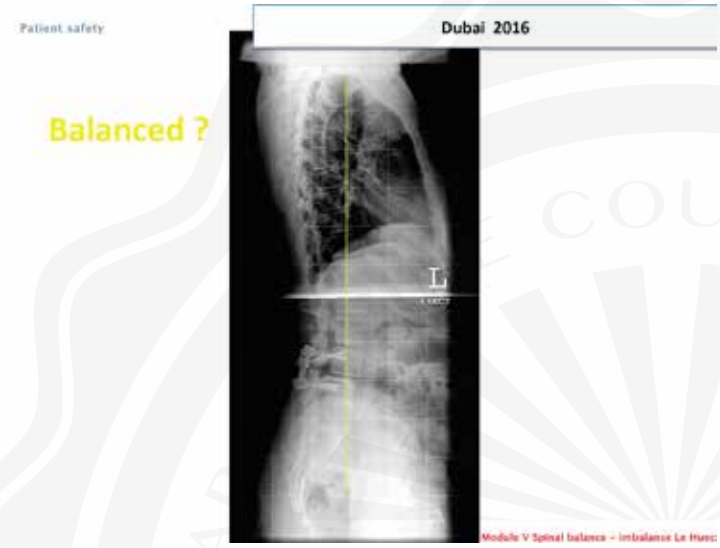

Patient safety
Dubai 2016
C7
SSA: Normal value: 134,7°± 8,1
Spino-Sacral Angle
Sacral Slope
12/Tot
Module V Spinal balance – imbalance Le Huec

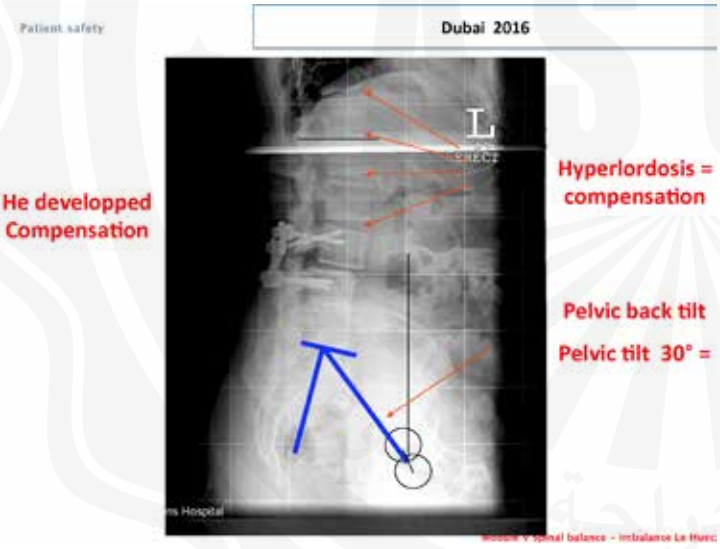

Patient safety
Dubai 2016
Disc collapsed
Pelvis rotates backward
IN AGING PROCESS is kyphogenic by disc collapsing (lumbar area)
Pelvis rotates backward to compensate :Increasing Pelvic Tilt
This retroversion has a limit
13/Tot
Module V Spinal balance – imbalance Le Huec

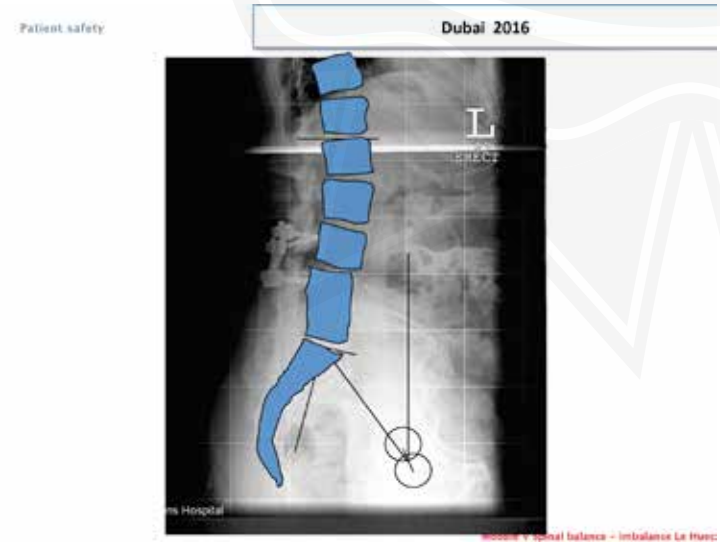

Patient safety
Imagine the same disc collapsed
Providing the same spine shape
But different pelvic incidence
↑ PI = ↑ ability to compensate : the pelvic incidence angle regulates the pelvic tilt capacity
High grade incidence: allows maximum compensation
Low grade incidence: Doesn't allow compensation
14/Tot
Module V Spinal balance – Imbalance Le Huec

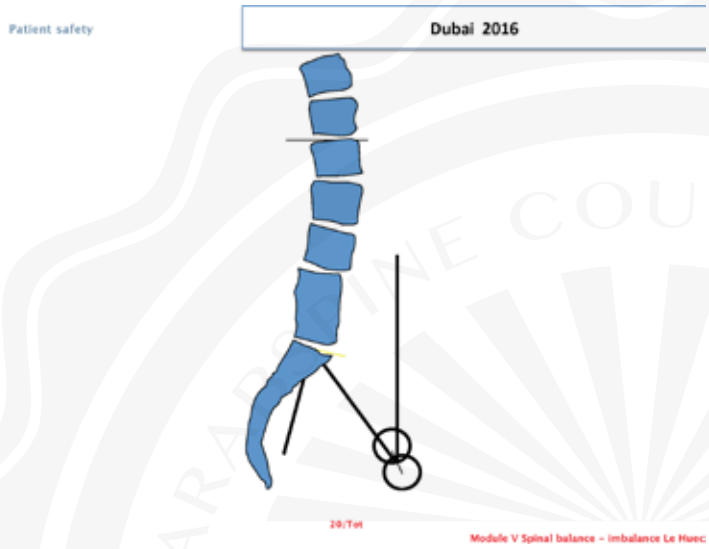

Patient safety
Dubai 2016
Low back pain
Radicular crural pain
Module V Spinal balance – Imbalance Le Huec


Patient safety
Disc collapse
DDD
Hypothesis: ANTERIOR DISC COLLAPSE
Module V Spinal balance – Imbalance Le Huec

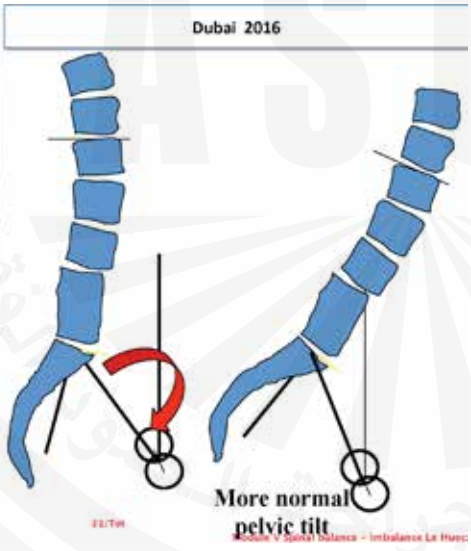

Patient safety
Dubai 2016
Balanced ?
L
Module V Spinal balance – Imbalance Le Huec

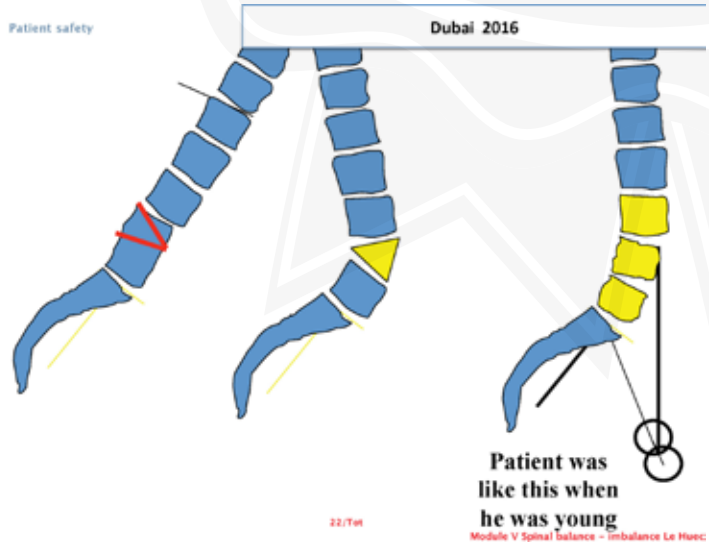

Patient safety
Dubai 2016
He developped
Compensation
L
Hyperlordosis =
compensation
Pelvic back tilt
Pelvic tilt 30° =
Module V Spinal balance – Imbalance Le Huec


Patient safety
Dubai 2016
L
Module V Spinal balance – Imbalance Le Huec


Patient safety
Dubai 2016
20/Tet
Module V Spinal balance – Imbalance Le Huec




Dubai 2016
More normal
pelvic tilt
21/Tet
Module V Spinal balance – Imbalance Le Huec


Patient safety
Dubai 2016
Patient was
like this when
he was young
22/Tet
Module V Spinal balance – Imbalance Le Huec

FBSS

Failed Back Surgery Syndrome

- Persistent or recurrent pain, mainly involving the lower back and/or legs, even after anatomically successful spinal surgery.

FBSS-Multifactorial

- Myofascial Syndrome
- Neural Compression Syndrome
- Mechanical (Instability) Syndrome
- Inflammatory syndrome
- Neuropathic Syndrome
- Psychosocio-economic syndrome

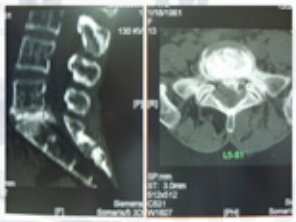
Surgery for LDH

COMPLICATIONS AND RISKS:

- Wrong level (1.2-3.3%)
- Dural tear (0.8-7.2%)
- Nerve root damage (0.2%)
- Infection (2-3%)
- Epidural hematoma
- Abdominal organs injury (1 in about 10000)
- Cauda equina syndrome (0.08-1.2%)
- Recurrent disc herniation (3-15%)
- Overlooked LDH
- Epidural scar
- Iatrogenic instability

Clinical Evaluation

- *Utmost importance*
- Meticulous and detailed history and physical examination
- Radiodiagnostic spinal imaging: don't hesitate if invasive tests are needed



Dynamic upright MRI can show you the hidden pathology



Clinical Evaluation

- Neurodiagnostic testing (SSEP, EMG/NCS, etc.)
- Physiological diagnostic testing (Nerve root block, provocative discography)
- Psychological, social and economic testing



Surgical Treatment

1- Decompression of compressed neural elements
2- Stabilization of unstable motion segment
3- Destruction of neural elements thought to be involved in the pathogenesis of pain
4- Electrical stimulation of neural structures to reduce the perception of pain
5- Intrathecal Pain Therapy

Surgical Treatment

1- Decompression of compressed neural elements (nerve roots, cauda equina by residual stenosis, missing disc fragment…)

Re-operation with adequate microsurgical decompression particularly when combined with a low back rehabilitation program results in substantial relief and improvement.

Recurrent DH

- Confirm recurrency, operation for scar alone is not helpful
- MRI with Gado is the exam. of choice
- Invasive investigations may be done: CT discography or CT myelography

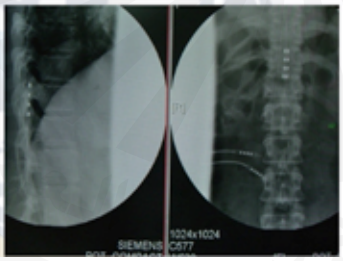


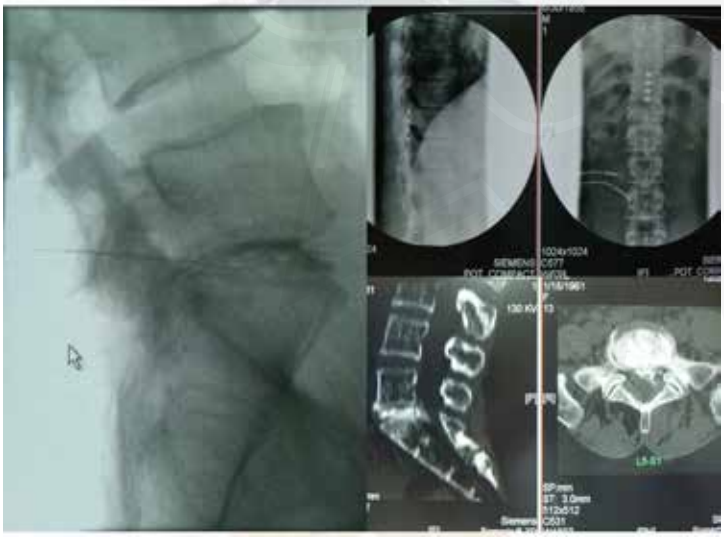




Missing treatable cause: Persisting DH

- 47y. Old GM
- 2001 L5-S1 discectomy no improvement, resisting sciatic pain, SCS inserted by pain physician, displacement of the percut. Lead.
- Change to plate electrode done in Dubai, mechanical type pain++, Investigated,residual DH, microdiscectomy and neurolysis done: Improved
  → Removal of SCS







Surgical Treatment

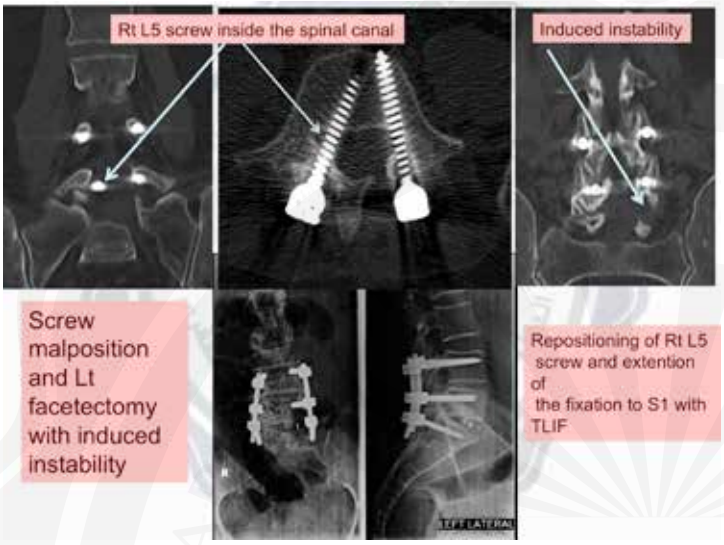
2- Stabilization of vertebral motion segments

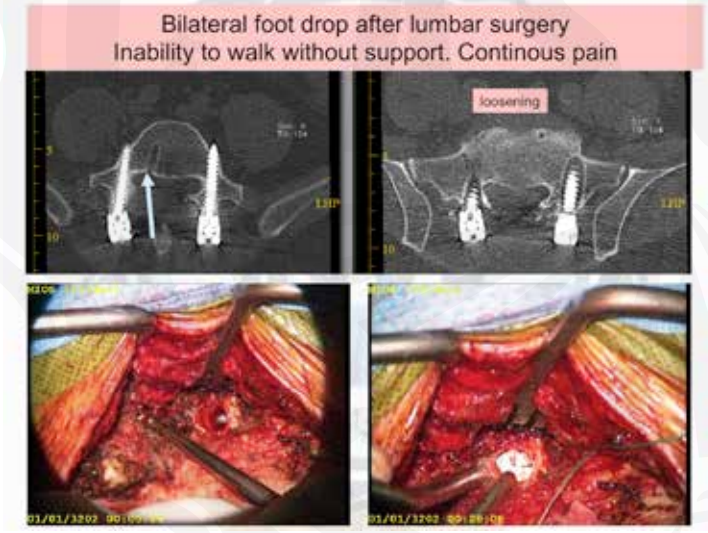
Dynamic Imaging studies helps localizing the segments: Spondylolisthesis, retrolisthesis

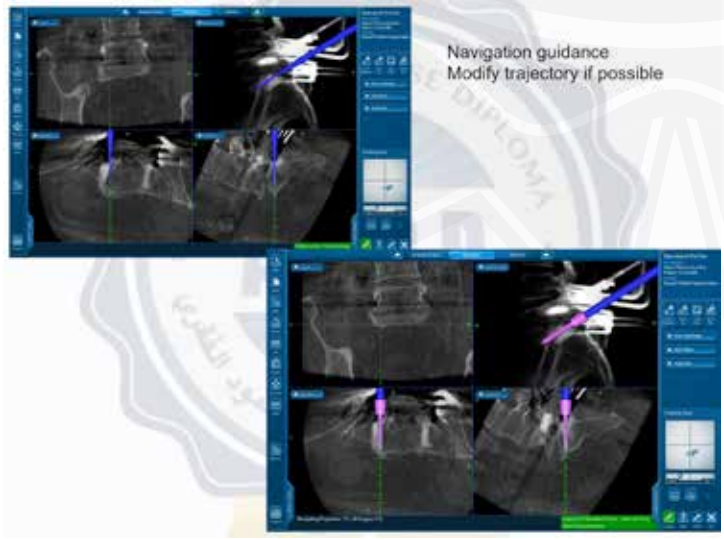
Excessive motion on flexion-extension (iatrogenic instability), disc arthropathy (vacuum disc, traction spurs), severe facet arthropathy, (synovial cysts, vacuum facet, hypertrophic changes) facet subluxation or absence(excessive facetectomy) and or fracture.

- Appropriate surgical stabilization are in general very gratifying.




Rt L5 screw inside the spinal canal
Induced instability
Screw malposition and Lt facetectomy with induced instability
Repositioning of Rt L5 screw and extention of the fixation to S1 with TLIF

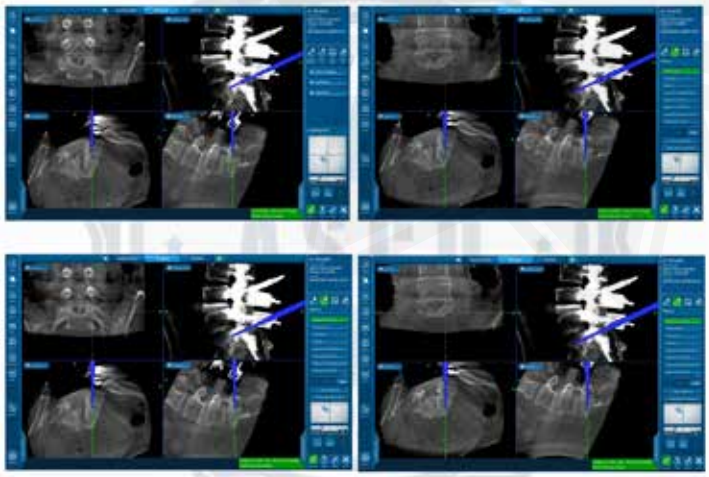

Bilateral foot drop after lumbar surgery
Inability to walk without support. Continous pain
loosening

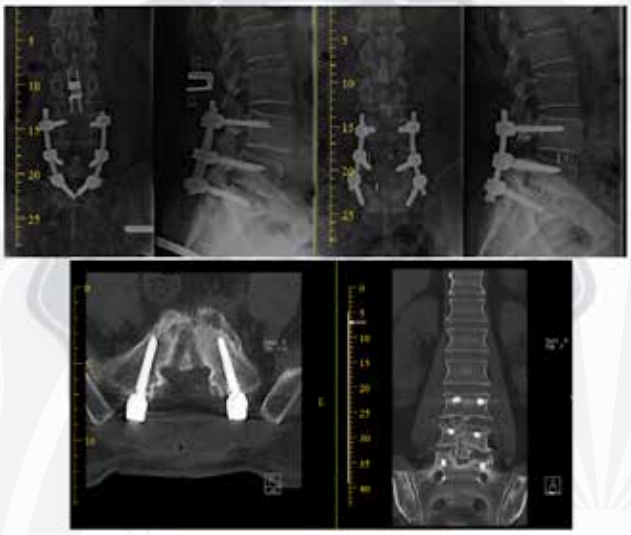

Navigation guidance
Modify trajectory if possible


Severe continuous pain with mild weakness




Intraoperative Monitoring
Pedicle screw
Current applied
EMG tracing





WRONG ASSESSMENT & TREATMENT:
missing instability, osteoporotic patient





Spinal stenosis in 65y. Old F.
osteoporotic
Interspinous Decompression
08/2008

Missing Instability

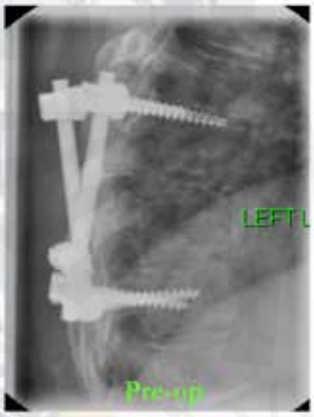






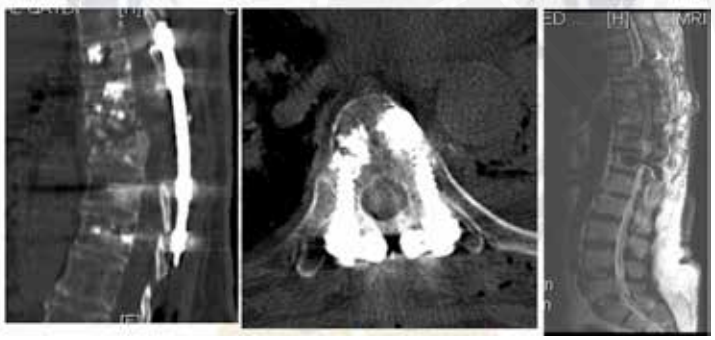
Spinal Infection and Osteoporosis

- 82 year old male, osteoporotic, operated abroad for T9-T10 infection.
- 2 Months post-op.
- At admission : Back pain with paraplegia, Asia score D, not walking since 2 months.



Procedure

Revision, decompression and kyphosis reduction, spinal stabilization with pedicle screws augmentation, neurological recovery in 2 weeks, able to walk alone.



FBSS in Endoscopic Techniques

Endoscopy is relatively popular but indications are limited to certain types of herniations and they have
higher complications risks,
lower success rate, and
long learning curve

Chains of complications

- L4-L5 endoscopic discectomy → hematoma →
- 2d Surgery → CSF leak
- 3d Surgery → CSF leak persisting
- 4th Surgery → Discitis and Instability

↓

- Admitted to NSH: treatment of infection followed by surgical stabilization

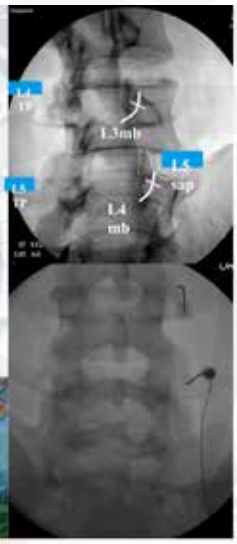


Surgical Treatment

3- Destruction of neural elements thought to be involved in the pathogenesis of pain:

RF medial branches ablation





Surgical Treatment

4- **Electrical stimulation** of neural structures to reduce the perception of pain, more efficient on neuropathic pain:

Spinal Cord Stimulation

Dorsal Root Ganglion Stimulation

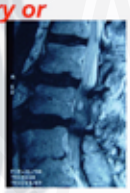
Peripheral Nerve Stimulation

Subcutaneous Small Nerves Stimulation

MCS / DBS

Lumbar Neuropathic Syndrome

- ***Mostly due to nerve root injury during surgery or other invasive procedures***
- May be due to:
  - Compression from disc herniation or canal stenosis
  - *Arachnoiditis*,
  - Sciatic nerve stretch injury
  - Retroperitoneal or pelvic surgical and injection injuries



- Accurate diagnosis is essential, further surgeries may aggravate this difficult pain
- Neuro-stimulation after psycho-social clearance may help and bring some relief to these patients.

SCS

- Activation of large myelinated fibers due to the surrounding electric field created by the epidural electrodes.
- Does not block C fibers directly or indirectly → *not really indicated for purely nociceptive pain.*
- Good results in chronic pain syndromes that include ***neurogenic component***:

Intractable chronic LBP with leg pain is the most frequent indication for SCS





Surgical plate vs.percutaneous



	Percutaneous	Surgical
Minimal invasiveness reversibility	X	
Overlap of pain by paresthesias	X	XX
Stability •Postural effects •Migration, Malposition		X
Reliability		X

Personal preference, Specialty (neurosurgery/anesthesia)



Trial



- Electrode Placement
  - Percutaneous: Quad under L/A.
  - Surgical: Surgical lead under G.A./or L.A.
- Adjustment of stimulation parameters by external programmer.
- Teach patient how to use his external programmer

Ensure maximal coverage of painful territory by painless paresthesias/tingling???

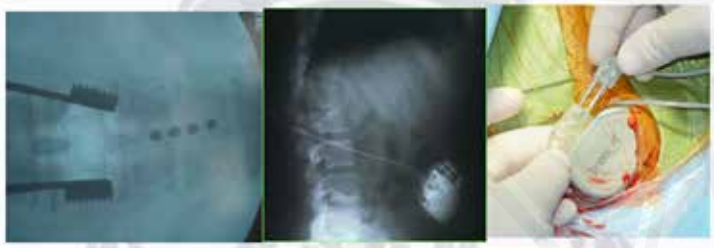
Generator Implantation



- 3 to 7-10 days.
- Decision taken with patient and family, after final discussion and evaluation of results.
- Under G/A:
  - Intervention at the connexion site.
  - Deep Tunnelization of the connexion.
  - Implantation of a Pulse Generator in the preoperative agreed region (abdominal wall, upper buttock++, Rt/Lt side as per Pt. prefference).



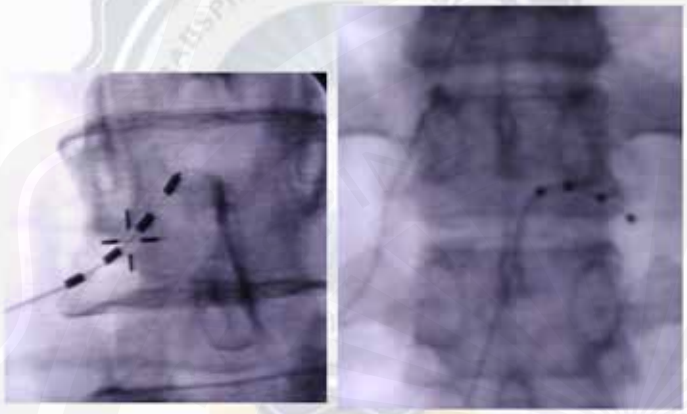




Even with surgical lead implantation can e done under L.A.



DRG Stimulation



When Pain Is Not Reachable By SCS

SPNS is a Minimally Invasive Surgical Technique

1- Precise ***marking of the painful area*** in fully awake patient.

2- Small skin incision *in the border of the painful area.*

Insertion of the Lead electrodes through a Tuohy needle ***into the subcutaneous layer.***

3- ***Connection*** and ***implantation of the permanent stimulator***

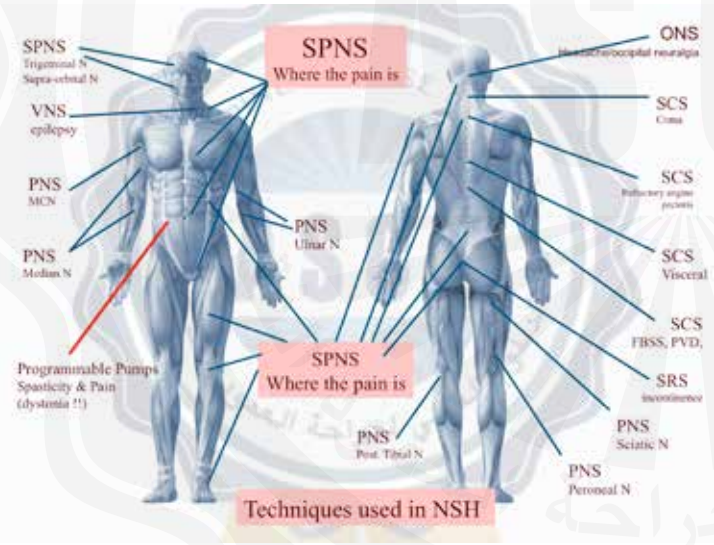









SPNS Technique


SPNS
Where the pain is
SPNS
Trigeminal N
Supra-orbital N
VNS
epilepsy
PNS
MCN
PNS
Median N
PNS
Ulnar N
Programmable Pumps
Spasticity & Pain
(dystonia ?!)
ONS
SCS
Coma
SCS
SCS
Visceral
SCS
FBSS, PVD,
SRS
PNS
Sciatic N
PNS
Peroneal N
SPNS
Where the pain is
PNS
Post. Tibial N
Techniques used in NSH


Intractable Back Pain
3y. duration not accessible by SCS
R

SCS was found to be superior to:

-Multiple Fusions for Intractable LBP

-Even patients who have NOT undergone Lumbar Spine Surgery can be candidates for SCS

SCS Was preferable to re-operation in patients with failed back surgery syndrome (*North, Stereotactic Functional Neurosurgery 1994;62: 267-272)*



SCS superior to major surgical procedure

52y. Female, 4y. post-op. for disc surgery with residua permanent LBP and both legs pain, Degenerative Scoliosis

SCS was the less invasive efficient solution

Surgical Treatment

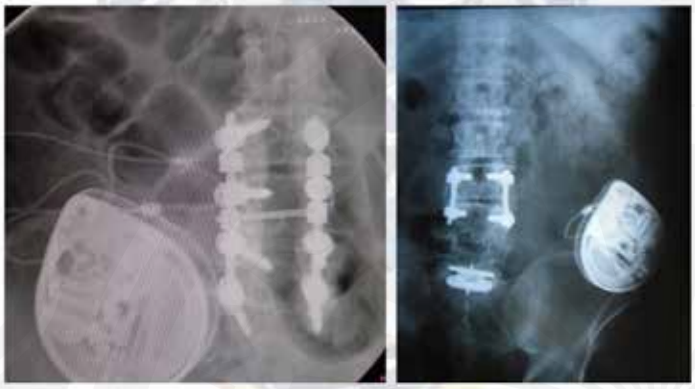


5- Intrathecal Opioid Therapy

Morphine(the main drug approved by FDA) is considered the "gold standard" because of its stability, receptor affinity and extensive experience of using the drug by this route



Intrathecal drugs therapy for FBSS



FBSS Avoidance



- Optimal patient selection
- Correct diagnosis
- Real expectation (surgeon/patient, agreement)
- Appropriate technique
- io 3D imaging with navigation allow real time correction of possible malposition
- IOM increase safety intraoperatively
- Neuropathic pain, if no treatable cause can be better managed by SCS
- All patients need comprehensive rehabilitation

Conclusion

- Failure of conservative treatment doesn't mean successful surgery
- ***Poor patient selection** is by far the main cause of bad results in spine surgery.*
- *Avoid operating in careless way*

PRINCIPLES IN REVISION IN SCOLIOSIS

Hospital Readmission After Spine Fusion for Adult Spinal Deformity

William W. Schairer, MD,* Alexandra Carrer, MD,* Vedat Deviren, MD,* Serena S. Hu, MD,* Steven Takemoto, PhD,* Praveen Mummaneni, MD,† Dean Chou, MD,† Christopher Ames, MD,† Shane Burch, MD,* Bobby Tay, MD,* Aenor Sawyer, MD,* and Sigurd H. Berven, MD*

Results. Eight hundred thirty-six patients were enrolled (111 short, 402 medium, and 323 long fusions). The overall unplanned readmission rate was 8.4% at 30 days and 12.3% at 90 days. Patients with long spine fusion had higher rates of readmission than patients with medium or short length fusions. Surgical site infection accounted for 45.6% of readmissions. Risk factors for readmission include longer fusion length, higher patient severity of illness, and specific medical comorbidities.

Conclusion. Unplanned hospital readmissions after spine fusion for adult spinal deformity are common, and are most often due to surgical site infection. Patient medical comorbidities are an important part of assessing risk and can be used by providers and patients to better assess individual risk prior to treatment.

Reoperation rates and impact on outcome in a large, prospective, multicenter, adult spinal deformity database

Clinical article

JUSTIN K. SCHEER, B.S.,[1] JESSICA A. TANG, B.S.,[1] JUSTIN S. SMITH, M.D., PH.D.,[2] ERIC KLINEBERG, M.D.,[3] ROBERT A. HART, M.D.,[4] GREGORY M. MUNDIS JR., M.D.,[5] DOUGLAS C. BURTON, M.D.,[6] RICHARD HOSTIN, M.D.,[7] MICHAEL F. O'BRIEN, M.D.,[7] SHAY BESS, M.D.,[8] KHALED M. KERAISH, M.D.,[9] VEDAT DEVIREN, M.D.,[10] VIRGENIE LAFAGE, PH.D.,[11] FRANK SCHWAB, M.D.,[11] CHRISTOPHER I. SHAFFREY, M.D.,[2] CHRISTOPHER P. AMES, M.D.,[12] AND THE INTERNATIONAL SPINE STUDY GROUP

[1]University of California, San Diego, School of Medicine; [2]San Diego Center for Spinal Disorders, La Jolla; [3]Department of Orthopaedic Surgery, University of California, Davis; Departments of [4]Orthopaedic Surgery and [5]Neurological Surgery, University of California, San Francisco, California; [6]Department of Neurosurgery, University of Virginia Health System, Charlottesville, Virginia; [7]Department of Orthopaedic Surgery, Oregon Health & Science University, Portland, Oregon; [8]Department of Orthopedic Surgery, University of Kansas Medical Center, Kansas City, Kansas; [9]Department of Orthopedic Surgery, Baylor Scoliosis Center, Plano, Texas; [10]Rocky Mountain Hospital for Children, Denver, Colorado; [11]Department of Orthopaedic Surgery, Johns Hopkins University, Baltimore, Maryland; and [12]Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, New York

Conclusions. Analysis of data from a large multicenter adult spinal deformity database shows an overall 17% reoperation rate, with a 19% reoperation rate for patients treated with 3-column osteotomy and a 16% reoperation rate for patients not treated with 3-column osteotomy. The most common indications for reoperation included instrumentation complications and radiographic failure. Reoperation significantly affected HRQOL outcomes at 1-year follow-up. The need for reoperation may be minimized by carefully considering spinal alignment, termination of fixation, and type of surgical procedure (presence of osteotomy). Precautions should be taken to avoid malposition or instrumentation (rod) failure.

Clin Orthop Relat Res. 2014 Feb 1. [Epub ahead of print]

Minimally Invasive Surgical Techniques in Adult Degenerative Spinal Deformity: A Systematic Review.

Bach K1, Ahmadian A, Deukmedjian A, Uribe JS.

RESULTS:
Four studies demonstrated improvement in leg/back visual analog scale, three demonstrated improvement in the Oswestry Disability Index, one demonstrated improvement in treatment intensity scale, and one improvement in SF-36. Reported fusion rates ranged from 71.4% to 100% 1 year postoperatively, but only two of 13 papers relied consistently on CT scan to assess fusion, and, interestingly, only four of 10 studies reporting radiographic results on deformity correction found the procedures effective in correcting deformity. There were 115 complications reported among the 258 patients (46%), including 37 neurological complications (14%).

CONCLUSIONS:
The literature on these techniques is scanty; only two of the 13 studies that met inclusion criteria were considered high quality; CT scans were not generally used to evaluate fusion, deformity correction was inconsistent, and complication rates were high. Future directions for analysis must include comparative trials, longer-term followup, and consistent use of CT scans to assess for fusion to determine the role of MIS techniques for adult spinal deformity.

Spine J. 2014 Jan 24. pii: S1529-9430(14)00109-0. doi: 10.1016/j.spinee.2014.01.032. [Epub ahead of print]

Total Hospital Costs of Surgical Treatment for Adult Spinal Deformity: An Extended Follow-up Study.

McCarthy I1, Hostin R2, Ames C3, Kim HJ4, Smith J5, Boachie-Adjei O4, Schwab F6, Klineberg E7, Shaffrey C5, Gupta M7, Polly D8; International Spine Study Group.

CONCLUSIONS:

The incidence of readmissions increased the average cost of ASD surgery by more than 170%, illustrating the financial burden of revisions/re-operations; however, the cost burden resulting from readmissions appeared to taper off within 5 years following surgery. The estimated impact of physician preference on OR costs also highlights the variation in current practice and the opportunity for large cost reductions via a more standardized approach in the use of implants and biologics.

Spine (Phila Pa 1976). 2013 Apr 20;38(9):732-6. doi: 10.1097/BRS.0b013e31827ae242.

Comparison of patient and surgeon perceptions of adverse events after adult spinal deformity surgery.

Hart RA1, Caballo A, Bess S, Akbarnia BA, Boachie-Adjei O, Burton D, Cunningham ME, Gupta M, Hostin R, Kebaish K, Klineberg E, Mundis G, Shaffrey C, Smith JS, Wood K; International Spine Study Group.

CONCLUSION:

There was substantial variation in how both surgeons and patients perceived impacts of various adverse events after spine surgery. Patients generally perceived the impact of adverse events to be greater than surgeons. Patient-centered descriptions of adverse events would provide a more complete description of surgical outcomes.

Proximal Junctional Failure

- Common cause of revision surgery in adult deformity
- Highly variable incidence reported in the literature
- Exact etiology unclear

Predictive factors for acute proximal junctional failure after adult deformity surgery with upper instrumented vertebra in the thoracolumbar spine

Annis P, Lawrence BD, Spiker WR, Zhang Y, Chen W, Daubs MD, Brodke DS
Evid Based Spine Care J 2014

- 135 patients with mean f/u 42 months
- APJF 38.5% (57.1% when UIV at T10)
- Overall revision rate 17% (most often for UIV fracture)
- Preoperative SVA >5cm, postoperative PJA>5 degrees, thoracic kyphosis > 30 degrees and instrumentation to the pelvis were all associated with APJF
- PJA and greater correction of lumbar lordosis were independent risk factors

Characterization and surgical outcomes of proximal junction failure in surgically treated patients with adult spinal deformity

Yagi M, et al (Complex Spine Study Group)
Spine 2014

- Proximal junction failure occurred in 23 of 1168 patients (1.4%)
- Bony failure
- Large SVA and large correction felt to be causative factors
- After revision further PJF commonly occurred

Incidence of proximal adjacent failure in adult lumbar deformity correction based on proximal fusion level

Kim JH, Kim SS, Suk SI
Asian Spine J. 2007 June 1(1)

- 35 patients
  - Group 1 (14) fusion to L1 or L2
  - Group 2 (14) fusion to T11/T12
  - Group 3 (7) fusion to T9/T10
- Sagittal Imbalance
  - 36% Group 1, 36% Group 2, None in Group 3
- Proximal pathology (DDD with Kyphosis, compression fractures, screw failure)
  - 7(50%) Group 1, 7(50%) Group 2, 1(14%) Group 3

Is the T9, T11, or L1 the more reliable proximal level after adult lumbar or lumbosacral instrumented fusion to L5 or S1?
Kim YJ, Bridwell KH, Lenke LG, Rhim S, Kim YW
Spine. 2007 Nov 15;32(24)

- 125 patients, minimum 2 year f/u
- Fusion T9-L2 to L5 or S1
- T9-10 (Group 1, n=37), T11-12 (Group 2, n=49), L1-2 (Group 3, n=39)
- No significant difference in PJK or revision

Short fusion versus long fusion for degenerative lumbar scoliosis
Cho KJ, Suk SI, Park SR, Kim JH, Kim SS, Lee TJ, Lee JJ, Lee JM
Eur Spine J 2008 May; 17(5)

- 50 patients with ADLS
- 28 patients with short fusion, 22 patients with long fusion
- Short fusion – within the curve, not exceeding UEV
- ASD occurred twice as often in the short fusion group

Selection of proximal fusion level for adult degenerative scoliosis
Cho KJ, Suk SI, Park SR, Kim JH, Jung JH
Eur Spine J 2013 Feb;22(2)

- 51 patients who underwent PSF for ADLS.
- ASD found in 47% of patients fused to L1-2 vs. 20% in patients fused to T11-12 and 9% in patients fused to T9-10
- Conclusion: "Proximal adjacent segment disease developed more commonly when the proximal fusion stopped at the UEV or below in adult degenerative scoliosis. UIV must be above UEV in the coronal plane. Fusion to T11 or T12 was acceptable when UIV was above UEV, since there was no significant difference in the rate of proximal adjacent segment between fusion to T10 and fusion to T11 or T12"

Incidence, mode, and location of acute proximal junction failures after surgical treatment of adult spinal deformity

Hostin et al (ISSG)
Spine 2013

- 1218 patients at 10 centers
- >15 degree increase in PJK postoperatively, fracture of UIV or UIV+1, failure of UIV fixation or need for extension of fusion
- 68 patients with PJF (5.6%)
- 66% in TL vs. 34% in the UT
- Fracture more common in TL vs. soft tissue failure in UT

Time to development, clinical and radiographic characteristics, and management of proximal junction kyphosis following thoracolumbar instrumented fusion for spinal deformity

Reames DC, Kasliwal MK, Smith JS, Hamilton DK, Arlet V, Shaffery CI
J Spinal Disord Tech 2015

- Total of 289 patients
- PJK > 10 degrees
- 32 patients (11%) at mean f/u of 34 months
- 16 revised
- Substantial positive SVA that remained inadequately corrected associated with PJK

Proximal junctional kyphosis and clinical outcomes in adult spinal deformity surgery with fusion from the thoracic spine to the sacrum: a comparison of proximal and distal upper instrumented vertebra

Ha Y,Maruo K, Racine L, Schairer WW, Hu SS, Deviren V, Burch S, Tay B, Chou D, Mummaneni PV, Ames CP, Berven SH
J Neurosurg Spine 2013

- 89 patients; 67 DT and 22 PT
- DT UIV T9-L1; PT UIV T2-T5
- PJK requiring revision – 11.9% in DT and 9.1% in PT
- Fracture more common in DT and subluxation in PT
- In the DT group patients with surgical PJK had a greater PJA than those without PJK and with radiological PJK

Patients with proximal junctional kyphosis requiring revision surgery have a higher postoperative lumbar lordosis and larger sagittal balance corrections

Kim HJ, Bridwell KH, Lenke LG, Park MS, Song KS, Piyaskulkaew C, Chuntarapas T
Spine 2014

- 206 patients
- PJK 34%
- Older
- Higher postoperative lumbar lordosis
- Larger sagittal balance correction

Predictive factors for proximal junctional kyphosis in long fusions to the sacrum in adult spinal deformity

Maruo K, Ha Y, Inone S, Samuel S, Okada E, Hu SS, Deviren V, Burch S William S, Ames CP, Mummaneni PV, Chou D, Berven SH
Spine 2013

- 90 patients with PJK in 37 (41%)
- Fracture of UIV in 19 patients (51%), 12 treated surgically
- Preoperative TK >30 degrees, PJA > 10 degrees, change in lumbar lordosis > 30 degrees and PI > 55 degrees associated with PJK
- Change in lumbar lordosis >30 degrees and TK > 30 degrees independent risk factors

Summary

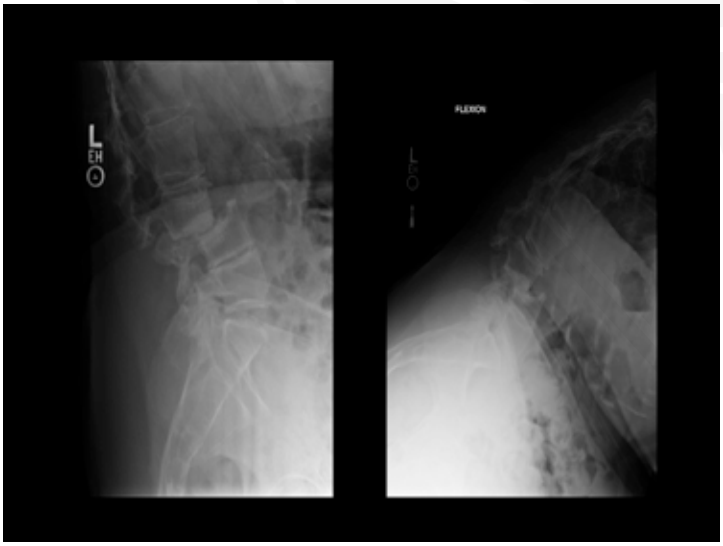
- Incidence of PJF variable in the literature
- Consistent risk factors appear to be incomplete correction of the SVA, large thoracic kyphosis, large lumbar lordosis, large change in lordosis and PJA over 5 degrees

Case examples

Case

- 62 y/o female with hx of lumbar laminectomy x2
- Worsening back pain, claudication, inability to stand upright for any length of time

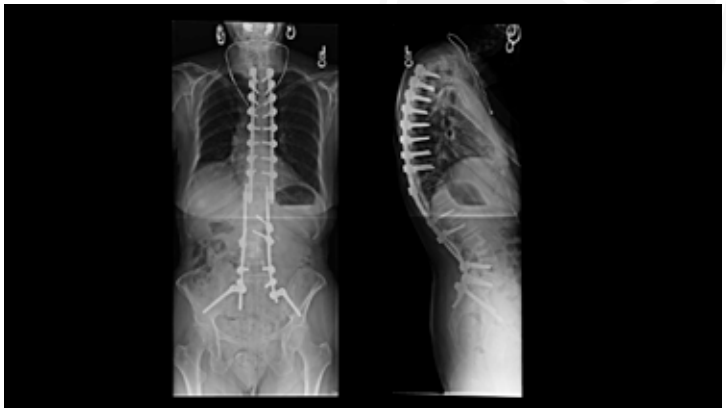








Options?

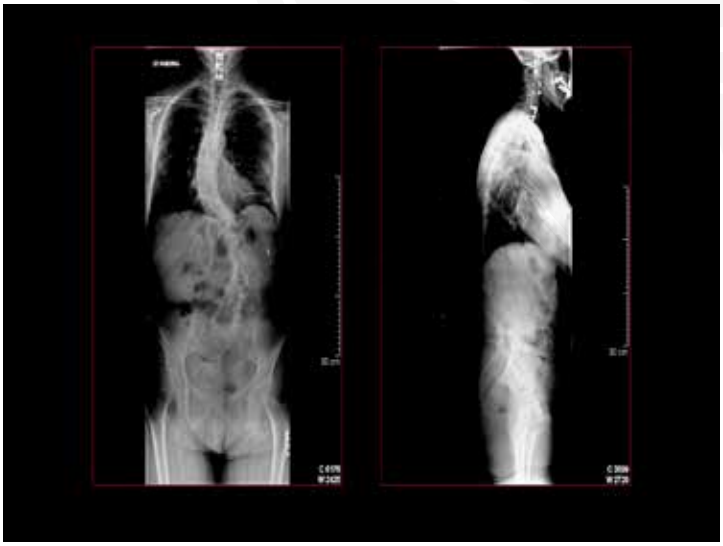


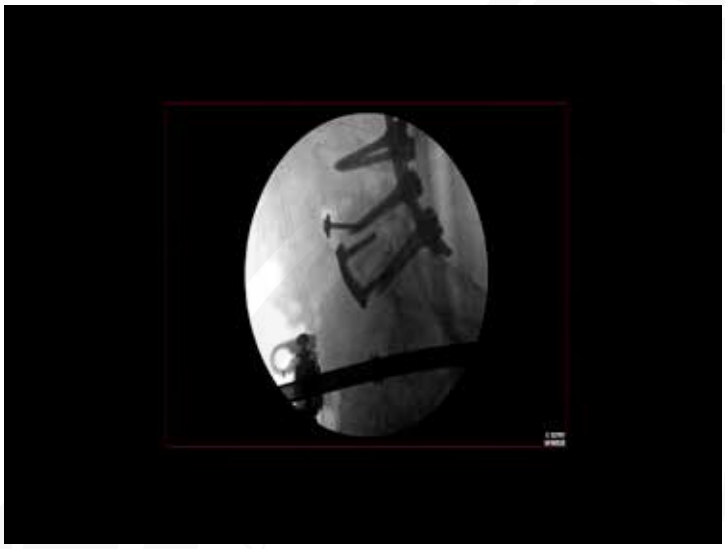
Lessons

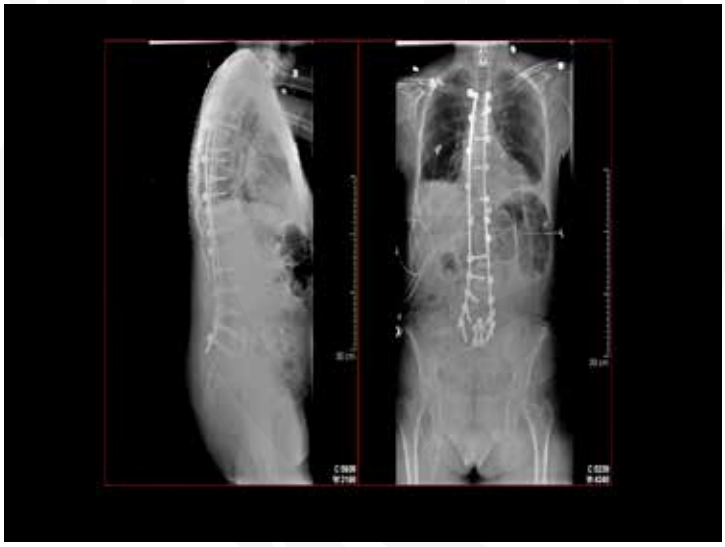
- Pay attention to balance!!!!!
- "If some is good more is not necessarily better"
- Yes you CAN give them too much lordosis

Case

- 66 y/o female with hx of LBP and B/L leg pain
- Back pain >> than leg pain
- Failed conservative management



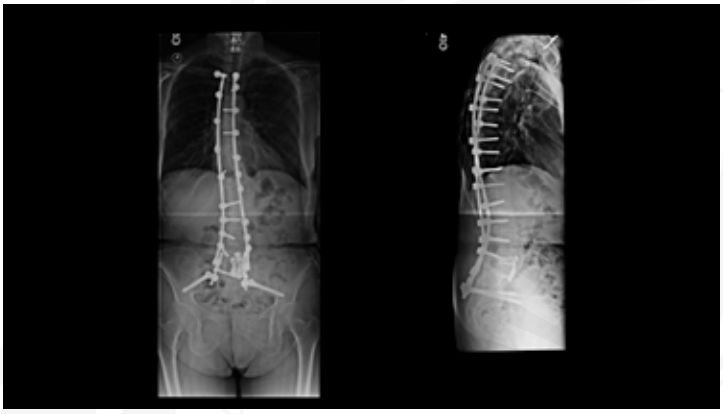




Thoughts?



Now what?

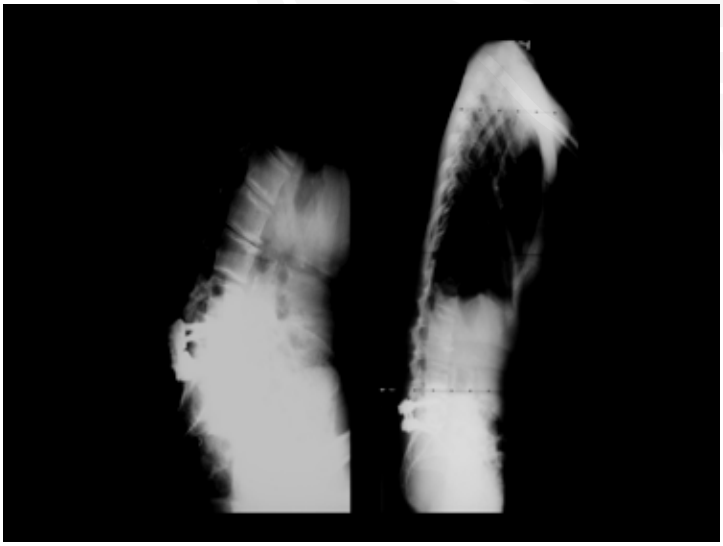


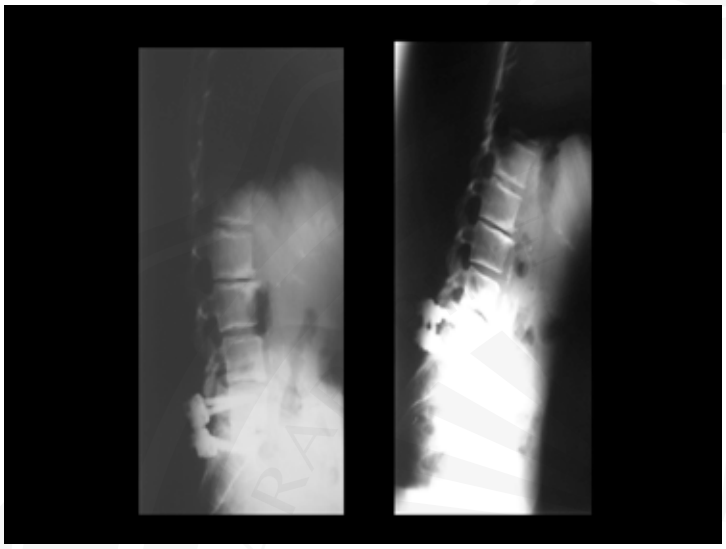
Lessons

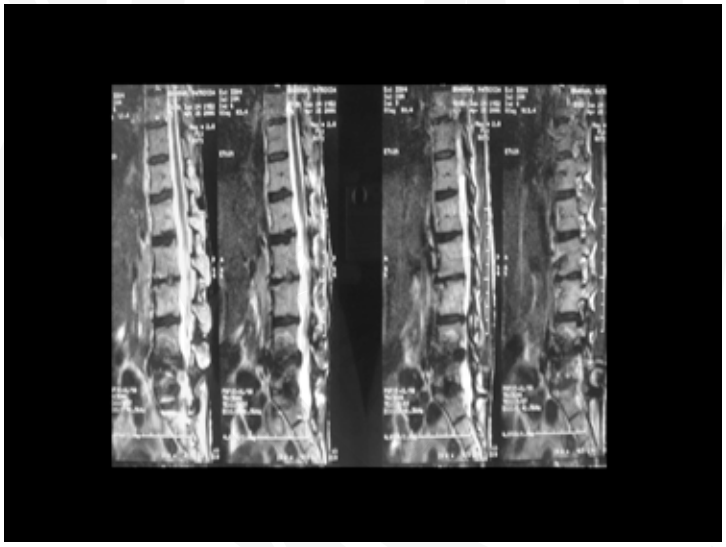
- If you are thinking about whether or not to go to the pelvis.....
- Go to the pelvis

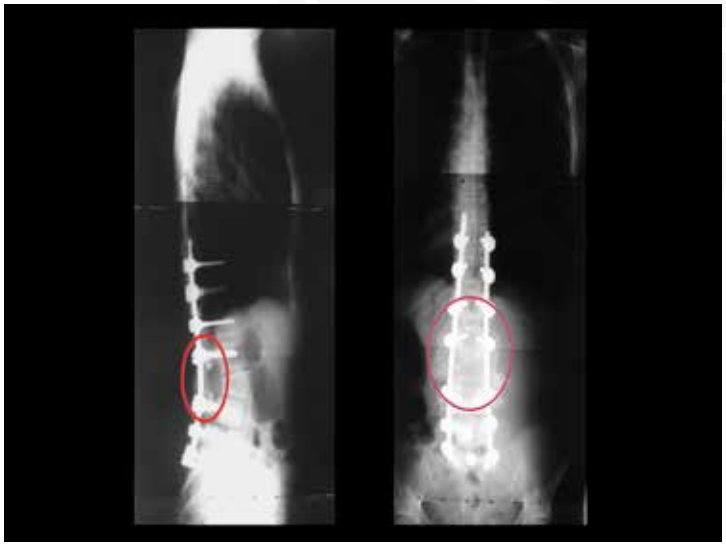
Case

- 56 y/o female with hx of TLIF 4 years earlier
- C/o back pain and inability to stand upright for any length of time

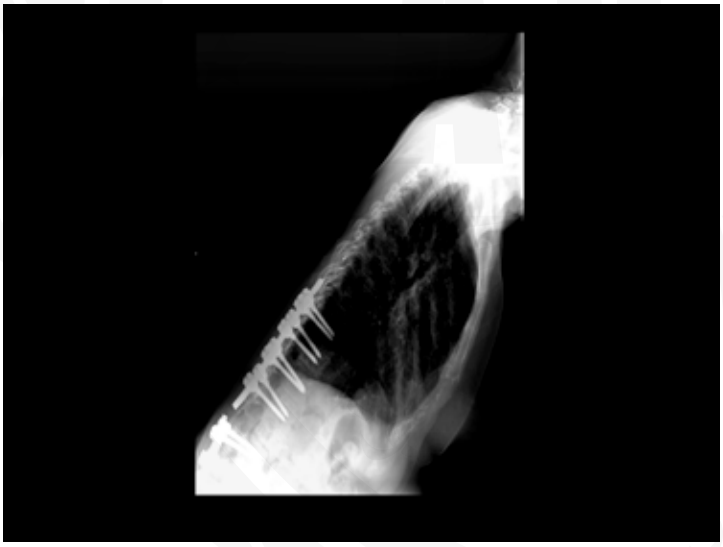










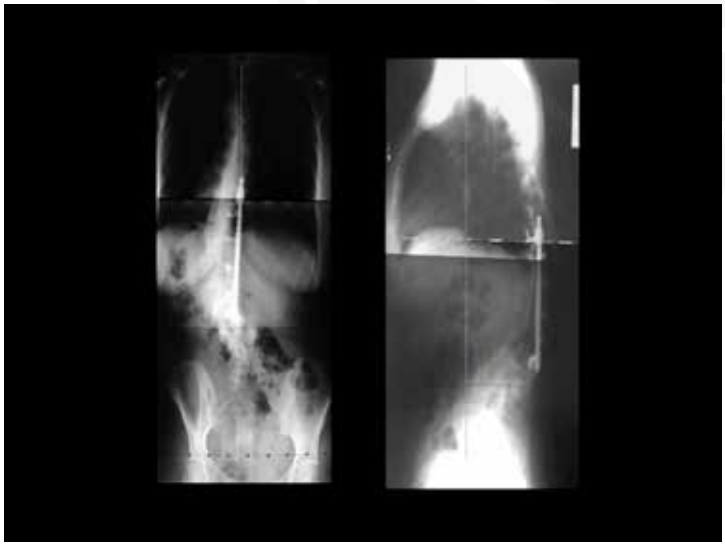




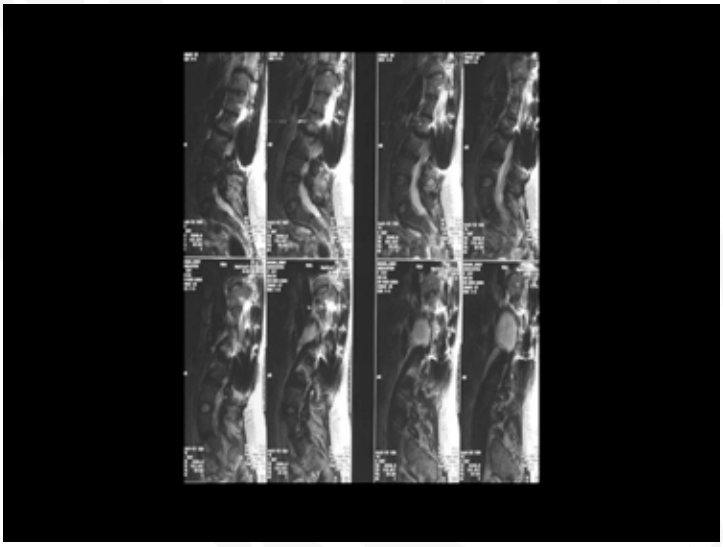


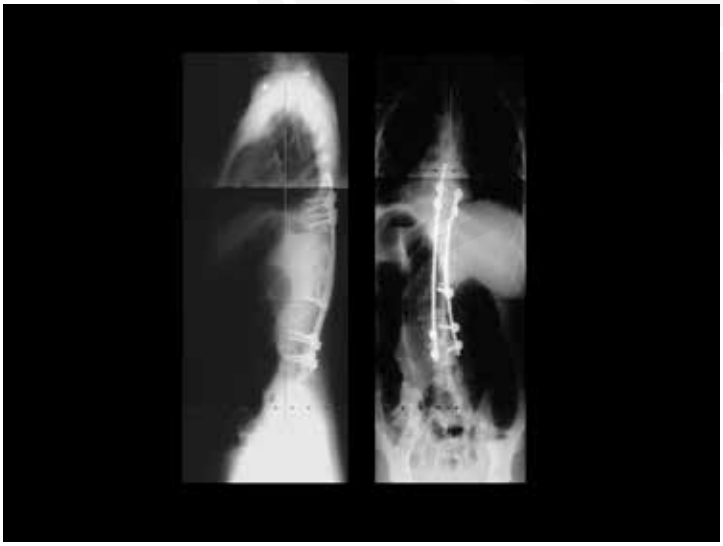
Lessons

- GO to the Pelvis – we already learned that
- Understand the limitations of both the biology of the patient and the ability of the instrumentation – pick the right procedure for the right patient

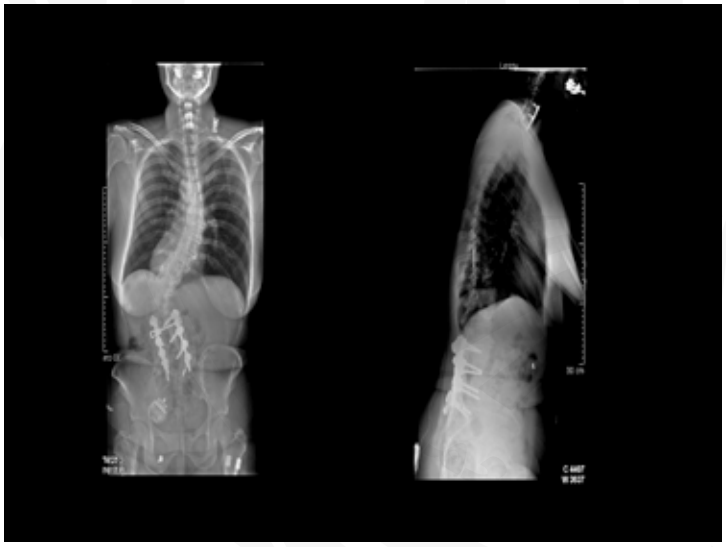


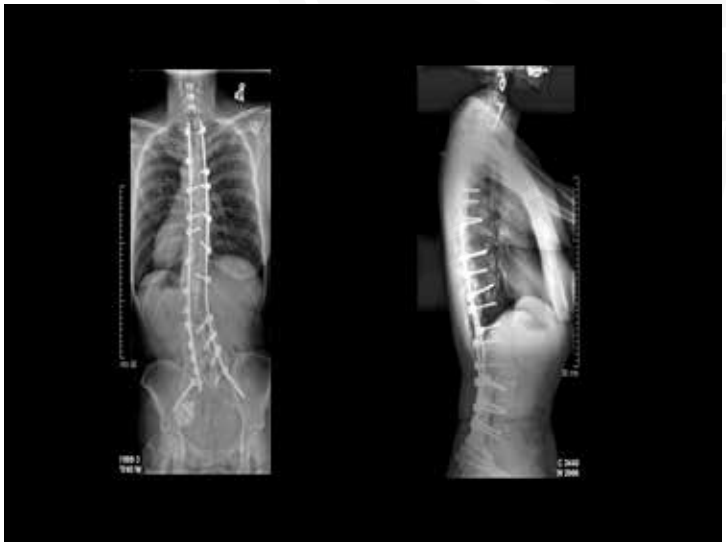






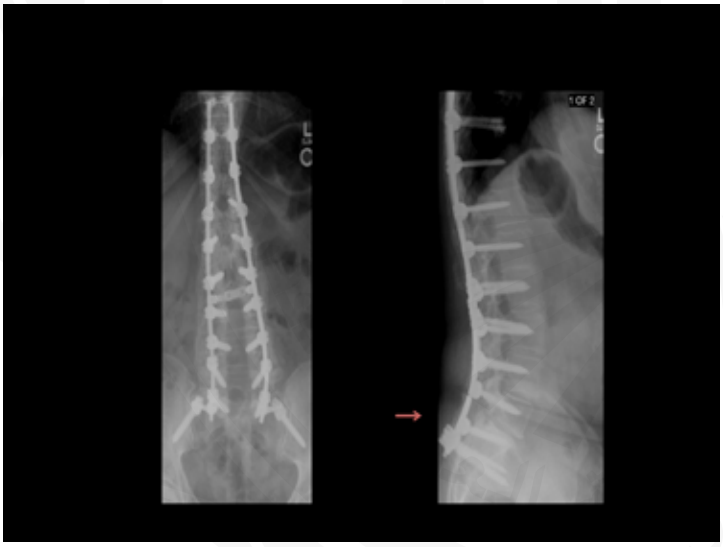




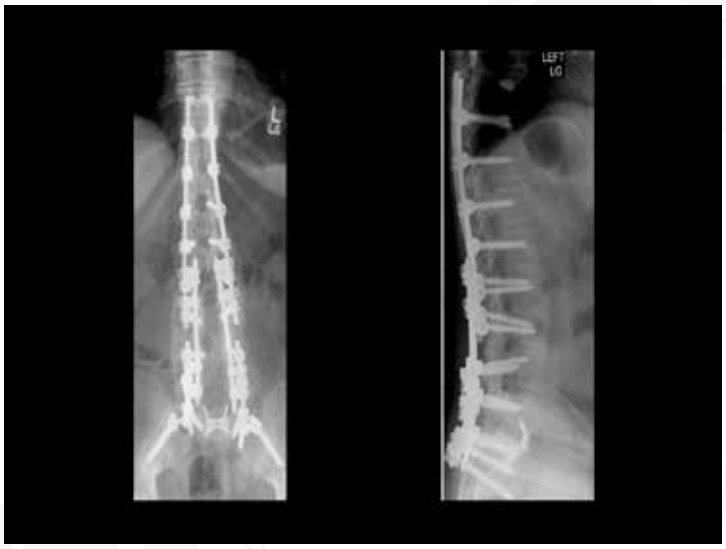


Case

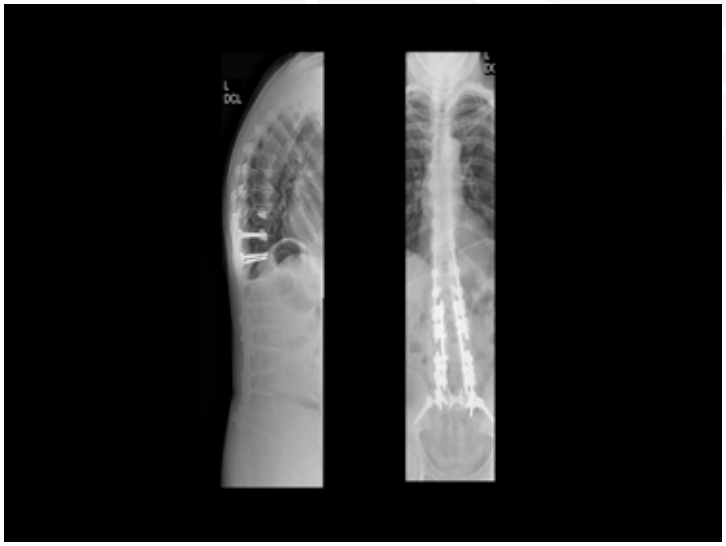
- 57 y/o female with hx of multiple prior lumbar surgeries
- Last surgery T10-pelvis PSF with L2-sacrum laminectomy
- Complaining of increasing low back pain with activities
- No significant radicular pain

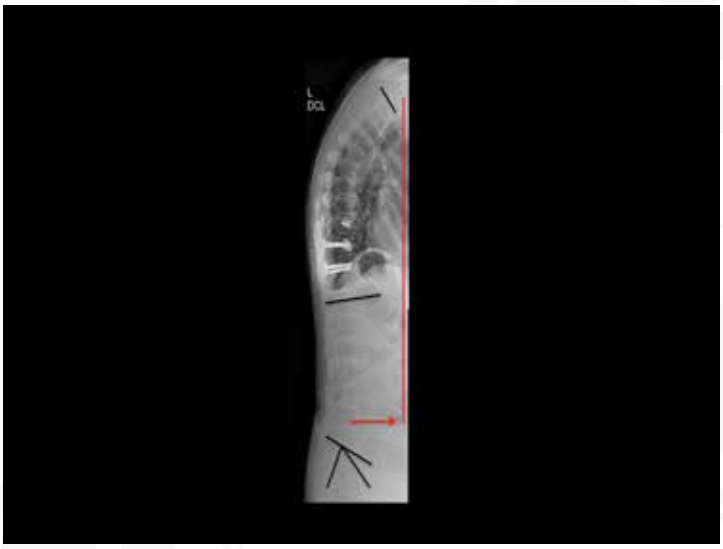




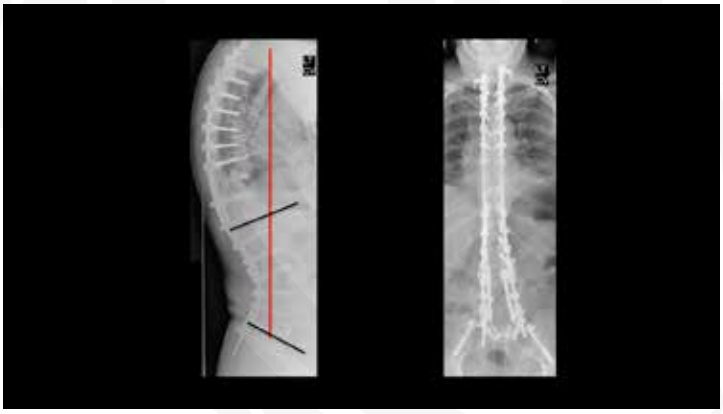


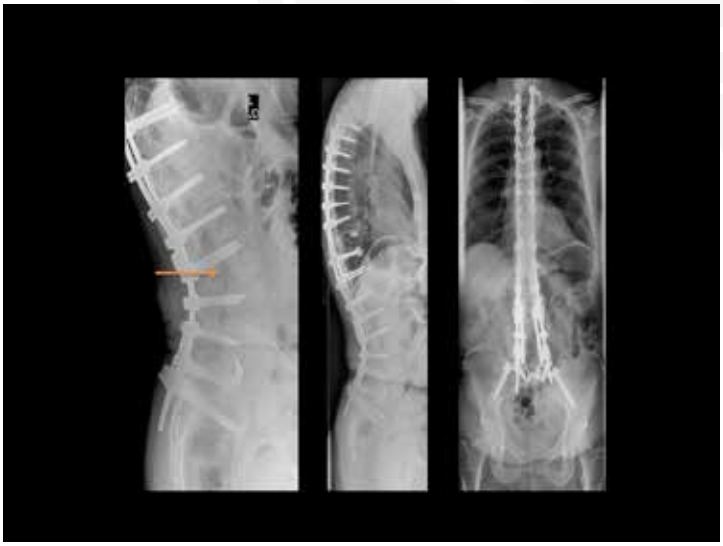
- Presents with difficulty standing erect
- Gluteal fatigue pain and increasing pain in the thoracolumbar junction
- Limited ambulation secondary to pain and fatigue

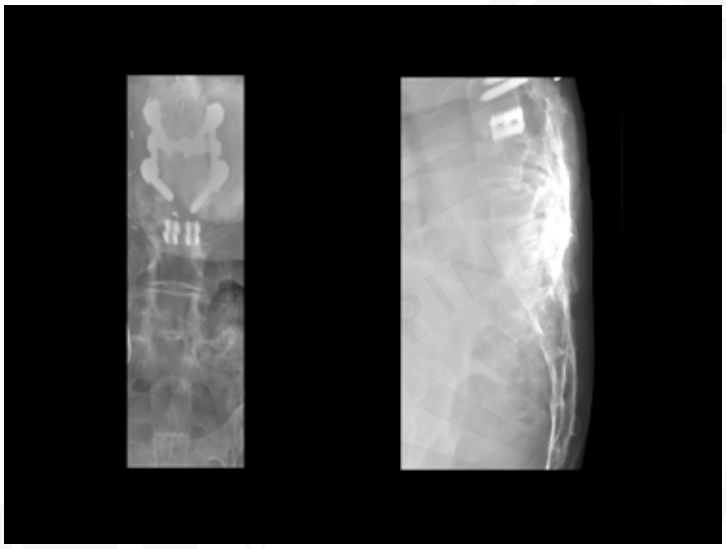




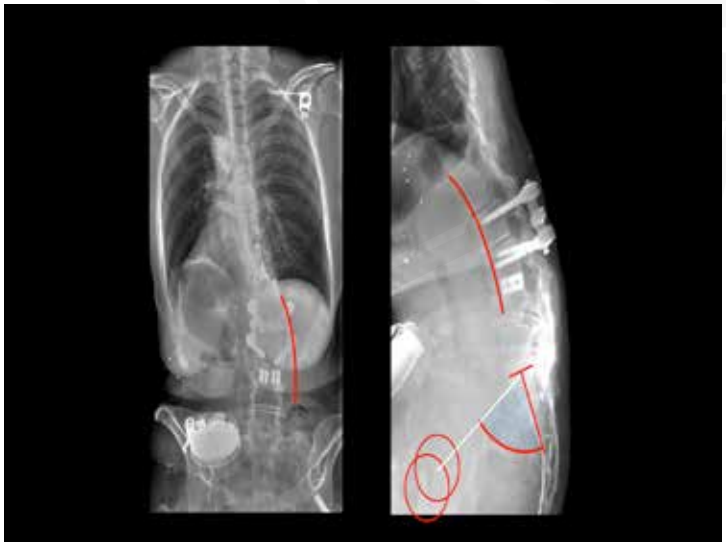
Options?

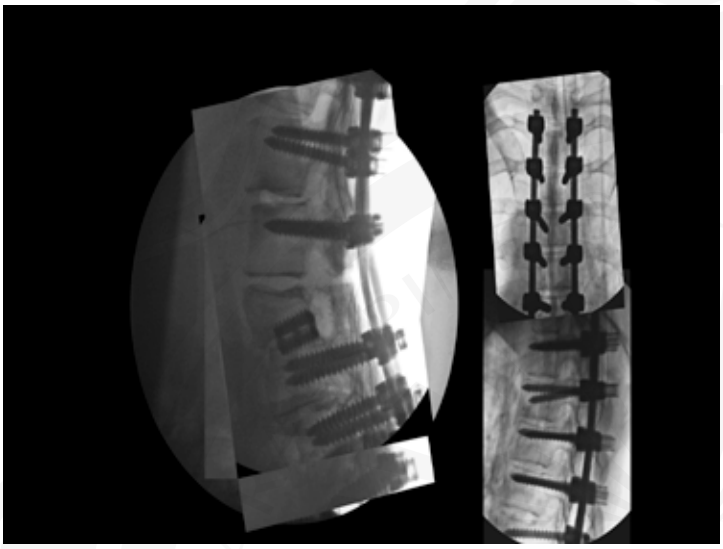


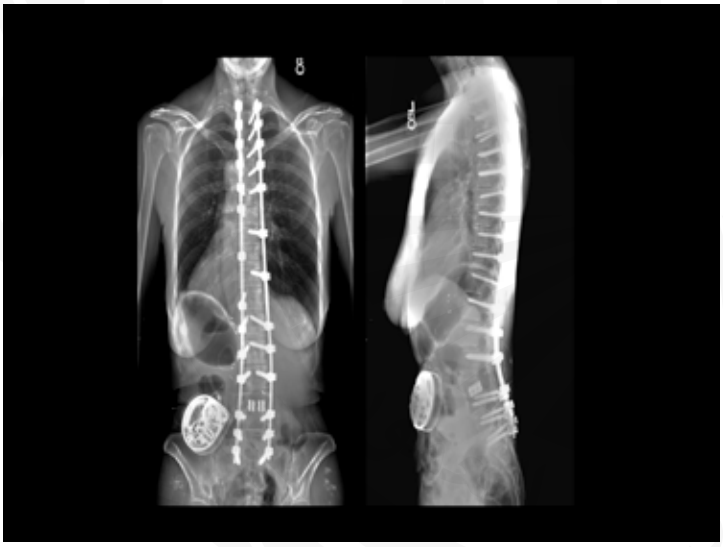






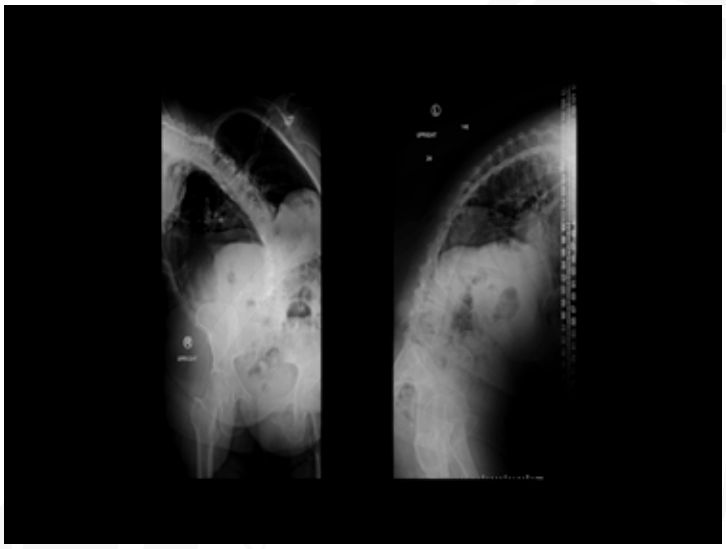


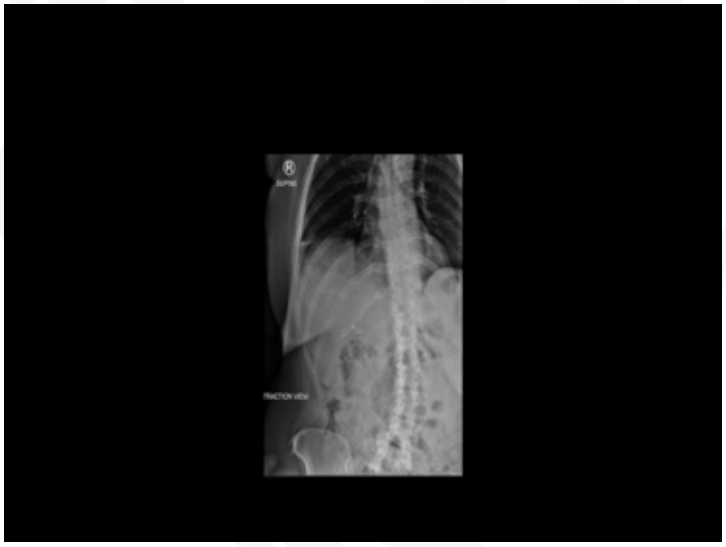




Case

- 49 y/o female
- 5 year history of increasing back pain and deformity
- Multiple rounds of injections with pain management
- Offered Spinal Cord Stimulator







REVISION IN LTDR

Disclosures

Guyer (a) Alphatec; (b) Spinal Kinetics, Spinal Ventures, Mimedix; (c) DePuy-Synthes Spine, K2M, Flexuspine, Mimedix, Aescalup; Safe Orthopedics (d) DePuy-Synthes Spine, K2M, Paradigm Spine

Key: (a) royalties; (b) stock/options; (c) consulting/SAB; (d) Speaker/ faculty; (e) Research; (f) Fellowship and related research; (g) other

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Complications with Lumbar TDR: Mitigation and Bailout During Challenging Cases





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Good Outcomes Require Wisdom

Wisdom comes from good judgment.

Good judgment comes from experience.

Experience comes from bad judgment.





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Introduction

- In any surgery, it's inevitable that there will be complications requiring revision
- Lumbar TDR is no different
- It is hard to meaningfully evaluate the incidence of re-operation by looking at small case series



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Anterior Revision at TBI

- Anterior revision is the most feared potential complication in lumbar ADR
- In only 13 of our first consecutive 1,000 pts (1.3%) was anterior re-op necessary at the index level
- In all of these cases, it was performed without additional complication

Blumenthal SL, et al, SAS11

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PRODISC-L IDE (17 sites): REOPERATIONS IN 1,094 PATIENTS (randomized and CA)

- TOTAL= 38/1094, 3.5 %
- POSTERIOR
  - 27 foramenotomy, SCS, fusion
  - 2.5 %
- ANTERIOR
  - 11/1094
  - 1.0 %

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ProDisc-L Post FDA Approval:

Anterior Revision Rates in the first 1,000 patients after formal training

- post-approval US 0.36%

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Complications

Pre Operative
- Patient Selection
- Surgeon training/experience

Intra Operative
- Approach Related
- Inadequate Release
- Implant Placement\

Post Operative
- Technique Related
- Device Related



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Pre Operative Er

Wrong Patient
- Osteoporosis
- Wrong pathology/crazy
- Multi-level DDD
- Prior retroperitoneal surgery

Wrong x-rays
- Pars defect
- Instability
- Facet DDD

Wrong MRI
- Stenosis
- Sequestered disc fragment

Wrong CT
- Inadequate endplates
- Gr 3-4 facet disease



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How Best to Avoid Preoperative Complications?

1. PICK THE RIGHT PATIENT

   PATIENT SELECTION
   PATIENT SELECTION
   PATIENT SELECTION
   PATIENT SELECTION

2. USE THE IDE CRITERIA

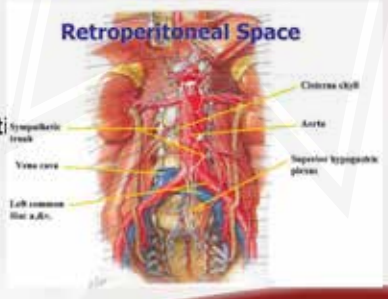
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How Best to Avoid IntraOperative Complications: Get a Good Access Partner



Intra Operative Approach Related Complications

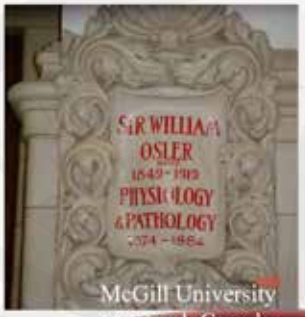
- Vein injury
- Arterial injury
- Sympathectomy
- Bowel Injury
- Retrograde Ejaculati
- Ureteral Injury



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Sir William Osler

" HEMORRHAGE is the sleeping patient's only defense against an inept surgeon"

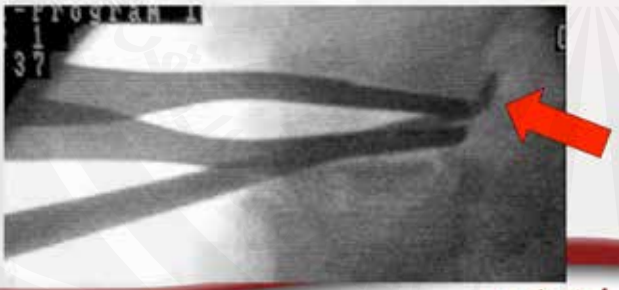


McGill University
Montreal, Canada

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What's Important Intra-Operatively for the Spine Surgeon ?

- Get Comfortable Doing a Good Posterior Release



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Doing a good Posterior Release is the KEY to good position of the Implant, and to a good clinical result



Tall discogenic pathology: discectomy and cleanout equals release…relatively easy



Narrow disc space with collapse and contracted posterior annulus = lots of work and skill (NOT your first case!!)

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INADEQUATE POSTERIOR RELEASE RESULTS IN:

- stuffed space
- poor motion
- possible endplate injury
- facet pain
- back pain
- unhappy patient
- unhappy surgeon



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WHAT HAPPENS DURING SURGERY IF TDR MOBILIZATION/IMPLANTATION CANNOT BE DONE?

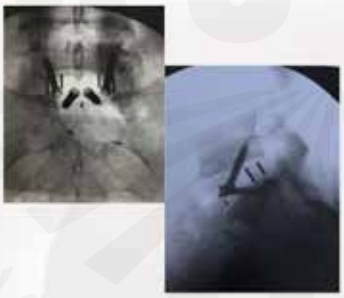
FUSION IS YOUR INTRAOPERATIVE BAILOUT

ALWAYS consent every ADR for a Fusion

- Make this your office standard
- Have fusion set available for every case

If you cannot mobilize, you break an endplate, find unexpected pathology, etc…

SA ALIF or 360



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Postoperative Complications: Monitor your patient carefully

- DVT
- Arterial Embolism
- Infection Early or Late
- Subsidence
- Migration
- Loosening
- Fracture
- Osteolysis



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Wisdom From Experienced Arthroplasty Surgeons...
• Lumbar TDR is not for every patient
• Lumbar TDR is not for every surgeon
• A good TDR is better than a good fusion
• A good fusion is better than a bad TDR
• A bad TDR is worse than a bad fusion
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CASES WITH COMPLICATIONS
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LUMBAR CASE #1
Arthroplasty With Sub-Acute Traumatic Displacement
How Do You Salvage This Situation?
Courtesy of Jack Zigler, MD
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- 34 year old healthy WF
- Working banker, single mother
- functionally disabling LBP



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Intra-Operative Films





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Post-Operative Course

- Patient does well
- Decreased pain, decreased meds
- Ready to RTW at 6 week visit



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Patient goes to Pharmacy directly after her 6 week office visit...

- She slips on wet floor...
- Falls forward, landing hard on her hands and knees...
- Hyperextends her lower back...
- Has immediate onset of severe pain

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She returns 3 weeks later because the pain remains severe



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Compare Before and After...



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How Should You Pre-operatively Evaluate This Situation?

- **CT should be done to evaluate implant, pedicles, and spinal canal**
- Not done in this case
  - **Pt was neuro intact**
  - **Radiographs gave enough info**
  - **Patient declined study**

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How Do You Salvage This?

- Bracing, allow to heal, then re-evaluate
-
- Revise ADR implant anteriorly
  - **do you also fix pedicles?**
  - **do you brace for pedicle fractures?**
- Posterior fusion alone, with screws?
- 360 fusion?

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Surgeon's Reasoning Process

- Unhappy Patient
- **Now with a "bad result" from ADR**
- **In more pain than ever**
- **Looking at delayed RTW**

- Potential litigation for slip-and-fall

- He felt the need to intervene with the procedure that has the highest potential for success in his hands, considering the pathology, and the risks of revision intervention

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The Solution: Anterior removal with ALIF and Perc Screws





Very Good Clinical Outcome

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Case #2:

Courtesy of Jack Zigler, MD

...ERATIVE FILMS

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ADR Expulsion

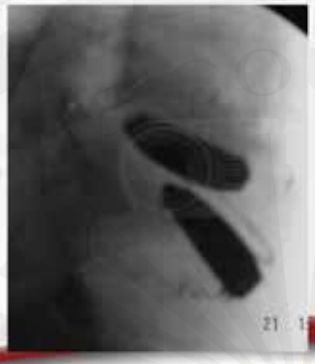
- 33 yo male with disabling DDD L5-S1
- Uncomplicated arthroplasty 3-24-05
- Benign postop course
- 2 week office visit doing well
- X-rays OK



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5 Weeks Post OP
Presents with this history:

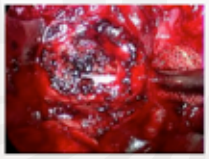
- Went to bed after playing with kids having no problems whatsoever
- Woke up in AM unable to straighten up or walk normally
- Transferred from local ER with this film



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Operative Findings

- Primary approach left retroperitoneal
- Revision through right retroperitoneal approach
- Thick anterior pseudocapsule containing serosanguinous fluid
- Inferior endplate and core anterior to spine easily removed once vessels protected
- Superior plate levered into disc space and easily removed
- Granulation tissue noted along posterior annulus



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Salvage With 360 Fusion





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The Real Story

Postop, patient admitted that this:

- Involved alcohol (a lot)
- Involved a fall from a 6 foot front porch

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CASE #3: REVISION ADR SURGERY IN AN ER DOC

Courtesy of Jack Zigler, MD

...ERATIVE FILMS

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Charite InMotion to 360 Fusion



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PATIENT HISTORY

- 45 yo female ER Physician
- L5-S1 InMotion ADR implanted for post-HNP disc space collapse with functionally disabling DDD
- Excellent pain relief x 8 months
- Now with 6 weeks of progressive RLE radiculopathy after 10 hour car ride; no trauma!

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PHYSICAL EXAM

- Pt comfortable only in fetal position
- c/o severe constant RLE pain
- + SLR RLE at 30 degrees
- Numbness Right L5 dermatome
- EHL weakness RLE
- 12 hour improvement w/ R L5 SNRB

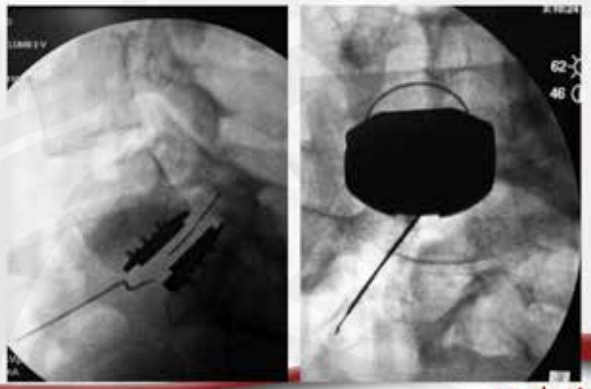
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OPERATIVE PLAN

- Revision thru R retroperitoneal approach if possible
- Explantation
- ALIF and posterior pedicle screws w/ posterolateral fusion
- Other options:
  foramenotomy + decompression
  exchange for new ADR

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INTRA-OPERATIVE IMAGES



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INTRA-OP PROCEDURE

- Anterior annulectomy to expose ADR
- Debridement of left side of disc space
- Bullet distractor placed to left of ADR for distraction of disc space
- Core removed with Kocher clamp
- Osteotome for leverage of metal endplates and removal
- Curettage of disc space w/ endplate prep

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INTRA-OPERATIVE 2



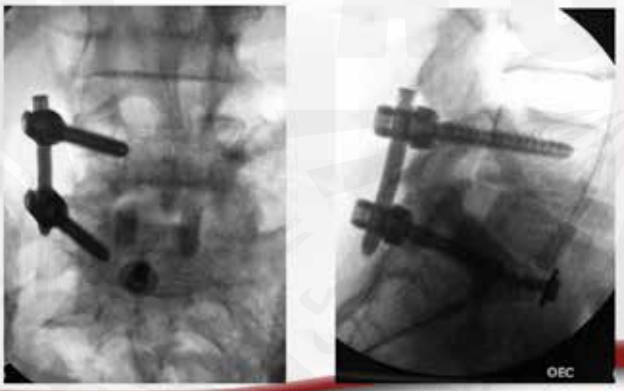
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INTRA-OPERATIVE 3



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FINAL INTRA-OP FILMS



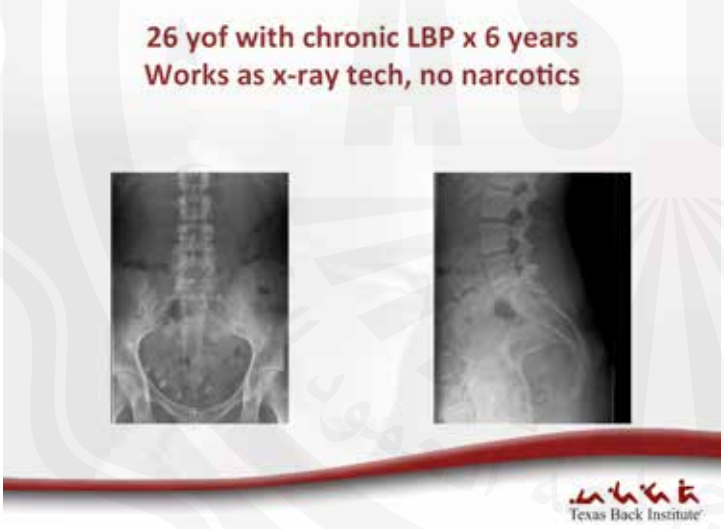
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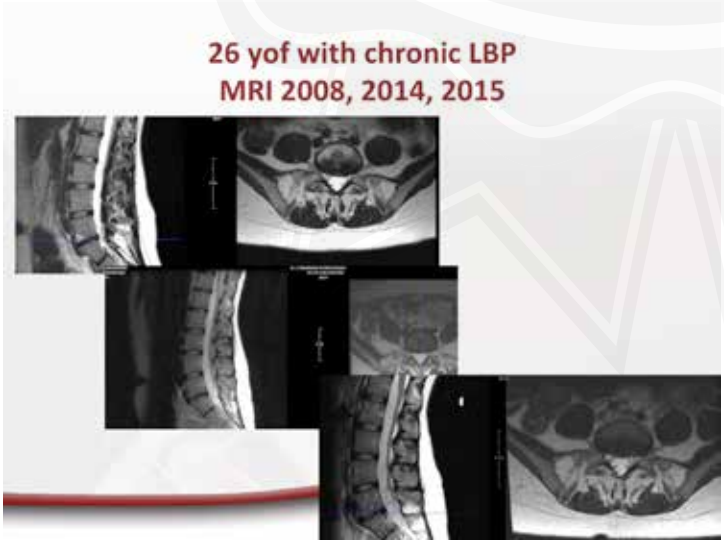
POST-OP EXAM

- Leg pain gone in Recovery Room
- EHL 5/5
- Neuro-monitoring showed improvement in RLE after core removed

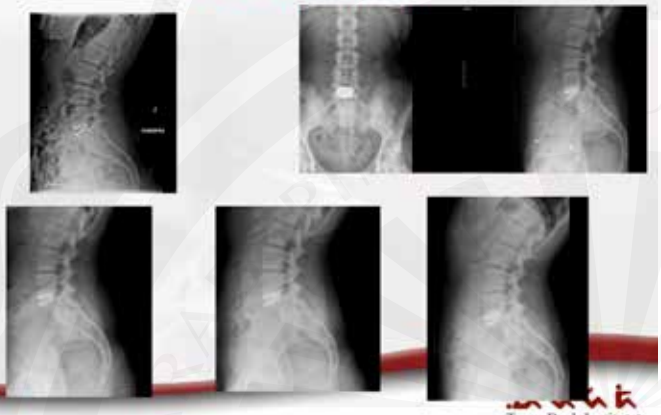
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Case #4:
Courtesy of Richard Guyer, MD
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26 yof with chronic LBP x 6 years
Works as x-ray tech, no narcotics
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26 yof with chronic LBP
MRI 2008, 2014, 2015

2 wk PO, 6wk PO, 12 wk, 36 wk PO
VAS = 0, Homerun



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CT Scan



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No pain, but progressive anterior migration and now with pedicle fracture???

- Leave her alone?
- Pedicle fixation and posterior fusion?
- Remove and revise?
- Remove and fuse?

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8 months after index surgery again VAS = 0





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Case #4:

Courtesy of Richard Guyer, MD

...ERATIVE FILMS

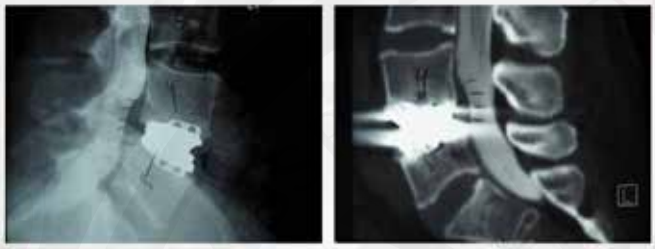
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Metal on metal TDR

- 53 yo female with L4/L5 Kinelfex L implanted 8/06
- Did well until 11/07 with onset of lbp and some left leg pain
- Treated conservatively with meds
- Increasing lbp and leg pain and now sweaking with flexion and extension

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Myelo/CT 2/13/08



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Myelo/CT 2/13/08



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Current studies as of 2/15/08

- CBC, CRP, ESR wnl
- MRI with gado
- Disc space aspiration yielded 0.5cc clear fliud sent for cultures

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Revision Strategies

- Remove disc primarily
- 360 fusion
- Implant choices: bone or peek with autograft or BMP
- Or explore posteriorly get tissue for culture and patholgy looking for foreign body reaction, tests fro metal ions, etc and then satge 2 weeks removal of implant based on findings?
- Antibiotic course length

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Revised Anteriorly

- Ureteral stents placed
- Slow and tedious dissection by access surgeon
- Removed core anterior laterally releasing endplates
- Allograft bone and percscrews



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"FUSION COVERS UP THE SURGEON'S SINS...

ARTHROPLASTY MAGNIFIES THE SURGEON'S SINS..."

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Intraoperative Decisions if Arthroplasty is Not Feasible

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Intraoperative flexibility may be required



Instability



Inadequate mobilization



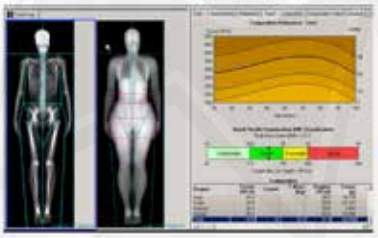
Intraoperative Fracture

Always consent the patient for a TDR and Fusion!
Stand-Alone ALIF, if appropriate, is the ideal alternative.

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Preoperative Planning

- Importance of pre-op dexa scan
- Possible pre-op CT scan to better evaluate endplate



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REVISION CTDR

Disclosures

Guyer (a) Alphatec; (b) Spinal Kinetics, Spinal Ventures, Mimedix; (c) DePuy-Synthes Spine, K2M, Flexuspine, Mimedix, Aescalup; Safe Orthopedics (d) DePuy-Synthes Spine, K2M, Paradigm Spine

Key: (a) royalties; (b) stock/options; (c) consulting/SAB; (d) Speaker/ faculty; (e) Research; (f) Fellowship and related research; (g) other

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Many Cervical TDR Options



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Introduction

- Decompression of neural elements is the primary focus with both ACDF and cervical TDR



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Adjacent Segment Deg/Dz

Radiculopathy and Myelopathy at Segments Adjacent to the Site of a Previous Anterior Cervical Arthrodesis*

BY ALAN S. HILIBRAND, M.D.†, GREGORY D. CARLSON, M.D.‡, MARK A. PALUMBO, M.D.§, PAUL K. JONES, PH.D.‖, AND HENRY H. BOHLMAN, M.D.‖, CLEVELAND, OHIO

Investigation performed at the Department of Orthopaedic Surgery, University Hospitals Spine Institute, Case Western Reserve University School of Medicine, Cleveland

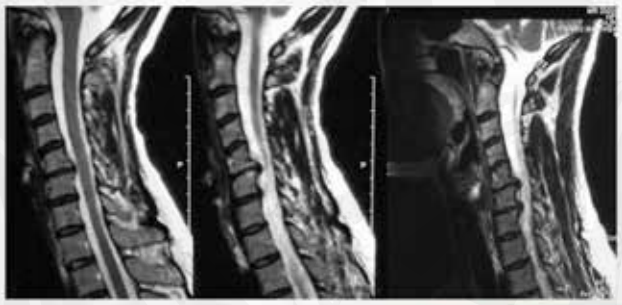
- 2.9%/yr : 25%/10 years *J Bone Joint Surg Am.* 1999;81:519-28

of the arthrodesis or its extent. Therefore, we believe that symptomatic adjacent-segment disease is the result of progressive cervical spondylosis at adjacent levels and is not caused by the arthrodesis itself.

- Similar rates to non-fusion discectomy

Henderson 1983 Neurosurgery

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Utilization Trends of Cervical Artificial Disc Replacement After FDA Approval Compared With Anterior Cervical Fusion

Adoption of New Technology

Young Lu, BA, Steven J. McAnany, MD, Andrew C. Hecht, MD, Samuel K. Cho, MD, and Sheeraz A. Qureshi, MD, MBA

"From 2008 to 2010, the estimated number of CDA surgical procedures per 100,000 capita increased by 11.8% (0.85 – 0.95) compared with a 4.9% increase in ACDF (43.8 – 45.9) (p=0.6977)."

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Revision Prevention

- Patient selection
- Technique

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Patient Selection

- Contraindications
  - Trauma
  - Morbid obesity
  - Hypermobility
  - Endocrine/autoimmune disease
  - Metabolic bone abnormality
  - Facet arthrosis
  - Metal allergy
  - DISH
  - No motion
  - OPLL
  - Osteoporosis
  - Active malignancy

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Complications

- Heterotopic ossification
- Implant migration, loosening
- Vertebral body fracture
- Posterior fracture of vertebral body
- Delayed compression of neural elements
- Hypersensitivity
- Dynamic radiculopathy
- Infection



Spine 2013;38:2223 –

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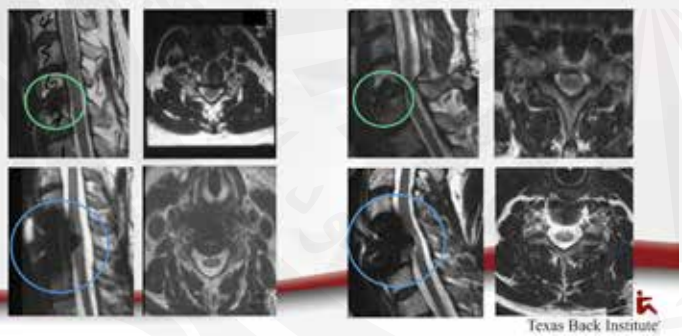
Work-up

- History and physical
  - Time course and symptoms important
- Infection work-up
- Imaging
  - Radiographs (dynamic)
  - MRI?
  - CT +/- myelogram

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Magnetic Resonance Imaging Clarity of the Bryan®, Prodisc-C®, Prestige LP®, and PCM® Cervical Arthroplasty Devices

Lali H. S. Sekhon, MBBS, PhD, FRACS,* Neil Duggal, MD, FRCSC,† James J. Lynch, MD, FRSC I,* Regis W. Haid, MD,‡ John G. Heller, MD,§ K. Daniel Riew, MD,‖ Kevin Seex, MBBS, FRACS, FRCS,¶ and Paul A. Anderson, MD**



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Approach

Anterior

Posterior

Both



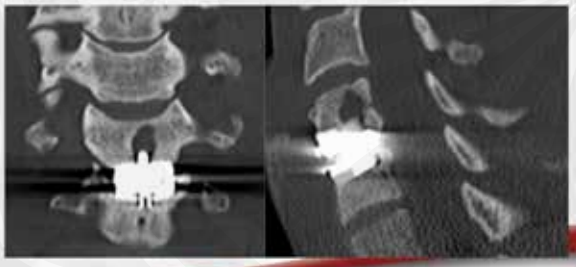


- Conversion to ACDF
- Replace TDR
- Conversion to corpectomy
- Anterior/Posterior

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Progressive Osteolysis

- ProDisc-C
- Anterior explant with conversion to fusion



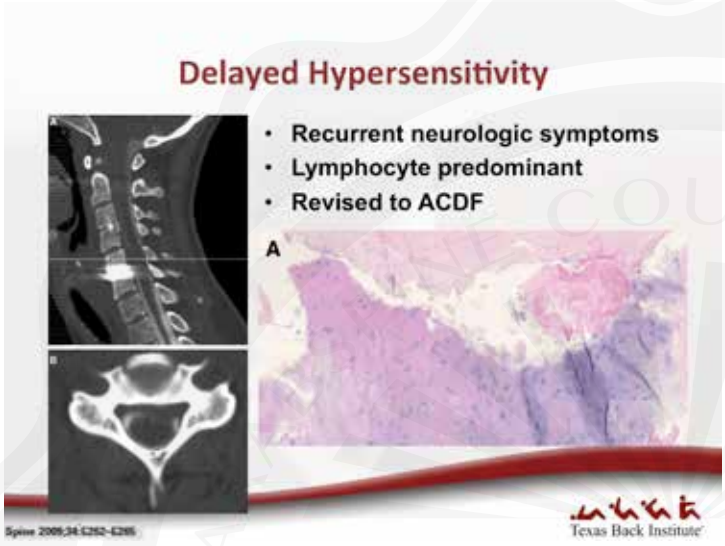
Spine, 2011;36:E973-E978

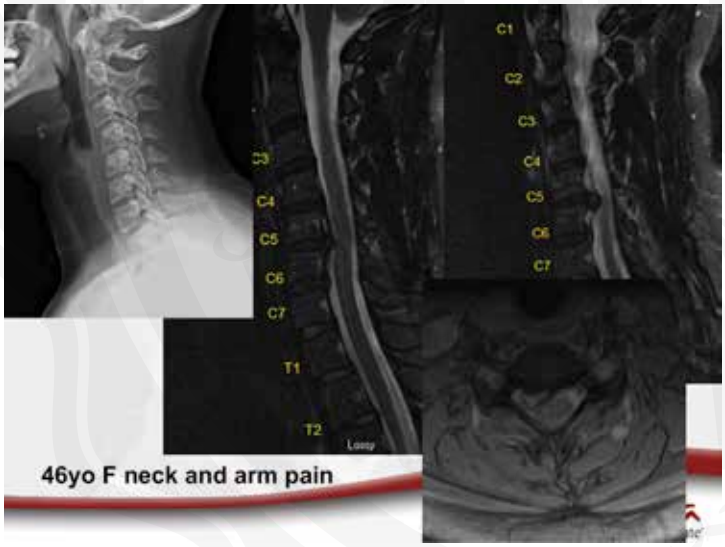
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Technique Issue



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Delayed Hypersensitivity
• Recurrent neurologic symptoms
• Lymphocyte predominant
• Revised to ACDF
A
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C1
C2
C3
C4
C5
C6
C7
T1
T2
46yo F neck and arm pain


Intra-op and immediate post-op films
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Case Example

- She did well for 5 months, then presented with abrupt onset neck pain

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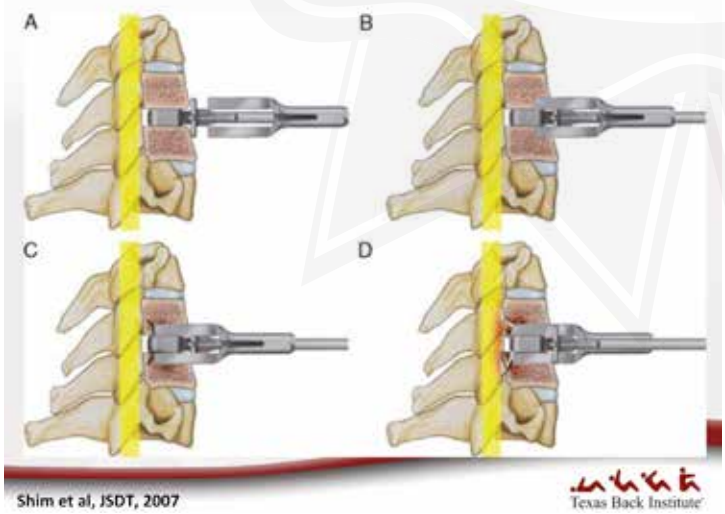
- Immediate post-op films
- Partial corpectomy and fusion

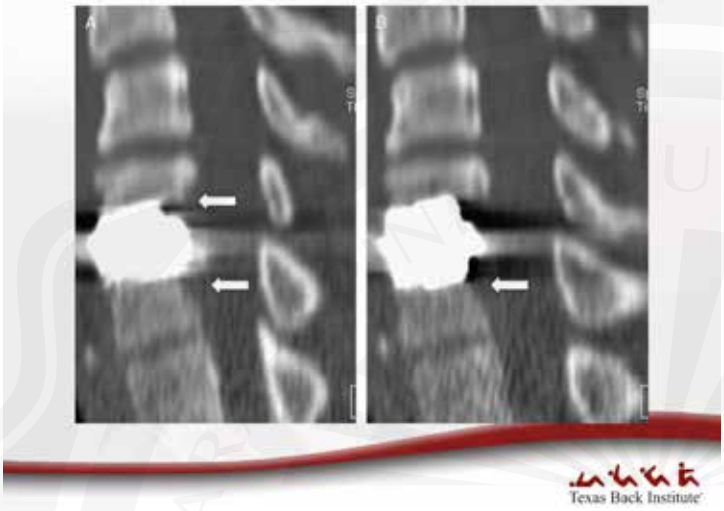
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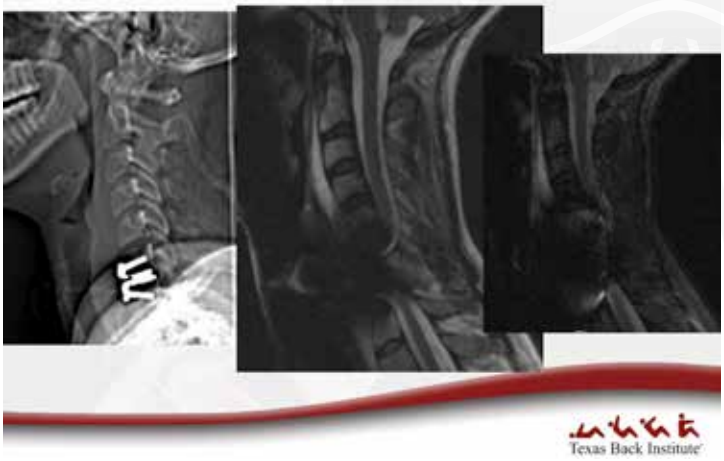
Authors	Year	Article type	No. of CDA patients	No. of migration cases	Direction of migration	Implant
Wagner et al[17]	2014	Case report	1	1	Posterior	Bryan Cervical Disc (Medtronic Sofamor Danek, Memphis, Tennessee, United States)
Anderson et al[19]	2004	Prospective	136	2	Anterior and posterior	Bryan Cervical Disc
Tsermoulas and Bhattathiri[20]	2013	Case report	1	1	Anterior	Mobi-C Cervical Disc Prosthesis (LDR Spine USA, Inc., Austin, Texas, United States)
Pickett et al[21]	2006	Prospective	74	1	Posterior	Bryan Cervical Disc
Zhang et al[22]	2014	Prospective	58	2	Posterior	Bryan Cervical Disc
Quan et al[23]	2011	Prospective	21	1	Posterior	Bryan Cervical Disc
Hacker et al[15]	2013	Prospective	94	1	Posterior	Bryan Cervical Disc

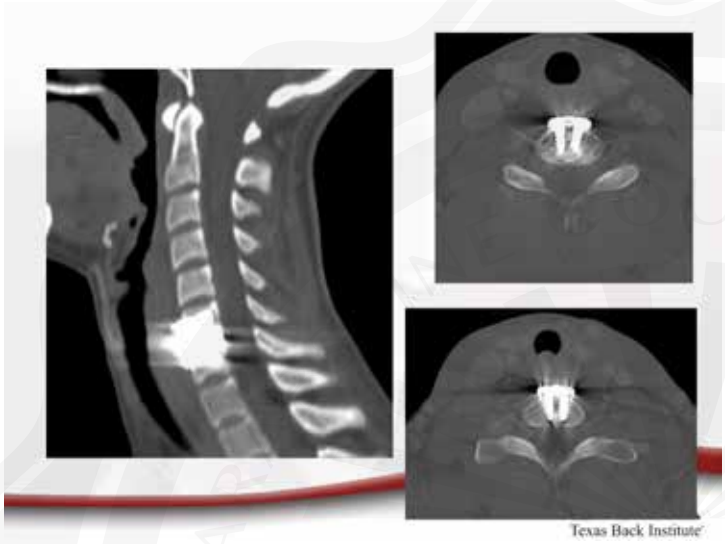
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Uncommon Infection
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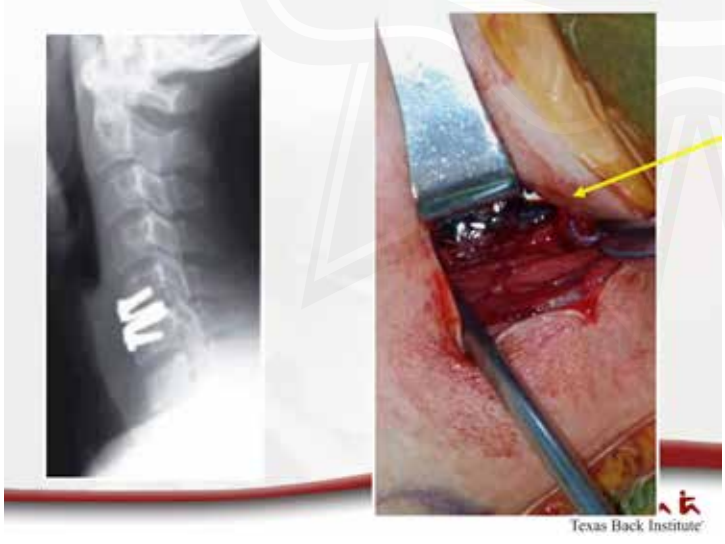

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Infection

- ESR 25, WBC 6, CRP 1.1
- Admitted for observation
- Blood cultures
  - Positive for MSSA
- Increasing dysphagia
- Increasing neck pain

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Delayed Complications

- Reported rates of surgical interventions following failed CDR are low (mean, 2.4%; range, 0%–4.1%)
- Similar to large joint arthroplasty, delayed device-related complications may occur
- Beyond time frame of traditional techniques

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Good Review

- Skovrlj B, Lee D-H, Caridi JM, Cho SK. Reoperations Following Cervical Disc Replacement, Asian Spine J 2015.
- Acknowledge Seth Williams, MD and Wellington Hsu, MD for contribution of some cases

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REVISION FOR PSEUDOARTHROSIS

Spinal Pseudarthrosis

- Very common problem
- Clinical significance is variable
- Significance depends on the goal of the original surgical intervention
- I will speak about my retrospective studies on classification and histology, as well as some unsupported opinions.

CLASSIFICATION

- In 1990, I did a retrospective review of 55 patients who had undergone a psueudarthrosis repair at the Toronto general hospital, for whom records of the original fusion procedure, follow-up Imaging and surgical repair notes were available.
- In 40 consecutive patients who underwent surgical repair, tissue specimens were harvested from an area of solid fusion, From the area of motion, and where possible, from the facet joint .

- All patients had complaints of persistent pain
- It was not possible to reliably ascribe the pain to the pseudarthrosis.

- The philosophy at the time was the complete acceptance of the ideas of Drs. Macnabb and Crock, who proposed that the “pain generator” was a degenerated disk.
- I personally no longer take this view, and do NOT now reccommend spinal fusions for mechanical pain.

Classification

- Pseurdarthroses present with variable anatomy.
- I initially thought that to classify the pseudarthroses might be useful in determining the cause of the fusion failure. And perhaps predicting the outcome of repairs based on the "Type" of pseudarthrosis.

Substantial graft resorption



Atrophic

A substantial fusion mass, but with a horizontal defect that appeared to be weight bearing



Transverse

Like the Transverse type but with a defect in the coronal plane

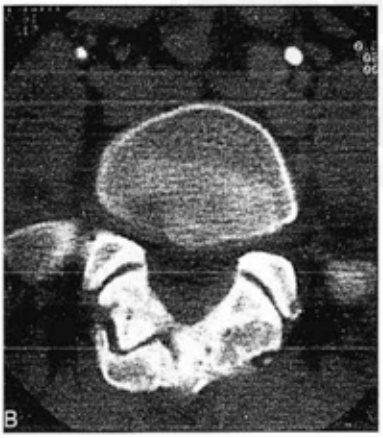


Shingle



Shingle Sign

Shingle sign



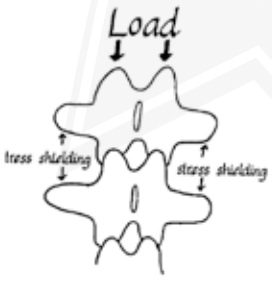
A catch-all for patients with multiple planes of motion



A Complex

Clinical results from our repair procedures were very poor

- No patient reported substantial pain relief.
- Many required increases in daily pain medications.
- None of the categories emerged as having a difference on prognosis.



Facets Intact

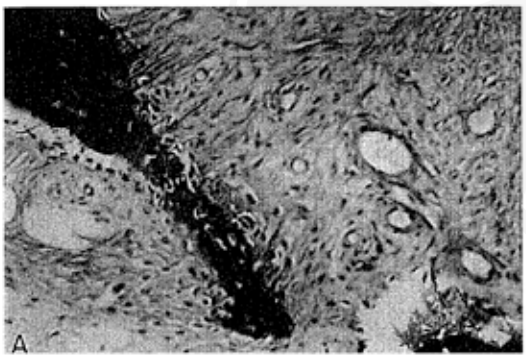
Histology

- The interval between the bone was universally composed of fibrous tissue, sometimes with non viable bone fragments.
- Small NERVES were sometimes seen in soft tissue adjacent to the fusion mass, but NEVER between weight bearing surfaces in a Transverse pseudarthrosis

Fibrocartilaginous tissue between the surfaces of a Transverse Pseudarthrosis



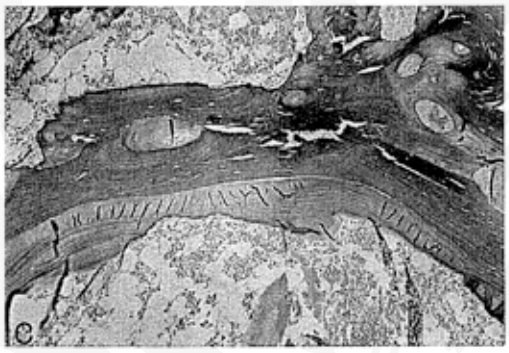
Fibrous tissue between bone surfaces of a transverse Pseudarthrosis



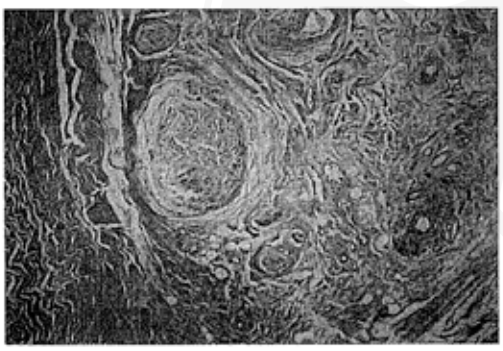
Histology

- The appearance was sometimes very similar to the histology of a Charcot joint, with non-viable bone fragments surrounded by dense fibrous tissue.
- In rare cases, active appositional new bone formation was seen.

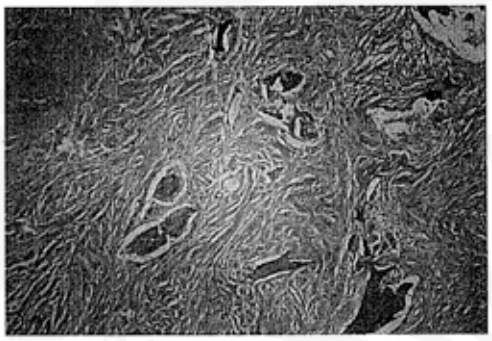
Trabecular fracture with appositional new bone formation



Nerve fibers seen in fibrous tissue adjacent to opposed bony surfaces



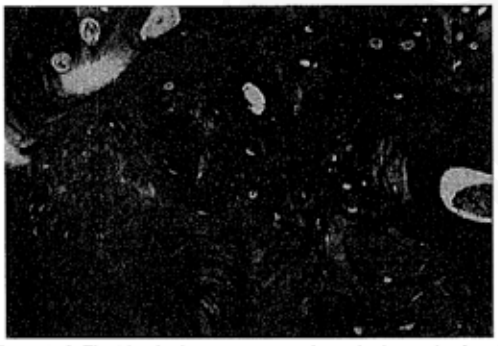
Interposed fibrous tissue with fragments of non-viable bone



Charcot Foot



Mixture of woven and lamellar bone



Mixture of woven and lamellar bone



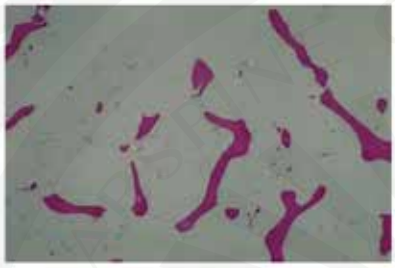
Microtrabecular fracture with fat necrosis, indicating recent injury



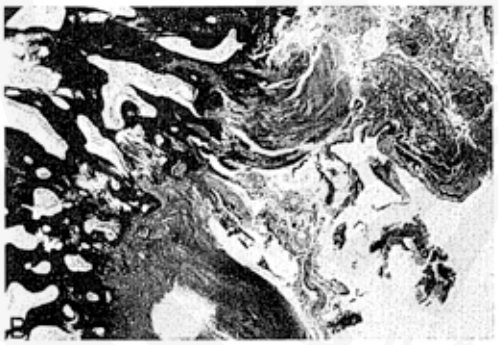
Microtrabecular fracture with mature callus (arrow)



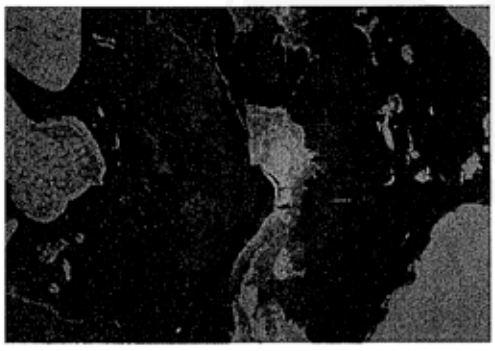
Histology of a Charcot joint

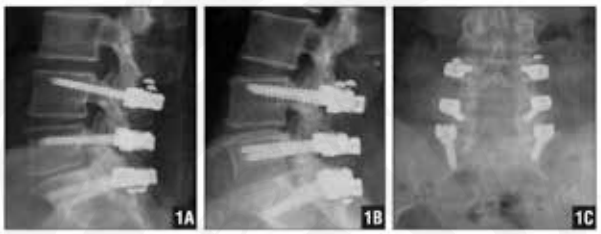


Facet Joints always had extremely advanced osteoarthritis



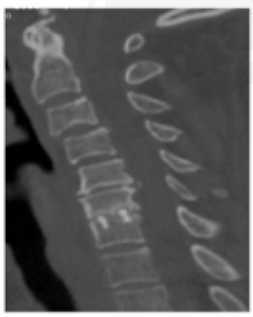
Facet remnant

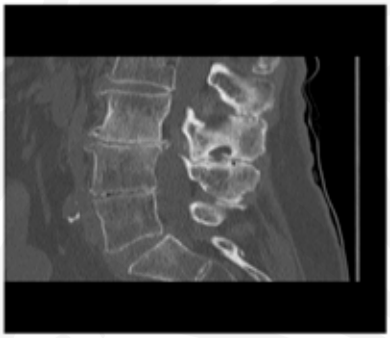


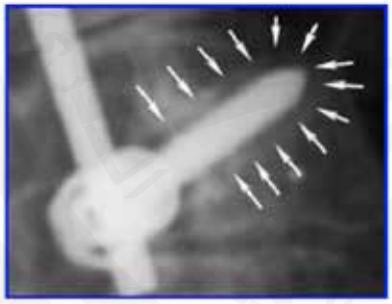


Diagnosis?

- Often obvious on plain films
- Motion studies?
- CT scanning is probably the most accurate method
- Loose hardware is a useful clue







What shall we do about this?

- Stop performing fusions for axial pain?
- Stop patients from smoking?



My Apologies!

- I have been very frustrated with the results of surgical treatments for Axial Pain.
- I challenge the idea that the pain is even coming from the disc.
- I do perform fusions when indicated for fracture or deformity, although I wish for an alternative

My advice?

- If you choose to perform a pseudarthrosis repair, this might be the rare case where I would consider using BMP2.
- But…
- If you use BMP2, keep it away from dura and any nerves in the field, and….
- Don't squeeze the sponge.

Thank you all!





www.arabspinediploma.org