ARABSPINE COURSE DIPLOMA

Module 4

Course Highlight Day-2

Deformity

Normal Growth & Congenital
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

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Avoiding Complications Relating to Patient Positioning

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Ideal Surgical Position

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

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Surgical Positions

- Prone
- Supine
- Kneeling
- Knee-Chest Position
- Knee-Elbow Position
- Lateral Decubitus

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Surgical Positions

- Knee-Chest/Elbow Position
  - Rest on Knees and Chest or elbow
  - Gynecology - chest
  - Arched back - knee
  - Andrews frame

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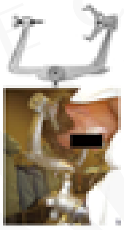
Positioning Complications

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



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Complications

FACIAL
- Conjunctival and Tongue Swelling
- Ischemic Orbital Compartment Syndrome
  - Differentiate from Ischemic Optic Neuropathy and
  - CRAO (central retinal artery occlusion)

SYSTEMIC
- Nerve Palsies
- Thromboembolic Complications
- Pressure Sores

EXTREMITY SPECIFIC
- Lower Extremity Compartment Syndrome
- Shoulder Dislocation/ Bursitis
- Upper Extremity Paresthesias

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Risk Factors Resulting in Poor Positioning

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

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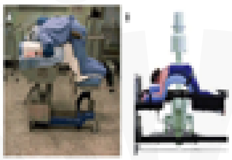
Ischemic Optic Neuropathy

- 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



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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

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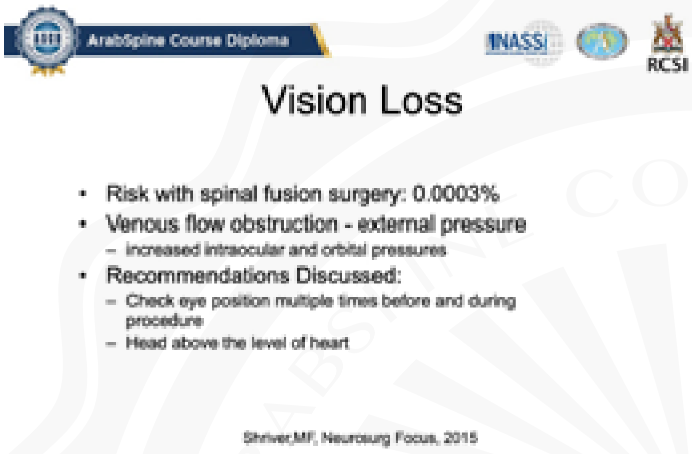
Lumbar Spine Positioning Complications

- 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
- Discussed Evidence-based Recommendations for Complication Avoidance

Shriver,MF, Neurosurg Focus, 2015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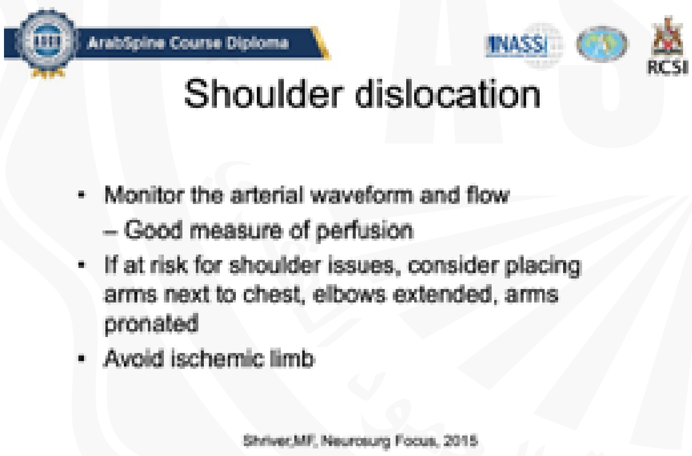
Vision Loss
• Risk with spinal fusion surgery: 0.0003%
• Venous flow obstruction - external pressure
– increased intraocular and orbital pressures
• Recommendations Discussed:
– Check eye position multiple times before and during procedure
– Head above the level of heart
Shriver,MF, Neurosurg Focus, 2015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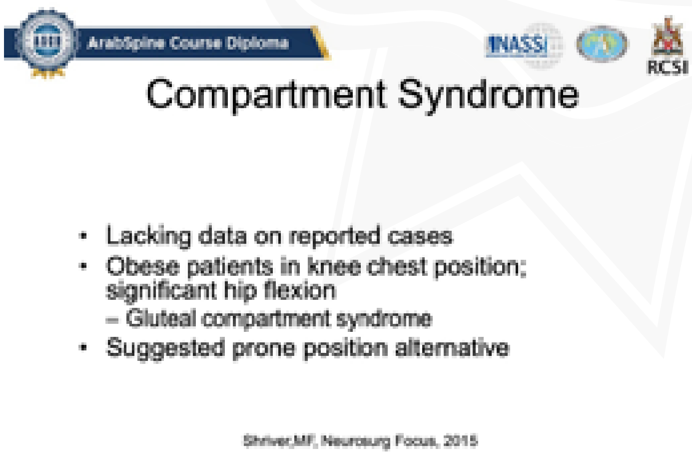
Shoulder dislocation
• Monitor the arterial waveform and flow
– Good measure of perfusion
• If at risk for shoulder issues, consider placing arms next to chest, elbows extended, arms pronated
• Avoid ischemic limb
Shriver,MF, Neurosurg Focus, 2015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Compartment Syndrome
• Lacking data on reported cases
• Obese patients in knee chest position; significant hip flexion
– Gluteal compartment syndrome
• Suggested prone position alternative
Shriver,MF, Neurosurg Focus, 2015

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Case Example - Bow Hunter's Syndrome

- 50+ year old male with cervical myelopathy and 3 level cord compression
- Positioned him supine on the table with minimal extension given known stenosis
- Glidescope intubation
- Began to turn purple in the face
- Never went forward with surgery
- Woke him up, flexed his neck, color returned; Neuro intact
- CT angiogram showed diminutive VA
- Bow Hunter's syndrome (BHS), also known as rotational vertebral artery syndrome is a form of vertebrobasilar insufficiency (VBI) in which the vertebral artery (VA) is mechanically compressed by the transverse process of a cervical vertebrae or surrounding structures when the head is turned more than 45° to the right or left

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Case Example

- Lumbar Spine Prone Positioning for Fusion Surgery (Head to Toes)
  - Pre-flip: appropriate bony prominence padding
  - Head: Neutral position, avoid hyperextension (towels)
  - Check facial and eye position - Avoid extraocular pressure
  - Ensure clearance between Chin and Chest Pads
  - Check Arm position - Brachial plexus stretch/Ulnar nerve padding/unloading
  - Check Chest wall location to pad (breasts)
  - Pelvis pads at ASIS; Abdomen hanging freely - improves bleeding control (epidural engorgement); Genitalia hanging freely (male)
  - Ensure abdomen not touching side bars (obese)
  - Padding underneath the knees (pressure sores)
  - Leg position: Flexed at knees to allow for appropriate lordosis and take tension off sciatic nerve
  - If nurse places restrictive belt over legs, ensure well padded underneath
  - Intraoperative BP management plan

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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

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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 (Opthamology), Resolve any Hypotension and Monitor Intraocular Pressure

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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

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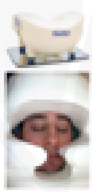
Summary

- 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

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Introduction

- Pre op
- Intra op

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Pre op

- Review home meds
- Optimize hemoglobin
- Optimize clotting factors
- History
  - Underlying coagulopathy
- Embolization

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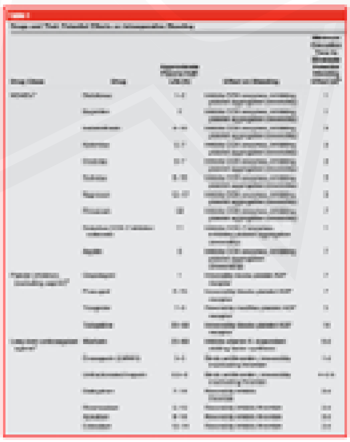
Home meds

- NSAIDs
- Platelet inhibitors
- Anticoagulation agents



Bible J. JAAOS. 2018

Home Meds

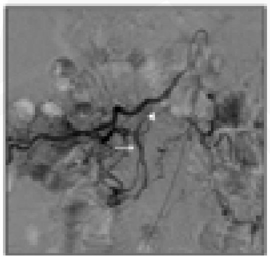
- Supplements – 14 days
  - Garlic
  - Ginkgo
  - Gins-seng
  - Fish oil
  - Flax seed oil
  - Chamomile
  - Vit E
  - Green tea

Hemoglobin

- Transfusion
- Erythropoietin

Pre Op

- Pre-donation
  - Rarely used
- Embolization



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Intraoperative

- Cell saver
- Anesthesia
- Antifibrinolytic agents
- Positioning
- Surgical technique

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Cell Saver

- Efficacy related to extent of blood loss
- Advantages – blood replacement
- Disadvantages
  - Cost
    - >500cc EBL cost effective
      - Kelly P. Spine. 2015
  - Irrigation solutions
  - Hemostatic agents
  - Qualitative

TABLE 4. Clinical Score for Preoperative Prediction of Patients Likely to Have Blood Loss Exceeding 500 mL

Preoperative Characteristic	Points
Age > 50 yr	1
Male sex	[illegible]
BMI ≥ 30	2
Number of vertebral levels involved	[illegible]
Interbody fusion	[illegible]

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Blood Replacement

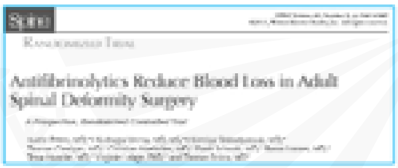
- Target Hgb 7 to 8
  - Critical care patients – Hgb 7 as good as 8
    - Hebert P. NEJM. 1999
- Hi Risk Patient
  - Indications based on surgical and medical factors
    - Identify pre op
  - Monitoring, access
  - BP
  - Antifibrinolytics
  - Regular lab monitoring
  - Specific transfusion triggers per lab data

Anesthesia

- Permissive Hypotension
  - Morrison C. J Trauma. 2011
  - Disadvantages end organ perfusion
    - Spinal cord
    - Optic nerve
- Temperature regulation
  - Room temp
  - Warming blankets (including anterior for prone cases)
  - Warm fluids

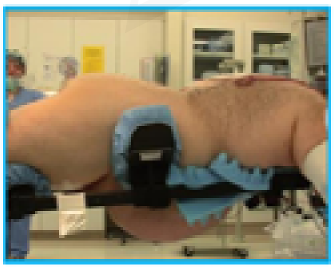
Antifibrinolytics

- Efficacy for reducing EBL
- TXA
  - Load 10/mg/kg
  - 1mg/kg/hr



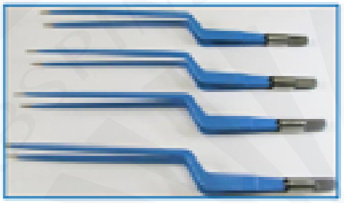
Positioning

- Reverse Trendelenberg
- Table frame with open abdomen

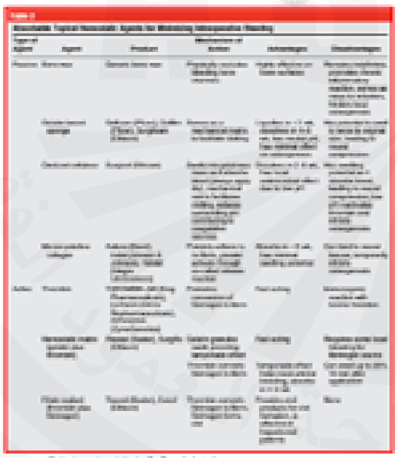


Surgical Technique

- Approach
  - Local infiltration of 1:500,000 epinephrine
  - Cautery
  - Packing
  - Time



- Hemostatic agents



Bible J. JAAOS, 2018

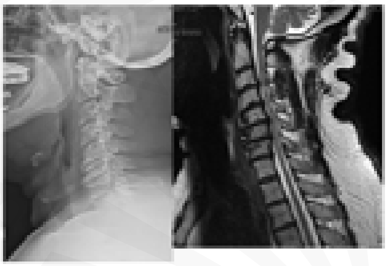
Summary

- Optimize patients pre op
- Identify hi risk patients
  - Implement protocol
- Intra-op factors
- Time

Thrombo-embolic Avoidance

Case

- 66 y/o male
- h/o chronic neck pain
- 4 month h/o progressive ataxia, hand numbness
- 3/5 hand intrinsics
- PMH remarkable for DVT in remote past



Case

- Underwent C3-C7 laminectomy, posterior instrumentation and fusion C2-T2
- VTE prophylaxis consisted of IPC, LMWH started postop day 2

Case

- POD # 3 pt c/o increasing neck pain, dysthesias BUE
- Motor exam 3/5 diffusely BUE
- Pt underwent emergent I&D

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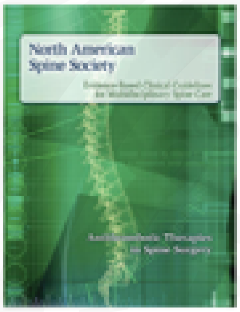
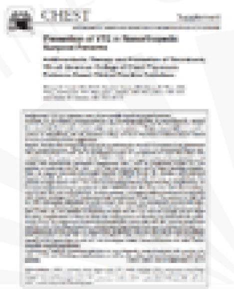
Avoiding Venous Thromboembolism

Guidelines exist





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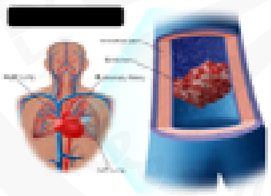
Thromboembolic?

- DVT

- PE



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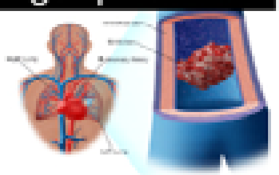
Thromboembolic?

- DVT

How big a problem?

- PE



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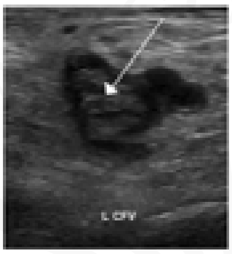
Avoiding Venous Thromboembolism

Natural History

Historically difficult to discern
- No studies of patients with no prophylaxis
- Diagnostic method between studies varies greatly
- Patient populations between studies varies widely



NASS Guidelines "unable to definitively answer" the question

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Avoiding Venous Thromboembolism

Big data able to provide answer Spine Journal 2017

Clinical Study

Risk factors and pharmacologic prophylaxis for venous thromboembolism in elective spine surgery

Ryan P. McLynn, BS, Pablo J. Diaz-Collado, MD, Taylor D. Ottesen, BS, Nathaniel T. Ondeck, BS, Jonathan J. Cui, BS, Patawut Bovonratwet, BS, Blake N. Shultz, BA, Jonathan N. Grauer, MD*

NSQIP studies
- 2005-2009 1.2% (0.4% PE, 0.8% DVT)
- 2004-2014 0.6%

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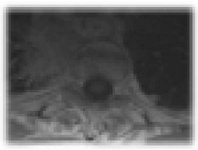
Incidence varies

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



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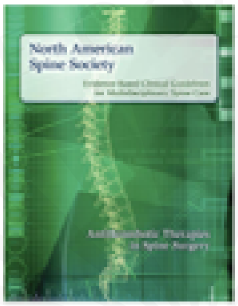
Avoiding Venous Thromboembolism

Efficacy of Prophylaxis

Mechanical Compression

- Two studies looking at mechanical prophylaxis
  - Compression comparable to compression with chemoprophylaxis *(Rokito et al. Spine 1996)*
  - Foot pumps and calf pumps equally effective *(Wood et al. J Spine Dis 1997)*



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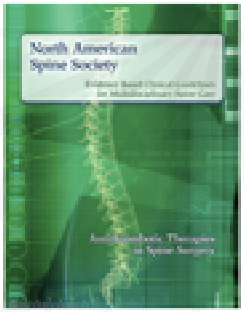
Avoiding Venous Thromboembolism

Efficacy of Prophylaxis

Mechanical Compression

Conclusion

- Mechanical compression devices are suggested in patients undergoing elective spine surgery (Grade B evidence)
- Should start at the time of surgery
- Should continue until pt fully ambulatory



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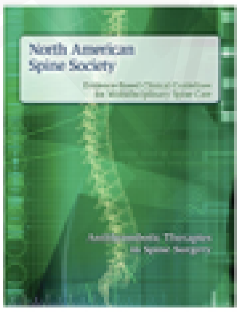
Avoiding Venous Thromboembolism

Chemoprophylaxis

- Recommendations from NASS Guidelines

"Most commonly performed elective spine surgeries done through a posterior approach are associated with a very low risk of VTE. In this instance chemoprophylaxis may not be warranted"

"Recommend LMWH be used cautiously prior to routine, elective spinal surgery and withheld unless there are other risk factors for thromboembolism"



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Avoiding Venous Thromboembolism

Chemoprophylaxis

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

≠

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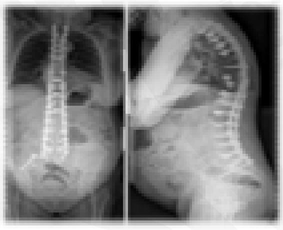
How long for chemoprophylaxis

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



OK for deformity
OK if can EVENTUALLY ambulate

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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

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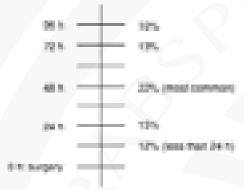
When is it safe to start chemoprophylaxis?

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



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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

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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

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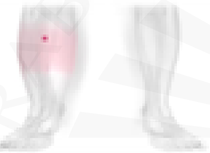
Special circumstances

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?



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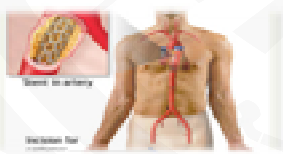
Special circumstances

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)



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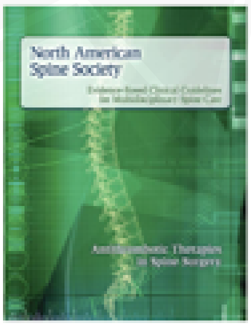
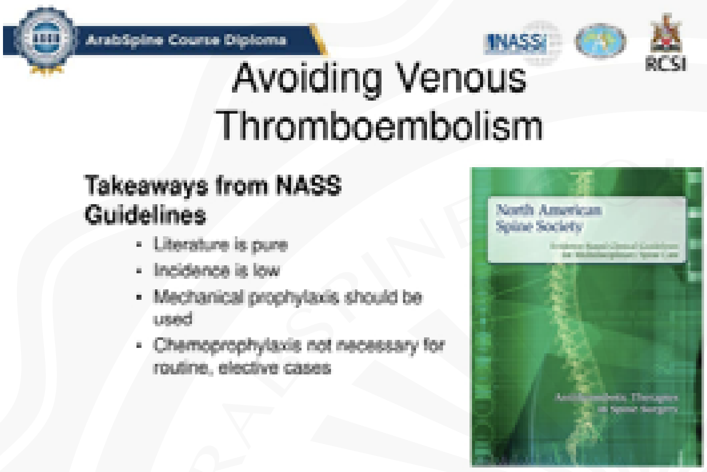
Avoiding Venous Thromboembolism

Wound Complications

- Does the use of chemoprophylaxis increase the risk of wound complications or neurologic decline from epidural hematoma?

Insufficient evidence to address the question

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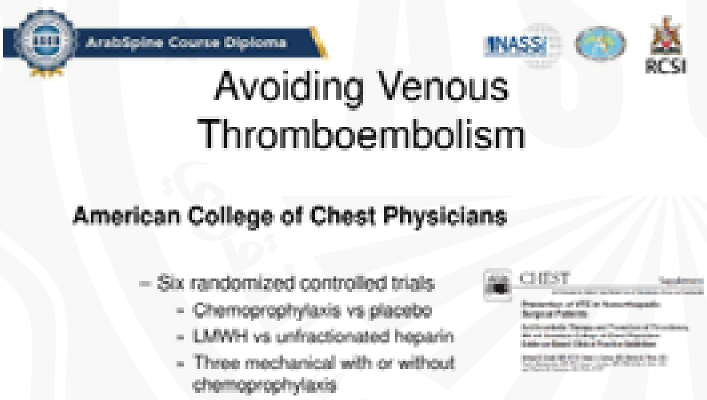
Avoiding Venous Thromboembolism
Takeaways from NASS Guidelines
• Literature is pure
• Incidence is low
• Mechanical prophylaxis should be used
• Chemoprophylaxis not necessary for routine, elective cases
North American Spine Society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Avoiding Venous Thromboembolism
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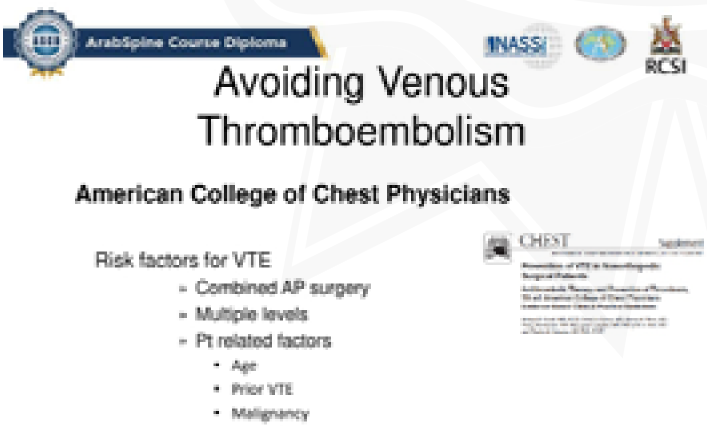
– Six randomized controlled trials
- Chemoprophylaxis vs placebo
- LMWH vs unfractionated heparin
- Three mechanical with or without chemoprophylaxis
CHEST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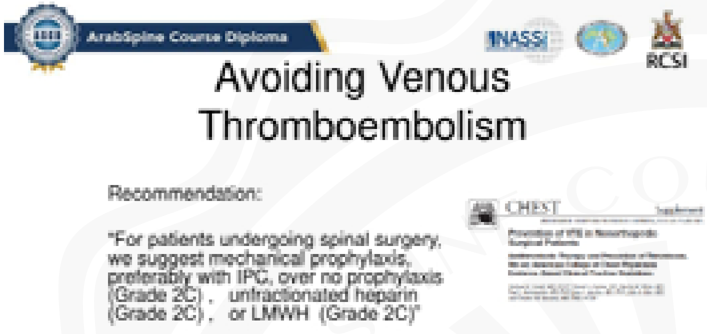
Risk factors for VTE
- Combined AP surgery
- Multiple levels
- Pt related factors
• Age
• Prior VTE
• Malignancy
CHEST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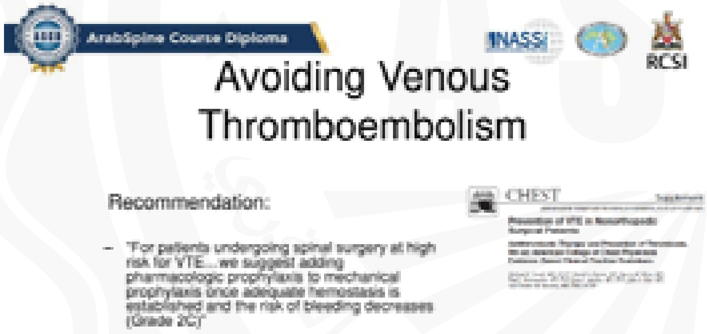
Avoiding Venous Thromboembolism
Recommendation:
"For patients undergoing spinal surgery, we suggest mechanical prophylaxis, preferably with IPC, over no prophylaxis (Grade 2C) , unfractionated heparin (Grade 2C) , or LMWH (Grade 2C)"
CHEST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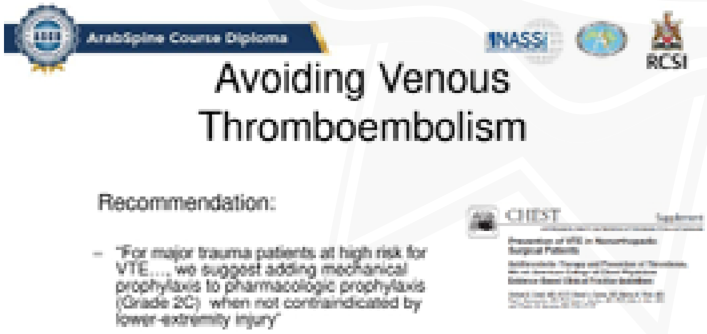
Avoiding Venous Thromboembolism
Recommendation:
– "For patients undergoing spinal surgery at high risk for VTE…we suggest adding pharmacologic prophylaxis to mechanical prophylaxis once adequate hemostasis is established and the risk of bleeding decreases (Grade 2C)"
CHEST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Recommendation:
– "For major trauma patients at high risk for VTE…, we suggest adding mechanical prophylaxis to pharmacologic prophylaxis (Grade 2C) when not contraindicated by lower-extremity injury"
CHEST

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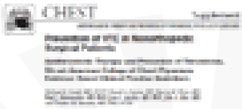
Avoiding Venous Thromboembolism

Additional Findings

- There was a modest increase in major bleeding complications with chemoprophylaxis
- Venous ultrasound should not be used for periodic surveillance of VTE



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Avoiding Venous Thromboembolism

Where does that leave us?

Summary from these guidelines

- All spine surgery patients should receive mechanical prophylaxis begun at the time of surgery and continued until d/c
- Patients at "high risk" should receive chemical prophylaxis as well when the risk of major bleeding has subsided
- Routine surveillance in asymptomatic patients with venous ultrasound is not recommended

Minimizing Surgical Site Infections

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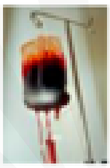
Center Medicare Medicaid Services-CMS "Never Events"

- "Zero Tolerance"
- Hospital Based Never Events
  - Wrong Site Surgery (WSS)
  - Foreign body left in Pt at Sx
  - Mismatch Blood Transfusion
  - Major Medication Error
  - Pressure Ulcers
  - **Surgical Site Infection (SSI)**
- If incidents do occur: **no** CMS reimbursement for treatment

CMS
CENTERS for MEDICARE & MEDICAID SERVICES



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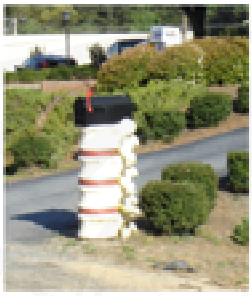
Outline

Post Op Wound Infections

(SSI-Surgical Site Infections)

- **Incidence**
- **Risk Factors**
  - **Nutrition**
  - **Systemic disease**
  - **Colonization**
- **Prevention**
  - **Antibiotic prophylaxis**
  - **Skin prep**
  - **irrigation**
  - **Drains**
- **Strategies=Care Bundles**



Appreciation
Dr. Hani Mhaidli, Spain

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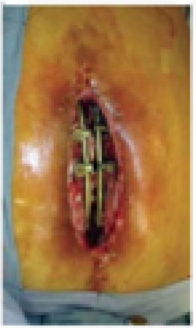
Wound Infection Incidence - Overview

Discectomy	<1%
Posterior Fusion -Uninstrumented	1-4%
Posterior Fusion-Instrumented	2-13% (6%)
Scoliosis - Neuromuscular	25%



- Abbey DM, J Spinal Disord 8:278–283, 1995
- Glassman SD, Spine 21:2163–2169, 1996
- Keller RB Orthop Clin North Am 3: 99–111, 1972
- Roberts FJ, Spine 23:366–370, 1988

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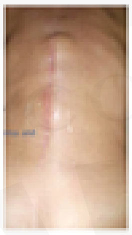
Wound Infection Incidence SRS



- SRS Morbidity & Mortality Comm 2010
  - 108,419 cases -2.1% overall
  - Degenerative 1.4%
  - Deformity 4.2%

Spine Deformity

Rates of Infection After Spine Surgery Based on 108,419 Procedures

A Report from the Scoliosis Research Society Morbidity and Mortality Committee

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WHO SSI Prevention Guidelines 2016 CDC SSI Guidelines 2017

GLOBAL GUIDELINES FOR THE PREVENTION OF SURGICAL SITE INFECTION

SSI GUIDELINES: CDC

- World Health Organization-WHO
  - https://www.who.int/gpsc/ssi-prevention-guidelines/en/
- Centers for Disease Control-CDC
  - Berrios-Torres S. JAMA Surg 2017;152(8):784-791

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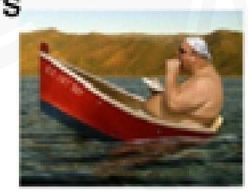
Wound Infections Risk Factors

- Patient/Systemic
  - Nutrition-Garfin Spine 1996;21:2676
    - Albumin<3.5/lymphocyte<1.5-2,000
    - 25% pts/ 42% >60 yr
  - Diabetes
  - Obesity BMI >30
  - Immune compromise
    - RA/Chemo/XRT/Steroids
  - UTI/Previous SSI
- Environmental/Procedural
  - Skin prep/ABX/Air Xchg/sterile proc



Risk Factors for Surgical Site Infection Following Orthopaedic Spinal Operations

By Margaret A. Olsen, PhD, MPH, Jeffrey J. Nepple, MD, K. Daniel Riew, MD, Lawrence G. Lenke, MD, Keith H. Bridwell, MD, Jennie Mayfield, BSN, MPH, CIC, and Victoria J. Fraser, MD

J Bone Joint Surg Am. 2008;90:62-9 • doi:10.2106/JBJS.F.01515

- 2316 Sx/46 infec=2%

Risk Factor/Odds Ratio

- Diabetes-Odds Ratio 3.5
  - BS pre>125/post>200-3.3
- Timing pre-op ABX 3.4
- Obesity-Odds Ratio 2.2
- 2 or more residents 2.2

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Wound Infections Risk Factors:

Perioperative Diabetic Control

TABLE V Risk of Spinal Surgical Site Infection According to Categorization of Serum Glucose Results

Glucose Level* (mg/dL (mmol/L))	No. of Patients with Surgical Site Infection/ No. Tested (%)	No. of Uninfected Patients/ No. Tested (%)	Odds Ratio (95% Confidence Interval)	P Value
Preoperative† >125 (>6.9)	20/39 (51)	30/182 (16)	5.3 (2.5, 11.2)	<0.001
Postoperative >200 (>11.1)	14/35 (40)	21/111 (19)	2.9 (1.2, 6.5)	0.011
Preoperative >125 or postoperative >200	25/45 (56)	45/215 (21)	4.7 (2.4, 9.3)	<0.001

- Suggest
  - Pre-op Blood Sugar <125
  - Post-op Blood Sugar <200

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Prophylactic Antibiotics: Single vs. Multiple Doses

(? Day SX)

SPINE Volume 28, Number 21, pp E453–E455
©2003, Lippincott Williams & Wilkins, Inc.

Single *Versus* Multiple Dose Antibiotic Prophylaxis in Lumbar Disc Surgery

Matthew A. Dobzyniak, MD, Jeffrey S. Fischgrund, MD, Steve Hankins, MD, and Harry N. Herkowitz, MD

- 635 pts HNP surgery
  - 201 single pre-op dose
  - 434 pre-op + 3 doses x 24h
- Infection
  - 3/201 single = 1.49%
  - 5/435 multiple=1.15%
- No Significant Difference

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Wound Infection Treatment Algorithm

Spine Unstable
- Debridement
- Remove necrotic tissue/ bone graft
- Deep Cultures
  - Appropriate IV ABX
- Repeat Sx prn
- Consider VAC
- **Retain Implants**
- >6 wks re-bone graft

Spine Stable
- Deep Cultures
  - Appropriate IV ABX
- Debridement
  - Necrotic tissue/bone graft
  - **?Remove implants**
- Repeat Sx prn
  - VAC if difficult close
  - ? Flap/plastic surgeon
- 6-12 wks re-instr/graft

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Implant Survival-Debride + ABX Nunez S ESJ 2011

- 44 pts Acute SSI
  - 15 lumbar degenerative
  - 13 Scoliosis
  - 10 fractures
  - 6 tumor
- Implant Survival
  - 85% at 6 months
  - 83% at 12 months
  - 73.4% at 24 months
  - 67% at 3 & 4 yrs

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Does Wound Drain Prevent Hematoma

CLINICAL RESEARCH

Is Closed-suction Drainage Necessary for Single-level Lumbar Decompression?

Review of 560 Cases

Masahiro Kanayama MD, Fumihiro Oha MD, Daisuke Togawa MD, Keiichi Shigenobu MD, Tomoyuki Hashimoto MD

- 560 patients – 1 level discectomies
- Retrospective review
- Split groups
  - prior 7/03 = drain 298 patients
  - Post 7/03 = no drain 262 patients
- Hematomas
  - 0.7% (2/298) drain
  - 0% (0/262) no drain
- 0% infections
- No difference hematoma/infection

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Skin Prep
Does Choice of Prep Solut'n Matter

Efficacy of Surgical Preparation Solutions in Foot and Ankle Surgery

Roger V. Ostrander, Michael J. Botte and Michael E. Brage
J Bone Joint Surg Am. 2005;87:980-985. doi:10.2106/JBJS.D.01977

+ Cultures foot area Pre-Prep				+ Culture Post prep	
Techni-Car 3% Chloroxylenol	95	98	35	6%	
DuraPrep 0.7% Iodine 74% Isopropyl Alcohol	65	45	23	6%	
ChloraPrep 2%Chlorhexidine Gluconate 70% Isopropyl Alcoh	30	23	10	0%	<0.0001

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Spine
SURGERY

Intrawound Vancomycin Decreases the Risk of Surgical Site Infection After Posterior Spine Surgery: A Multicenter Analysis

- 2056 pts/7 centers
  - Av levels 3.6
  - AV LOS 5 D (±4.7)
  - 1695 (82%) incl fusion
  - 1628 (79%) instrument
  - 434 (21.1%) ICU post op
  - 996 (47%) vanco pdr
    - SSI 2.2%/returnOR 0.7%
  - 1090 (53%) no vanco
    - SSI 5.1%/returnOR 3.9%
  - Risk factors
    - # levels/post op ICU
    - ↑ B NSD DM/Obese/Renal

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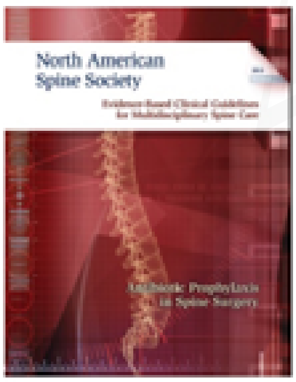
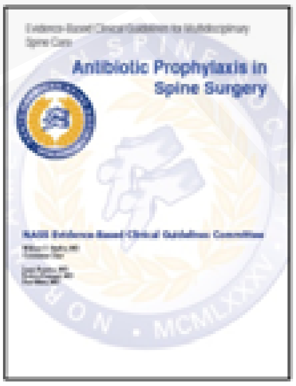
NASS Clinical Guideline
Antibiotic Prophylaxis Spine Sx





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SSI "Care Bundle"

Comparing Surgical Site Infection (SSI) Prevention Guidelines: WHO, CDC, ACS/SIS, and Wisconsin DPH

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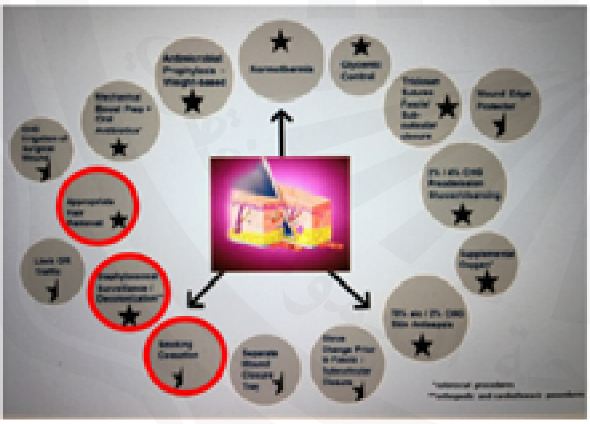
SSI Care Bundle



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Risk Factors
Post Op Wound Infection

Risk Factor	Adjusted Odds Ratios (95% Confidence Interval)	P Value
Diabetes	3.5 (1.2-10)	0.020
Suboptimal timing Prophylactic ABX (>1 hr prior or after incision)	3.4 (1.5-7.9)	0.005
Elevated Serum Glucose >125 mg/dl pre-op >200 mg/dl post op	3.3 (1.4-7.5)	0.005
Obesity (BMI>30 kg/m²)	2.2 (1.1-4.7)	0.034
≥2 resident surgeons	2.2 (1.0-4.7)	0.048

Choosing Graft Materials to Avoid Pseudarthrosis

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Spectrum of Bone Graft Options

- Bone graft extenders
  - Osteoconductive matrices, Demineralized matrices
- Bone graft enhancers
  - Osteopromotive materials (AGF, PDGF)
- Bone graft substitutes
  - Osteoinductive-
    - Recombinant proteins, Demineralized Matrices
  - Osteogenic-
    - Cell-based technologies with synthetic matrices

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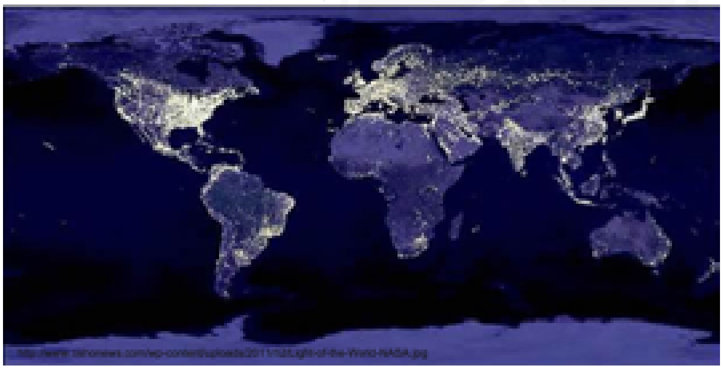
Bone Graft Choices

- Characterized by significant variability



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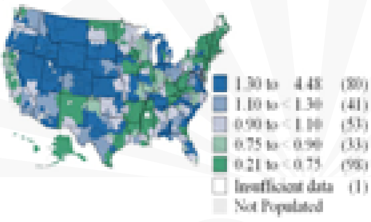
Variability in approach to care

- The presence of Variability is clear evidence of the absence of an evidence-based approach to care.
- Information on clinical outcomes is the fundamental requirement of informed decision-making
- There is significant heterogeneity of application
  - Diagnosis
  - Surgical Approach
  - Comorbidities
  - Cost
  - Complication Profile



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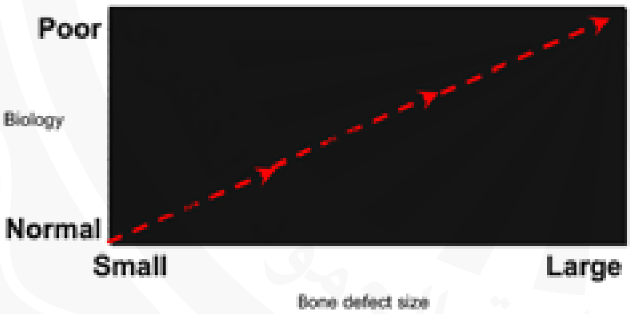
Bone Graft Applications:



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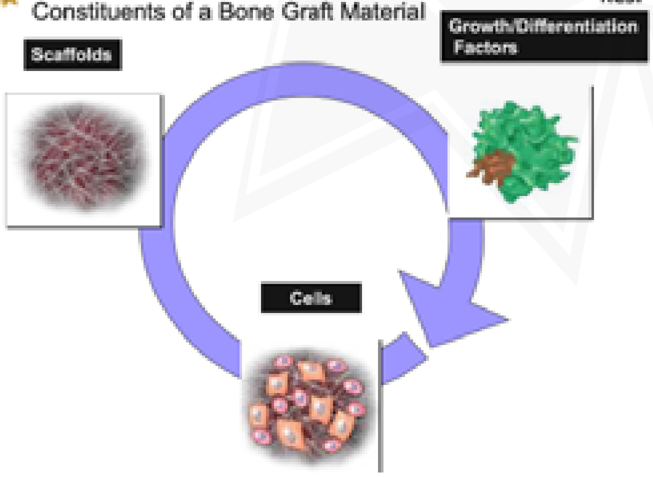
Constituents of a Bone Graft Material

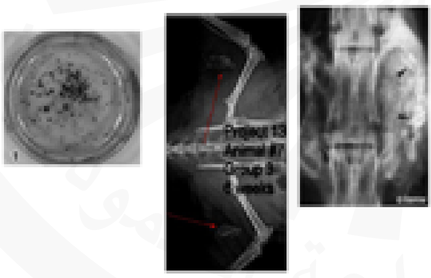


Levels of Proof

- Beyond a Reasonable Doubt
  - Randomized prospective clinical trial
- Preponderance of evidence
  - Preclinical studies
  - Prospective cohort studies; retrospective review
  - Clinical experience

Levels of Proof

- Preclinical
  - In vitro
  - In vivo
- Clinical data



Burden of Proof for Osteobiologics

- Hierarchy of credibility:
  - Cell culture
  - Heterotopic Organogenesis
  - Orthotopic application
  - Phylogenetic progression
    - Rodents
    - Non-human primates
  - Human clinical trials

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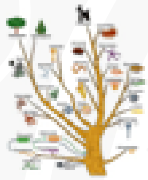
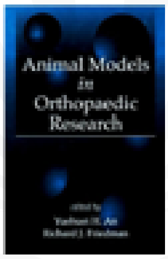
Hierarchy of Evidence

- Progression of evidence
  - Preclinical to Clinical
    - Alkaline phosphatase expression in cell culture to human clinical trials
  - Heterotopic to orthotopic
    - Calvarial defects to posterolateral spine models
  - Phylogenetic progression
    - Eukaryotic cells to human trials





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Overview

- Autograft
- Graft Properties
- Problems with Pre-Clinical Variables
- Problems with literature
- Problems with surgeons
- Biologic Controversies

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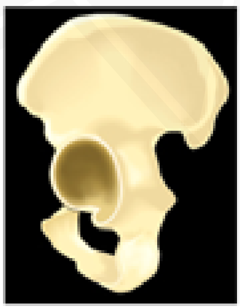

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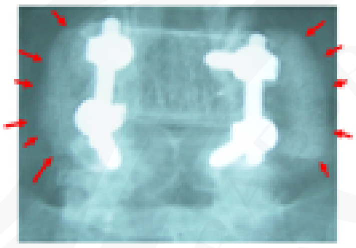
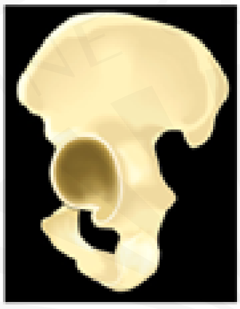
Spinal Fusion





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The Gold Standard

- Historical
- Availability
- Morbidity
- Donor site pain
  - Efficacy of new product
  - Take into account complications
  - Lost art form

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Biological Products

Overview

- Autograft
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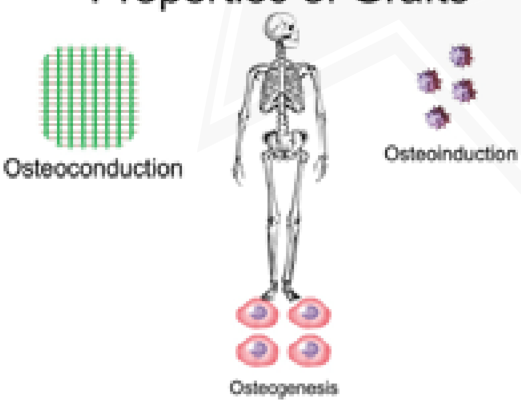
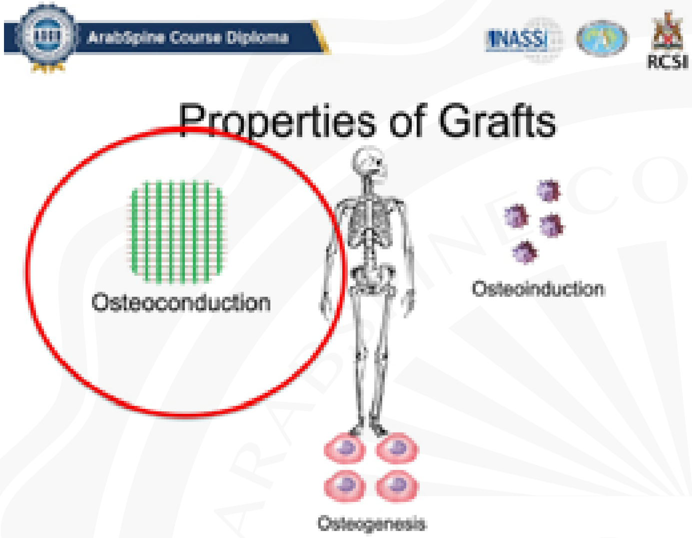
Properties of Grafts

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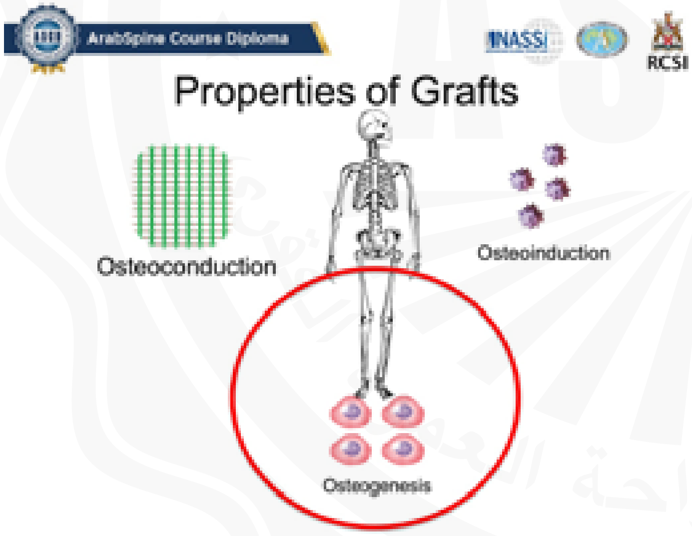
RCSI
Properties of Grafts
Osteoconduction
Osteoinduction
Osteogenesis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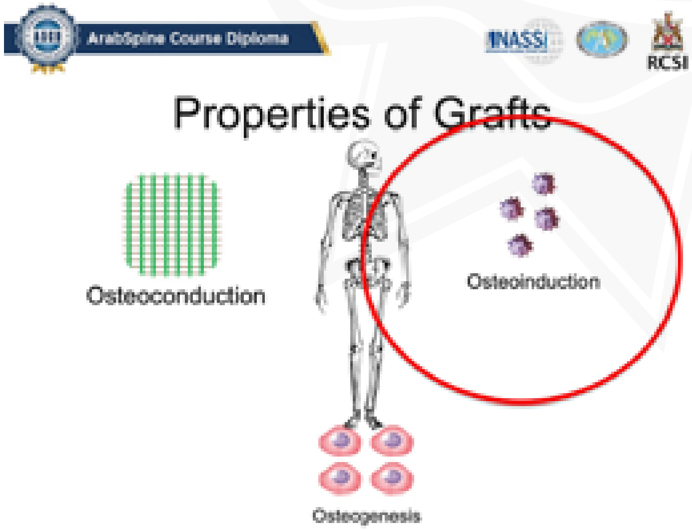
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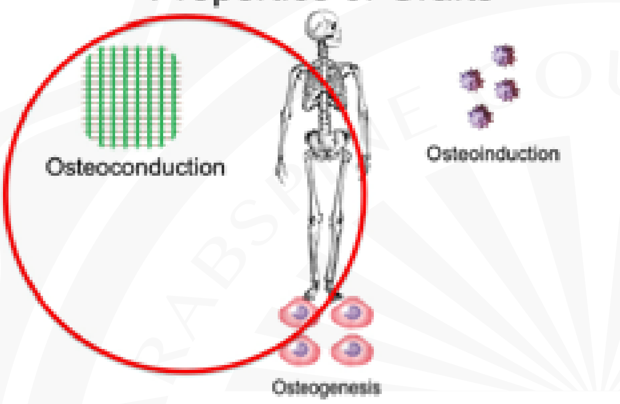
Properties of Grafts



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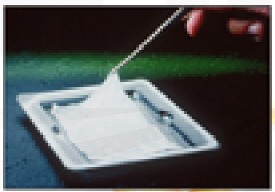
Posterior Lumbar Fusion Model

- Growth factor
- Placed onto collagen sponge
- Needs structural carrier
- Prevent muscles from compressing sponge



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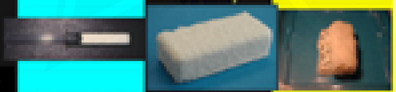
Carriers Structure

Carrier	BCP (60 HA : 40 TCP)	CRM (Collagen + Ceramic)	MasterGraft
			
Concentration	2.0 mg/mL	2.0 mg/mL	1.5 mg/mL
Dose	20 mg/side	20 mg/side	6 mg/side

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Results

Assessment of Spinal Fusion Via Manual Palpation

Treatment Group	No. Assessed Manually for Fusion	No. Assessed As Fusion	Fusion Rate (%)
Group V 1ug BMP-2 + CS	10	4	40
Group VI 1ug BMP-2 + E-Matrix GEL + CS	10	10	100 *
Group VII 0.5ug BMP-2 + CS	10	1	10
Group VIII 0.5ug BMP-2 + E-Matrix GEL + CS	10	10	100 **

*P<0.01

**P<0.001

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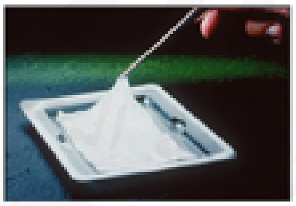
New Carriers

- Patents with collagen delivery
- Carriers to extend dosage
- Lab studies
  - Growth factors – 20% healing rate
  - With new carrier healing rate increases to 100%
  - Lower dosages
  - Decreased cost



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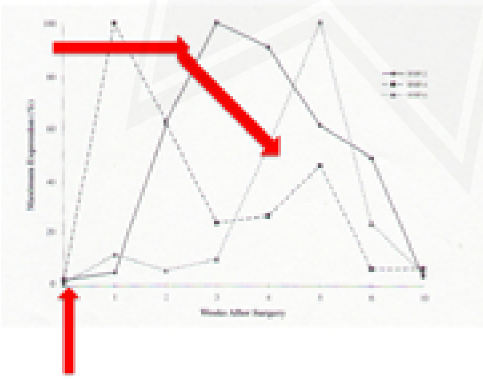
Time Release

- BMP-2
- BMP-4
- BMP-6



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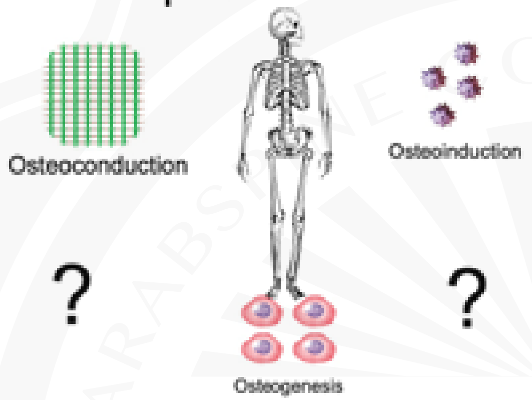
Properties of Grafts



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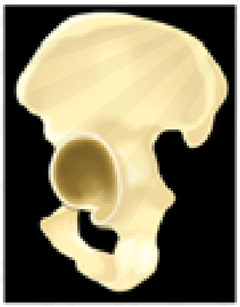

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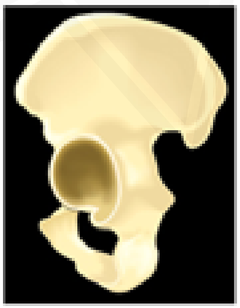
- Biologic Controversies



Dosage

Species	BMP Dose (mg/cc)	Healing Time
Rat	0.02	2-3 weeks
Rabbit	0.20	3-4 weeks
Dog	0.40	6-8 weeks
Monkey	0.75-1.5	3-5 months
Human	1.5	4-6 months

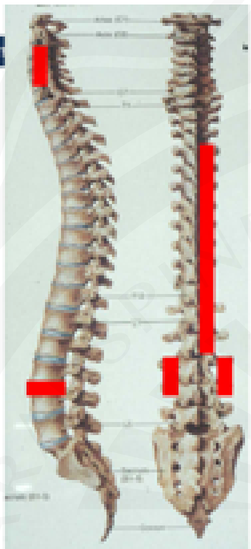
Martin, Boden et al., Journal of Spinal Disorders, 1999

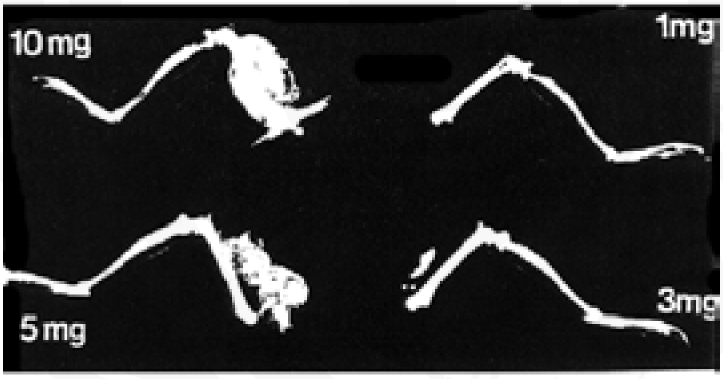
Differences in Environments

- Animal studies
- Pediatric fractures
- Adult fractures
- Oral/maxillofacial/dentistry
- Cavitary defects
- Cervical fusion
- Tibial non-unions
- Interbody fusion
- Lumbar posterolateral fusion
- Lumbar pseudarthrosis

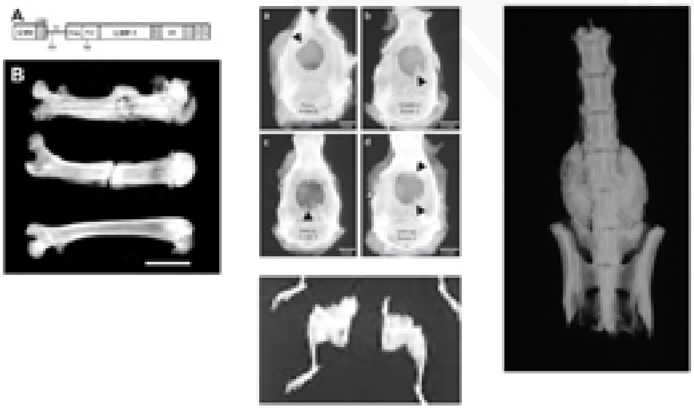
Differences in Environments

- Pediatric patient
- Healthy adult
- Unhealthy adult
- Elderly
- Osteoporotic patients
- Rheumatoid arthritis
- Multiple surgeries
- Revisions



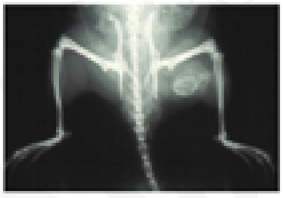


Variable Models



Variables

- Animal models used
  - Lower or higher order animal
- Location/site of testing
  - Rat model – tibial defect versus spinal fusion
  - Canine model – same area – more difficult to heal
  - Rat model – tibial defect – non critical
  - Sheep model
- Environment of the animal/model
  - Age of the animal



Overview

- Autograft
- Graft Properties
- Problems with Pre-Clinical Variables
- Problems with literature
- Problems with surgeons
- Biologic Controversies

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Literature

- Novel technology
- Approach cautiously
- Perform well-designed studies
- Outcomes
- Results
- Pass judgement on the merits of the new technology
- Media disseminates information

The Evidence

- How do we choose the best options?
- Scientific data
- PubMed/Medline
- Peer-reviewed published literature
- Evidence/studies – structured
- Personal experience/try products
- Case series – unstructured
- No Science

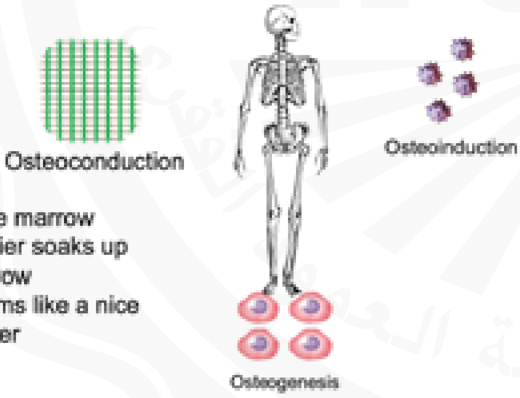
The Evidence

- How do we choose the best options?
- Scientific data
- PubMed/Medline
- Peer-reviewed published literature
- Evidence/studies – structured
- Personal experience/try products
- Case series – unstructured
- No Science

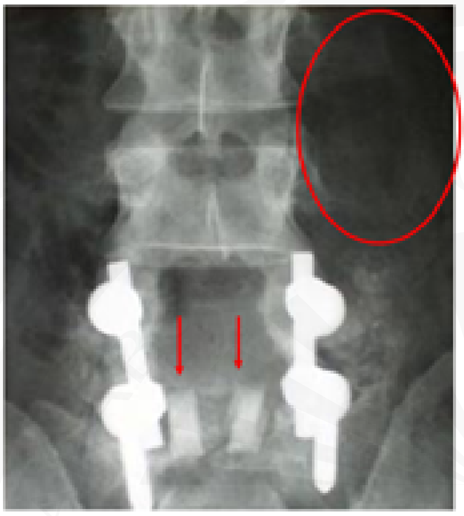
Evidence

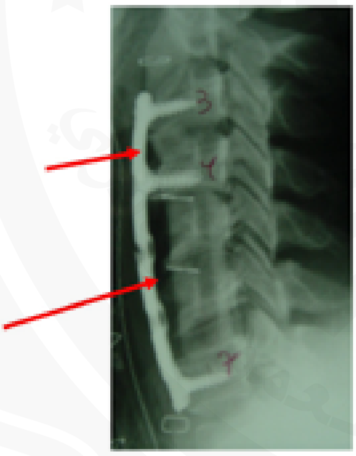
- Many products released without any preclinical studies
- Many feel they are in a class of biologics and the evidence is inferred by other products
  - DBM
- Many have no evidence of efficacy for the intended use in patients
  - Heals in lab, human efficacy implied

Combination Studies



- Bone marrow
- Carrier soaks up marrow
- Seems like a nice carrier



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Potency of DBMs

BMP-2 pg/cc DBM	Lot #1	Lot #2	Lot #3
Allomatrix	118.8	67.8	66.3
DBX Demineralized Bone Matrix	179.7	94.1	90.9
Dynagraft II Osteoinductive Gel	188.9	95.6	54.2
Dynagraft II Osteoinductive Putty	226.8	67.9	55
Grafton Crunch	73.5	68.1	66.9
Grafton Gel	70.5	69.9	60.3
Grafton Putty	84.7	80	78.6
Intergro DBM Putty	77.5	72.7	72.74
Osteofil Allograft Paste	81.6	68.1	66.5
F=6.43, p<0.01; F=1.19 NS	122.4444444	76.02222222	67.93777778

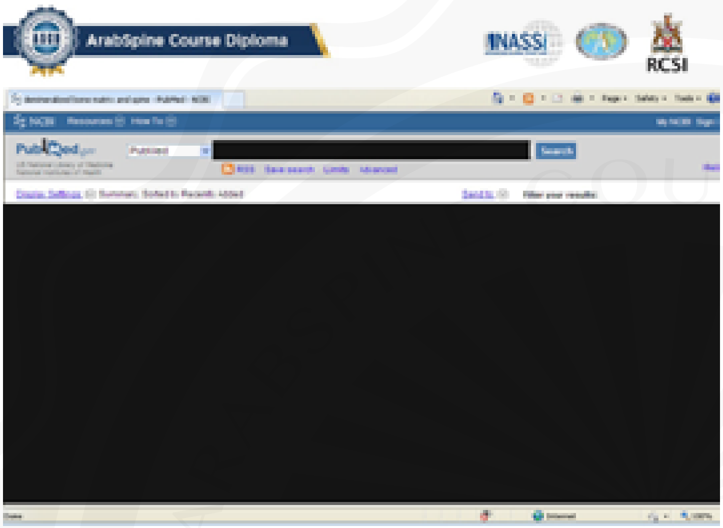
Pre-Clinical Evidence on DBMs

POSITIVE

- Wang, NASS, 2000
- Wang, ORS, 2001
- Lee, NASS, 2001
- Frenkel, Spine, 1993 (Grafton, dog)
- Lindholm, CORR, 1982 (rats)
- Morone, Spine, 1998 (rabbit)
- Oikarinen, CORR, 1982
- Martin, Spine, 1999 (Grafton, rabbit)

NEGATIVE

- Cook, Spine, 1994
- Cook, Spine, 1995 (NS, dogs)
- Boden, Spine, 1995
- Boden JBJS, 1995 (rabbits)
- Silcox, Spine, 1998 (rabbits)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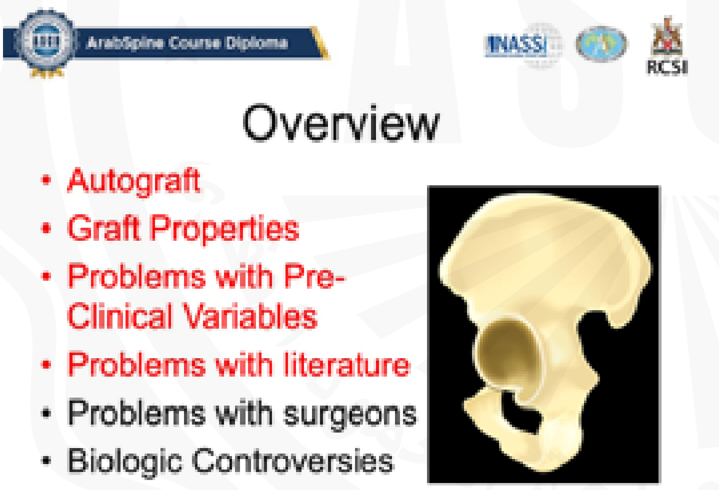
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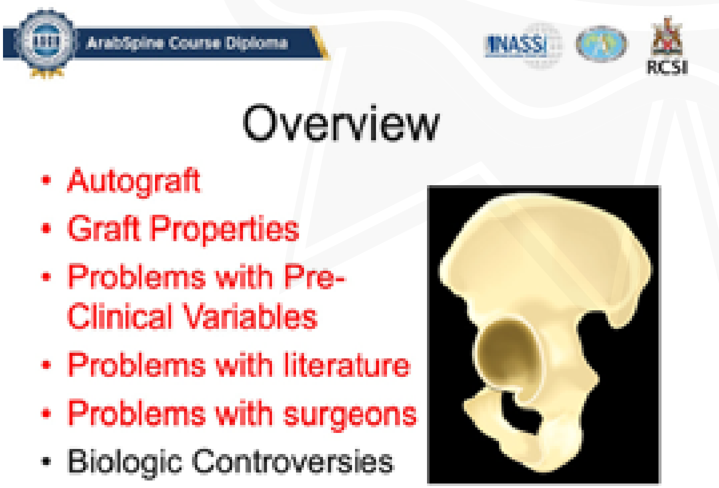
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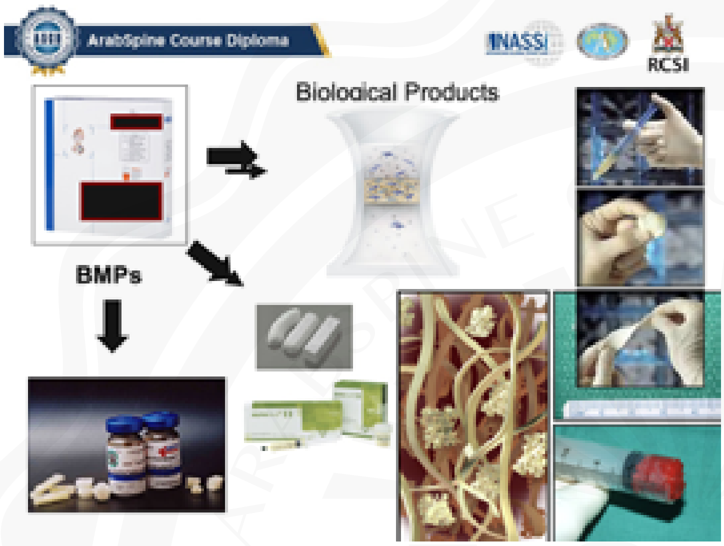
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Biological Products
BMPs

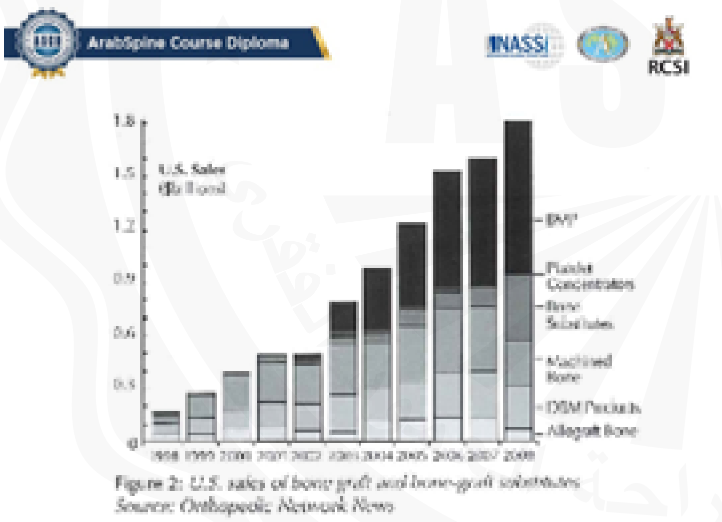
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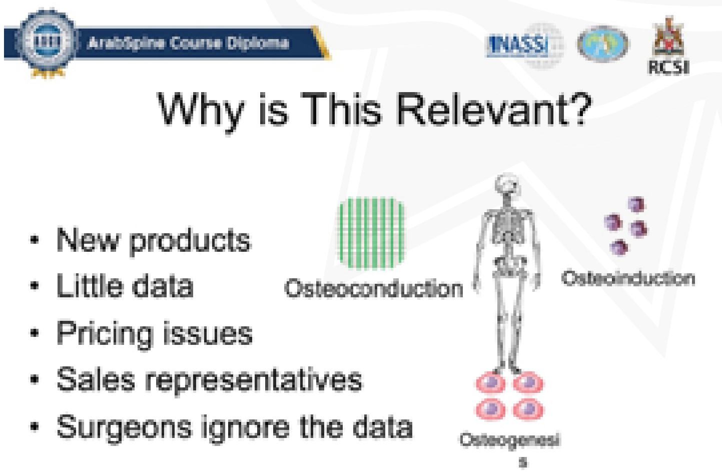
Figure 2: U.S. sales of bone graft and bone-graft substitutes
Source: Orthopedic Network News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Why is This Relevant?
• New products
• Little data
• Pricing issues
• Sales representatives
• Surgeons ignore the data
Osteoconduction
Osteoinduction
Osteogenesis

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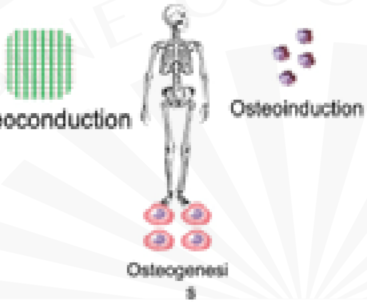
Problems

- Platelet gels
  - Data shows inhibition
  - Still in use
- DBM
  - How many tested in humans?
  - rhBMP
  - Infuse - actifuse
  - Science ignored
  - 300 Million – poor data
- Allograft + cells
  - Pricing equivalent to BMP
  - No data



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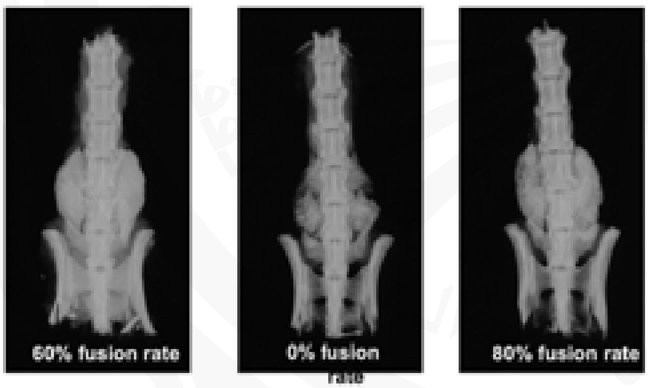
DBM

Wang et al. Spine 2002



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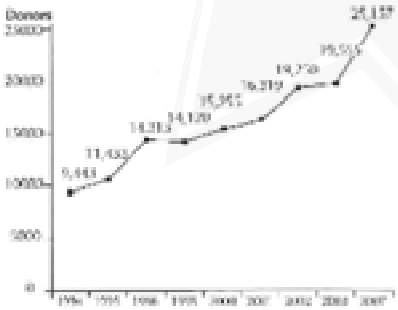

Figure 1: U.S. trends in musculoskeletal tissue donors. Source: AATB Annual Survey

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Controversy

- Question of under-reporting of complications
- Industry sponsored trials for FDA approval

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Adverse Events: Recent Data

Mroz TE, Wang JC, Hashimoto R, et al. Complications related to osteobiologics use in spine surgery: a systematic review. Spine 2010;35:S86-104.

- Systematic review of the literature on adverse events
- Cervical, thoracic, and lumbar

Cervical

Table 2. Summary of Complications Associated With BMP Use in Cervical Spine Surgery

Outcomes	Studies (n)	References	Patients (n)
Resorption/osteolysis (vertebrae, endplate, or endplate)	[illegible]	[illegible]	[illegible]
Extradural, ectopic, or heterotopic bone formation	[illegible]	[illegible]	[illegible]
Graft subsidence	[illegible]	[illegible]	[illegible]
Graft migration	[illegible]	[illegible]	[illegible]
Dysphagia, neck swelling, respiratory difficulties	[illegible]	[illegible]	[illegible]
Elevated antibody response to rhBMP-2	[illegible]	[illegible]	[illegible]
Elevated antibody response to bovine type I collagen	[illegible]	[illegible]	[illegible]
Wound complications (including hematoma, seroma, infection, or dehiscence)	[illegible]	[illegible]	[illegible]
Hematoma	[illegible]	[illegible]	[illegible]
Seroma	[illegible]	[illegible]	[illegible]
Wound infection	[illegible]	[illegible]	[illegible]
Local or systemic toxicity	[illegible]	[illegible]	[illegible]

Thoracic

Table 3. Summary of Complications Associated With BMP Use in Thoracic Spine

Outcomes	Studies (n)	References	Patients (n)
Dysphagia, neck swelling, respiratory difficulties	[illegible]	[illegible]	[illegible]
Wound complications (including hematoma, seroma, infection, or dehiscence)	[illegible]	[illegible]	[illegible]

Lumbar

Table 1. Summary of Complications Associated With BMP Use in Lumbar Spine Surgery

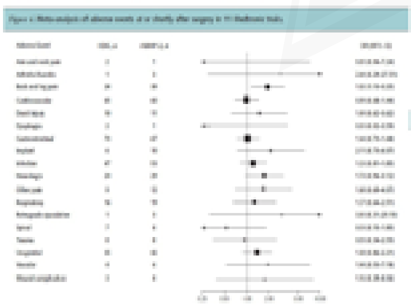
Outcomes	Studies (n)	References	Patients (n)
Resorption/osteolysis (vertebrae, graft, or endplate)	[illegible]	[illegible]	[illegible]
Extradural, ectopic, or heterotopic bone formation	[illegible]	[illegible]	[illegible]
Graft subsidence	[illegible]	[illegible]	[illegible]
Cage migration	[illegible]	[illegible]	[illegible]
Dysphagia, neck swelling, respiratory difficulties	[illegible]	[illegible]	[illegible]
Elevated antibody response to rhBMP-2	[illegible]	[illegible]	[illegible]
Presence of neutralizing antibodies against rhBMP-2	[illegible]	[illegible]	[illegible]
Elevated antibody response to bovine type I collagen	[illegible]	[illegible]	[illegible]
Wound complications (including hematoma, seroma, infection, or dehiscence)	[illegible]	[illegible]	[illegible]
Hematoma	[illegible]	[illegible]	[illegible]
Seroma	[illegible]	[illegible]	[illegible]
Wound infection or dehiscence	[illegible]	[illegible]	[illegible]
Radiculitis (new onset)	[illegible]	[illegible]	[illegible]
Inflammatory response to collagen carrier	[illegible]	[illegible]	[illegible]
Local or systemic toxicity	[illegible]	[illegible]	[illegible]

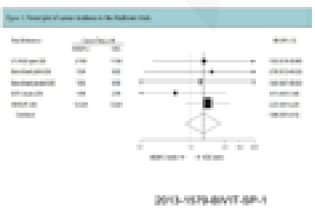
Annals of Internal Medicine | Review

Safety and Effectiveness of Recombinant Human Bone Morphogenetic Protein-2 for Spinal Fusion

A Meta-analysis of Individual-Participant Data

Mark C. Simmonds, PhD, MA; Jennifer V.E. Brown, MSc, BA; Morag K. Heirs, MSc, MA; Julian P.T. Higgins, PhD, BA; Richard J. Mannion, PhD; Mark A. Rodgers, MSc, BSc; and Lesley A. Stewart, PhD, MSc, BSc





REVIEW | Annals of Internal Medicine

Effectiveness and Harms of Recombinant Human Bone Morphogenetic Protein-2 in Spine Fusion

A Systematic Review and Meta-analysis

Rongwei Fu, PhD; Shelley Selph, MD; Marian McDonagh, PharmD; Kimberly Peterson, MS; Arpita Tiwari, MHS; Roger Chou, MD; and Mark Helfand, MD, MS

- 13 RCTs and 31 Prospective Cohort Studies
  - Similar Fusion Rates and Overall Success
  - Similar adverse events
  - BMP-2 associated with increased cancer rate
    - Small numbers and heterogeneous tumors
  - Early disclosure of all data would have better informed physicians and public than original trial publications did

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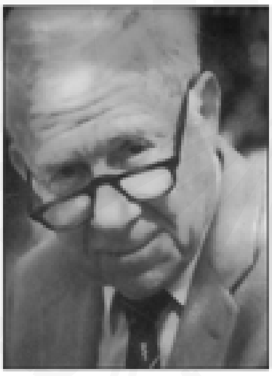
The Future

- Biologics will play a key role in the future of Orthopaedic surgery
- Scientific advances made by scientists
- We must critically review the evidence and make decisions based on good science



CSF Leak: Management

Educational objectives:

- Incidence of iatrogenic dural lesions
- Differentiate types of dural lesions
- Understand different methods of repairing dural lesions
- Understand postoperative management of dural lesions

Outline

- Epidemiology
- Durotomy types and principles of dural closure

Epidemiology

- ~4-8% incidental durotomy rate primary lumbar procedure
- ~16% in lumbar revision cases
- ~1% in anterior cervical spine
- Khan et al Spine 2006
- Hannalah et al JBJS am 2008
- Cammisa et al Spine 2000

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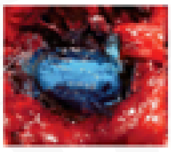
Sealants:
DuraSeal
Resorbable hydrogel (4-8 weeks)
Polyethylene glycol & trilysin amine
FDA approved as spinal sealant



Two cases of neural injury
-swelling cervical spine
-cauda equina due to dislodgement
Thavarajah et al. Spine 2010
Mulder et al. Spine 2009

Tisseel
Human cryoprecipitate and thrombin
Used widely but not FDA approved

Review: *Epstein Spine J 2011*

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The FDA has approved **Nycomed Austria** GmbH's TachoSil, an absorbable sealant patch designed to prevent bleeding from small blood vessels after cardiovascular surgery. The patch is composed of collagen from horse tendons, and coated with fibrinogen and thrombin which are extracted from donated human plasma. When applied to the wound site, the thrombin and fibrinogen combine to form fibrin monomers, and endogenous factor XIII facilitates the cross-linking of these monomers, forming an air- and liquid-tight seal.

Tachosil adhesive patch

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Incidental durotomy types:

1. Posterior tear (no dural defect)
2. Posterior tear with defect (suturable patch)
3. Lateral tear (not reachable with suture)
4. Anterior tear (transthoracic)

adhesive patch and or sealant

lumbar drain (preoperative)

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TYPE 1

- CSF
- No visable tear

- FIBRIN GLUE
- LAYERED CLOSURE

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TYPE 2

- DURAL TEAR
- NO CSF
- ARACHNOID INTACT

- LAYER FIBRIN GLUE
- LAYERED CLOSURE

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TYPE 3

- OBVIOUS DURAL TEAR
- CSF LEAK
- NO HERNIATION

- FAT PLUG
- FIBRIN GLUE
- LAYERED CLOSURE

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TYPE 4

- OBVIOUS DURAL TEAR
- CSF LEAK
- SINGLE ROOT PARTIAL HERNIATION

- FAT PLUG
- FIBRIN GLUE
- LAYERED CLOSURE

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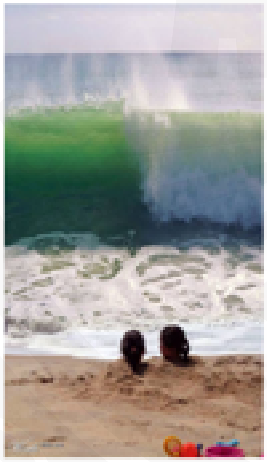

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TYPE 5

- OBVIOUS DURAL TEAR
- CSF LEAK
- MULTIPLE ROOT HERNIATION

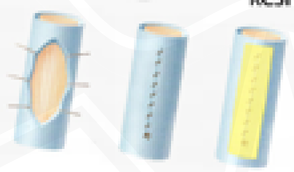
'SPAGETTI'

TREATMENT TYPE 5

- DROP THE LEGS
- MANIPULATE ROOTS INTO DURAL CAVITY WITH PATTI
- LEAVE THE PATTI IN PLACE
- SUCK OFF CSF
- FINISH THE DECOMPRESSION !!!!!
- IF NOT POSSIBLE MAKE DEFECT LARGER
- REPAIR

Round needle

Cutting needle



Technical points:

Use toothed forceps to grasp dural edges

Use stay sutures if necessary (lift dural edges)

Keep cauda fibres away from dural edge with neuro patty or L-shaped feeler

Preferably monofilament suture

Optional gravity or low suction drain (Jackson-Pratt) – exit lateral from wound

Postoperative care:

Optional bedrest in minor tear

Strict bedrest if CSF in drain or headache

Epidural drain for up to 10 days if CSF fistula (consider antibiotics)

Lumbar drain (~150 ml per day) if major repair or anterior thoracic

Post Operative Leak

- Skin Suture
- Lumbar Drain
- Explore

Key Messages

- Incidence <10% for primary lumbar procedures
- Incidence ~1% for primary anterior cervical procedures
- Preoperative recognition of dural defect / calcification
- Range of material necessary (sutures, patches, sealants)
- Gelfoam and hydrogels can swell
- Diverting low suction drain useful

MIS Complications

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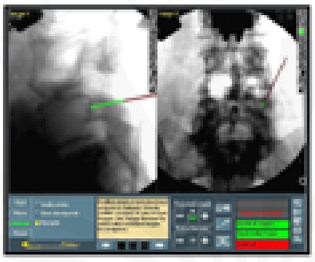
Complications

- Complications will occur
- Understand limitations of approach
- Learning curve
- Proper education
  - Learn how to handle complications as you are learning the procedure



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Surgical Complications

- Define the pathology
- Pre-operative Studies
- Intraoperative anatomy
- Surgery

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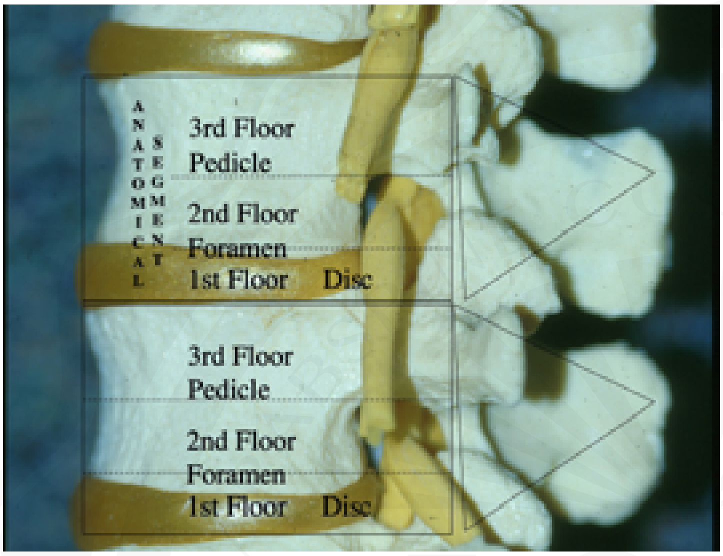

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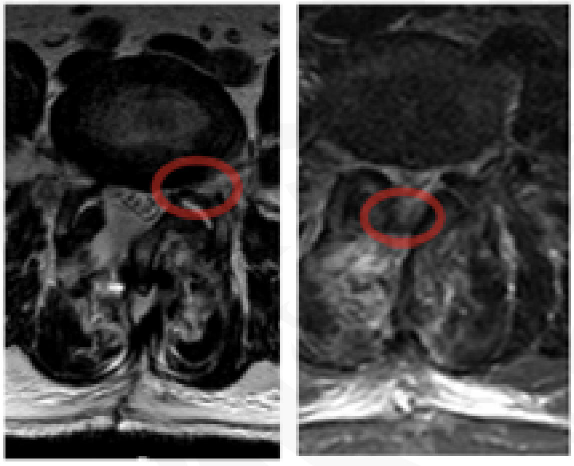

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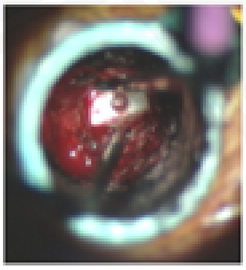

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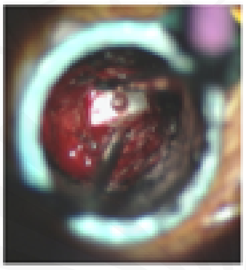

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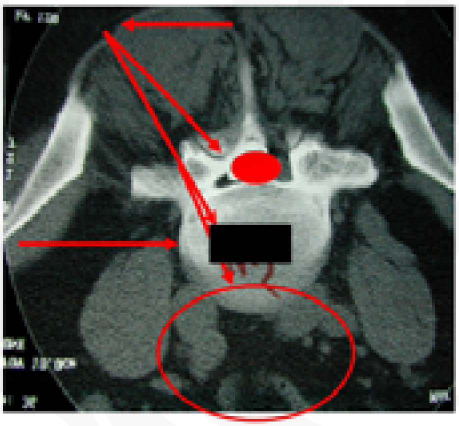
Pre-Op Planning



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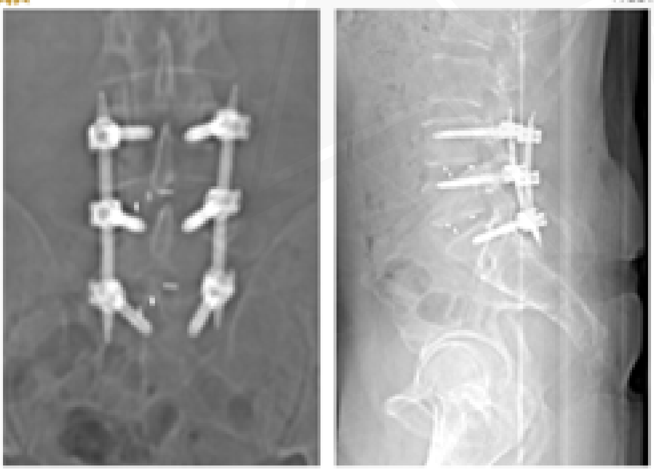


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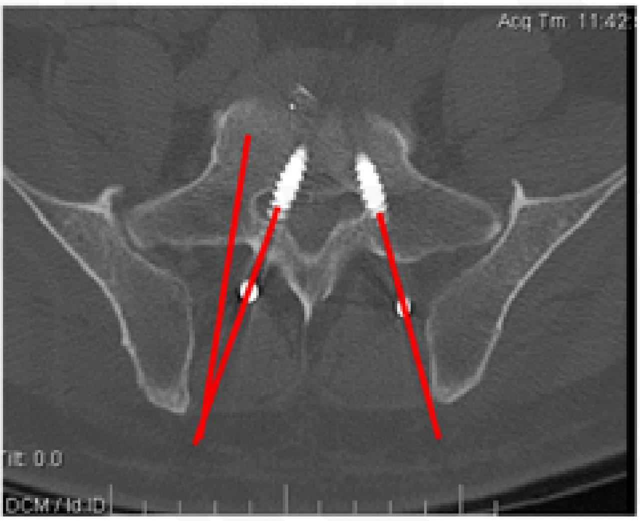
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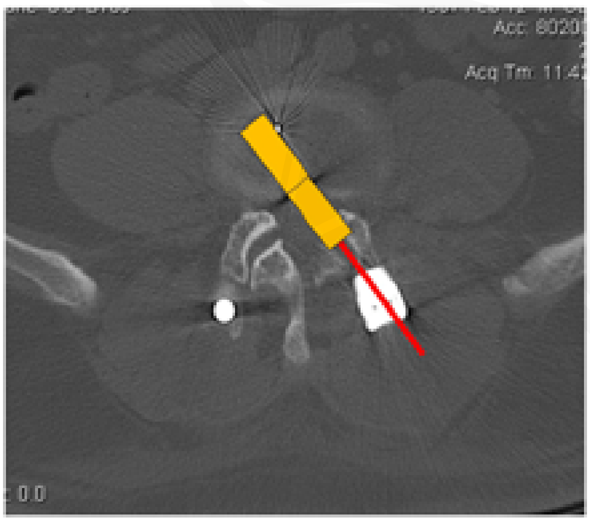
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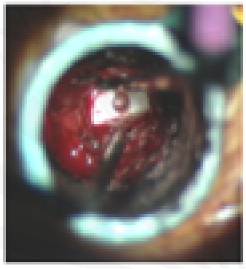
Surgical Complications

- Define the pathology
- Pre-operative Studies
- Intraoperative anatomy
- Surgery



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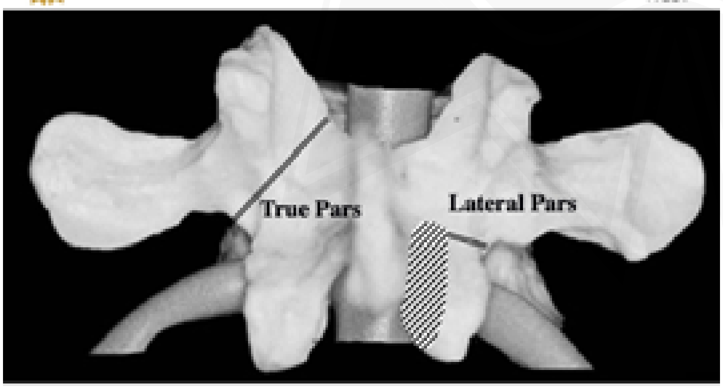
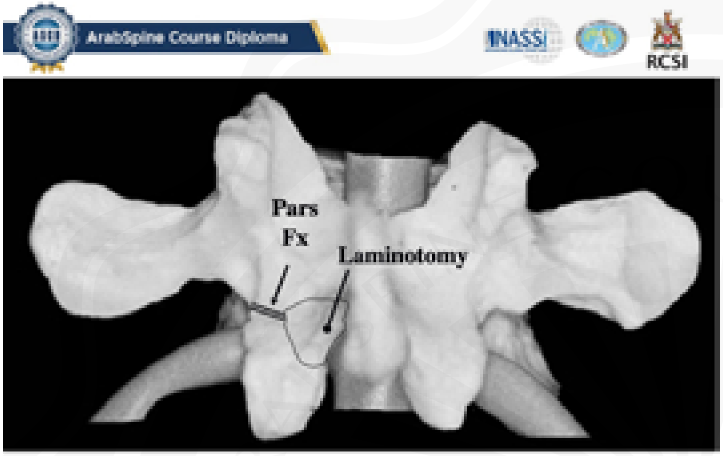
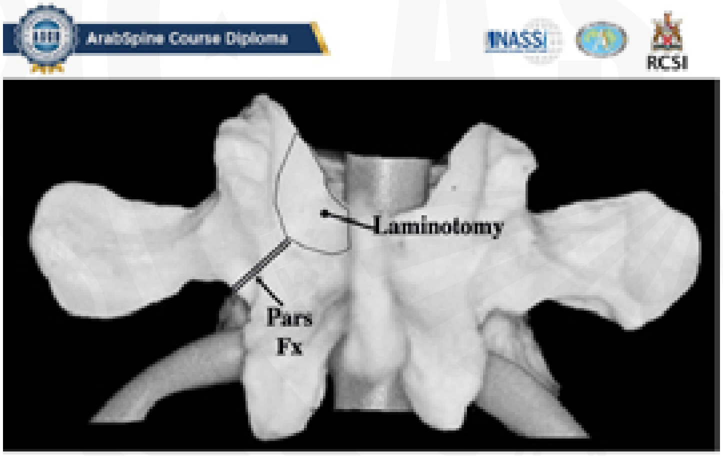
- Surgery




ArabSpine Course Diploma
INASS
RCSI
Pars
Fx
Laminotomy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RCSI
Laminotomy
Pars
Fx


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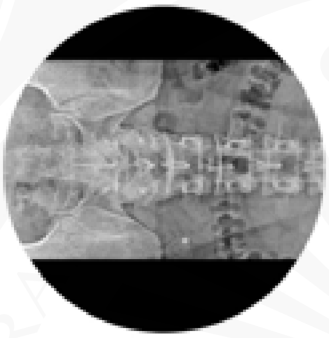
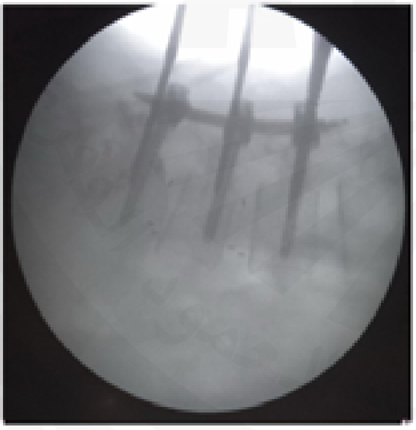
INASS
RCSI
Microscopic View





- Scoliosis
- Rotation
- Lateral pedicle not symmetric

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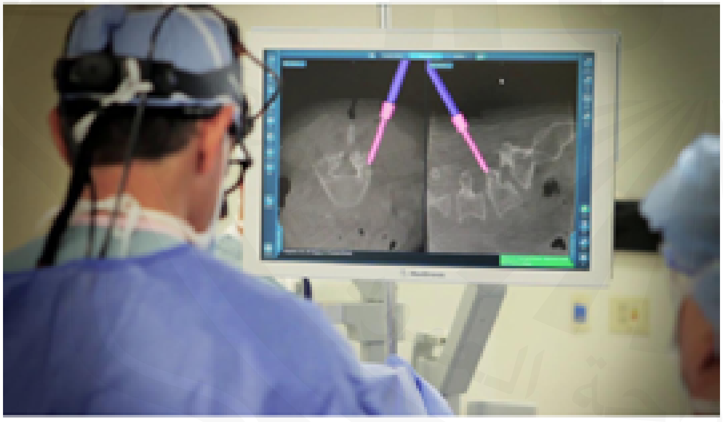

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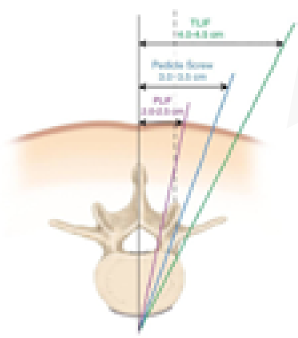
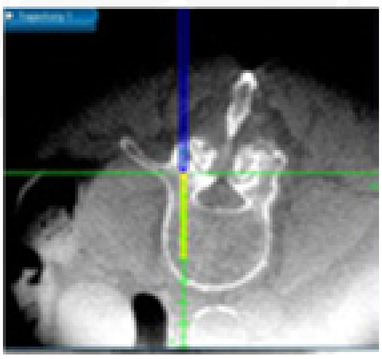
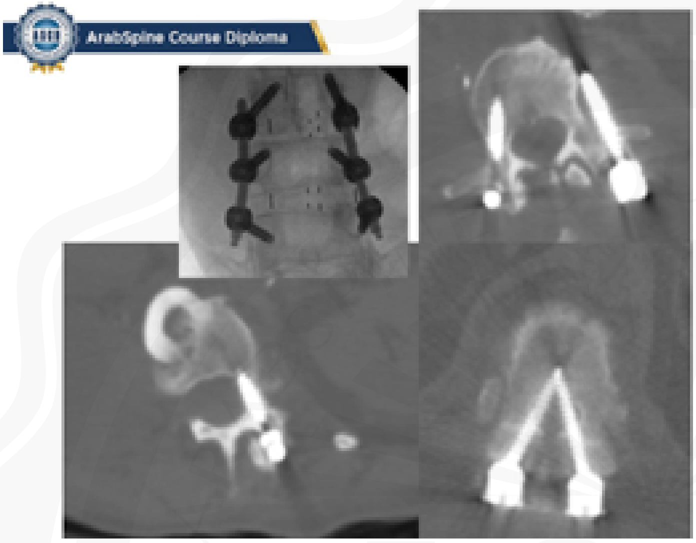
Double Check Everything



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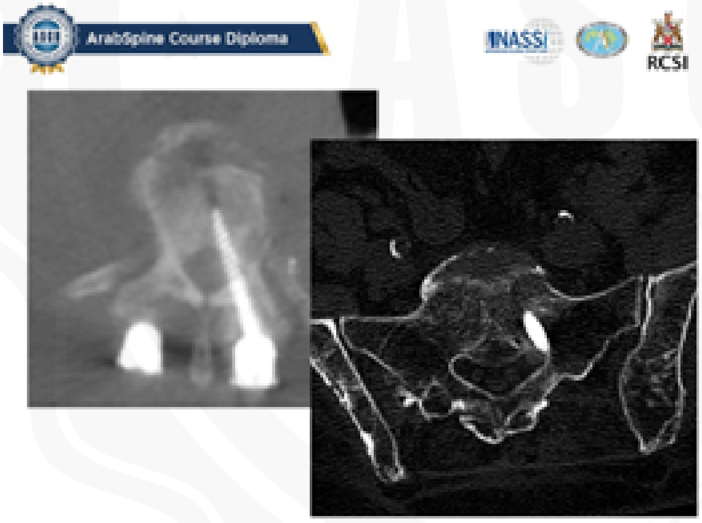
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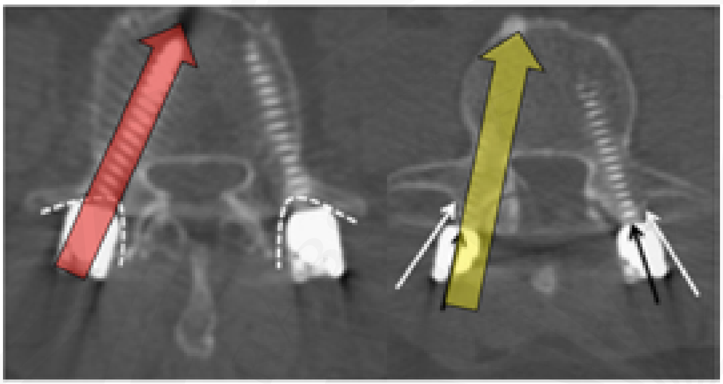

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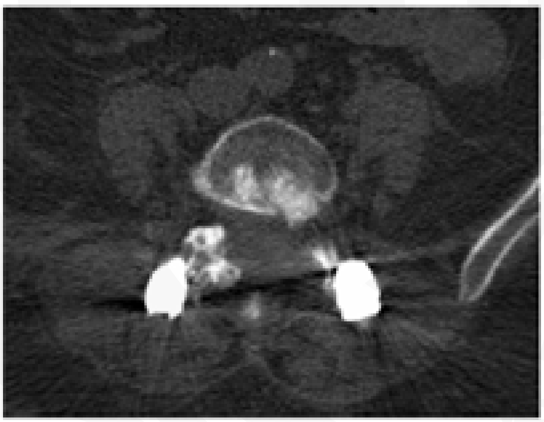

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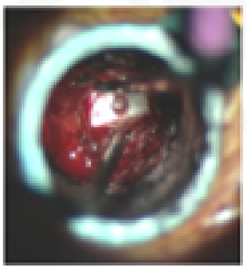
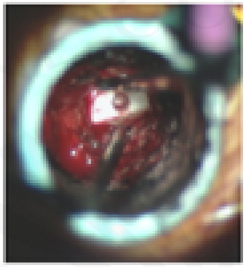
Surgical Complications

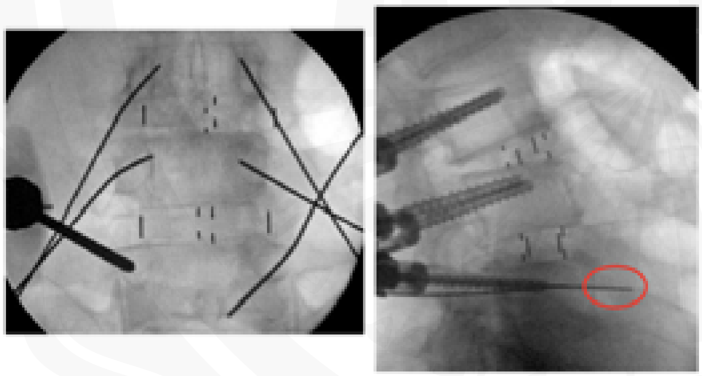
- Define the pathology
- Pre-operative Studies
- Intraoperative anatomy
- Surgery

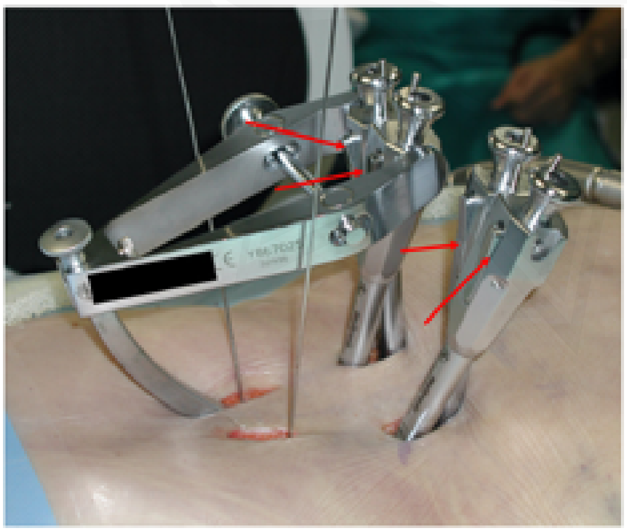


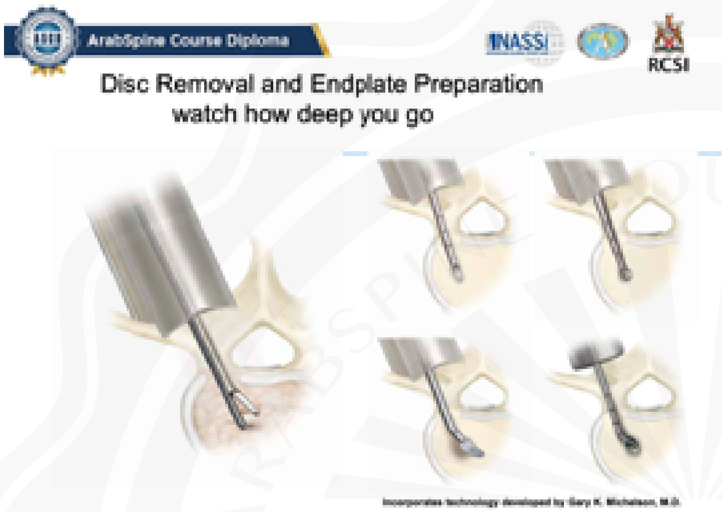
Surgical Complications

- Define the pathology
- Pre-operative Studies
- Intraoperative anatomy
- Surgery





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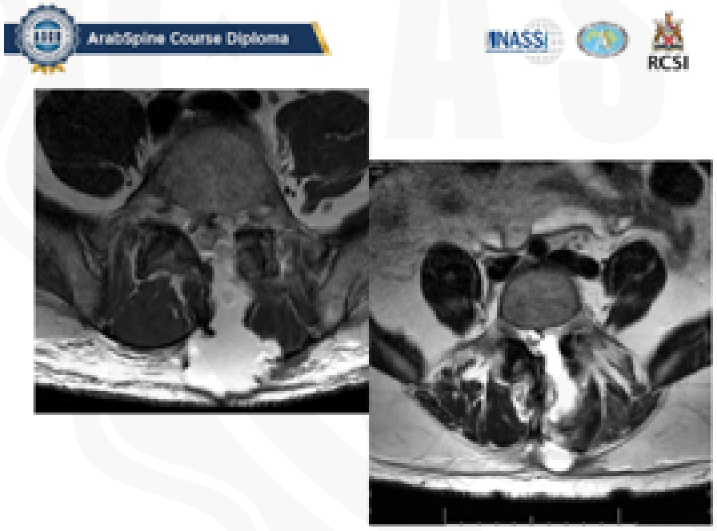
Disc Removal and Endplate Preparation
watch how deep you go
Incorporates technology developed by Gary K. Michelson, M.D.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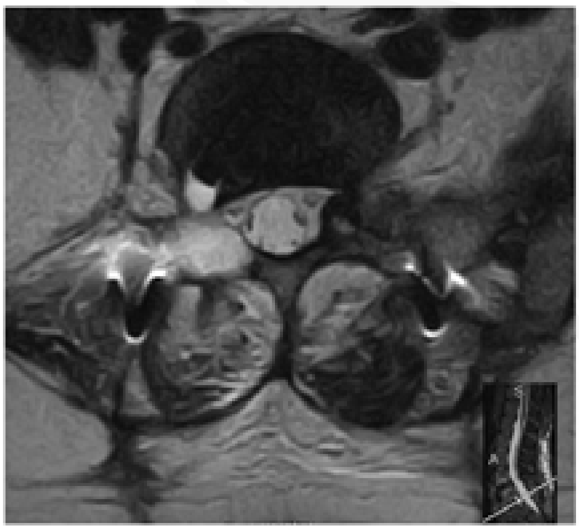

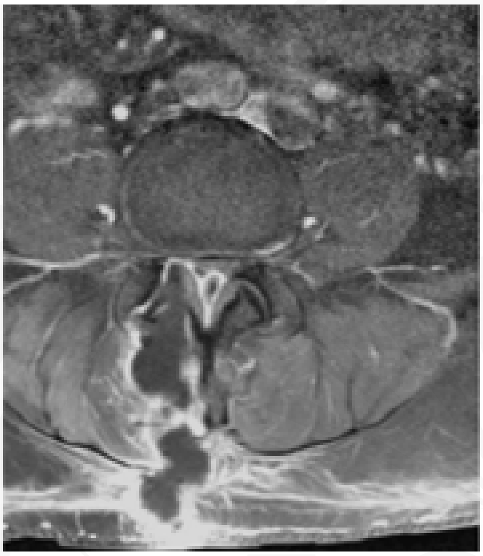

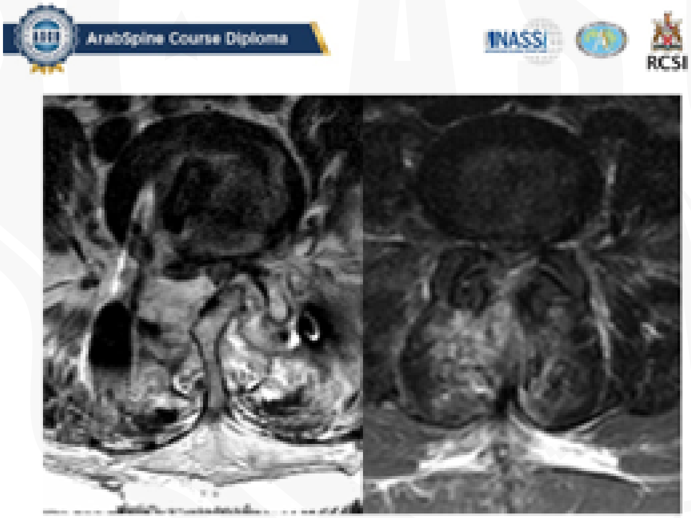
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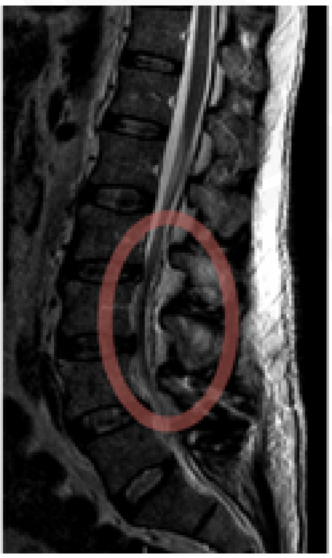

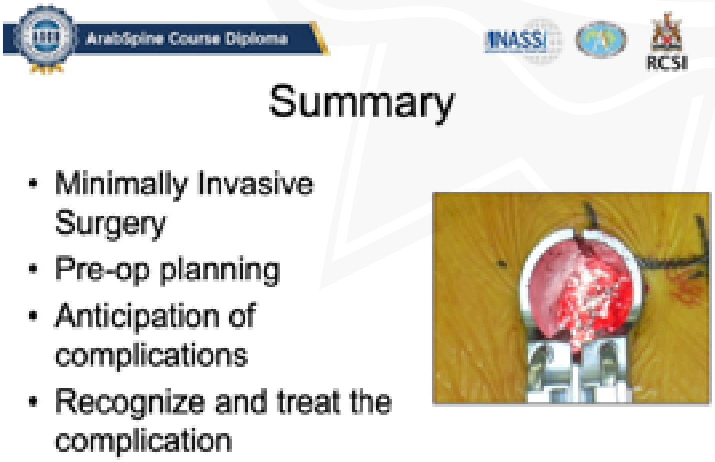
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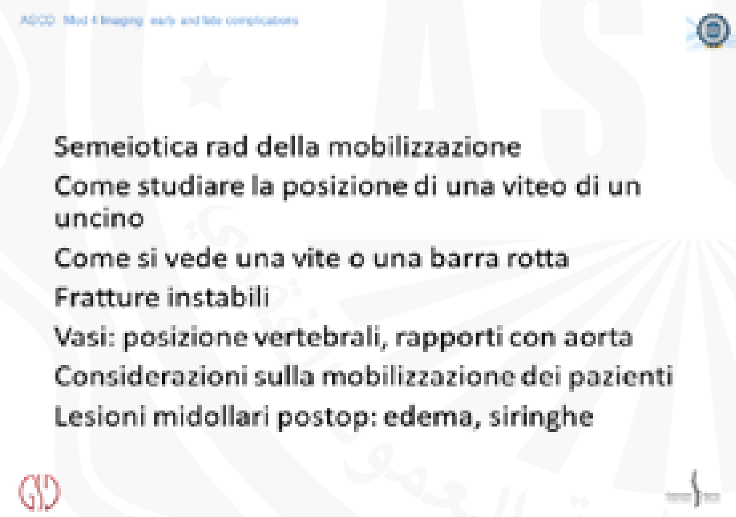
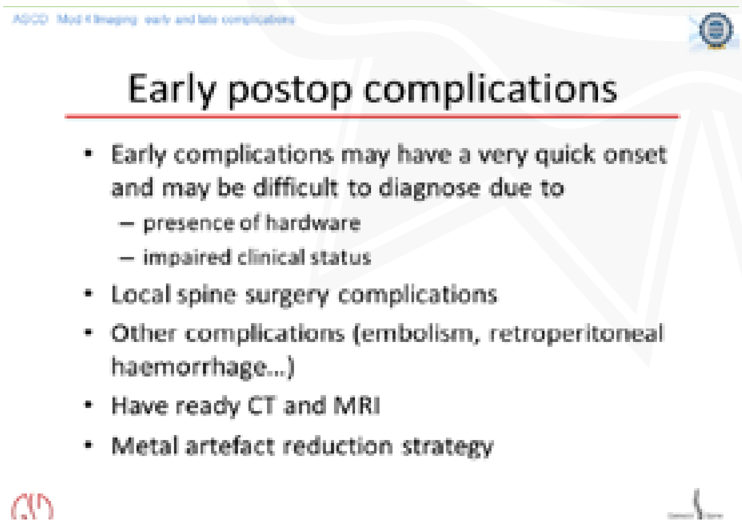
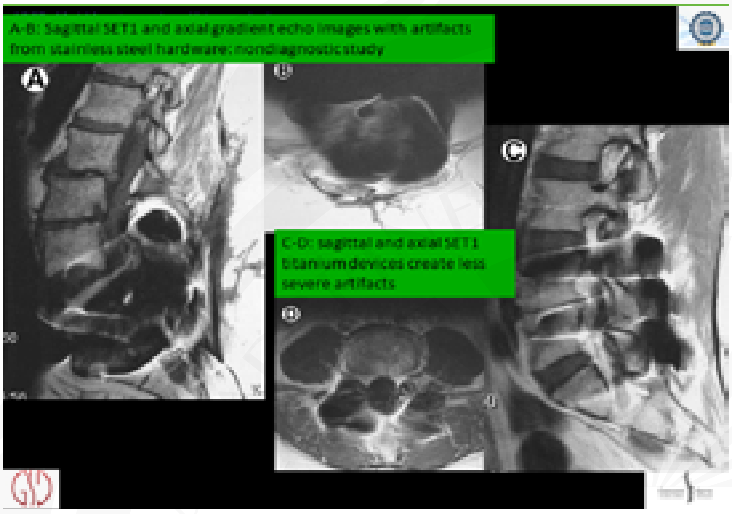
Summary
• Minimally Invasive Surgery
• Pre-op planning
• Anticipation of complications
• Recognize and treat the complication

Value of Imaging in Post-Op Spivne: Imaging of Early & Late Complications





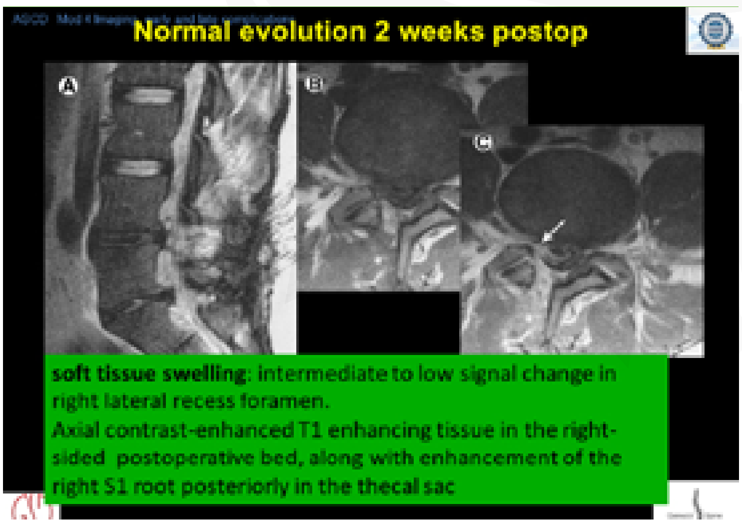


ASCD Mod 4 Imaging early and late complications

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

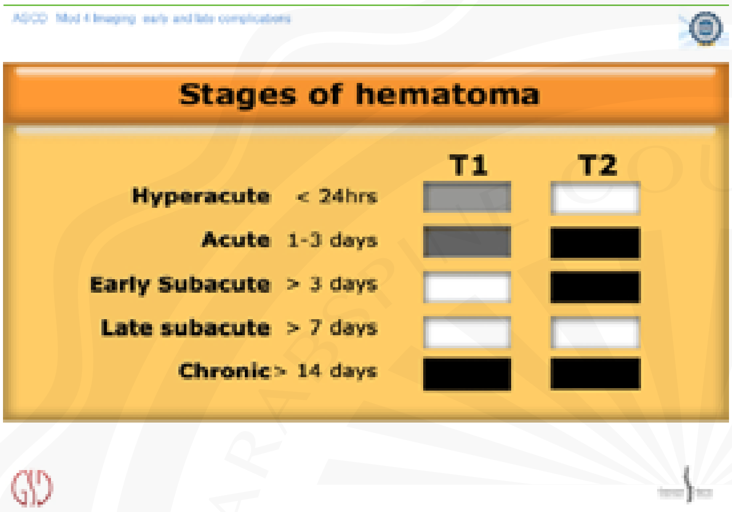


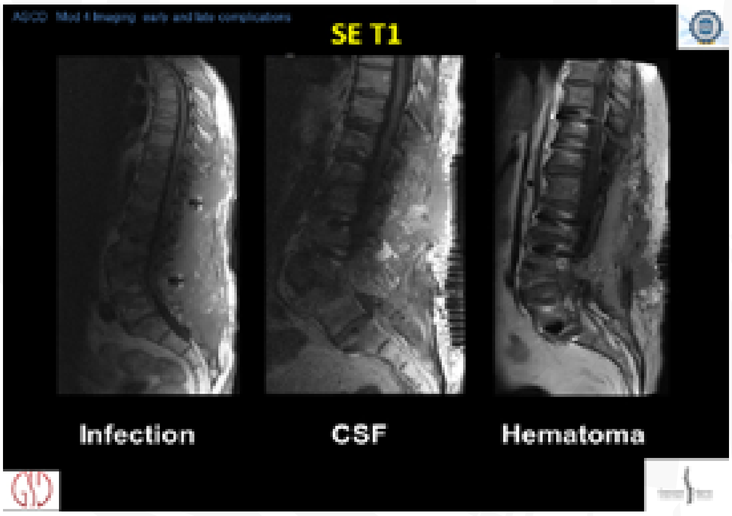
Early postop complications

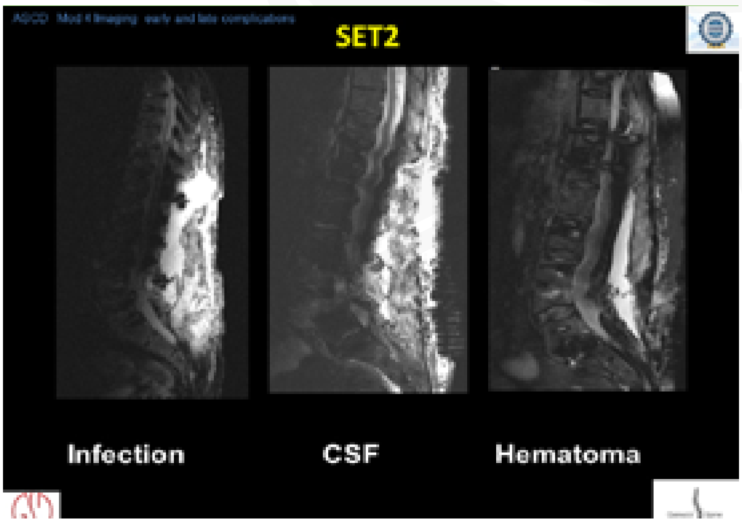
- Postoperative fluid collections
  - Seromas
  - CSF collections from dural leaks
  - Hematomas
  - Intraspinal hematomas
  - Postoperative abscess or subdural abscess
  - Texiloma
- Cord: direct or indirect lesions
- Misplaced instrumentation
  - direct lesions of anatomical structures dural sac, cord,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

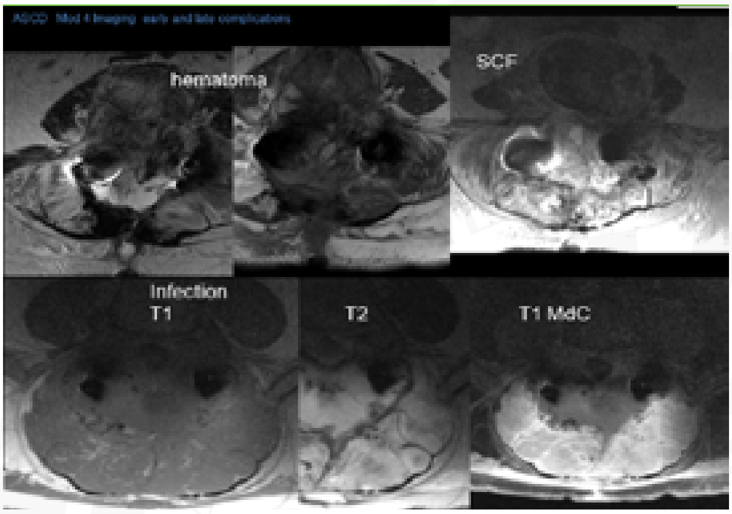
MR differential diagnosis findings

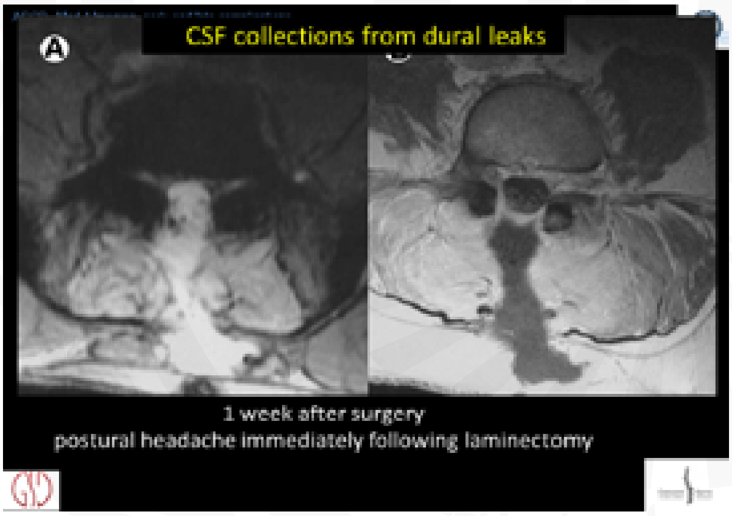
- **Hematoma**
  - Well defined borders
  - Intermediate signal intensity in T1, high in T2 and STIR
  - Hemosiderin spots
- **CSF**
  - poorly defined
  - Low signal in T1, high in STIR and T2
- **Abscess**
  - Well defined
  - Intermediate to low signal intensity in T1, high in STIR and T2
  - Wall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

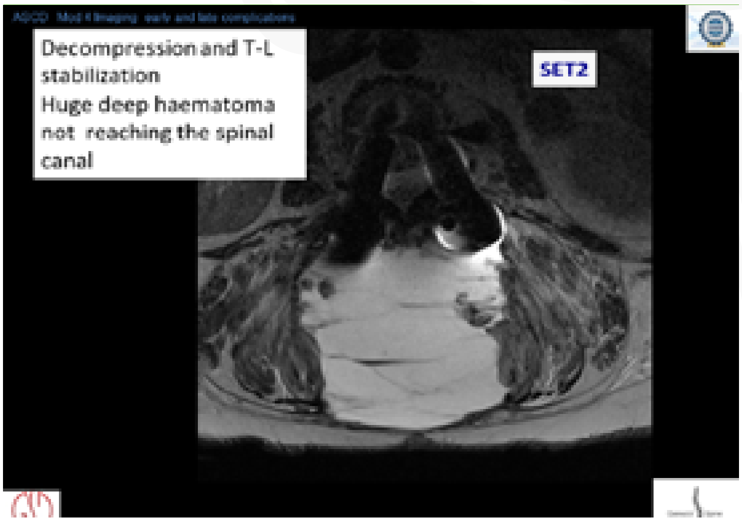

Stages of hematoma
T1
T2
Hyperacute < 24hrs
Acute 1-3 days
Early Subacute > 3 days
Late subacute > 7 days
Chronic > 14 days

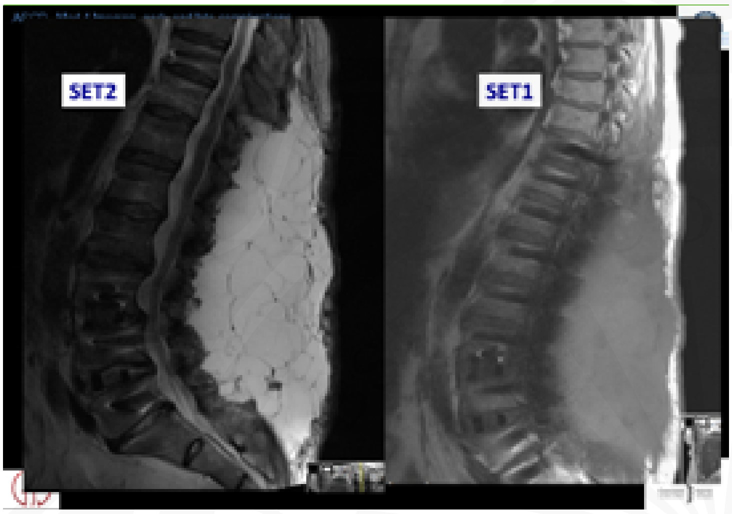

SE T1
Infection
CSF
Hematoma

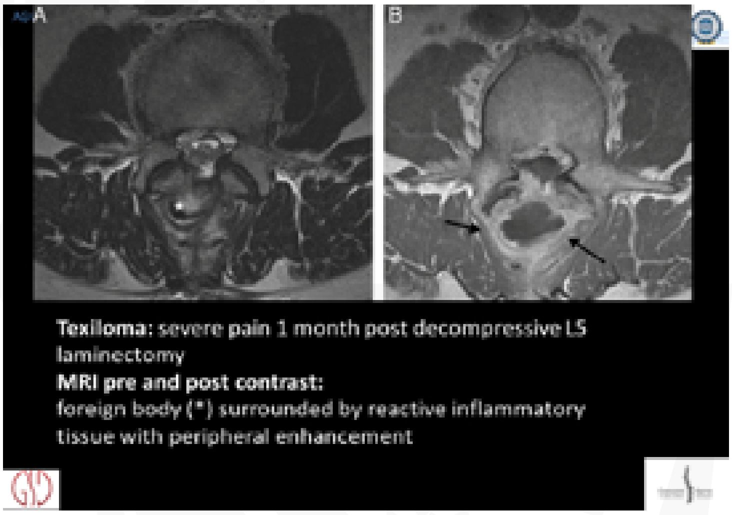

SET2
Infection
CSF
Hematoma

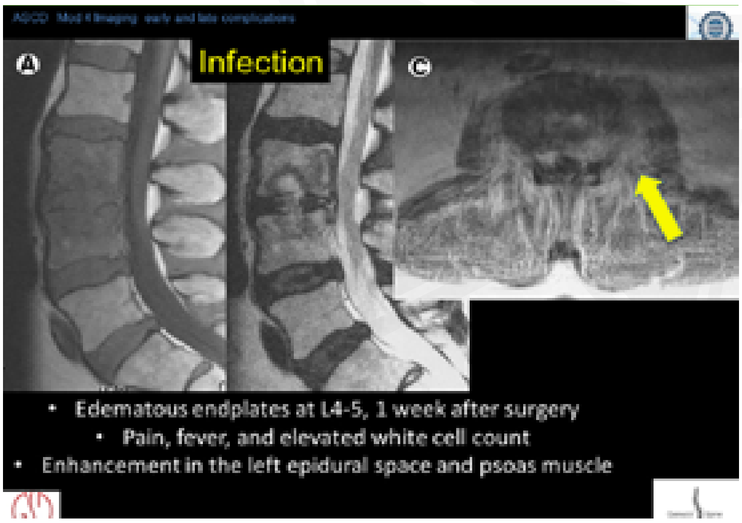

hematoma
SCF
Infection
T1
T2
T1 MdC

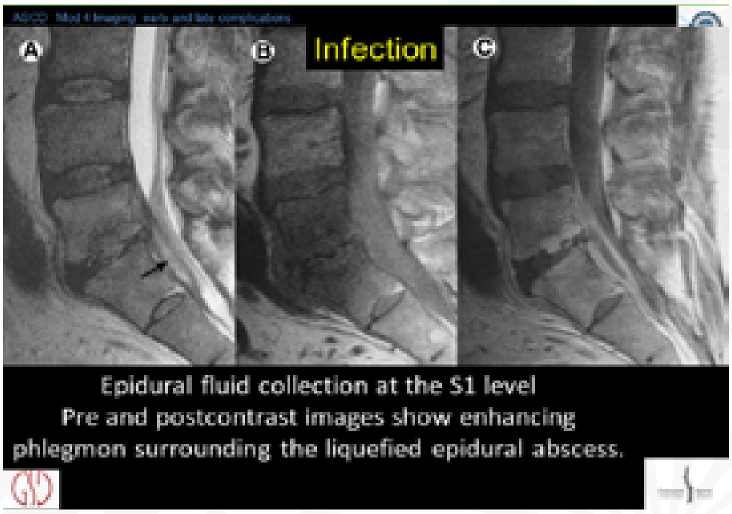

CSF collections from dural leaks
A
1 week after surgery
postural headache immediately following laminectomy

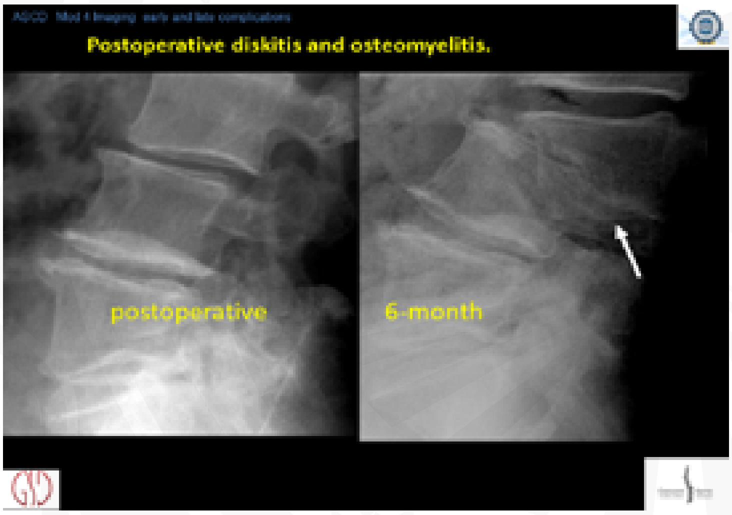

Decompression and T-L stabilization
Huge deep haematoma not reaching the spinal canal
SET2

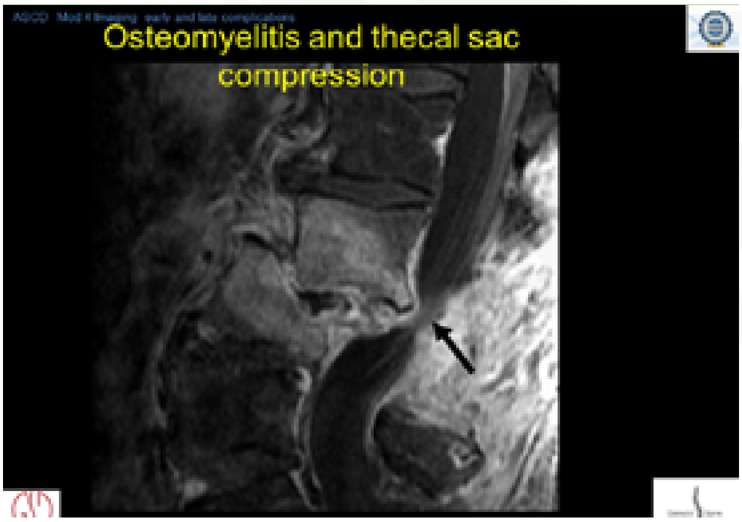

SET2
SET1

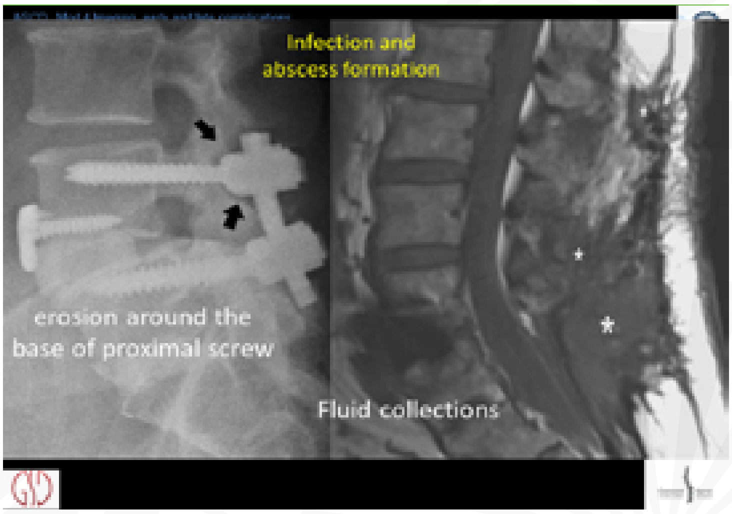

A
B
Texiloma: severe pain 1 month post decompressive L5 laminectomy
MRI pre and post contrast:
foreign body (*) surrounded by reactive inflammatory tissue with peripheral enhancement

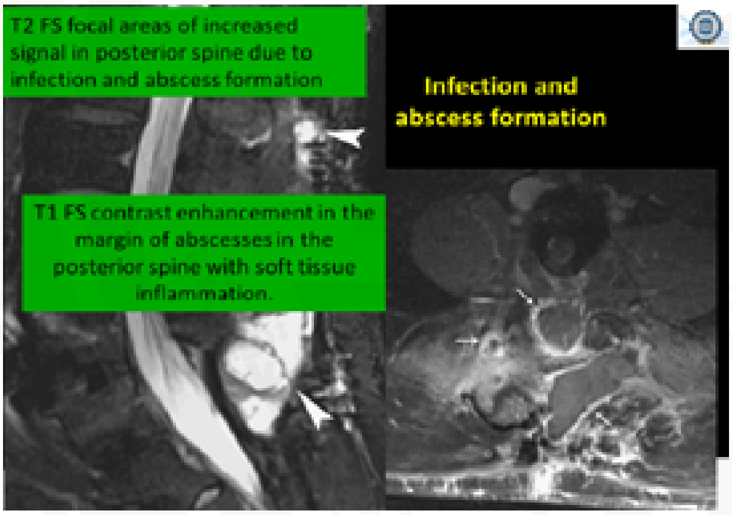

A
Infection
C
Edematous endplates at L4-5, 1 week after surgery
Pain, fever, and elevated white cell count
Enhancement in the left epidural space and psoas muscle

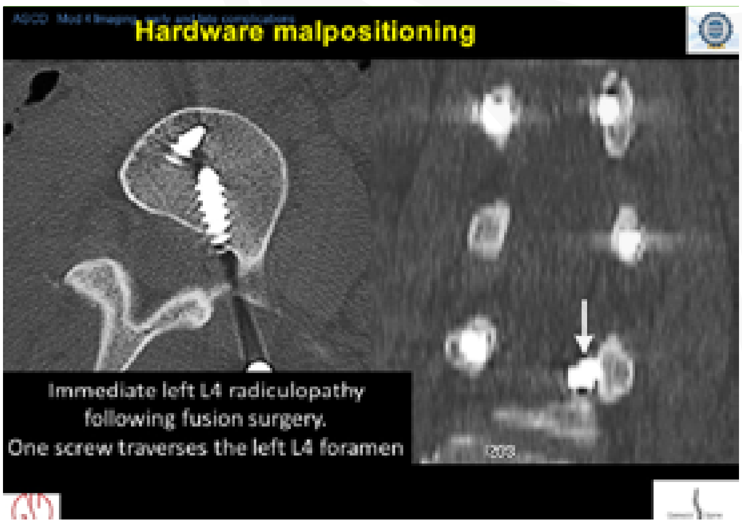

Infection
A
B
C
Epidural fluid collection at the S1 level
Pre and postcontrast images show enhancing
phlegmon surrounding the liquefied epidural abscess.

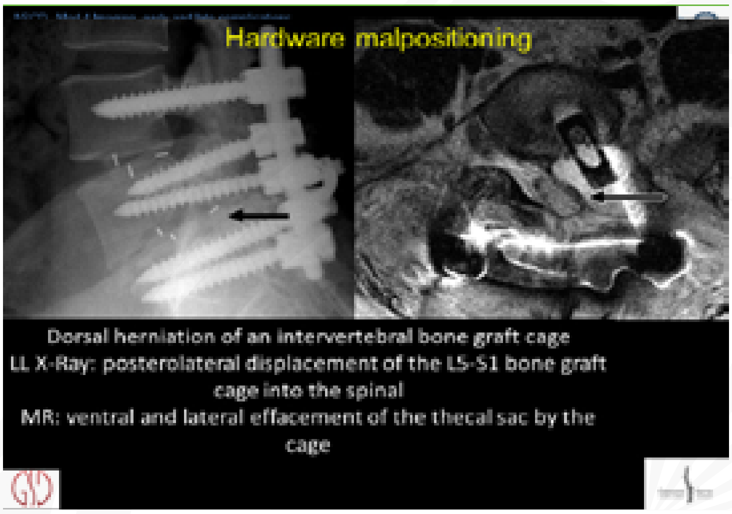

Postoperative diskitis and osteomyelitis.
postoperative
6-month

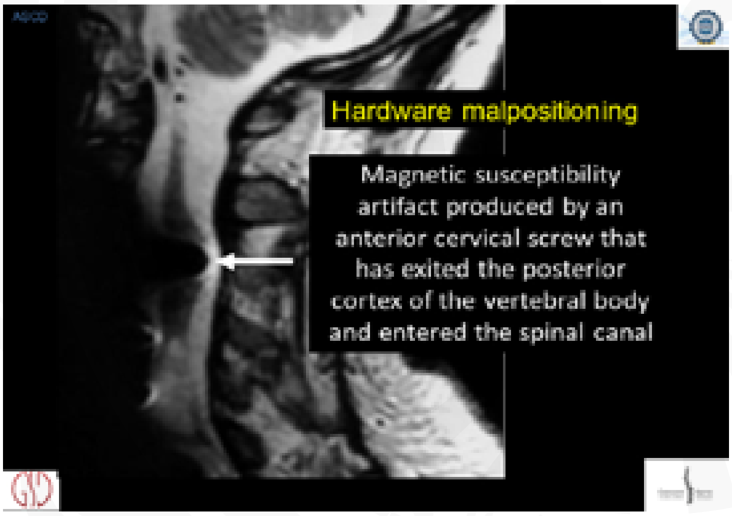

Osteomyelitis and thecal sac
compression

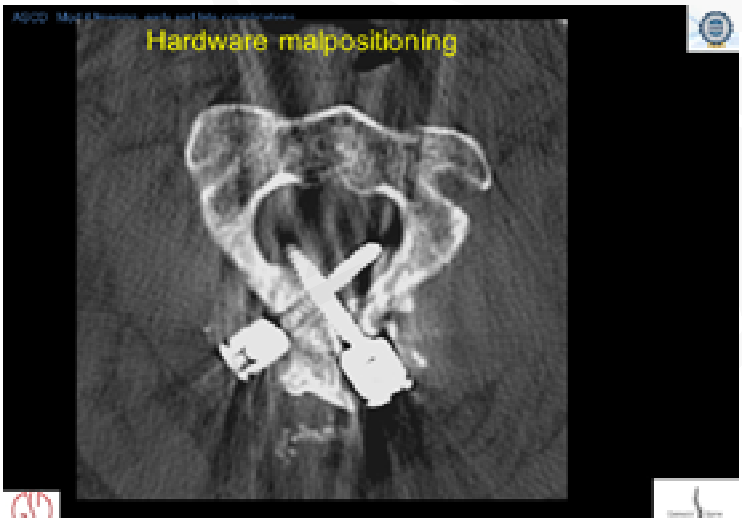

Infection and
abscess formation
erosion around the
base of proximal screw
Fluid collections

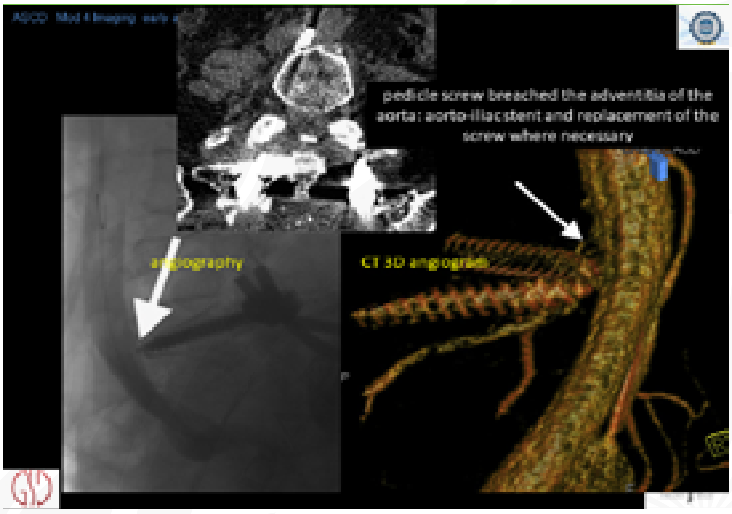

T2 FS focal areas of increased
signal in posterior spine due to
infection and abscess formation
Infection and
abscess formation
T1 FS contrast enhancement in the
margin of abscesses in the
posterior spine with soft tissue
inflammation.


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

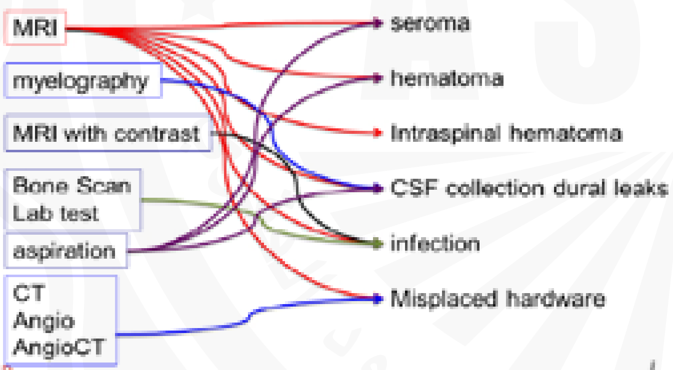

Hardware malpositioning
Dorsal herniation of an intervertebral bone graft cage
LL X-Ray: posterolateral displacement of the L5-S1 bone graft cage into the spinal
MR: ventral and lateral effacement of the thecal sac by the cage


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


Hardware malpositioning



Early postop complications



Late complications

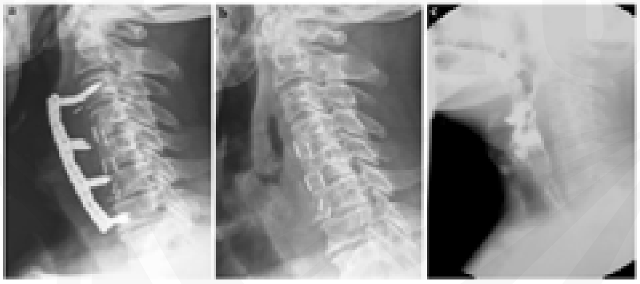
- Post surgery late complications
  - Delayed oesophagus perforation
  - Scar tissue
  - Arachnoiditis
  - Fluid in site of hemiectomy
- Late complications due to non-union
  - Aseptic loosening
  - Hardware yielding
- Septic loosening
- Adjacent segment pathology
  - Degenerative
  - Trauma

Oesophagus perforation

- Intraoperative
- Acute within 24 h
- Subacute after 24 h
- Delayed up to 10 years

- Early perforation is related to direct iatrogenic maneuvres
- Delayed perforation is related to chronic compression, dislocation or migration of the grafts or internal fixation material

Esophagus perforation



a. Hardware mobilization
b. Prevertebral air at C3-5 after hardware removual
c. Contrast esophogram confirming healing of the esophagus perforation at 39 days after diagnosis

Arachnoiditis after L4 and L5 laminectomy

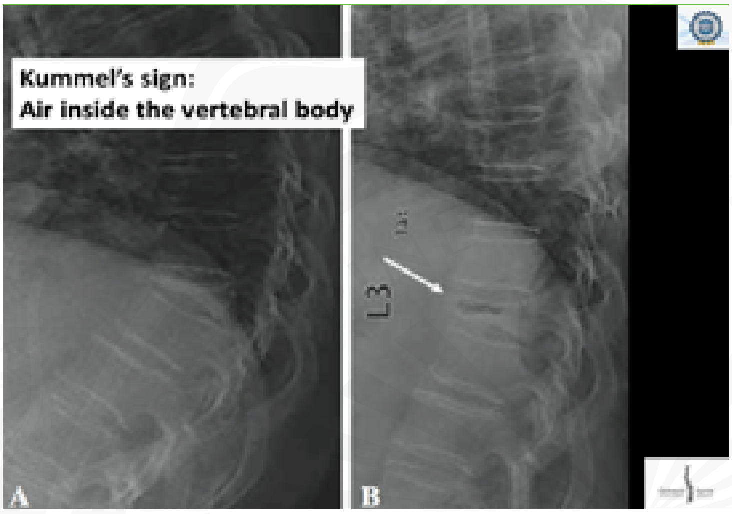
ASCD Mod 4 imaging early and late complications

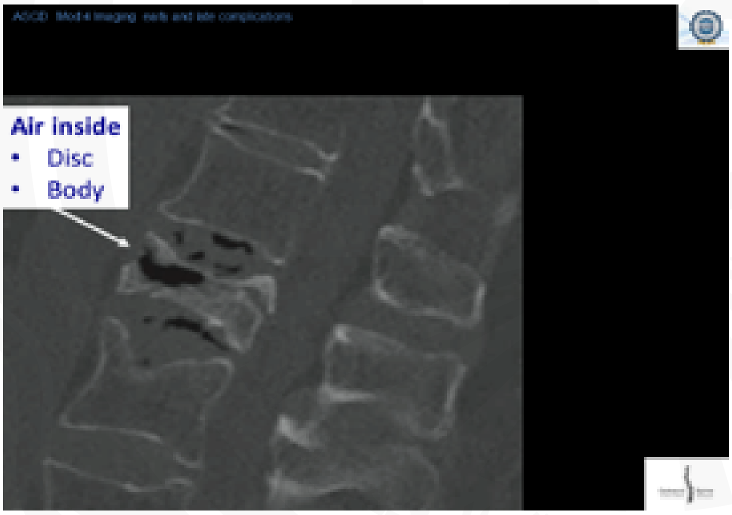
Late complications due to non-union

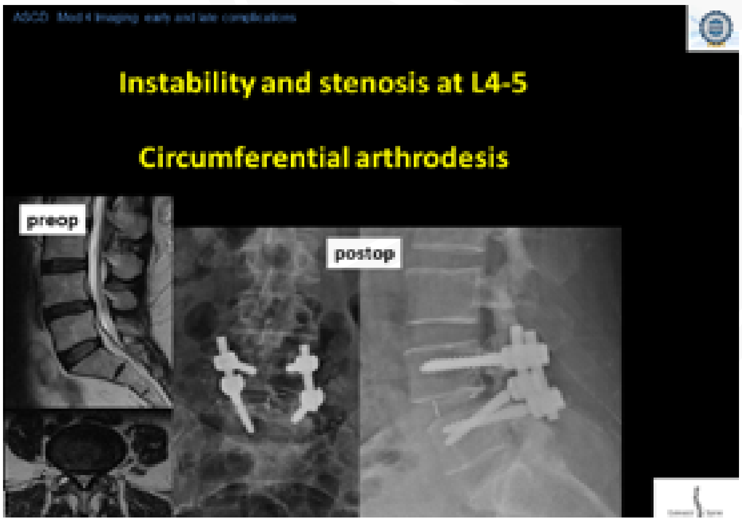
- Non union
- Aseptic loosening
- Hardware yielding

Vertebral body pseudoartrosis: CT or X-Ray findings

- Inhomogeneous bone sclerosis
- Corticals interruption
- Intrasomatic vacuum
- Intradiscal vacuum


Kummel's sign:
Air inside the vertebral body
L3
A
B


Air inside
• Disc
• Body


Instability and stenosis at L4-5
Circumferential arthrodesis
preop
postop

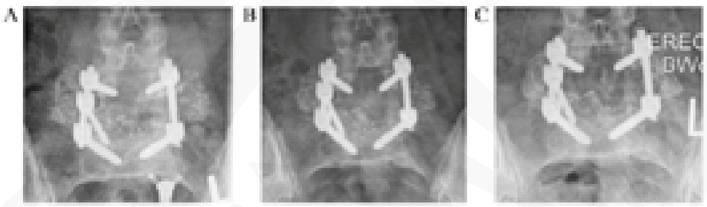

postop
Pedicular screws
Rods
Cage
Postero-lateral bone graft


Hardware failure: cage subsidence, screw loosening
14 m

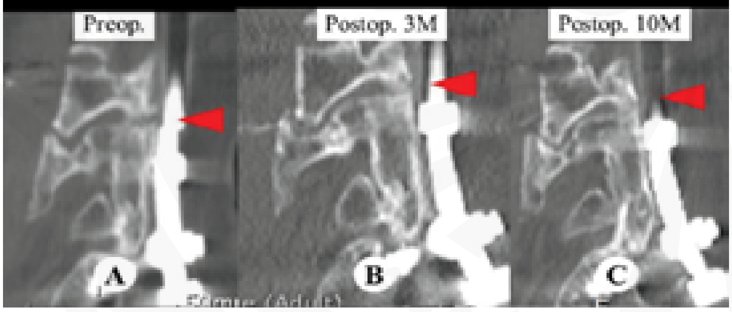

Non-union: cage subsidence, screw loosening, postero-lateral and interbody bone graft reabsorption
14 m

Posterolateral instrumented fusion with autogenous iliac crest bone graft

1, 6 and 24 months postop

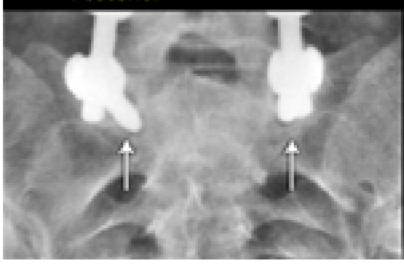


Implant failure due to non-union



Pseudortrosis X-Ray findings

- Dynamic instability at F-E
- Hardware failure (loosening or breach)
- Cortical bone sclerosis
- Intravertebral vacuum
- Fusion discontinuity
  - Anterior
  - Posterior



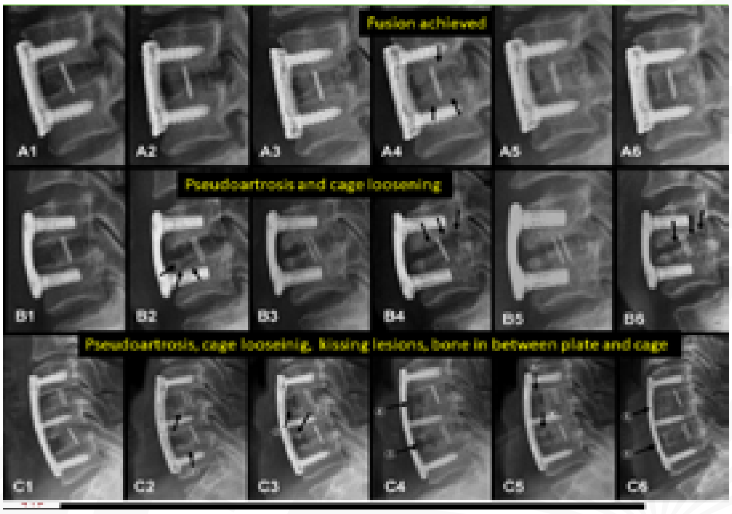


Table 1
Cervical interbody fusion reliability studies.

Study	Design	Investigations	Results
Buchowski et al.[8]	Prospective cohort involving 14 patients an average of 6 months following ACDF	Surgical exploration within 1 month of imaging compared to plain radiographs (bridging trabeculae and <1 mm of motion) and CT scan (1.5 mm cuts with sagittal and coronal reconstructions; bridging trabeculae with no lucencies at the graft–bone interface)	89% agreement (71.4–92.8%) between radiographs and surgical exploration and 83.3% agreement (78.6–85.7%) between CT and surgery. Higher interobserver agreement for CT scans (mean κ = 0.62) than radiographs (mean κ = 0.46)
Cannada et al.[10]	Retrospective cohort involving 29 ACDF levels in 27 patients	Lateral flexion–extension radiographs showing >2 mm increase in interspinous distance or >2 degrees of motion as measured using the Cobb method compared to AP/lateral radiographs demonstrating mature, bridging bony trabeculae across the disc space. Surgical exploration in 5 patients	Interspinous method gave a sensitivity of 0.89 and specificity of 0.91 for diagnosing non-union. Cobb method gave values of 0.82 and 0.39 for sensitivity and specificity. Higher correlation between diagnosis with interspinous method (Pearson's r = 0.72) versus Cobb method (Pearson's r = 0.28)
Chiselli et al.[20]	Cohort of patients with symptoms 1 year following ACDF	Surgical exploration during posterior cervical fusion compared to flexion–extension radiographs (>1 degree of motion or >4 degrees of motion) and CT scans	Improved specificity of flexion–extension radiographs using 1 degree cutoff compared to 4 degrees (PPV 100% for both; NPV 57% for 4 degrees and 79% for 1 degree). CT alone showed a PPV of 100% and NPV of 73%. Combining the investigations gave a PPV of 100% and NPV of 92%, thus increasing the specificity of diagnosing non-union

Table 2
Lumbar interbody fusion reliability studies.

Study	Design	Investigations	Results
Carreon et al.[11]	Prospective cohort of 49 patients undergoing ALIF with metallic cages	Surgical exploration and fine-cut CT with sagittal and coronal reconstructions. Fusion determined by considering the disc space around and within the cages as well as presence of the anterior and posterior "sentinel signs". Fusion across the anterior and posterior margins of the disc space	Interobserver variability in fusion determination using CT scans showed a kappa of 0.25 (p < 0.0001) with sensitivity of 0.7–0.97 and specificity from 0.28 to 0.85. Poor reliability in detection of "sentinel sign" (anterior κ = 0.34, posterior κ = 0.22) with variable sensitivity and specificity (anterior 0.20 and 0.92, respectively; posterior 0.67 and 0.76, respectively)
Fogel et al.[18]	Retrospective cohort of 172 fusion levels in 90 consecutive patients following PLIF with radiolucent cages and posterolateral fusion	Surgical exploration compared to AP, lateral and Ferguson radiographs and thin-slice CT scan (n = 54; 1-mm cuts with sagittal and coronal reconstructions) looking for bone bridging at least half of the fusion area for the PLIF for fusion to be present	Sensitivity of XR and CT in diagnosing non-union was 100%. Specificity was similar for the two with values of 0.89 and 0.86 for radiographs and CT, respectively

When is a spine fused? Injury 42 2011 306-313 C. Goldstein et al.

ASCD Mod 4 lesson: early and late complications

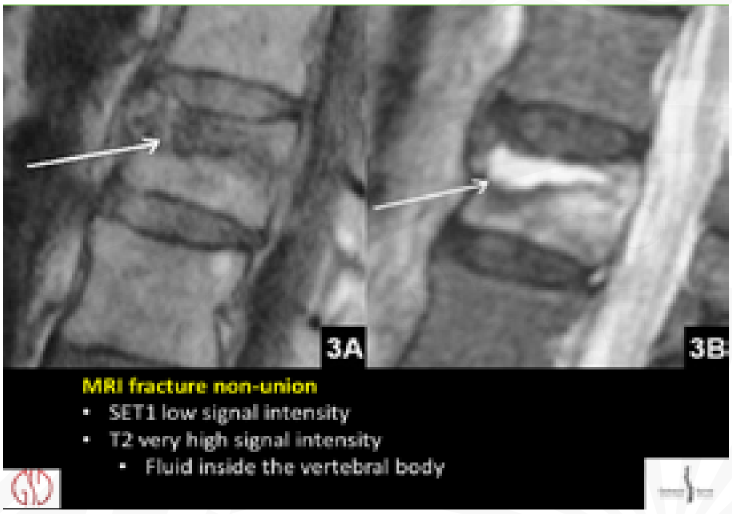
C. Goldstein, B. Drew / Injury, Int. J. Care Injured 42 (2011) 306–313

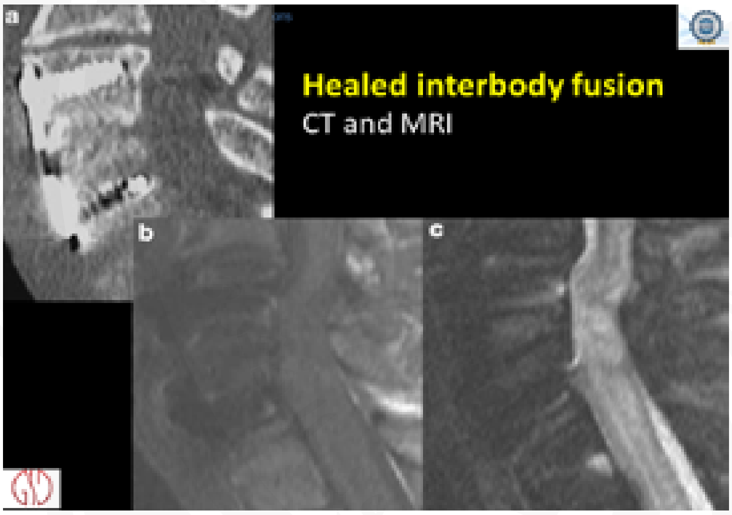
When is a spine fused? Injury 42 2011 306-313 C. Goldstein et al.

Table 3
Lumbar posterolateral fusion reliability studies.

Study	Design	Investigations	Results
Blumenthal and Gill[4]	Cohort study of 49 patients undergoing hardware removal following interbody and instrumented posterolateral fusion	Surgical exploration versus AP and lateral radiographs. No definition for successful fusion provided	Intraobserver agreement gave a kappa of 0.42–0.72. Wide ranges in sensitivity (0.49–0.85, mean = 0.72) and specificity (0.25–1.0, mean = 0.16). Overall correlation of 69% between radiographic diagnosis and surgical exploration
Brodsky et al.[7]	Retrospective cohort study involving 174 patients following posterolateral spine fusion	Surgical exploration versus preoperative AP, lateral and oblique radiographs, biplane bending radiographs (n = 64) and CT scans (n = 42; 3-mm axial cuts). No definitions for successful fusion provided	Biplane bending films showed the lowest specificity (0.37) but highest sensitivity for the diagnosis of non-union (0.96). Plain radiographs performed moderately well with a sensitivity of 0.89 and specificity of 0.60. CT scans showed the highest specificity (0.86) but lowest sensitivity (0.63) for detecting non-union
Carreon et al.[12]	Retrospective cohort study of 163 levels in 93 patients who had undergone instrumented posterolateral lumbar fusion	Surgical exploration compared to thin-slice (1 mm) CT with axial and coronal reconstructions looking for continuous trabeculated bone connecting the transverse processes	Substantial interobserver agreement for posterolateral gutter fusion (Cohen's κ = 0.62). When both posterolateral gutters were read as fused the likelihood ratio of fusion at surgery was 8.31 (positive predictive value 0.91). When neither gutter was read as fused a non-union was 2.9 times more likely to be found at surgery
Kant et al.[26]	Retrospective cohort study of 75 patients with instrumented posterolateral spine fusion	Surgical exploration compared to AP, lateral, oblique and Ferguson radiographs demonstrating bridging bone between the transverse processes and obliteration of the facet joints	Overall agreement between surgical exploration and radiographs was poor with a mean kappa of 0.25 (range 0.14–0.50; 95% CI 0.07–0.44). Sensitivity for a diagnosis of successful fusion was 0.85 with a specificity of 0.58.
Larsen et al.[28]	Prospective cohort study of 25 consecutive patients undergoing surgical exploration following instrumented posterolateral lumbar fusion	Surgical exploration compared to AP, lateral and oblique radiographs (n = 21; bridging bony trabeculae), lateral flexion–extension radiographs (<3 degrees of motion) and CT scans (n = 24; 5-mm thick overlapping cuts with sagittal and coronal reconstructions; bridging bony trabeculae)	Sensitivity and specificity of plain radiographs was 0.42 and 0.85, respectively, for flexion–extension radiographs was 0.86 and 0, and for CT scans was 0.53 and 0.78

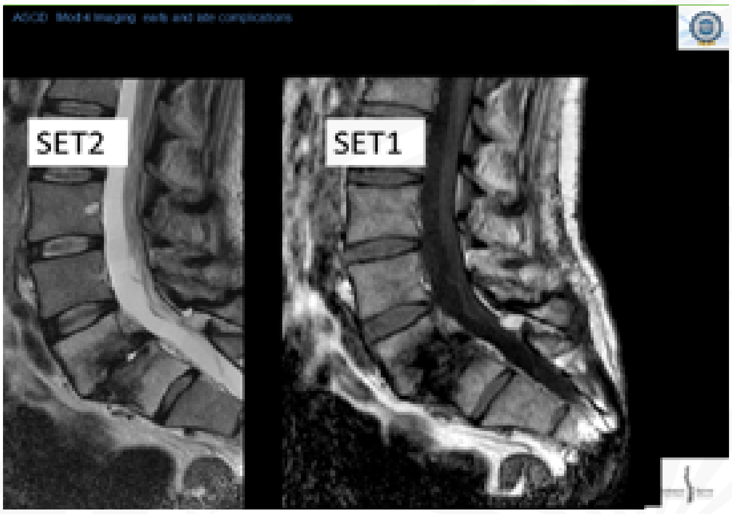
X-ray standard and bending
HQCT: thin slices and multiplanar reformations
Fusion assessment rate: 70-100%

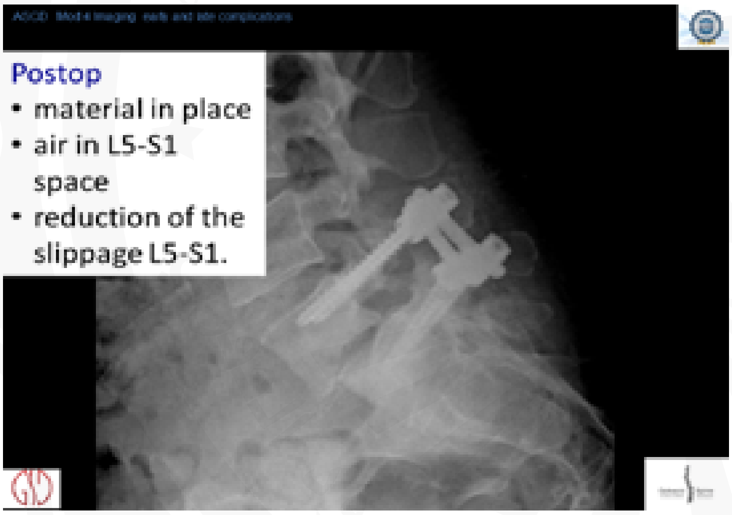


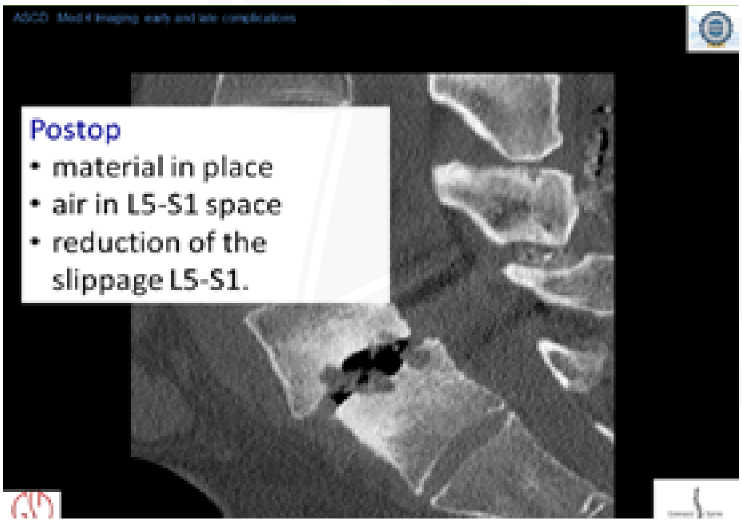


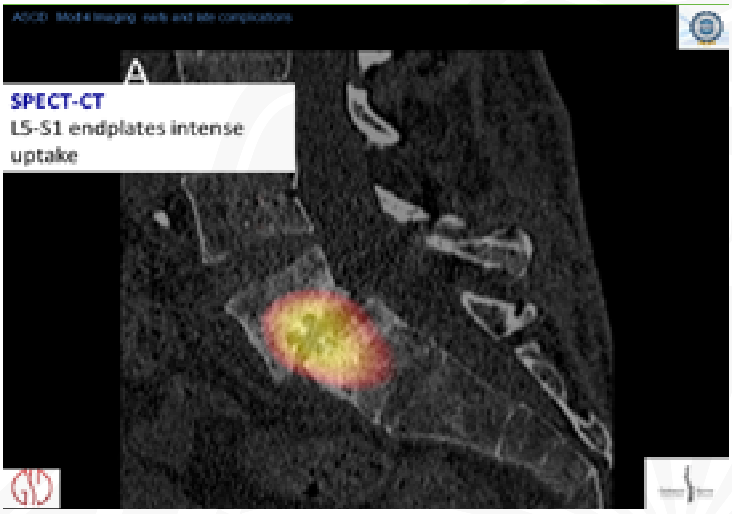
SPECT-CT – 18F Fluoride PET-CT

- Hybrid imaging using SPECT-CT (Tc-99m HDP) or PET-CT (F-18 NaF) may improve diagnostic accuracy compared to CT scan alone
- It adds to the CT ability to show hardware loosening and bone lesions the possibility of the bone scan to show intense uptake at the site of the pseudoarthroisis

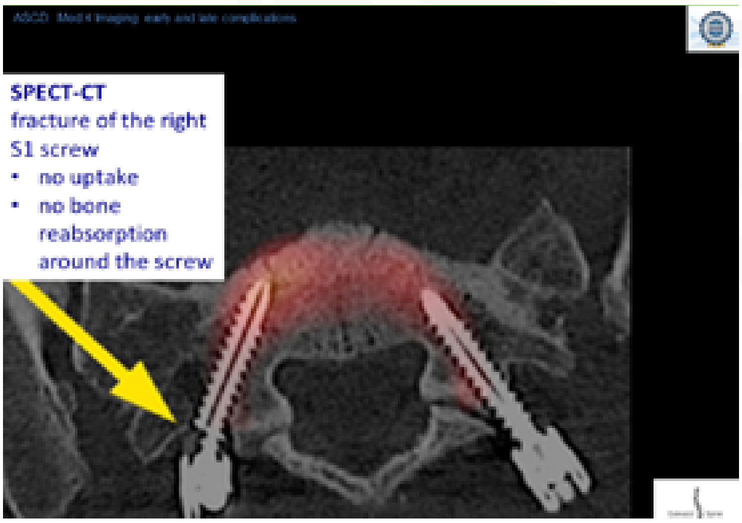

SET2
SET1


Postop
• material in place
• air in L5-S1 space
• reduction of the slippage L5-S1.

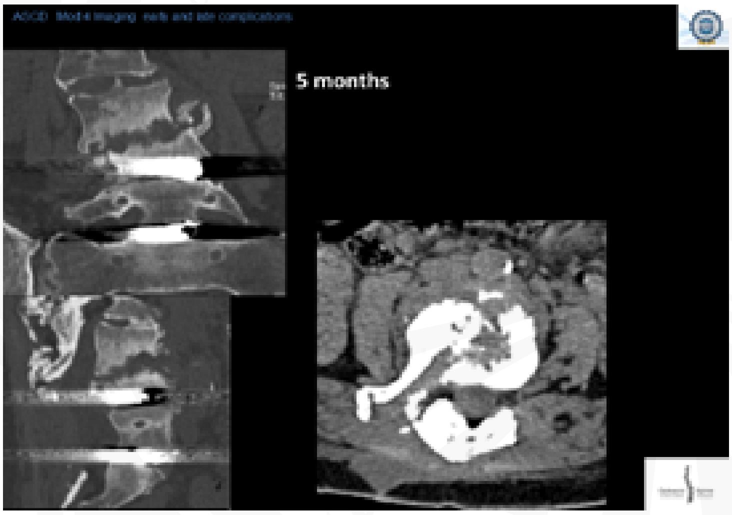

Postop
• material in place
• air in L5-S1 space
• reduction of the slippage L5-S1.

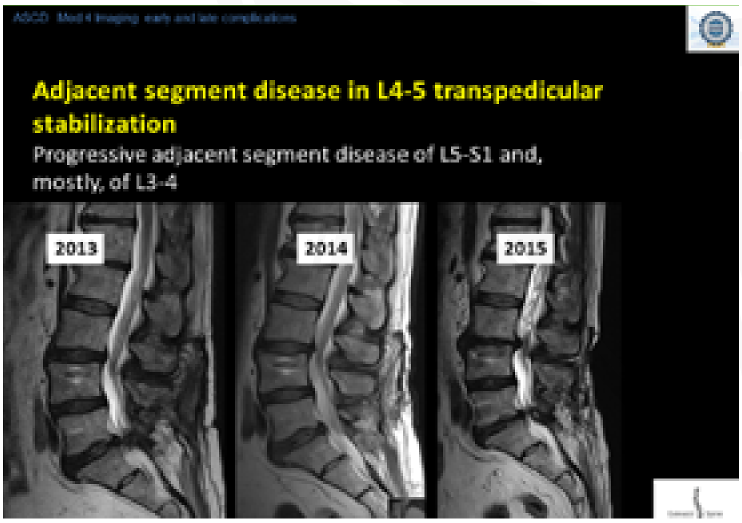

A
SPECT-CT
L5-S1 endplates intense uptake


SPECT-CT
L5 screws showed no abnormalities
B

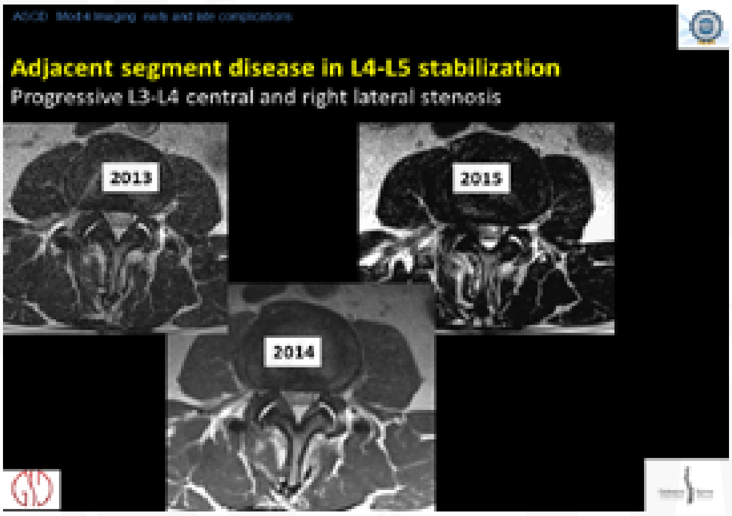

SPECT-CT
fracture of the right S1 screw
• no uptake
• no bone reabsorption around the screw

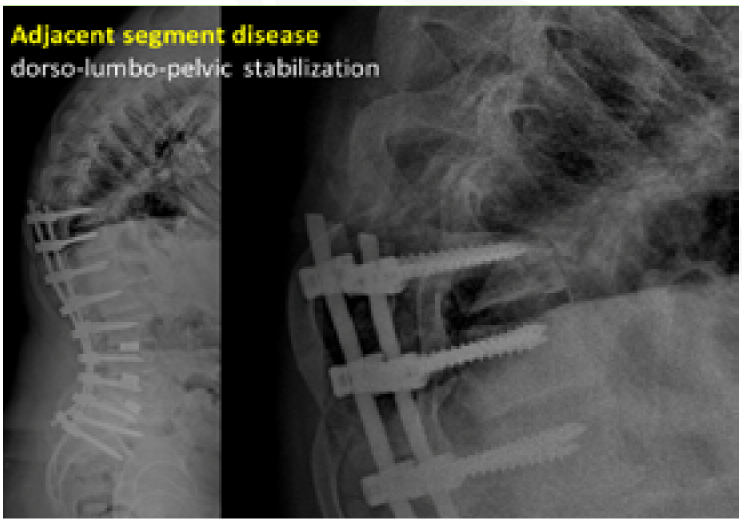

5 months


5 months

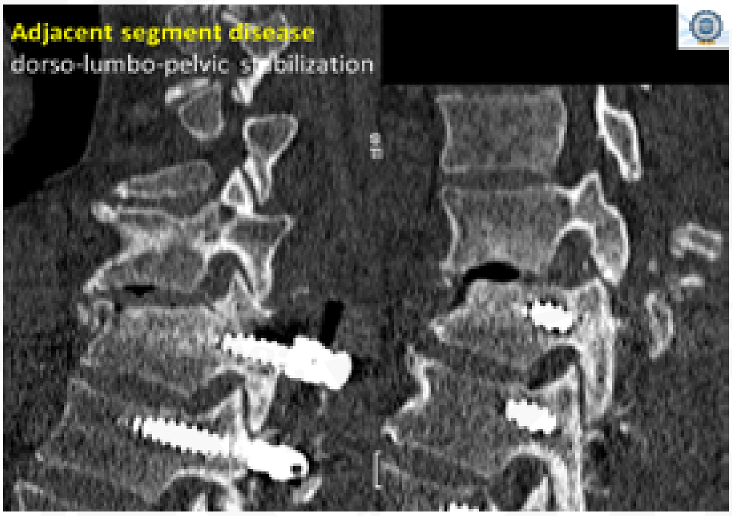

Adjacent segment disease in L4-5 transpedicular stabilization
Progressive adjacent segment disease of L5-S1 and, mostly, of L3-4
2013
2014
2015

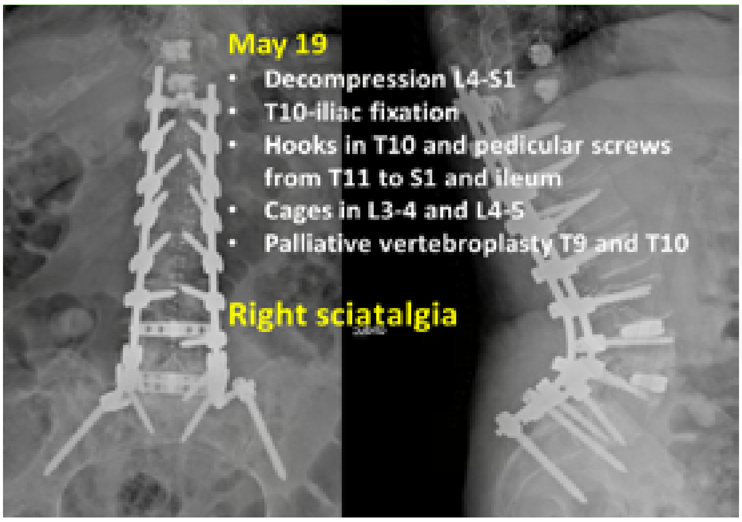

Adjacent segment disease in L4-L5 stabilization
Progressive laterolisthesis of L3 over L4
2014
2015


Adjacent segment disease in L4-L5 stabilization
Progressive L3-L4 central and right lateral stenosis
2013
2015
2014


Adjacent segment disease
dorso-lumbo-pelvic stabilization


Adjacent segment disease
dorso-lumbo-pelvic stabilization


Adjacent segment disease
dorso-lumbo-pelvic stabilization


May 19
• Decompression L4-S1
• T10-iliac fixation
• Hooks in T10 and pedicular screws from T11 to S1 and ileum
• Cages in L3-4 and L4-5
• Palliative vertebroplasty T9 and T10
Right sciatalgia

Late complication imaging

- **X-Ray:** standard and dynamic imaging
- **CT:** bone setting
  - Thin slices
  - MPR
- **MR:** standard plus STIR imaging
  - Gadolinium
  - MARS (Magnetic Artifacts Reduction Seq.)
- **SPECT-CT e 18F Fluoride PET-CT:**
  - Aseptic or septic mobilization

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

Iatrogenic Nerve and Spinal Cord Injury Management Options

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Iatrogenic Radicular Trauma

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Iatrogenic Radicular Trauma

- Nerve injuries can occur in 3 basic ways: stretching, compression, or laceration.

TABLE 3: Classification of neural injury type with associated characteristics[1]

Injury Type	Etiology	Clinical Presentation	Pathology	Recovery
neuropraxia	compression or ischemia	motor deficits > sensory deficits, autonomic function preserved	axonal continuity preserved	complete
axonotmesis	crush or stretch	motor, sensory, & autonomic deficits	damage to axons w/ preservation of neural connective tissue	complete
neurotmesis	severe contusion, stretch, or laceration	complete loss of motor, sensory, & autonomic function	axon, myelin, & connective tissue damaged, disrupted, or transected	incomplete

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Indirect Radicular Trauma

- C5 Nerve Palsy in Cervical Decompression
  - Definition
    - New onset/post-operative motor weakness in the deltoid or biceps brachii
    - Time frame
      - Onset within 24hrs- 2week
      - Resolution 6 months
  - Incidence
    - In a review of 750 consecutive cervical decompression cases, Nassar et al noted an incidence of 6.7%.
    - Highest Incidence was in laminectomy and fusion group (9.5%)
    - corpectomy with posterior fusion group (8.4%),
    - corpectomy group (5.1%),
    - laminoplasty group (4.8%),

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Indirect Radicular Trauma

Anatomy/Pathology

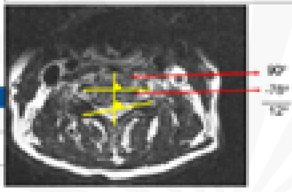
- Possible anatomical factors in C5 palsy and cervical decompression
  - Eskander et al noted their series of 176 anterior cervical decompression or corpectomy that a strong predictor of C5 palsy is cord rotation
  - In this retrospective review they established three groups based on degree of rotation and incidence of C5 Palsy.

TABLE I Relationship Between C5 Palsy and Cord Rotation*

	C5 Palsy		
Cord Rotation	No	Yes	Total
0° to 5°	159	0	159
6° to 10°	5	8	13
≥11°	0	4	4
Total	164	12	176

*The values are given as the number of patients.

Classification	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



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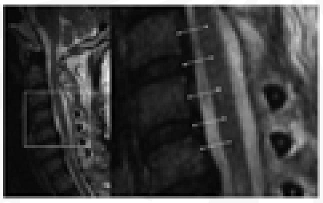
Indirect Radicular Trauma

Anatomy/Pathology

- Posterior Shift of Spinal cord after Cervical decompression
  - Shiozaki et al measured the degree of posterior shift of spinal cord after 19 conseuctive cervical laminoplasties at two time points; 24 hrs and 2 weeks.
  - Within this paper it was noted that the posterior shift of the spinal cord is maximal at 24 hrs and reduces by 2 weeks.
  - Patients that experienced C5 symptoms had the greatest posterior shift.



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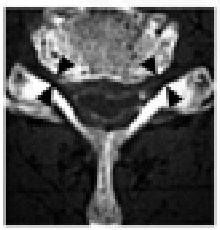
Indirect Radicular Trauma

Anatomy/Pathology

- Katsumi et al hypothesized that C5 palsy after laminoplasty is due the pre-existing C4/C5 foraminal stenosis and posterior shift of the cord following laminoplasty.
- A prospective trial of prophylactic bilateral C4/C5 foraminotomy was designed to test this.
- The incidence of C5 palsy was 1.4% (2 of 141 cases) in the prophylactic group, and 6.4% (9 of 141 cases) in the control group.



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Indirect Radicular Trauma

- C5 Palsy in Laminoplasty and Fusion
  - Takemitsu et al reported a 50% incidence in patients with laminoplasty and posterior instrumented fusion.
    - Incidence of C5 palsy in case with instrumentation was 11.6 times higher than without instrumentation.
  - Both Takemitsu et al and Hojo et al hypothese that it is aggressive reduction in C4 anteriorlethsis or correction of the kyphosis that induces an iatrogenic C4/C5 forminal stenosis and therefore causing the C5 palsy in these cases.

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Other risk factors for C5 Palsy

- Retrospective study of 640 patients who underwent posterior cervical spine surgery (PCSS)
- Independent risk factors:
  - Preoperative C4-C5 high spinal cord signal on T2
  - Cord signal on T2 in the presence of OPLL
  - Higher preoperative cervical spine curvature

Liu, B., Chu, Y., Ma, J., Tang, X., Pan, J., Wu, C., Chen, X., Zhao, C., & Wang, Z. (2021). Analysis of risk factors for C5 nerve root paralysis after posterior cervical decompression. *BMC musculoskeletal disorders*, 22(1), 614.

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Management of C5 Palsy

- Prophylactic Foraminotomy
  - Based on Anatomy and surgical strategy

- Conservative measures
  - Physiotherapy.
  - Nerve root injections.
  - Majority resolve by 6 months.

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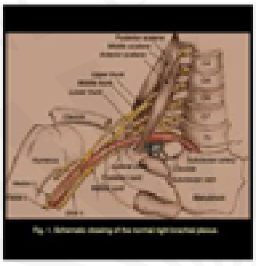
Indirect Radicular Trauma

Patient Positioning and Brachial plexus injury

- C-5, C-6, C-7, C-8, and T-1 nerve roots
- 2 firm points of fixation:
  - vertebrae proximally in the neck
  - axillary fascia distally in the arm
- Venerable at three points:
  - Clavicle- Anteriorly
  - 1st Rib- Inferiorly
  - Head of Humerus- Posteriorly and laterally



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Indirect Radicular Trauma

Patient Positioning and Brachial plexus injury

- Prone Positioning and Risk of Brachial Plexus Injury.
  - Arms abducted greater than 90°.
  - Extension and external rotation of the abducted arm.
  - Rotation and lateral flexion of the neck toward the same side.
  - Application of shoulder braces if placed over clavicle and not the acromion.
- Results In damage to lower roots of Brachial Plexus (C8 and T1)
  - Paresis/Paralysis of intrinsic muscles of hand and forearm flexors

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Indirect Radicular Trauma

Supine positioning and Brachial plexus Injury

- Traction on arms
  - can lead to damage on upper roots of Brachial Plexus
    - C5 and C6
  - Results in
    - Loss of sensation in arm.
    - Paresis/Paralysis of deltoid, biceps and brachialis.

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Indirect Radicular Trauma

Patient Positioning and Brachial plexus injury

- Prognosis
  - With rehabilitation majority make a full recovery.
  - Sensation returns first, followed by motor of lower roots then motor function of upper roots.
  - No improvement in symptoms by one week may imply a protracted course and referral to Hand Clinic/Plastic Surgeons may be required.

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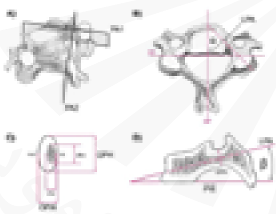
Direct Radicular Trauma

Pedicle screws and the Cervical

- Cervical Pedicle screws
  - Posterior aspect of the lamina has few anatomical landmarks.
  - Pedicle axis is largely inclined in the transverse plane.
  - Pedicle diameters are small in the subaxial cervical spine.



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Direct Radicular Trauma

Pedicle screws and the Cervical

- Nakashima et al in 2010 report an incidence of 0.8% of direct nerve root injury and 0% spinal cord injury from a series total of 390 cervical pedicle screws in 84 patients.
  - The largest complication group was the C5 nerve root palsy

Type of Complication	Complication	No. of Observed Cases (%)
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	C5 palsy	[illegible]
	C7 palsy	[illegible]
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]

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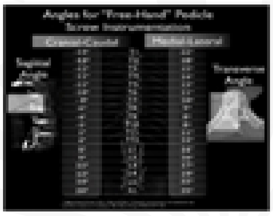
Incidence of Nerve Root or Spinal Cord trauma in Scoliosis Correction

- Incidence range reported in the literature 0.3-1.4%
  - The most recent data from the Scoliosis Research Society reveals
    - 0.3% incidence all of which were incomplete cord injuries. (Total no of corrections=2,031)
  - Cord trauma can result from
    - Direct malposition of instrumentation
    - Indirect from distraction of neural elements during corrective manoeuvre or tension on vasculature.



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Spinal Cord trauma in Scoliosis Correction

- Intra-operative Neurophysiology Monitoring
  - changes of >50% amplitude and >10% latency in the SSEP
  - Changes of >75% in MEP signals.
    - Simple steps of ensuring MAP, Temperature and Hb parameters are met to increase spinal cord perfusion
    - If the changes are not reversed there are 2 options
      - Attempt a Stagnara Wake-up Test and assess motor function

        OR

      - Release Correction

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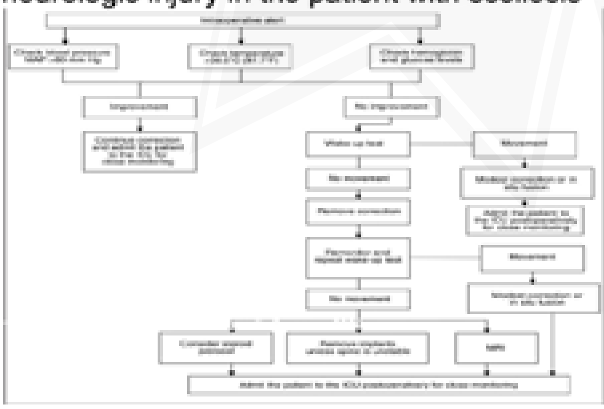
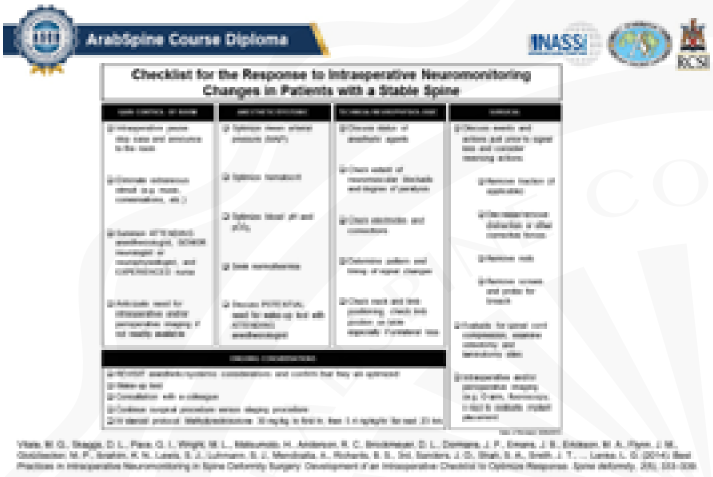
Algorithm for management of intraoperative neurologic injury in the patient with scoliosis

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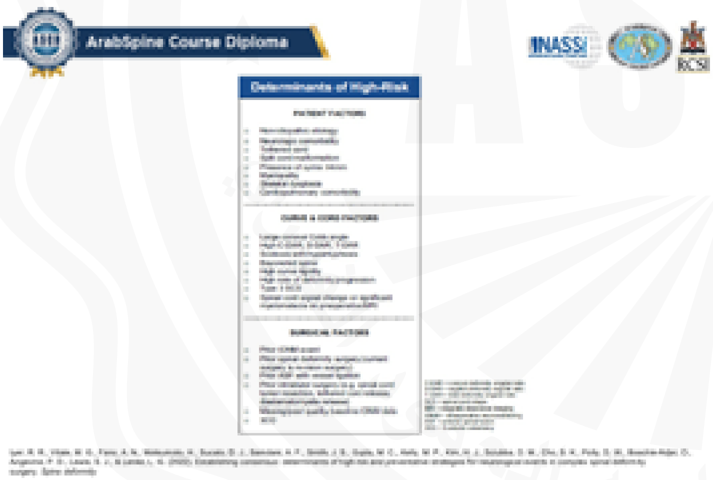
Checklist for the Response to Intraoperative Neuromonitoring Changes in Patients with a Stable Spine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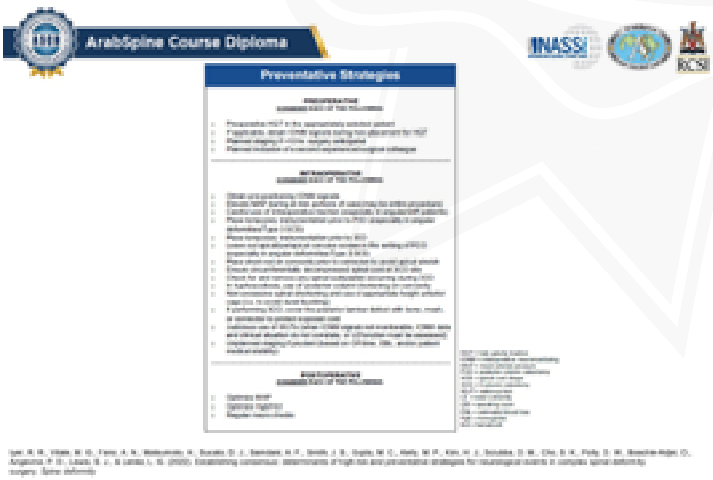
Determinants of High-Risk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Preventative Strategies

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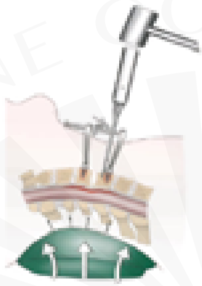
Iatrogenic Spinal Cord Trauma

- Aetiology
  - Direct
    - Surgical technique causing contusion
    - Malposition of instrumentation
  - Indirect
    - Vascular compromise
      - D/T direct vascular injury or tension placed on vasculature during corrective manoeuvres
    - Spinal Cord compression d/t epidural haematomas



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Iatrogenic Spinal Cord Trauma

- Intra-operative monitoring or the post-operative neurological examination demonstrates a spinal cord injury.
  - Patient should have an immediate post-operative MRI.
  - If there is no structural compression that can be relieved
    - Manage the patient as per current 2013 AANS/CNS Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries.
      - Use of cardiac, hemodynamic, and respiratory monitoring devices to detect cardiovascular dysfunction and respiratory insufficiency in patients following acute spinal cord injury is recommended.
      - Correction of hypotension in spinal cord injury (systolic blood pressure , 90 mm Hg) when possible and as soon as possible is recommended.
      - Maintenance of mean arterial blood pressure between 85 and 90 mm Hg for the first 7 days following an acute spinal cord injury is recommended.

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Iatrogenic Spinal Cord Trauma

- Spinal Epidural Haematoma
  - Incidence of EDH requiring evacuation ranges from 0.2-0.41%
  - Risk Factors for EDH
    - Age >60
    - Perioperative coagulopathies
      - Anti-platelet agents
      - Anti-coagulants
      - NSAIDs
        - Nonspecific COX inhibitors
    - Estimated blood loss
      - Range 655-1000mls
    - Area of bony decompression
    - Number of levels operated
    - Vascularity of tumour

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Iatrogenic Spinal Cord Trauma

- Spinal Epidural Haematoma
  - Symptomatic Spinal EDH requires immediate evacuation to decompress the spinal cord.

"better neurologic outcomes in those that undergo early evacuation"

  - The patient should be then managed as per 2013 AANS/CNS guidelines with admission to ICU for monitoring.

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Summary

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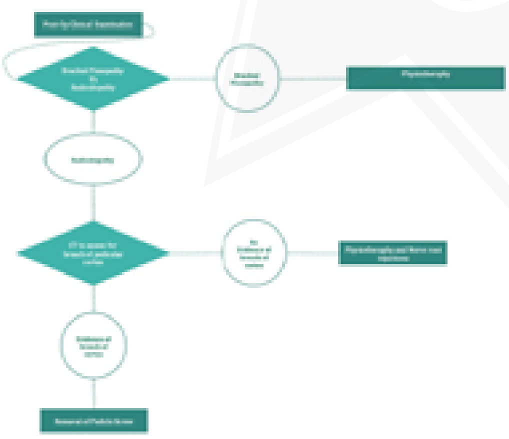
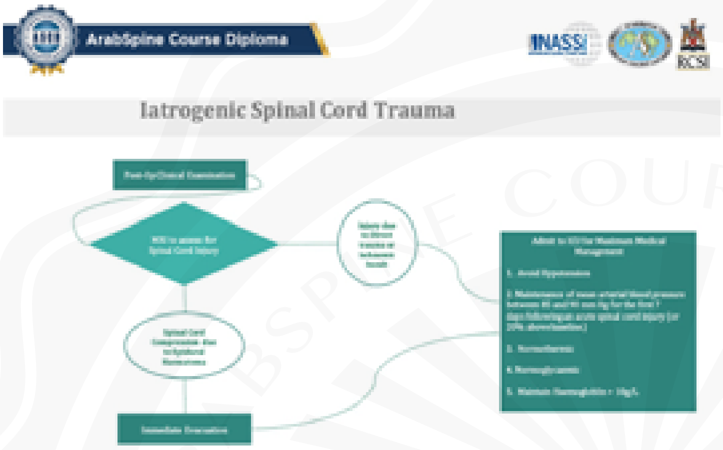
Iatrogenic Radicular Trauma

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Iatrogenic Spinal Cord Trauma

Avoidance of Instrumentation Failure

Goals

- Optimize host pre operatively
- Normal alignment
- Fusion
- Prevent infection
- Prevent implant failure
- Prevent adjacent segment disease

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Introduction

- Pre op evaluation
- Pre op planning
- Intra operative considerations
- Post op

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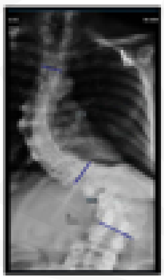
Pre op Eval

- Bone density
  - DEXA
  - Pre op medical management
- Weight
  - BMI 30 to 35
- Nutrition
- Smoking
- Stable medical comordities
  - Diabetic control
- Dental health

- Puvanesarajah V. JNS Spine. 2016

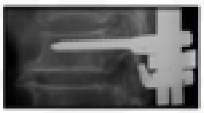
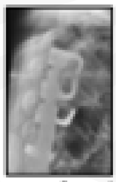
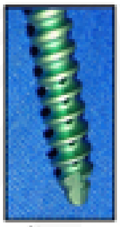
Pre Op Planning

- Implants
- Alignment
- UIV and LIV
- Cement
- Biologics
- Anterior, Posterior, both




Pre Op Planning - Implants

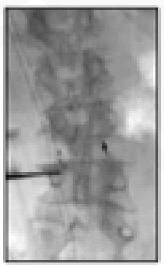
- Pedicle screws
  - Size
  - Density
  - Expandable
  - HA coated
  - Fenestrated
- Hooks
  - Claw construct
- Screws with hooks
- Sublaminar wire
- ~~Apical or junctional vertebrae for deformity~~

» Hasegawa K. Spine. 1997
» Hilibrand A. Spine. 1996.
» Lotz J. Spine. 1997

Pre Op Planning - Alignment

- Coronal plane
  - Posterior release
  - LLIF
  - Osteotomies
    - Asymmetrical PSO
    - VCR



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Pre Op Planning - Alignment

- Sagittal plane
  - Lumbar lordosis within 10 degrees of PI
  - SVA Less than 4 cm positive
  - Less correction with age
  - Sagittal plane correction
    - SPO
    - PSO
    - VCR
    - LLIF
    - ALIF

- Rose P. Spine. 2009
- Kim Y. Spine. 2007.
- Lafage V. Spine. 2011
- Ames C. JNS Spine. 2012

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Pre Op Planning

- UIV
  - Avoid apical
  - Cement
    - Upper instrumented ± one above
  - Soft landing
  - Soft tissue dissection
    - Kim Y. Spine. 2007
    - Martin C. Spine Deformity. 2013
    - Hassenzadeh H. Spine Deformity. 2013.
    - Yagi M. Spine. 2014
    - Lehman R. JAAOS. 2015
    - Kim H. JAAOS. 2016

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Pre Op Planning

- LIV
  - L5, S1, Pelvis
  - Anterior
    - Polly D. Spine. 2006.
    - Kuklo T. Spine. 2001
    - Harimaya K. Spine. 2011

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Pre Op Planning - Cement

- Upper
- Lower
- Adjacent vertebra above
- PMMA vs. biologic (calcium sulfate)
- Cement volume
- Fenestrated screws
- Disadvantages
  - Revision
    - Deformity
    - Infection

- Renner S. Spine. 2004.
- Hassenzadeh H. Spine Deformity. 2013.
- Erdem M. TSJ. 2017
- Lehman R. JAAOS. 2015

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Pre Op Planning - Biologics

- Local bone
- Iliac crest
- Decortication
- DBM
- Synthetics
- BMA
- Stem cells
- BMP

» Poorman G. ESJ. 2017
» Hsu W. Global Spine J. 2012

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Pre Op Planning – Anterior

- Increases fusion rate
- Improves sagittal alignment
- MIS

Intra Op - positioning

- Prone
  - Sagittal alignment
    - Avoid taking away lumbar lordosis
    - Avoid overcorrecting thoracic kyphosis, particularly at the top of reconstruction

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Intra op - infection

- Prevention
  - Peri op antibiotics
  - Prep
    - Chloroprep
  - Vanc powder
  - Irrigation
    - Betadine
    - Chlorhexidine
  - Incisional wound VAC

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Intra Op

- Screw triangulation
- Proximity to superior endplate UIV
- Cross links
- Rod diameter, material
- Implant stress
  - Compression, distraction, persuasion, in situ bending
- Sacral screw – into promontory
- Iliac screws vs. S2-AI
- Dual rods
  - Shen F. TSJ. 2018

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Post Op

- Bracing – no evidence
- Rehab – no evidence

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SUMMARY

- Optimize patient
- Pre op plan
- Technical results – achieve your goals

Complications in Deformity Surgery

- Vascular and visceral injuries.
- Hemodynamic complications.
- Neurological complications.
- Gastrointestinal complications.
- Infections.
- Failure of instrumentation and nonunion.
- Decompensation and increased deformity.
- Pathology of adjacent level.
- Other complications.

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Vascular and visceral injuries:

- Occur more frequently in the anterior approach **(big vessels, preitonium and bowel , ureter or Lung)**
- In the posterior approach of the thoracic spine, pleural damage may occur.
- The risk of misplacement of pedicle screws is increased in scoliosis surgery, especially of high magnitude.
- Vascular injuries may occur during insertion of pedicle screws or delayed and presents as pseudo-aneurysms.

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During spinal osteotomies

- **Smith Peterson Osteotomy**

Closed injury (stretching) of Aorta

Pedicle Subtraction Osteotomy and Vertebral Colmn Resection

Direct injury of big vessels

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Minimally Invasive Anterior fusions

- **(ALIF , OLIF, DLIF)**

Can result in **DIRECT** injury to the big vessels

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Hemodynamic complications:

- Scoliosis surgery is surgery of long duration, with large exposure and high blood loss.
- The need of curettage large bone areas or the need of vertebral osteotomies can produce excessive bleeding.
- Intraoperative hypothermia can trigger an arrhythmia and myocardial depression.
- The controlled hypotension and self transfusion technique are very important for greater hemodynamic stability.

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Neurological complications:

- The **most feared** injuries in deformity surgery.
- Neuro-physiological monitoring in deformity surgery should be considered mandatory.
- The most traditional method used to monitor neurological function is Stagnara wake-up test.

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- This test is performed after completion of the reduction maneuvers for scoliosis or osteotomy and fixation for kyphosis.
- Neurophysiological monitoring of somatosensory and\or motor evoked potentials is done by analyzing the latency and amplitude of the response to the stimulus caused.
- The somatosensory evoked potentials analyzes the integrity of the posterior column from the peripheral nerves to the cerebral cortex.

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- The motor evoked potentials is the result of stimulating the cortex or the medulla and collecting the response in the peripheral nerves or muscles directly innervated by these nerves. Keep in mind that these potentials may be affected by hypothermia and hypoxia.
- Neurological complications may be due to
  reduced vascular blood flow
  metabolic or mechanical direct injury or stretching.
- Depending on the cause, the injuries can range from root injury to paraplegia and quadriplegia **(1-3 % AIS ,10 – 26% PSO)** . In rare cases it may also present as a cauda equina syndrome when working distally to L3.

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- **Dural tears** may occur infrequently when performing **sublaminar wires**.
- The critical point to cause spinal cord injury during surgery is when **derotation and distraction maneuvers** of the spine are performed to correct scoliosis.
- When a neurological disorder at the time of awakening test or a change in the amplitude or latency of the SSEP is noted, the **correction should be decreased,**
  Elevate BP,
  Restore body temp.,
  Steroids until the patient move his limbs normally and / or potentials recover.

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- The type of instrumentation used also has a direct relationship to neurological damage. The pedicle screw may violate the medial pedicle wall and invade the spinal canal or break the lateral wall.

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Gastrontestinal complications:

- Stress ulcers, like all major surgery can occur after surgery for scoliosis (ASD).
- Postoperative ileus (anterior surgery) and along with the use of opioids.

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- The syndrome of the superior mesenteric artery is produced by a closure of the exit angle of the superior mesenteric artery from the aorta that causes extrinsic compression of the third portion of duodenum. (CAST syndrome)
- This is attributed to excessive stretching of the spine. These patients may present in postoperative nausea and permanent bilious vomiting.

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Infections:

- Risk factors include prolonged duration of surgery, severe blood loss and scoliosis requiring multiple procedures or stages.
- Infections can occur **immediately** after surgery or **late** presenting with fever, wound erythema, pain and drainage with rise in Erythrocyte Sedimentation Rate and C-reactive protein.

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- Surgical debridement may be needed with copious irrigation of the wound, removal of slough and closing the wound leaving drain. Then, specific intravenous antibiotics according to the culture result should be instituted.

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Failure of instrumentation and nonunion:

- Implant failure may occur due to mal-insertion.
- **Pedicle screws** placed outside the pedicle have less gripping force and compromise the stability of the reduction.
- **Pedicle hooks** can also migrate if not properly hooked on the pedicle.
- **Laminar hooks** under excessive kyphosis pressure can dislodge because of a fracture of the lamina and, compromising stability.

- The late failure of the instrumentation is often associated with nonunion.
- If a nonunion is diagnosed, it must be repaired by defect curettage and new bone grafting & proper fixation.
  It may be necessary to perform an **anterior approach** to ensure a circumferential fusion.
- Instrumentation failure can occur because of the emergence of **infections**.

Decompensation and increased deformity:

- Classically it was very common when using Harrington rods acting on distraction which did not correct the vertebral rotation. The result was a loss of lumbar lordosis (flat back syndrome).
- This **fixed sagittal imbalance syndrome** is characterized by progressive lumbosacral pain, forward bending of the trunk and inability to maintain an upright position.

- Selective application of fusion trying to preserve lumbar segments that should be fused to preserve motion. In these cases, **progression of the non-fused curve** results in imbalances of the trunk .
- The use of **anterior instrumentation** can also cause an alteration of the sagittal profile as it is known to have a **recognized kyphosis effect**. Surgeon must know very well the anterior instrumentation indications and try to avoid them in case of thoracic kyphosis above 40º.

- **Crank-shaft phenomenon** occurs after posterior spinal fusion in immature patients (Risser less than 1 and less than 10 years) and is attributed to the constant growth of the vertebral body in the anterior part which takes the posterior fixed structures as the axis of rotation.
- The consequence is an **increase in the angular value** of the curve and an **increase in the thoracic hump**.

Pathology of adjacent level:

- The appearance of **disc degeneration** above or below the instrumentation in **ASD** is a common complication , especially if there is a **sagittal imbalance**.
- Some of the patients experiencing this problem may require revision surgery to perform an **extension of the arthrodesis**.

Other rare complications:

- The syndrome of inappropriate secretion of antidiuretic hormone,
- Blindness caused by occlusion of the central retinal artery,

  Peripheral nerve injuries (position related).
- DVT and thromboembolism.
- Urinary infections.

Risks and Complications in Lumbar Interventional Spine Procedures

Definitions

Steroid Side Effects - secondary unwanted **effect** that occurs due to drug therapy

- Facial flushing
- Elevated blood glucose

Adverse Events- unintended pharmacologic **effects** that occur when a medication is administered correctly

- Epidural hematoma
- Nerve injury
- Insufficiency fracture

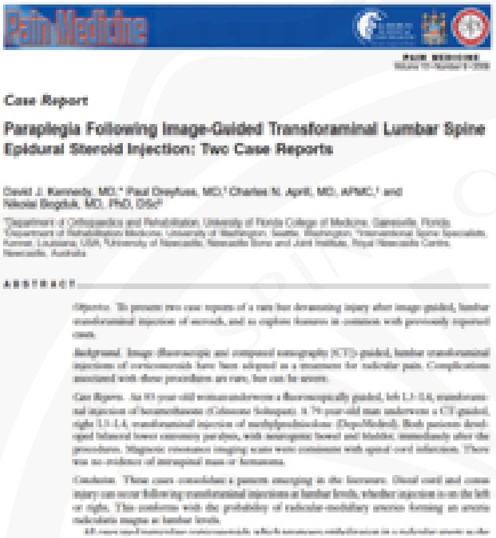
Neither imply wrong doing

Outline

- Major complications
  - Paralysis
    - Thrombosis
    - Hematoma
- Large Cohort Studies
  - Show overall safety
- Possible adverse events
  - Procedural
  - Medication related

Things that could go wrong

- Procedural
  - Vasovagal
  - Intradiscal injection
  - Dural puncture
    - Intrathecal injection
  - Infection
- Allergic Reaction
- Medication Side Effect
  - Steroids


Pain Medicine

Case Report

Paraplegia Following Image-Guided Transforaminal Lumbar Spine Epidural Steroid Injection: Two Case Reports

ABSTRACT

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PARTICULATE STEROIDS

16 Cases of spinal cord infarction reported in the literature after L(S)TFESI of particulate steroid (1 w/ Dexamethasone)

Injection of particulate matter into a medullary artery is HIGH RISK

SIS Practice Guidelines 2nd Edition Edited by N Bogduk 2013

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Mechanism of Injury

- Inadvertent injection of particulate steroids into vulnerable arteries feeding the CNS were resulting in embolic infarcts (Tiso et al., 2004)

Steroid Properties

- Particulate steroids (methylprednisolone, betamethasone, triamcinolone) are insoluble in water and form large particles or aggregates (Derby, Lee, Date, Lee, & Lee, 2008a)
  - 50-100 micrometers
  - RBC diameter is 6-8 micrometer

Animal models

- Direct injection of steroids into the vertebral artery of pigs
  - methylprednisolone resulted in permanent neurologic hypoxic/ischemic damage (Okubadejo et al., 2008)
- Direct injection of particulate steroids into the carotid artery of rats has also been found to cause permanent neurologic injury (Tiso et al., 2004)(Honorio T. Benzon et al., 2007) (Laemmel et al., 2016) (Dawley, Moeller-Bertram, Wallace, & Patel, 2009).

Dexamethasone!

- Dexamethasone is smaller than the size of an rbc, with particles only 0.5 µm in size (Derby et al., 2008b)
- Animal studies have then shown that intra-arterial injection of dexamethasone into swine or mice does not cause neurologic injury (Tiso et al., 2004)(Honorio T. Benzon et al., 2007) (Laemmel et al., 2016) (Okubadejo et al., 2008)(Dawley et al., 2009)

SPECIAL ARTICLES

Safeguards to Prevent Neurologic Complications after Epidural Steroid Injections

Consensus Opinions from a Multidisciplinary Working Group and National Organizations

A nonparticulate steroid (e.g., dexamethasone) should be used for the initial injection in lumbar transforaminal epidural injections.

Lumbar TF ESIs should be performed by injecting contrast medium under real-time fluoroscopy and/or digital subtraction imaging, using an AP view, before injecting any substance that may be hazardous to the patient (fig. 7).

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Paralysis from ILESI

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Space occupying lesion: Epidural Hematoma

Williams et al., 1990	Urinary retention, then paralysis	Indomethacin	Yes	Urinary retention
H. T. Benzon et al., 1999	Weakness, numbness	Diclofenac, clopidogrel, possibly aspirin	Yes	Paraplegia
Schreiber et al., 2015	Not reported	*anticoagulation*	Yes	T2 AIS C
Reitman & Watters, 2002	Neck/shoulder pain, then weakness/numbness	None reported	Yes	Death

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Space occupying lesion: Epidural Hematoma

	Symptoms	Meds	Surgery	Residual deficits
Stoll & Sanchez, 2002	Brown-sequard	None – possible post injection manipulation	Yes	Persistent numbness
Ghaly, 2001	Right sided hemiplegia, left sided numbness	Diclofenac	Yes	none
Yagi et al., 1998	Neck pain, brow-sequard syndrome	None reported	Yes	none
Benyamin et al., 2016	Neck pain, UE paresthesia	Clopidogrel held	Yes	none

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Risks and Benefits of Ceasing or Continuing Anticoagulant Medication for Image-Guided Procedures for Spine Pain: A Systematic Review

Clark C. Smith, MD, MPH, Byron Schneider, MD, Zachary L. McCormick, MD, Jatinder Gill, MD, Vivek Loomba, MD, Andrew J. Engel, MD, Belinda Duszynski, Wade King, MMedSc MMed(Pain),
on behalf of the Standards Division of the Spine Intervention Society

Pain Medicine, pnx152, https://doi.org/10.1093/pm/pnx152
Published: 28 July 2017

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Morbidity	Anticoagulant	Indication	When	Procedure
Fatal myocardial infarction	Warfarin	IHD	7 days after	Cervical epidural
Fatal stroke	Warfarin	AF	Morning of	Lumbar RFN
Non-fatal stroke	Warfarin	AF	2 days after	Cervical MBB
Non-fatal stroke	Warfarin	AF	5 days after	Cervical epidural
Non-fatal stroke	Warfarin	AF	3 days after	Lumbar TFI
Non-fatal stroke	Warfarin	AF	4 days after	Lumbar interlaminar
Non-fatal stroke	Warfarin	AF	3 days after	Lumbar interlaminar
Pulmonary embolism	Warfarin	PE	2 days after	Lumbar intrathecal injection
Myocardial infarction	Warfarin	IHD/AF	5 days after	Cervical epidural

IHD = ischemic heart disease; AF = atrial fibrillation; PE = pulmonary embolism; RFN = radiofrequency neurotomy; MBB = medial branch block; TFI = transforaminal injection.

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Paralysis from other spine injections

- None
  - At least reported
  - Presuming proper techniques and safeguards are followed

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Fortunately

- Large studies have confirmed very low rate of complications when recommended guidelines are followed.

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Even Larger Studies

Pain Medicine 2016; 17: 2155–2161

OXFORD

SPINE SECTION

Original Research Articles

Immediate Adverse Events in Interventional Pain Procedures: A Multi-Institutional Study

Carrie M. Carr, MD,[*] Christopher T. Plastaras, MD,[†]
Matthew J. Pingree, MD,[‡] Matthew Smuck, MD,[§]
Timothy P. Maus, MD,[*] Jennifer R. Geske, MS,[¶]
Christine A. El-Yahchouchi, MD,[‖]
Zachary L. McCormick, MD,[‖‖] and
David J. Kennedy, MD[§]

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Discussion

- Data available for N = 26,062 procedures
- No major complications
  - No permanent neurologic deficit
  - No clinically significant bleeding
    - No epidural or subdural hematoma

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Discussion

- Overall adverse event rate: 1.9%
  - Most frequent:
    - Vasovagal reactions: 1.1%
    - Majority required no medications
    - No sequelae
  - Aborted procedures: 0.6%
    - Primarily epidurals, TFESI > IL
      - Vasovagal, vascular uptake, pain
    - No sequelae

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Discussion

- Overall adverse event rate: 1.9%
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    - Primarily epidurals, TFESI > IL
      - Vasovagal, vascular uptake, pain
    - No sequelae

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Discussion

- ED transfers: <0.1%
  - Allergic reactions
  - Chest pain
  - Symptomatic hypertension
  - Vasovagal reaction
  - No sequelae
- Allergic Reactions, Dural punctures < 0.1%
  - Allergic reactions to both iodine based contrast & gadolinium
  - Primarily rashes, one laryngospasm

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Epidural steroid injection-related events requiring hospitalisation or emergency room visits among 52,935 procedures performed at a single centre

Joon Woo Lee, Eugene Lee, Guen Young Lee, Yusuhn Kang, Joong Mo Ahn, Heung Sik Kang

- 6/25,935 had major complication (0.011%)
  - 2 hematomas
  - 4 infections
- 56/25,935 drug-related systemic effects
- 174 "uncertain"

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Collectively

There are clearly major complications
that occur at a low rate
and may have mitigating factors

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Things that could go wrong

- Procedural
  - Vasovagal
  - Intradiscal injection
  - Dural puncture
    - Intrathecal injection
  - Infection
- Allergic Reaction
- Medication Side Effect
  - Steroids

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Vasovagal Rates in Flouroscopically Guided Interventional Procedures: A Study of Over 8,000 Injections

David J. Kennedy, MD[1], Byron Schneider, MD[1], Ellen Casey, MD[1], Joshua Rittenberg, MD[1], Bryan Conrad, PhD[1], Matthew Smuck, MD[1], and Christopher T. Plastaras, MD[1]

- 8,010 injections looked at
- VV rate of 2.6%
- TFESI VV rate of 3.5%
- Predictors included:
  - VAS <5 (P<0004)
  - Male (p<0.001)
  - Age < 65 yo (p<0.001)

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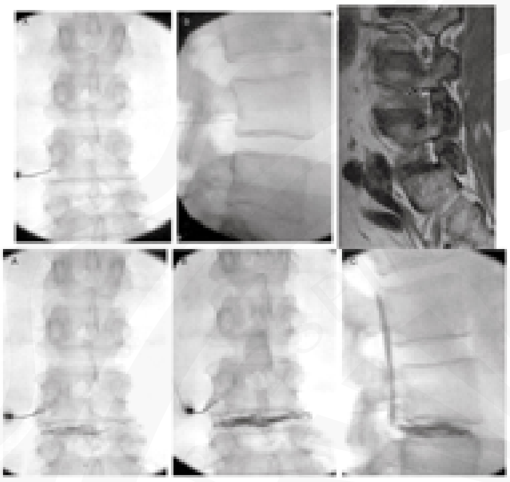
Intradiscal Flow TFESI

- Multiple case reports
- Rate reported as 0.17-0.25% *(Plastaras, Candido)*
  - 1 reported with interlaminar *(Candido 2010 Anesth Analg)*
- Predisposing factors
  - Foraminal disc herniation
  - Foraminal stenosis
  - Malpositioned needle

(Plastaras 2010, Pain Medicine)



From Levy, D. Pain Medicine Volume 11, Issue 5, pages 716–718, May 2010

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Infection

Rates between 1/12,500 and 1/250,000 reported

- Most case reports develop weeks later

-CBC late finding (WBC shift with steroids)

Highest in intradiscal

-unclear role for antibiotics in inadvertent injection

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Dural Puncture < 0.5% incidence

- Interlaminar ESI
  - Smaller gauge epidural needle (Lambert)
    - » 17 gauge: 75% required blood patch
    - » 25-27 gauge: 13-39% require blood patch
    - » Can happen with TF , unclear rates <IL
- Spinal headache
  - Not all dural punctures will result in a spinal headache
  - From CSF leak
  - Tension on cranial meningeal vessels and nerves
  - Headache is **positional**

Intrathecal Injections

- Contrast
  - Iodinate based contrast
  - Gadolinium
- Anesthetic
  - Spinal Anesthesia
- Corticosteroids
  - Possible arachnoiditis

Intrathecal Gadolinium

•AVOID Intrathecal Space- Neurotoxicity in higher doses

•Not for Epidural Use

(Safriel, AJNR 2006)

Anesthetics

- Intrathecal
- Spinal anesthesia
- Loss of consciousness
- Hypotension
- Apnea
- Cardiac arrest
- Death

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Arachnoiditis

Animal Studies & Case Reports

Multiple animal studies re arachnoiditis due to preservative in corticosteroids

Case reports of arachnoiditis following injection of anything (lidocaine, steroids, blood patch)

? Natural history

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Injectates

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Local Anesthetics

Lidocaine:
Maximum dose 300-500 mg

Bupivacaine:
Maximum dose 175 mg

You should not get near these numbers

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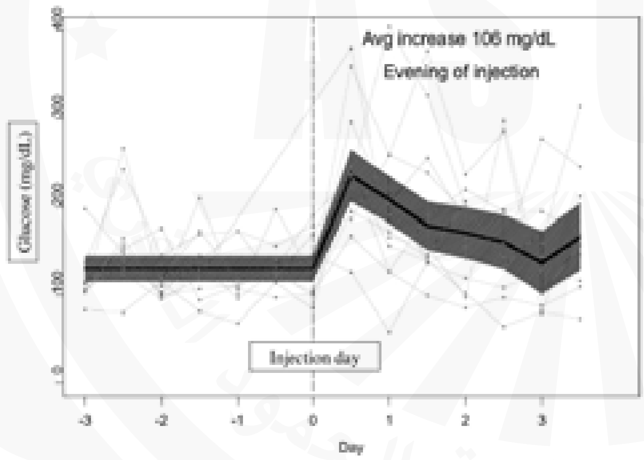
Steroids

Systemic Effects
Hyperglycemia
  increase in 140mg/dL for 2-3 days
Hypothalamic Pituitary Access
Suppression
  Lasts up to three weeks
  Most common long term sequela is
  Osteoperosis



Gonzalez 2009 PM&R Journal

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Summary of suppression literature

- Adrenal suppression is exceedingly common after corticosteroid exposure
  - Day 0- Week 1: 90% severely suppressed
  - Week 1-2: 30-50% suppressed
  - Week 3: 10% severely suppressed
  - Week 6: 3% severely suppressed
- Most adrenal suppression occurs in the first week and recovers around 3-4 weeks
- The total corticosteroid dose is potentially more important to adrenal suppression than the exact number of injections

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ESI before surgery

- Yang S, Werner BC, Cancienne JM, Hassanzadeh H, Shimer AL, Shen FH, Singla A. Preoperative epidural injections are associated with increased risk of infection after single-level lumbar decompression. Spine J. 2016;16:191-6.
- Donnally CJ 3rd, Rush AJ 3rd, Rivera S, Vakharia RM, Vakharia AM, Massel DH, Eismont FJ. An epidural steroid injection in the 6 months preceding a lumbar decompression without fusion predisposes patients to post-operative infections. J Spine Surg. 2018;4:529-533.
- Hartveldt S, Janssen SJ, Wood KB, Cha TD, Schwab JH, Bono CM, Jenis LG. Is there an association of epidural corticosteroid injection with postoperative surgical site infection after surgery for lumbar degenerative spine disease? Spine. 2016;41:1542-1547.
- Ozturk S, Akgun B, Erol FS, Onal SA, Kaplan M. Intraoperative results and postoperative clinical outcomes of lumbar microdiscectomy in patients who previously received a transforaminal anterior epidural steroid injection for lumbar radiculopathy. Turk Neurosurg. 2018;28:263-269.
- Seavey JG, Balazs GC, Steelman T, Helgeson M, Gwinn DE, Wagner SC. The effect of preoperative lumbar epidural corticosteroid injection on postoperative infection rate in patients undergoing single-level lumbar decompression. Spine J. 2017;17:1209-1214.
- Zusman N, Munch JL, Ching A, Hart R, Yoo J. Preoperative epidural spinal injections increase the risk of surgical wound complications but do not affect overall complication risk or patient-perceived outcomes. J Neurosurg Spine. 2015;23:652-655.
- Singla A, Yang S, Werner BC, Cancienne JM, Nourbakhsh A, Shimer AL, Hassanzadeh H, Shen FH. The impact of preoperative epidural injections on postoperative infection in lumbar fusion surgery. J Neurosurg Spine. 2017;26:645-649.

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In Summary

- Low risk of major complications (<0.01%)
- Known transient minor side effects (10%)
- Adverse effects to specific medications (gad, steroids, preservatives ,etc)

Avoiding and Managing Adjacent Segment Disease

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Adjacent Segment Pathology (ASP)

- Pathology adjacent to previous lumbar fusion
  - Can include:
    - Listhesis / Instability
    - Stenosis
    - HNP / Disc degeneration
    - Facet degeneration
    - Compression fractures

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Hypothesis

- Increased biomechanical stress and facet joint loading results in accelerated degeneration

Hillbrand AS et al., Spine J 2004
Lee CK et al., Spine 1984

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Radiographic ASP: Imaging findings of pathology ≠ Clinical ASP: Symptoms + RASP

Mannion et al. Spine 2014

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Normal Degeneration versus ASP

- Natural history of degenerative changes versus fusion-induced ASD symptoms
- Disc degeneration is natural progression of aging; 41%

Elfering A et al. Spine 2002

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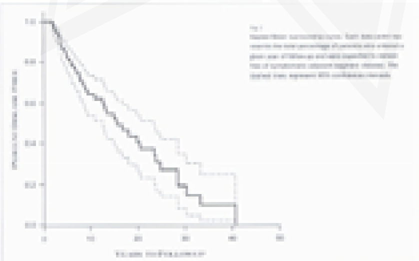
Why is ASP prevention important?

- CASP requiring reoperation reported up to 16.5% at 5 years and 36.1% at 10 years.
- 2-3 % / year



Ghiselli, Wang et al . *J Bone Joint Surg Am.* 2004

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Adjacent Segment Disease After Posterior Lumbar Fusion: Long-term Follow-up and Survivorship Analysis

Gary Ghiselli, MD
Jeffrey C Wang, MD
Nitin N Bhatia, MD
Wellington K Hsu, MD
Edgar G Dawson, MD

Journal of Bone and Joint Surgery 2004

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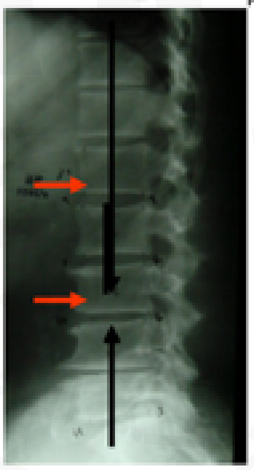
Results

- Three fusion levels analyzed
  - Thoracolumbar
    - Fused from thoracic to lumbar spine (scoliosis)
  - Floating
    - Not fused to sacrum or thoracic spine
  - Lumbosacral
    - Fused to sacrum



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Re-operation Analysis

- Overall, 37% of patients will need another procedure at an adjacent segment in 10 years
- 3.7% per year
- Curves modified for age showed better correlation with thoracolumbar fusions

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Subsequent L5-S1 Disc Degeneration After L4-L5 Isolated Lumbar Fusion: Long-term Survivorship Analysis

Gary Ghiselli, MD
Jeffrey C. Wang, MD
Wellington K. Hsu, MD
Edgar G. Dawson, MD

Spine 2003

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Introduction

- There is current controversy regarding future degeneration of the L5-S1 segment following adjacent segment fusion at the L4-L5 level.
- There are no long-term studies which specifically look at the L5-S1 level after L4-L5 fusion to assess the rate of degeneration at this adjacent segment.

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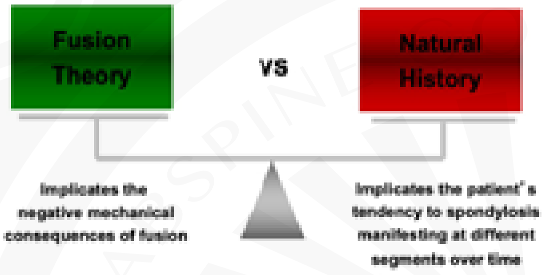
Results

- 31 (97%) had no evidence of symptomatic degeneration at the L5-S1 level requiring additional decompression or fusion
- One patient had clinical symptoms that required a foraminotomy and laminotomy at the L5-S1 level 7.9 years after fusion (3%)

"What *causes* ASDz?"



Currently, the fusion theory is popular

Common scenario:

Patient:

"I don't want a fusion. I heard it will put too much stress on my other discs."

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This view has a simplistic, knee-jerk appeal…

Blame the fusion!!!!

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This simplistic view is flawed and ignores a basic fact:

There is a certain rate of cervical spondylosis <u>even in the absence of fusion</u>!

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Reality of Natl Hx:

Would've happened anyway!!!

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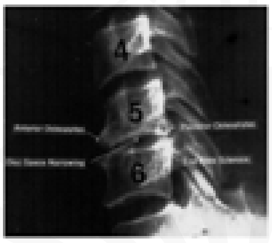
Natural history of spondylosis in those who have never had fusion

n = 159 initially aSx people

10 yr radiographic FU



Gore, *Spine* 2001

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34% new degen changes

Without initial degen changes

66% NO new changes

97% progression

With initial degen changes

3% no progression

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Prevention

- Avoid known risk factors
- But….conflicting data

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Spine

ADJACENT SEGMENT PATHOLOGY OF THE THORACOLUMBAR SPINE

Predicting the Risk of Adjacent Segment Pathology After Lumbar Fusion

A Systematic Review

Consensus Statements

1. The risk of developing CASP after lumbar fusion occurs at a mean annual incidence of 0.6% to 3.9%.
   Strength of Statement: Strong
2. Patients older than 60 years or who have pre-existing facet/disc degeneration may have an increased risk of developing CASP.
   Strength of Statement: Strong
3. The risk of developing CASP may be greater after multilevel fusions and fusions adjacent to but not including the L5–S1 level, and may increase when performing a laminectomy adjacent to a fusion.
   Strength of Statement: Strong

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ASP Risk Factors

- Age > 55 years old
- Obesity
- Occupational Lifting
- Sporting Activities
- Post-menopausal women
- Preexisting degenerative disc disease of facet degeneration
- Positive sagittal balance
- High Pelvic Incidence
- Presence of instrumentation (+/-)
- Excess disc height distraction in PLIF/TLIF
- Length of fusion
- Facet / PLC injury
- Previous disc disease at adjacent segment
- Laminectomy adjacent to fusion
- Stopping fusion at the apical level of deformity
- Smoking (+/-)
- Interbody fusion (+/-)

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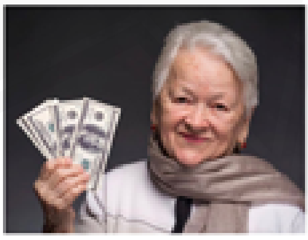
Age

- Decreased accommodation of aging spine
- Multiple studies: Age >55 is a risk factor for ASP



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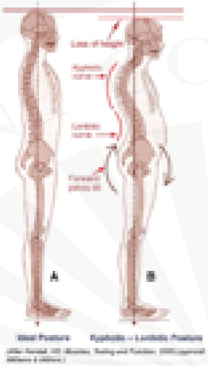
Obesity

- Some studies suggest that obesity may be a risk factor for the development of ASP with a BMI > 25



Yugue et al. Eur Spine J 2016
Wang et al. Medicine 2017

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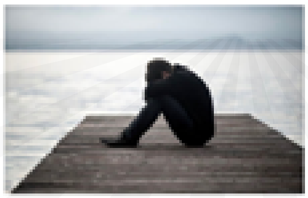
Preoperative Antidepressant Use

- 5.4x odds ratio of ASP



Alentado et al. SPINE 2016

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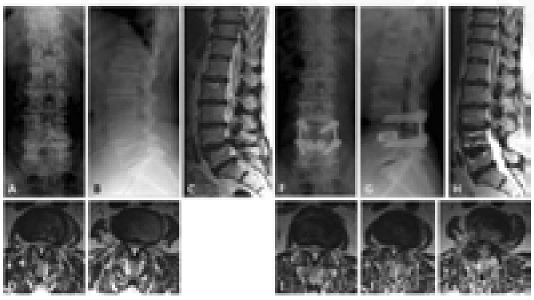
Preoperative Adjacent Segment Facet Degeneration

- Conflicting data whether this truly increases the ASP incidence



Lee et al., Eur Spine J 2009

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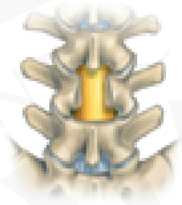
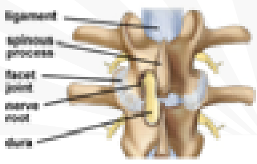
Laminectomy at Adjacent Segment

- 2.4x increased risk of revision surgery for ASP
- Conflicting data whether this truly increases the ASP incidence

Sears WR et al. Spine J 2011
Lee JC, et al. Spine 2014





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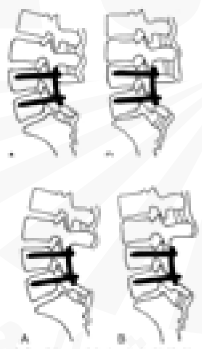
PLC Injury

- Injury to the adjacent segment posterior ligamentous complex has been shown to contribute to ASP
- Avoidance of facet or PLC injury by avoiding complete laminectomy at the level above fusion may be preventative of ASP

Liu et al. JNS 2013
Po-Liang Lai, MD et al., SPINE 2004



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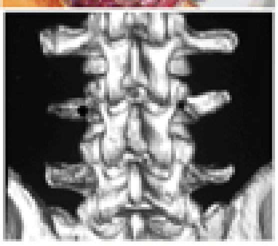
Facet Injury

- Injury to the cranial facet during pedicle screw placement or dissection is associated with higher rates of ASP
- Capsule preservation during initial dissection and more lateral pedicle screw starting point

Wang et al. Medicine (2017)
He et al. SPINE 2014



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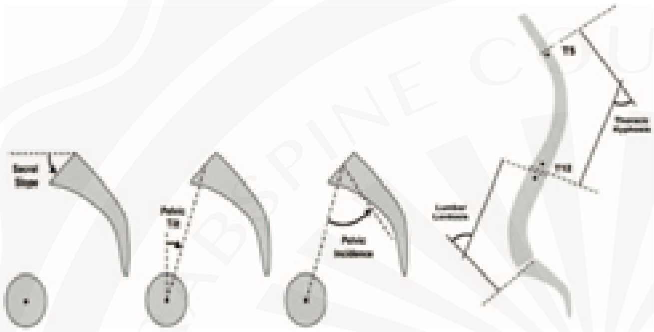
Sagittal balance



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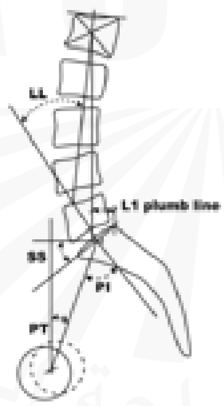
Sagittal Balance

- PI – LL Mismatch > 10 degrees has a 10x increased risk for revision surgery for CASP

Rothenfluh et al. Eur Spine J 2015



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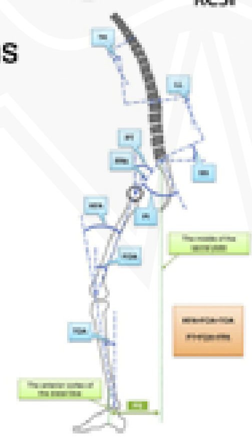
Compensatory mechanisms

- 5x risk of development of ASP in patients with a preoperative PT > 22.5 degrees
- This is associated with pelvic retroversion and compensatory mechanisms including hip and knee flexion for sagittal imbalance

Yamasaki et al., Spine 2017



Cheng et al., Gait & Posture 2017

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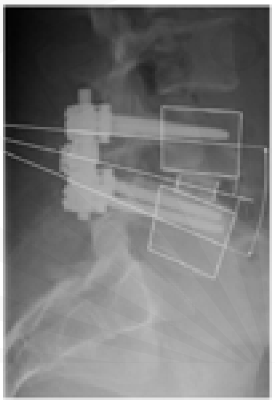
Interbody Fusion Consideration

- For isolated L4-5 interbody fusions, maintaining a segmental lordotic alignment has been shown to be critical for preventing ASP



Kim et al. Spine 2010
Akamaru et al., Spine 2003

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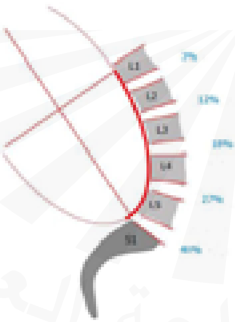
How do we do it?

- Appropriate counseling
- Restoration of global sagittal balance
- Maintaining segmental lordosis in short segment fusion
- Avoiding PI-LL mismatch > 10 degrees



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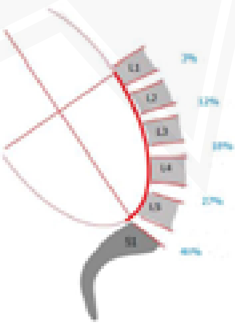

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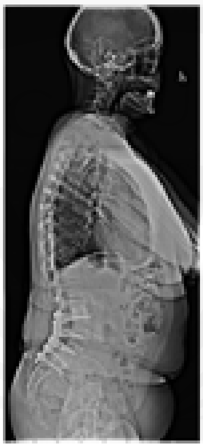
How do we do it?

- 36" standing radiographs to evaluate the entire axis and help guide goals of treatment
- Anterior column support for disc height and lordosis restoration
- Attention to segmental lordosis



Kim KT, *Spine* 2006

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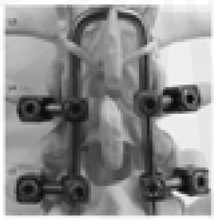
Dynamic Stabilization

- Sublaminar taping of the adjacent segment above has been described and in one study has shown a reduction in radiographic ASD, however this did not affect clinical outcomes



Tachibana et al. *Spine* 2016

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Dynamic Stabilization

- Similar pedicle based screw dynamic systems have also been described for the adjacent upper level

Imagama et al. Spine 2009

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Alternative Technologies

- Disc arthroplasty
- Dynamic posterior instrumentation

- Little high-quality evidence to support their use in prevention of ASD, perhaps even the opposite

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Future Directions

- Alendronate
  - Recent animal study data has shown beneficial effect in preventing ASP
    - *Zhou et al. Spine 2015*
- Calcitonin
  - Recent animal study data has shown beneficial effect in preventing ASP
    - *Liu et al. BMC Musculoskeletal 2015*

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Interventional Pain Techniques in Patients with Pain After Back Surgery

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Spinal Cord Stimulation for pain:

Introduction:

Nociceptive Pain:
- Direct activation of nociceptors & their afferent pathways
  - Chronic OA, Cancer pain, Trauma

De-afferentation Pain:
- Arises from NS injury
- "Central Pain" if brain or SC injured
  - CVA, MS, SCI

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Spinal Cord Stimulation for pain:

Introduction:

Nociceptive Pain:
- Direct activation of nociceptors & their afferent pathways
  - Chronic OA,

MIXED

De-afferentation Pain:
- Arises from NS injury
- "Central Pain" if brain or SC injured
  - CVA, MS, SCI

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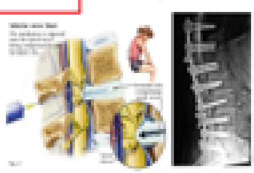
Spinal Cord Stimulation for pain:

Introduction:

Nociceptive Pain:
- NSAID
- Injections
- Decompressive/ Stabilization Surgery



Spinal Cord Stimulation for pain:

Introduction:

De-afferentation Pain:

- Oral analgesia
- Opioid
- Anti-epileptic Meds., Anti-Depressant
- Spinal Cord Stimulation

Spinal Cord Stimulation for pain:

Introduction:

Nociceptive Pain:

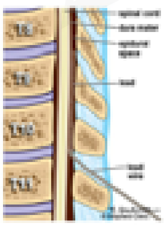
- NSAID
- Injections
- Decompr
- cordotom
- Intrat
- DBS: pathw

De-afferentation Pain:

- Oral analgesia
- Opioid
- Anti-siezure Meds.
- tion
- ducing (VPL
- Motor Cortex Stimulation

MIXED

Spinal Cord Stimulation for pain:



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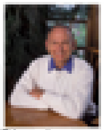
Spinal Cord Stimulation for pain:

Introduction:

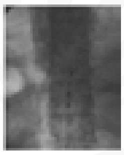
History of Spinal Cord Stimulation

- 1969: Shealy, SCS in humans
- 1975: Dooley, perc. Electrode
- 1970s: self-powered battery
- 1980s: programmable quad electrode
- 1980s -1990s: Primary cell IPG
- 2004: Rechargeable IPG

High Frequency Stim



Shealy, 1969



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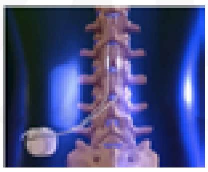
Spinal Cord Stimulation for pain:

Mechanism of Action:

Not well-understood



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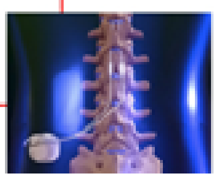
Spinal Cord Stimulation for pain:

Mechanism of Action:

- Gate control theory
- Direct inhibition of spincthalamic neurons
- Descending modulatory effects
- Alteration of sympathetic activity
- Neurochemical modulation

Not well-understood



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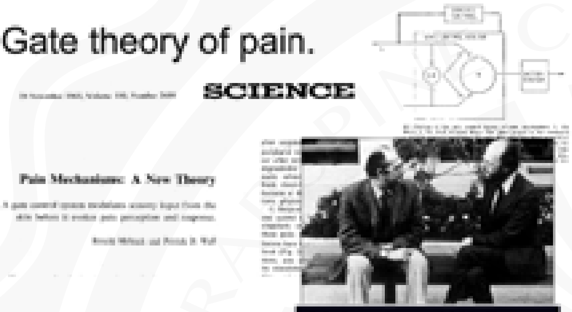
Spinal Cord Stimulation for pain:

Mechanism of Action:

Gate theory of pain.



Melzack and Wall (1965)

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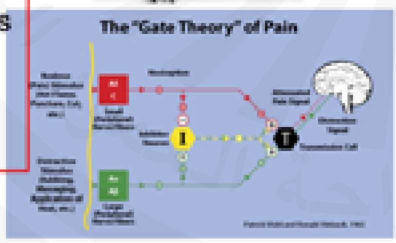
Spinal Cord Stimulation for pain:

Mechanism of Action:

Gate theory of pain.

Stimulation of large, myelinated fibers results in paresthesia that will block the activities in small, nociceptive projections.



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Spinal Cord Stimulation for pain:

Patient Selection:

Indications (Painful disorders):

- Failed Back Surgery Syndrome
- Reflex Sympathetic Dystrophy
- Phantom Limb Pain/ Stump Pain
- Peripheral neuropathies/Brachial plexitis
- Radiculopathies
- Angina
- Peripheral Vascular Disease/ Ischemic Pain

Others: Perineal pain, Zoster pain

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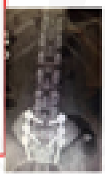
Spinal Cord Stimulation for pain:

Patient Selection:

Failed Back Surgery Syndrome FBSS:

- Most common indication for SCS
- Pain after more than one surgeries on the L/S spine
- Etiology; difficult to pinpoint
- FBSS; improper patient selection
- 1-10% of patients will be worse after surgery
- Characteristics: pain, numbness/tingling, stabbing burning and shooting pain



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Spinal Cord Stimulation for pain:

Patient Selection:

The Good Candidate:

- Last resort; no more conservative therapies
- No further surgery is indicated
- No drug habituation/ psychological clearance
- No contraindications; sepsis, coagulopathy, etc.
- Successful trial
- Multidisciplinary screening
- Patient motivation and willing

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Spinal Cord Stimulation for pain:

Patient Selection:

The Good Candidate:

- Last resort; no more conservative therapies
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- No drug habituation/ psychological clearance
- No contraindications; sepsis, coagulopathy, etc.
- Successful trial
- Multidisciplinary screening
- Patient motivation and willing

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Spinal Cord Stimulation for pain:

Patient Selection:

Stimulation trial period:

A trail of ext. Stim. 2- 3 days preoperatively is needed to determine the value of stimulation.

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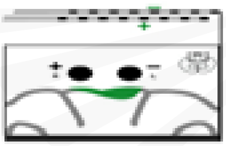
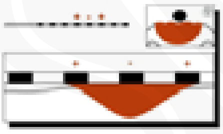
Electrical Field Shaping

Single Lead Bipole

Dual Lead Bipole



Single Lead Guarded Array



Transverse Guarded Array

8/3/2006

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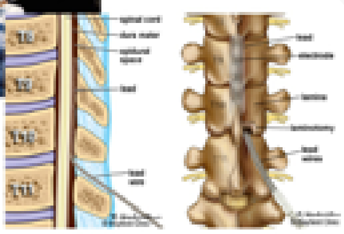
Spinal Cord Stimulation for pain:

Surgical Techniques:

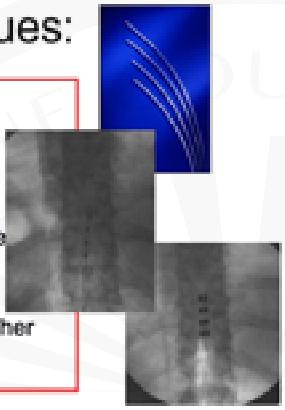


Spinal Cord Stimulation for pain:

Surgical Techniques:

Electrodes:

- Easy to insert
- Ideal for screening trial
  - Avoids 2nd procedure
- Migration; esp. cervical spine
- Insertion difficulties post decompression surgery
- Circumferential contacts; higher power requirements

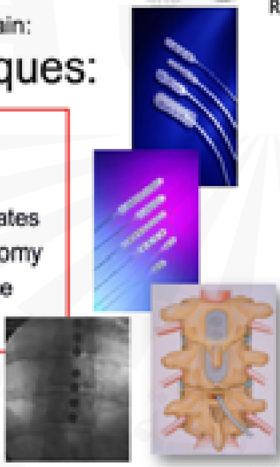


Spinal Cord Stimulation for pain:

Surgical Techniques:

Plate :

- Laminotomy required
- Less migration and revision rates
- Easier to place after laminectomy
- Insulated contacts may reduce power requirements



Spinal Cord Stimulation for pain:

Surgical Techniques:

Power Sources

- External RF system
  - More power and flexibility
  - Inconvenience for patient
  - Unable to use during certain activities
- Primary cell IPG system
  - More convenient
  - Finite battery life
- Rechargeable IPG system
  - Extended battery life
  - 16 contacts programming flexibility
  - Requires recharging by patient

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Spinal Cord Stimulation for pain:

Clinical Outcome:

Benefits of Surgery:

- Pain relief
- Reduction in pain medication intake
- Return to work
- Return to daily activities
- Improving quality of life
- Improving depression symptoms

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Spinal Cord Stimulation for pain:

Clinical Outcome:

The Biggest Lies Ever Told

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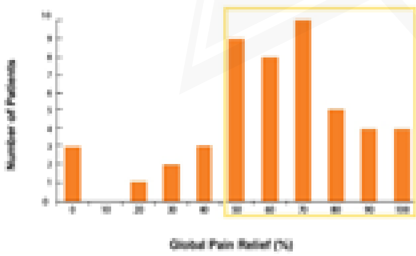
Spinal Cord Stimulation for pain:

Clinical Outcome:

Overall Global Pain Relief



Key Findings:
Overall pain relief of ≥50% was reported by 82% of patients

Roberts, et al., *European Journal of Pain.*

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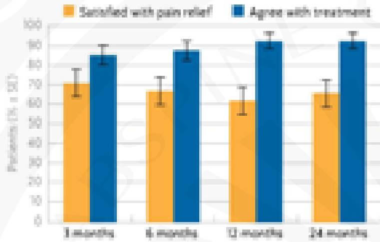
Spinal Cord Stimulation for pain:

Clinical Outcome:
Patient Satisfaction



Key Findings:
Treatment satisfaction among patients continuing SCS @ 24 months

Kumar, et al. *Pain* 2007; n = 100

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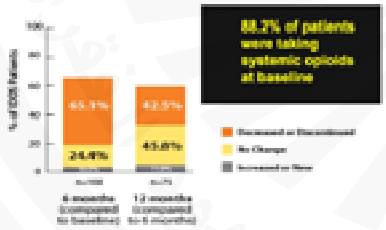
Spinal Cord Stimulation for pain:

Clinical Outcome:
Decreased Use of Pain Medications



88.2% of patients were taking systemic opioids at baseline

Key Findings:
At 6/12, 65% of patients decreased systemic opioids from baseline
At 12/12, 42% of patients decreased their usage compared with the 6/12 f/u

Deer, et al. *Pain Medicine* 2004; n=12

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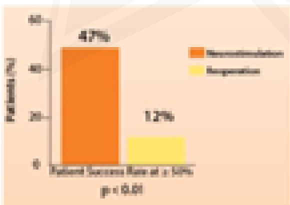
Spinal Cord Stimulation for pain:

Clinical Outcome:
More Effective than Repeat Surgery



Key Findings:
SCS was significantly more successful than reoperation: 47% Vs. 12% randomized to reoperation

North, et al. *Neurosurgery* 2005 ; n=45

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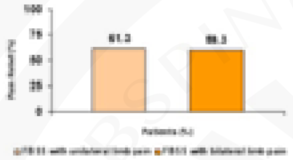
Spinal Cord Stimulation for pain:

Clinical Outcome:

Long-Term Pain Relief



Key Findings:

61.3% of failed back surgery syndrome patients with bilateral limb pain and 59.3% of patients with unilateral limb pain reported >50%

Kumar, et al. *Neurosurgery* 2006

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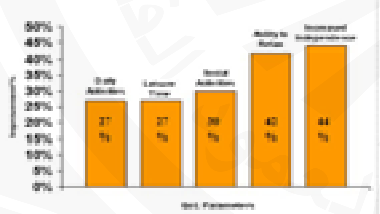
Spinal Cord Stimulation for pain:

Clinical Outcome:

10-Year Experience:

Neurostimulation Improves Quality of Life



Van Buyten J-P, et al. *Eur J Pain* 2001;5:299-307; n=125 pain cases; P<0.01 for all activities

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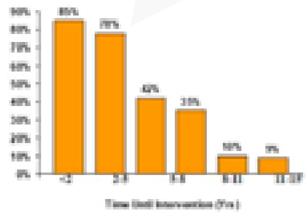
Spinal Cord Stimulation for pain:

Clinical Outcome:

Neurostimulation is Most Effective When Considered Early



Kumar K, et al. *Neurosurg* 2006;58:481-496

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Spinal Cord Stimulation for pain:

Clinical Outcome:

Risks of Neurostimulation:

- Lead migration
- uncomfortable stimulation
- Wrong location
- Neurological damage during procedure
- Risk of infection at implantation

North R, Kidd D, Zahurak M, et al. Neurosurgery. 1993;32:384-395.

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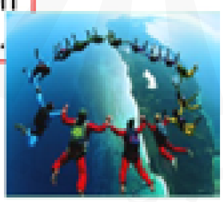
Spinal Cord Stimulation for pain:

Conclusion:

Teamwork:
Evaluation of the patient by a multidisciplinary pain team with strict adherence to the selection criteria can optimize responses.



Surgical Options in Patients with Pain After Back Surgery

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Objectives

Establish an approach to these patients

Develop an algorithm for assessment

Assess index surgery

Comprehensive review of available studies

Preoperative optimization strategies

Review revision Spine Surgery options

Last resort options

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Patient Approach

- Tricky Patient Population
  - Acute Postoperative Issues
  - Physician - Patient communication
  - Most worrisome: Infection, Active CSF L
- Establish Office Criteria
  - > 1 year out from surgery
    - Time to heal
      - Nerve root
      - Fusion healing
  - Exceptions:
    - Build your practice
    - Build your revision experience
- Plan for a complicated visit
  - Prior documentation
  - Imaging
    - Preoperative films

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Physician Approach

- Avoid dismissive approach or looking for an easy out
  - Remove hardware
  - Stimulator
- Accept the challenge
- Detailed Surgical History

Straightforward Data
- Surgeon
- Date
- Location
- Number
- Type

Clinical History
- Preoperative symptoms
- Preoperative treatment
- EMG/NCS
- Preoperative deficits
- Surgical plan
- Complications/Changes in plan

Postoperative course
- Relief of symptoms?
  - Temporary?
- Hospital Course
- What did the surgeon tell you?
- What is your new goal?

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Diagnostic Workup

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Pathologies (Stories)

Epidural Hematoma (acute)

Infection (acute versus chronic)

Hardware Failure/Misplacement

Nonunion/Pseudoarthrosis

Residual Neural compression (central or foraminal)

Dural Etiologies - CSF leak to Pseudomenigocoele

Adjacent segment disease

Post Junctional Kyphotic Failure

Deformity - Sagittal Imbalance

Chronic Pain

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Advanced Imaging Study Options

- MRI
  - Metal Artifact Reduction
    - Surgical Date
  - Evaluate
    - Soft tissues
      - Central canal
      - Foramen
      - Surgical Bed
      - Future Surgical beds
- CT
  - Evaluate
    - Fusion
    - Hardware
    - Anatomy
    - Decompression

- CT Myelogram
  - Combination of Studies
  - Not all features of MRI
  - Invasive procedure
  - Anticoagulation
  - Important to indicate where to enter canal

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Patient Approach

- Review the study in detail with the patient
  - Pertinent Positives
  - Confidence
    - Comprehensive
    - Focus on the pathology
      - Avoid Surgeon related discussion

- Think About the Patient
  - Reasonable
  - Exam versus Objective data (Imaging)
  - Persistently Sought Treatment
  - Gap in Treatment

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Surgical Principles

Infection	Superficial - Consider Washout/Debridement Deep - Hardware – Involve ID, understand extent of infection, ID bacteria, Abx
Hardware Failure/Misplacement	Determine Underlying Etiology if Present
Nonunion/Pseudoarthrosis	Revision Fusion Strategies Interbody Fusion Grafting options – Biologics - BMP
Residual Neural compression (central or foraminal)	Direct Revision Decompression Indirect Decompression Options (interbody)
Dural Etiologies - CSF leak to Pseudomeningocele	Direct Repair - Fat Graft, Patch/Sealant vs. Nonop Plastic Surgery
Adjacent segment disease	Various options
Post Junctional Kyphotic Failure	Extension of Fusion Careful attention to Balance
Deformity – Sagittal Imbalance	Deformity Correction
Chronic Pain	Pain Management Evaluation Spinal Cord Stimulator

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Preoperative Optimization

**Infection/ Nonunion/ Junctional Failure

Protoplasm Assessment

- Nutritional Status
  - Serum Albumin levels
  - Pre-Albumin levels
  - Total lymphocyte count
  - Transferrin levels
- Glucose control
  - HgA1C - optimal number? (<7%)
  - Improved glycemic control
- Obesity
  - Weight loss management
- Smoking status

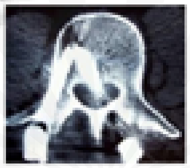
Osteoporosis
- DEXA scan
  - Endocrinology
  - Preop Forteo
    - Postop - not proven

Guzman, et al. Outcomes and Complications of Diabetes Mellitus on Patients Undergoing Degenerative Lumbar Spine Surgery. Spine 2014

Salvetti, et al. Low preoperative serum prealbumin levels and the postoperative surgical site infection risk in elective spine surgery: a consecutive series. JNS 2018

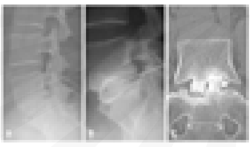
Hardware Failure/Misplacement

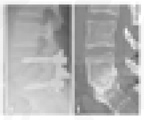
- Loosening
  - Nonunion Strategies
- Failure
  - Nonunion Stratgies
  - Pros/Cons of Hardware Removal
  - Fusion status
  - System - Removal tools
  - Replace Hardware - Plan Options & Siz
- Misplacement
  - Violation of Canal
    - Plug the hole
  - Plan a different trajectory
    - Navigation



Pseudoarthrosis

- Identify Location of Nonunion
  - Labs - Infection
- Approach Depends on Current Instrumentation Or lack thereof
- Consider Various Options to Fuse
  - Posterolateral fusion bed
  - Interbody Space
    - ALIF
    - TLIF (usually index)
    - LIF
  - Removal of failed interbody graft/cage
- Discuss Grafting/Biologic Options
  - Gold Standard
  - BMP





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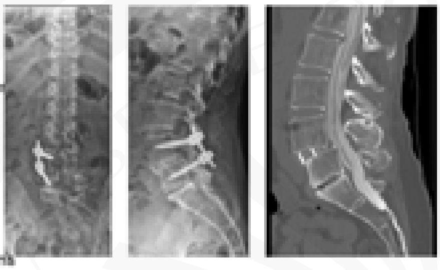

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Residual Neural Compression

- Consider revision direct decompression
  - Infection
  - Durotomy
- Consider indirect decompression
  - May have to unlock construct
  - May have to takedown a fusion
  - Interbody approach
    - ALIF
    - LIF

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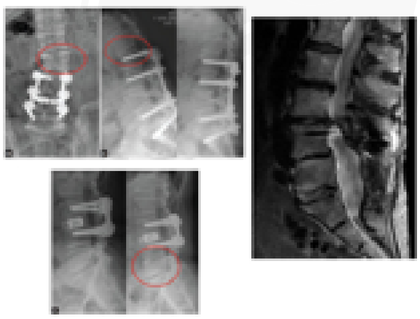
Adjacent Segment

- Instability versus Degeneration
  - Consider associated canal/foraminal pathology
- Symptom complex
  - Back pain
  - Claudication
  - Leg pain
- Decompressive approach vs.
- Extension of Fusion
  - Consider Interbody
  - Connect to old Fusion
  - Exchange of Hardware
- Pan out
  - Deformity



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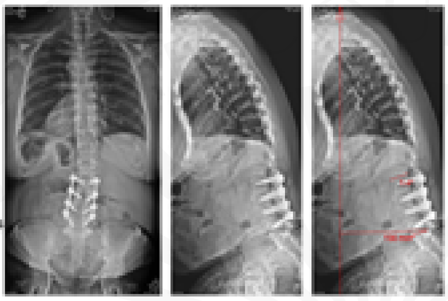
Deformity

- Consider overall alignment
- Patient expectations
  - activity level
- Counseling
- Appropriate Parameters
  - Pelvic Incidence
  - Lumbar lordosis
  - Mismatch
  - Pelvic Tilt
- Consider osteotomies versus interbody correction
  - Hyperlordotic
- Staging



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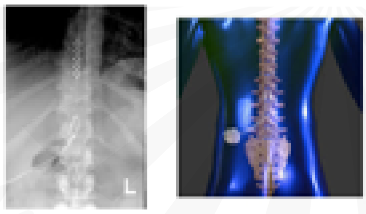
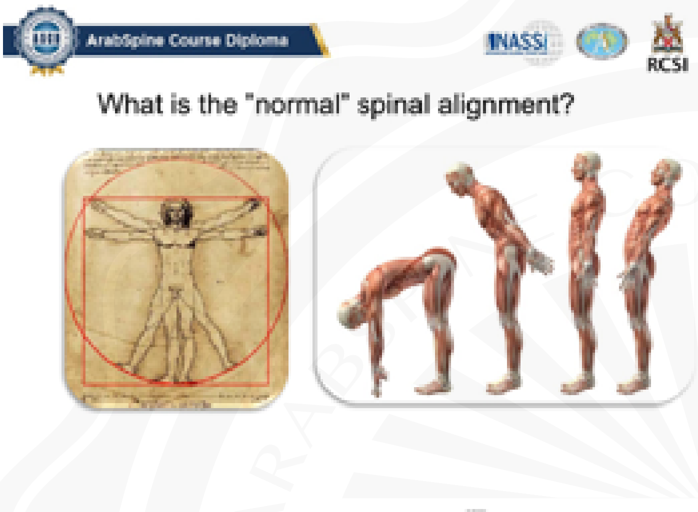
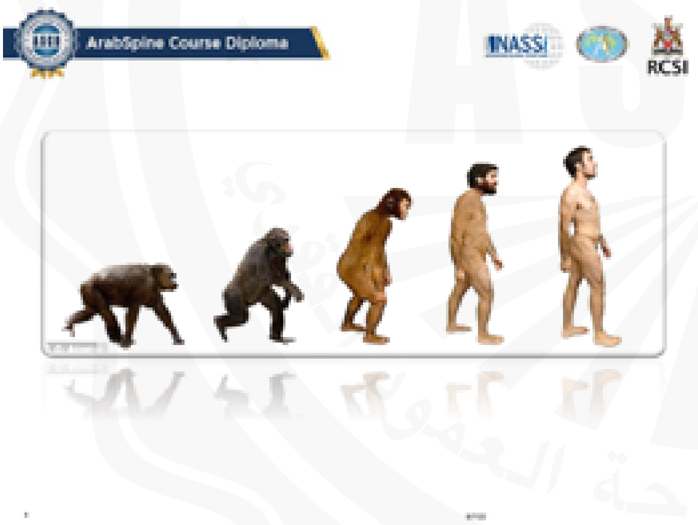
Chronic Pain

- Exhaust nonsurgical management
- Ensure pathology is not being missed
  - Look for UMN lesions
  - Proximal pathology T or C spine
- Last Resort: Spinal Cord Stimulator
  - MRI restrictions
  - Trial*
    - at least 50%
    - > 75% ideal
  - Psychiatric Clearance
  - Ideal placement Leads
  - Expanding technology



Sagittal Imbalance: Principles in Revision





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Spinopelvic parameters

PI = PT + SS

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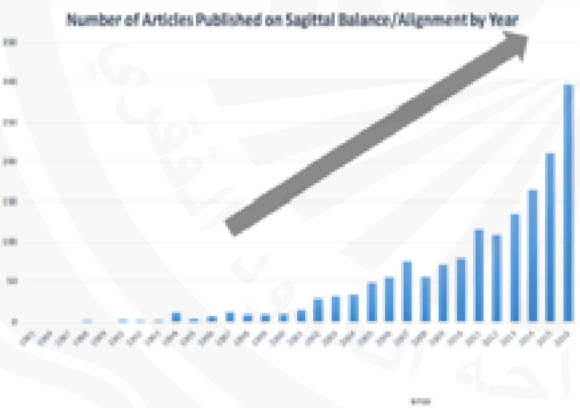

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Bernhardt & Bridwell 1989

"Average thoracic kyphosis = 36 deg
Average lumbar lordosis = 44 deg
Two thirds of LL occur at L4-5, L5-S1"

Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction.

Author information

Abstract

[illegible]

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Table 1. Normal values of the spino-pelvic relationship.

Parameters	Variation in degrees (º)	Mean in degrees (º)
Pelvic incidence (PI)	40 - 65º	51º
Pelvic tilt (PT)	10 - 25º	12º
Sacral slope (SS)	30 - 50º	39º

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"Cone of Economy"

Dubousset J. Three-dimensional analysis of the scoliotic deformity. In Weinstein SL (ed): The Pediatric Spine: Principles and Practice. New York, NY: Raven Press, 1994, pp 479-496.

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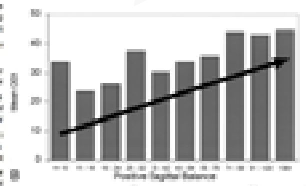
Glassman et al. 2005

"All measures of health status showed significantly poorer scores as C7 plumb line deviation increased."

The impact of positive sagittal balance in adult spinal deformity.

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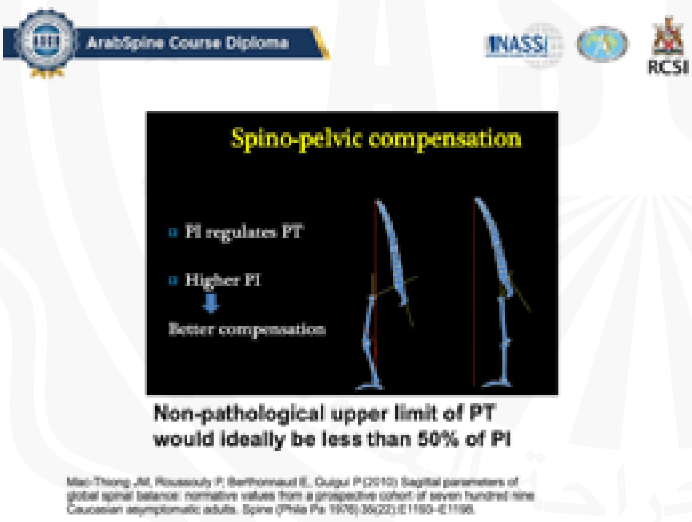
Spino-pelvic pathology patterns
Progressive kyphosis
Gravity line drifts forwards
Pelvis rotates backwards
Sacral slope decreases
Knee flexion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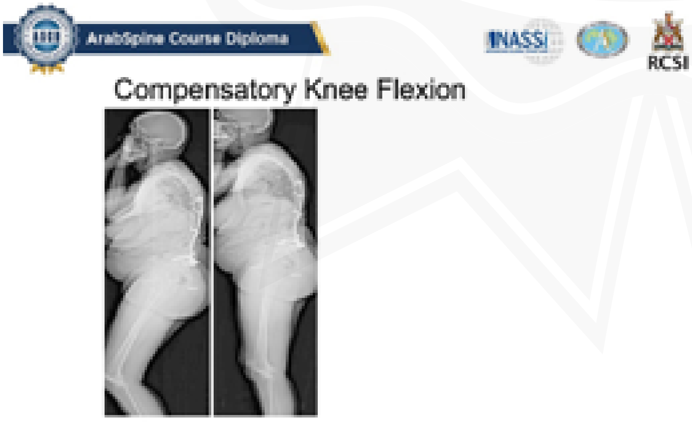
Spino-pelvic compensation
PI regulates PT
Higher PI
Better compensation
Non-pathological upper limit of PT
would ideally be less than 50% of PI
Mac-Thiong JM, Roussouly P, Berthonnaud E, Guigui P (2010) Sagittal parameters of global spinal balance: normative values from a prospective cohort of seven hundred nine Caucasian asymptomatic adults. Spine (Phila Pa 1976) 35(22):E1193–E1198.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NASS
RCSI
Compensatory Knee Flexion

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[illegible]

Classification of the Normal Variation in the Sagittal Alignment of the Human Lumbar Spine and Pelvis in the Standing Position

[illegible]

Methods. In the course of this study, anteroposterior and lateral radiographs of 160 volunteers in a standardized standing position were taken. A custom computer application was used to analyze the alignment of the spine and pelvis on the lateral radiographs. A four-part classification scheme of sagittal morphology was used to classify each patient.

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- 160 healthy volunteers
- Average age is 27 years old
- Standing erect by comfortable position

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Table 3. The Characteristics of the Lumbar Lordosis as a Function of the Type of Sagittal Morphology

Sacral Slope	No.	Incidence (mean [range]) (°)	Apex	Lordosis Tilt Angle (mean [range]) (°)	Global Lordosis (mean [range]) (°)	No. of Lordotic Vertebrae (mean [range]) (°)	Upper Arc (mean [range]) (°)
[illegible]	[illegible]	[illegible]	Middle L5	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Base L4	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Middle L4	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Base L3	[illegible]	[illegible]	[illegible]	[illegible]

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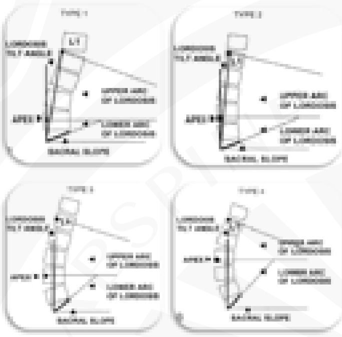

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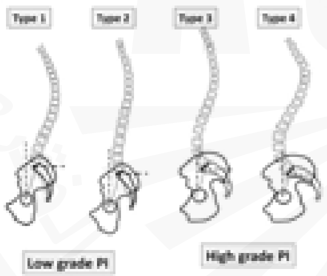

Fig. 4 The shape of lumbar lordosis depends on SS orientation. Type 1 and 2 have SS < 35°; Type 3 has 35° < SS < 45°; Type 4 has SS > 45°. Generally Type 1 and 2 have a low PI and Type 3 and 4 have a high PI

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ORIGINAL ARTICLE

Classification of normal sagittal spine alignment: refounding the Roussouly classification

Abstract

Purpose Although the Roussouly classification of common variants in spinal sagittal alignment is well accepted, no studies have implemented it in an asymptomatic adult population. In addition, no study investigated the radiographic features of asymptomatic patients with an anteverted pelvis. The aim of this prospective radiographic study of 296 asymptomatic adults without spinal pathology was to investigate how the Roussouly classification could include the anteverted pelvis concept.

Methods Pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), and the lumbar parameters lumbar lordosis (Global LL), lordosis tilt angle (LTA), total number of lordotic vertebra (LL vertebra), and C7 plumbline/sacrofemoral distance ratio (C7PL ratio) were evaluated in 296 healthy volunteers (126 males, 170 females; mean age, 27 years; range 18–48 years). Comparison between the five types of the Roussouly classification used Student, ANOVA, and Tukey tests for quantitative variables and χ^2, Fischer, and Holm tests for qualitative variables.

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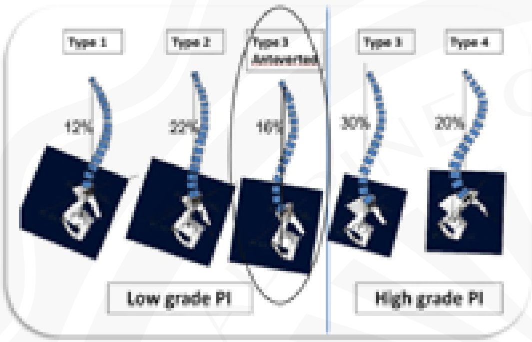

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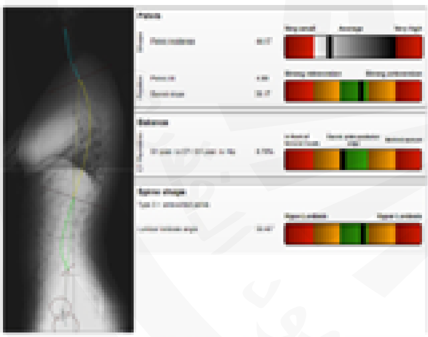

Type 3 + anteverted pelvis (AP): a new, unusual shape (Figs. 5, 6): a sizable portion (16%) of the population showed low-grade PI (mean 40°) despite having SS > 35°.

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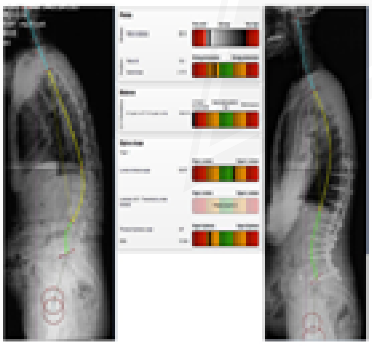

Type 1 pre-op → AP Type 3 post-op

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Journal of Anatomy

Standing sagittal alignment of the whole axial skeleton with reference to the gravity line in humans

Kazuhiro Hasegawa, Masashi Okamoto, Shun Hatsushikano, Haruka Shimoda, Masatoshi Ono, Takao Homma and Kei Watanabe

Materials and methods

After institutional review board approval, 158 volunteers with no history of treatment for spinal disease were enrolled. Informed con-

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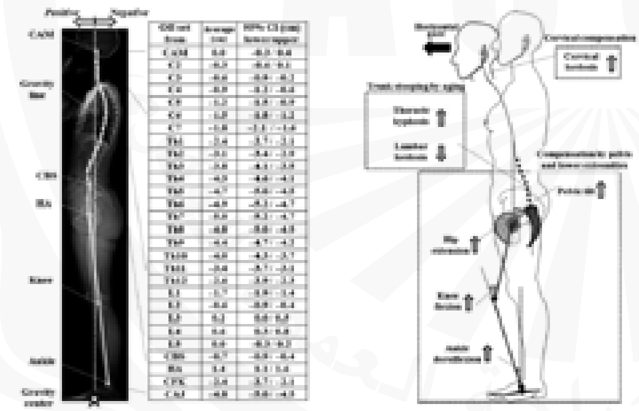

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PI increases ~0.2 deg/yr with aging

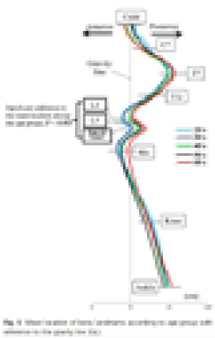

Table 4 Result of simple linear regression analyses among the measured parameters and age.

Parameters	Decision coefficient (r^2)	P-value	Slope of the regression line	Intercept of the regression
CBVA	0.0058	0.3910	−0.0400	6.9720
SLS	0.0069	0.3388	−0.0441	2.4807
McGS	0.0095	0.2598	−0.0532	5.9153
CL	0.1058	0.0001	0.3225	−15.9544
Kyph	0.0457	0.0125	0.1918	34.1563
LL	0.0093	0.2628	−0.0968	58.3261
SS	0.0004	0.8218	−0.0148	41.3323
PT	0.0945	0.0003	0.2085	3.0202
PI	0.0385	0.0220	0.1936	44.3585
PTx	0.0068	0.3385	−0.0054	11.1312
SVA	0.1368	<0.0001	0.0781	−3.0971
TPA	0.0562	0.0055	0.1797	8.2725
APP	0.0394	0.0206	0.1430	191.0203
KneeFlex	0.0621	0.0034	0.1008	−5.5798
AnkleFlex	0.0341	0.0313	0.0384	2.4860

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[illegible]
ORIGINAL ARTICLE

Normative data for parameters of sagittal spinal alignment in healthy subjects: an analysis of gender specific differences and changes with aging in 626 asymptomatic individuals

Yasutsugu Yukawa · Fumihiko Kato · Kota Suda · Masatsune Yamagata · Takayoshi Ueta · Munehito Yoshida

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Table 6 Pelvic tilt (PT)

Decade	Male	Female	P value
20–29	12.9 ± 8.1	11.4 ± 6.6	NS
30–39	13.1 ± 7.7	12.0 ± 6.7	NS
40–49	11.5 ± 5.8	16.2 ± 8.4	<0.001
50–59	13.3 ± 9.8	15.1 ± 7.5	NS
60–69	13.7 ± 7.1	18.4 ± 9.2	<0.01
70–79	15.3 ± 7.4	21.0 ± 7.8	<0.001
All	13.2 ± 7.7	15.8 ± 8.6	<0.001
Total	14.5 ± 8.4		

NS indicates not significant

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Table 8 Sagittal vertical axis (SVA)

Decade	Male	Female	P value
20–29	−2.1 ± 8.2	−4.6 ± 13.5	NS
30–39	3.0 ± 9.2	−4.1 ± 13.0	<0.01
40–49	5.0 ± 13.7	0.9 ± 9.0	0.070
50–59	4.5 ± 11.8	3.4 ± 11.1	NS
60–69	5.5 ± 14.0	4.6 ± 10.4	NS
70–79	10.3 ± 14.4	10.7 ± 15.2	NS
All	4.5 ± 11.9	1.8 ± 13.1	<0.01
Total	3.1 ± 12.6		

NS indicates not significant

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What is the ideal amount of correction? What is acceptable amount of correction? How much can the patient tolerate?

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JNS SPINE CLINICAL ARTICLE

Is achieving optimal spinopelvic parameters necessary to obtain substantial clinical benefit? An analysis of patients who underwent circumferential minimally invasive surgery or hybrid surgery with open posterior instrumentation

Paul Park, MD,[1] Kai-Ming Fu, MD, PhD,[2] Robert K. Eastlack, MD,[3] Stacie Tran, MPH,[3] Gregory M. Mundis Jr., MD,[3] Juan S. Uribe, MD,[4] Michael Y. Wang, MD,[5] Khoi D. Than, MD,[6] David O. Okonkwo, MD, PhD,[7] Adam S. Kanter, MD,[7] Pierce D. Nunley, MD,[8] Neel Anand, MD,[10] Richard G. Fessler, MD, PhD,[11] Dean Chou, MD,[12] Mark E. Oppenlander, MD,[1] Praveen V. Mummaneni, MD,[12] and the International Spine Study Group

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METHODS A multicenter retrospective review of patients who underwent less invasive surgery for ASD was conducted. Inclusion criteria were age ≥ 18 years and one of the following: coronal Cobb angle > 20°, sagittal vertical axis (SVA) > 5 cm, pelvic tilt (PT) > 20°, or pelvic incidence to lumbar lordosis (PI-LL) mismatch > 10°. A total of 223 patients who were treated with circumferential minimally invasive surgery or hybrid surgery and had a minimum 2-year follow-up were identified. Based on optimal spinopelvic parameters (PI-LL mismatch ≤ 10° and SVA < 5 cm), patients were divided into aligned (AL) or malaligned (MAL) groups. The primary clinical outcome studied was the Oswestry Disability Index (ODI) score.

RESULTS There were 74 patients in the AL group and 149 patients in the MAL group. Age and body mass index were similar between groups. Although the baseline SVA was similar, PI-LL mismatch (9.9° vs 17.7°, $p = 0.002$) and PT (19° vs 24.7°, $p = 0.001$) significantly differed between AL and MAL groups, respectively. As expected postoperatively, the AL and MAL groups differed significantly in PI-LL mismatch (−0.9° vs 13.1°, $p < 0.001$), PT (84° vs 25.5°, $p < 0.001$), and SVA (11.8 mm vs 48.3 mm, $p < 0.001$), respectively. Notably, there was no difference in the proportion of AL or MAL patients in whom an MCID (52.75% vs 61.1%, $p > 0.05$) or SCB (40.5% vs 46.3%, $p > 0.05$) was achieved for ODI score, respectively. Similarly, no differences in percentage of patients obtaining an MCID or SCB for visual analog scale back and leg pain score were observed. On multivariate analysis controlling for surgical and preoperative demographic differences, achieving optimal spinopelvic parameters was not associated with achieving an MCID (OR 0.645, 95% CI 0.31–1.33) or an SCB (OR 0.644, 95% CI 0.31–1.35) for ODI score.

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TABLE 1. Subanalysis of preoperative patients with malalignment who achieved alignment versus patients whose malalignment persisted postoperatively

Variable	Achieved Alignment	Malalignment Persisted	p Value
No. of patients	36	126	
Age (yrs)	60.1	62.9	0.158
Body mass index (kg/m²)	27.8	28.0	0.967
Follow-up (mos)	39.7	40.1	0.952
Δ VAS back pain score	−2.6	−3.4	0.203
Δ VAS leg pain score	−4.0	−3.2	0.188
Δ ODI score	−19.7	−18.4	0.742
SCB ODI score, no. (%)	15 (41.7%)	54 (42.9%)	0.527
MCID ODI score, no. (%)	21 (58.3%)	73 (57.9%)	0.948

Values are presented as the mean or as the number (%) of patients.
* Denotes statistical significance.

Conclusions

Achieving optimal spinopelvic parameters was not a predictor for achieving an MCID or SCB in this patient population. Since spinopelvic parameters are correlated with clinical outcomes, our findings suggest that the previously accepted optimal spinopelvic parameters may require modification. It is also probable that some of the clinical benefits seen in this series were attributable to other relevant factors, such as the improvement of neurological symptoms and/or the alleviation of local spinal instability.

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JNS SPINE CLINICAL ARTICLE

Treatment of only the fractional curve for radiculopathy in adult scoliosis: comparison to lower thoracic and upper thoracic fusions

Dominic Amara, BA,[1] Praveen V. Mummaneni, MD,[1] Christopher P. Ames, MD,[1] Bobby Tay, MD,[1] Vedat Deviren, MD,[1] Shane Burch, MD,[1] Sigurd H. Berven, MD,[1] and Dean Chou, MD[1]

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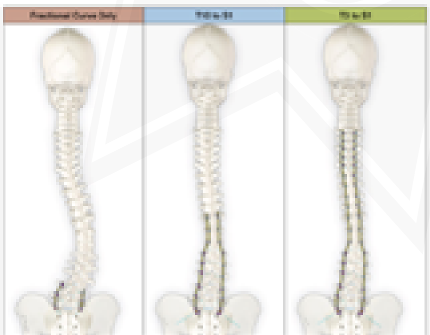

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TABLE 3. Summary of complications and outcomes

Outcome	Total	FC	LT	UT	p Value*	FC vs LT p Value	FC vs UT p Value	UT vs LT p Value
No. of patients	99	27	46	26				
Any complication (medical or revision op), no. (%)	52 (52.5)	11 (40.7)	26 (56.5)	15 (57.7)	0.35	—	—	—
Medical complications, no. (%)	47 (47.5)	6 (22.2)	26 (56.5)	15 (57.7)	<0.01	<0.01	<0.01	0.90
Overall revision op, no. (%)	34 (34.3)	7 (25.9)	18 (39.1)	9 (34.6)	0.52	—	—	—
Extension op	14 (14.1)	7 (25.9)	6 (13)	1 (3.8)	0.068	0.21	0.030	0.41
Time to extension in days	953	1089	761	1147	0.76	—	—	—
Non-extension revision op	23 (23.2)	0 (0)	14 (30.4)	9 (34.6)	<0.01	<0.01	<0.01	0.79
Discharge to acute rehabilitation, no. (%)	51 (51.5)	8 (29.6)	21 (45.7)	22 (84.6)	<0.01	0.22	<0.01	<0.01
30-day readmission, no. (%)	7 (7.1)	1 (3.7)	5 (10.9)	1 (3.8)	0.47	—	—	—
Postop spinal imaging characteristics								
FC in °	5.9	7.1	5.8	5.0	0.11	—	—	—
PT in °	23.6	23.7	24.2	22.6	0.77	—	—	—
LL in °	43.6	42.3	44.3	44.6	0.78	—	—	—
PI-LL mismatch in °	11.6	17.9	7.7	12.7	0.037	0.029	0.46	0.43
SVA in cm	4.6	4.4	5.5	3.4	0.18	—	—	—
Coronal balance magnitude in °	2.0	1.6	2.1	2.5	0.25	—	—	—
Scoliosis major curve in °†	16.6	28.1	11.6	15.4	<0.01	<0.01	<0.01	0.21

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RESULTS Of the 99 patients eligible for inclusion in the study, 27 were in the FC group, 46 in the LT group, and 26 in the UT group. There were no significant preoperative differences in age, sex, smoking status, prior operation, FC magnitude, pelvic tilt (PT), sagittal vertical axis (SVA), coronal balance, pelvic incidence–lumbar lordosis (PI-LL) mismatch, or proportion of well-aligned spines (SVA < 5 cm, PI-LL mismatch < 10°, and PT < 20°) among the three treatment groups. Mean follow-up was 30 (range 12–112) months, with a minimum 1-year follow-up. The FC group had a lower medical complication rate (22% [FC] vs 57% [LT] vs 58% [UT], p < 0.009) but a higher rate of extension surgery (26% [FC] vs 13% [LT] vs 4% [UT], p = 0.068). The respective average estimated blood loss (992 vs 1950 vs 2634 ml, p < 0.001), length of hospital stay (5.5 vs 8.3 vs 8.3 days, p < 0.001), and rate of discharge to acute rehabilitation (30% vs 46% vs 85%, p < 0.001) were all lower for FC and highest for UT.

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JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 27:[illegible], 2017

Complication rates associated with 3-column osteotomy in 82 adult spinal deformity patients: retrospective review of a prospectively collected multicenter consecutive series with 2-year follow-up

Justin S. Smith, MD, PhD,[1] Christopher I. Shaffrey, MD,[1] Eric Klineberg, MD,[2]
Virginie Lafage, PhD,[3] Frank Schwab, MD,[3] Renaud Lafage, MS,[3] Han Jo Kim, MD,[3]
Richard Hostin, MD,[4] Gregory M. Mundis Jr., MD,[5] Munish Gupta, MD,[6] Barthelemy Liabaud, MD,[7]
Justin K. Scheer, MD,[8] Bassel G. Diebo, MD,[7] Themistocles S. Protopsaltis, MD,[7]
Michael P. Kelly, MD,[6] Vedat Deviren, MD,[9] Robert Hart, MD,[10] Doug Burton, MD,[11]
Shay Bess, MD,[4] and Christopher P. Ames, MD,[9] on behalf of the International Spine Study Group

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TABLE 2. Rates of complications in 82 adults with surgical treatment that included a 3-column osteotomy for spinal deformity with 2-year follow-up

Complication Category	No. of Complications, Major/Minor (%) Early	Delayed	Total
Implant	[illegible]	[illegible]	[illegible]
Neurologic	[illegible]	[illegible]	[illegible]
Operative	[illegible]	[illegible]	[illegible]
Cardiopulmonary	[illegible]	[illegible]	[illegible]
Radiographic	[illegible]	[illegible]	[illegible]
Infection	[illegible]	[illegible]	[illegible]
Wound (excluding infection)	[illegible]	[illegible]	[illegible]
Gastrointestinal	[illegible]	[illegible]	[illegible]
Vascular	[illegible]	[illegible]	[illegible]
Total (minor/major)	[illegible]	[illegible]	[illegible]
Mean no. of complications per patient (minor/major)	[illegible]	[illegible]	[illegible]
No. of patients affected (%)	[illegible]	[illegible]	[illegible]

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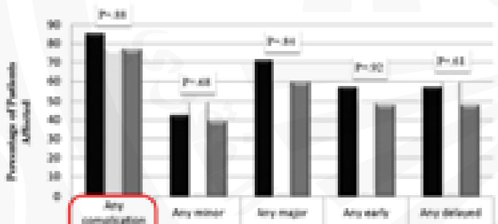

	Any complication	Any minor	Any major	Any early	Any delayed
18-44 y/o	85.7	42.9	71.4	57.1	57.1
45-64 y/o	77.5	50	60	50	60
65-86 y/o	77.1	40	60	48.6	48.6

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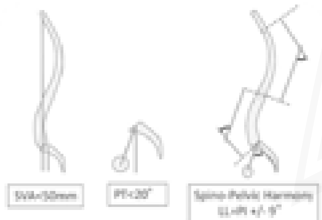

Surgical goals need to be individualized based pathology and patient-specific factors to minimize complications

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SEQUENCES OF POSTERIOR SPINAL DEFORMITY CORRECTION

- Positioning/Establishing baseline neuromonitoring data
- Exposure
- Decompression/Facetectomies
- Instrumentation
- Addition Posterior Release If Needed
  - PCOs (workhorse), PSO, VCR
- Rodding (deformity correction step)
- Decortication/bone grafting
- Closure

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BASIC POST CORRECTION TECHNIQUE BIOMECHANICS

Distraction – Concavity = "Kyphogenic"
Compression – Convexity = "Lordogenic"
Cantilever Rod Application = "Lordogenic"
Translation Forces = Post/Ant/Lat/Medial
In-Situ Rod Contouring = Post/Ant/Lat/Med
Rod Rotation Maneuvers = Kypho/Lordo
Apical Derotation Maneuvers = Untwisting
Kickstand rod to facilitate coronal correction

ALL POSSIBLE WITH PEDICLE SCREWS!

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Case #1

HPI: 21M presents with low back pain with last 6 months referred for evaluation of scoliosis by his PCP. Also complains of some right leg pain.

PMH/PSH: none
All: NKDA
Meds: none
SHx: smoker

PHYSICAL EXAM

MAE 5/5 except for right EHL/DF 4/5
Sensation grossly full
Reflexes 2+

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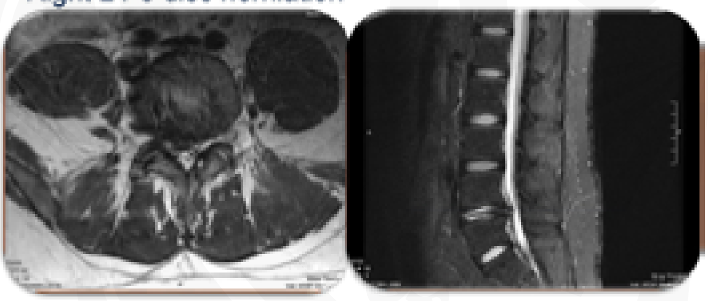
Right L4-5 disc herniation



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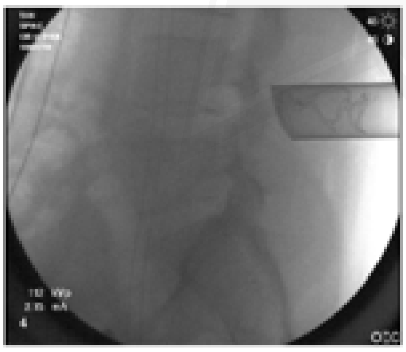


Case #2

HPI: 38F presents with worsening mid-thoracic back pain 7-9/10, and progressive shoulder imbalance, worsening curve (scoliosis xrays 3 years ago had 40 degree curve, now 52 deg). Very unhappy about shoulder imbalance

PMH/PSH:

Anxiety, asthma, HTN

All: lithium

Meds: ASA81mg,atomexetine, baclofen, buprenorphine, clonazepam, gabapentin, tramadol, metoprolol

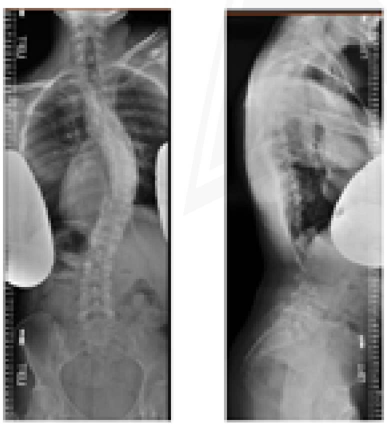
PHYSICAL EXAM

MAE 5/5

Sensation grossly full

Reflexes 2+

MT = 52 deg

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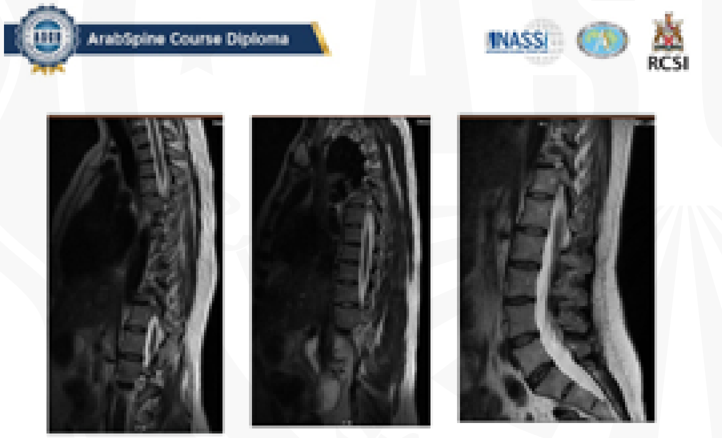
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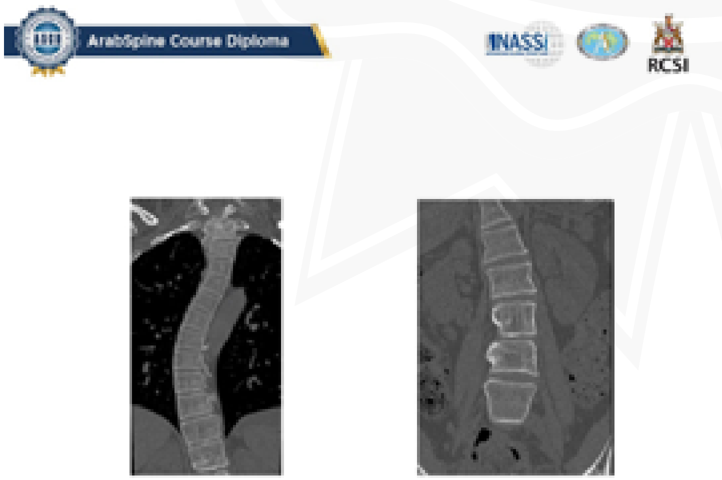
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Multi-level PCOs at curve apex →
followed by Post. Distraction on concavity


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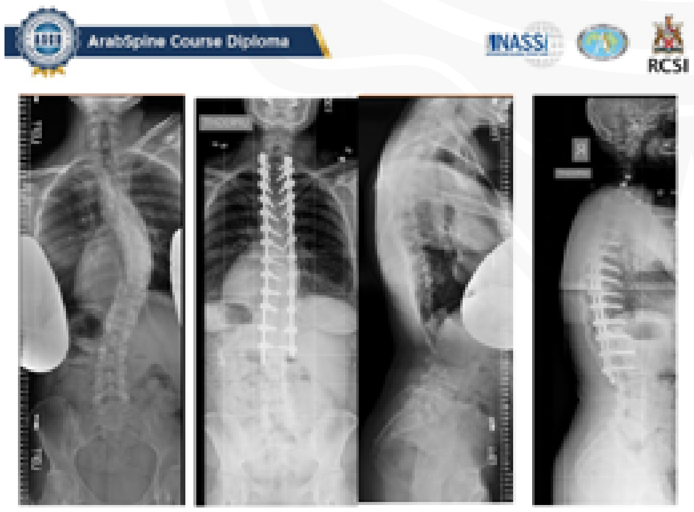
Convex Rod Placed/sequential Compression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Case #3

HPI: 77M presents with worsening low back pain and bilateral leg pain radiating down to the toes, worse on the right side. Also complains of neurogenic claudication symptoms.

PMH/PSH:

HTN, RA

cervical laminoplasty

All: NKDA

Meds: MTX, celebrex, ASA81, lisinopril

PHYSICAL EXAM

AAOx3

MAE 5/5 except rt EHL 4+/5

Sensation grossly full

Reflexes 1+

EMG

+Rt L5 radic

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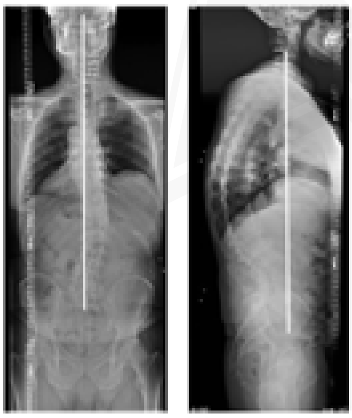

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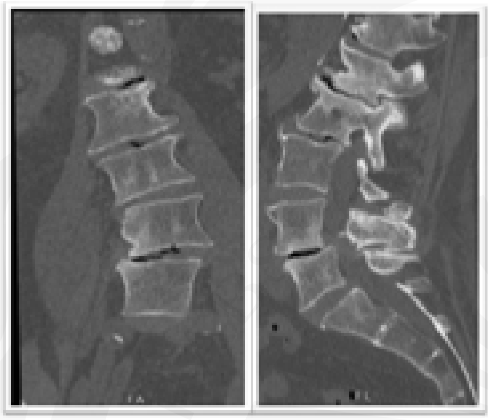

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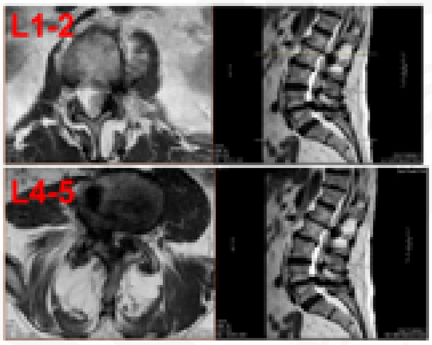

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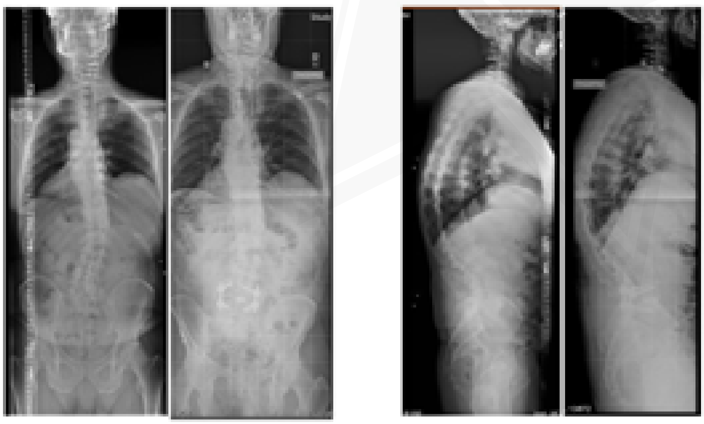

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Case #4 60M Jehovah's witness, severe back and BLE pain with adult degenerative scoliosis

PI = 55 deg
LL= 32 deg

PI-LL = 22 deg

Grade 2 Spondy at L5-S1

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PI = 55 deg
LL= 32 deg

PI-LL = 22 deg

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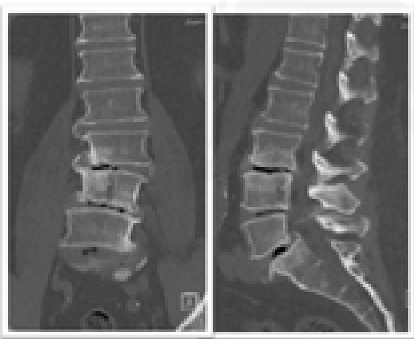

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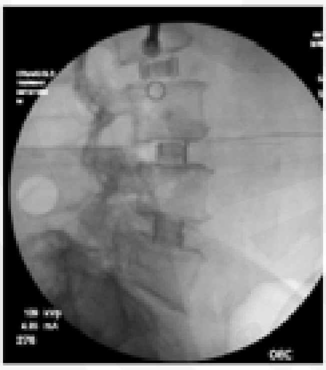

L2-5 DLIF

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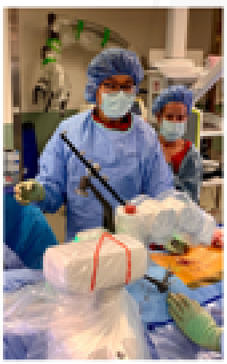
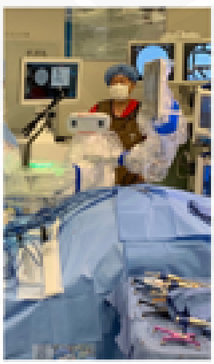
L2-S1 Perc Screw + MIS L5-S1 TLIF





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Robotic Assisted Surgery = Decreased Cognitive Workload

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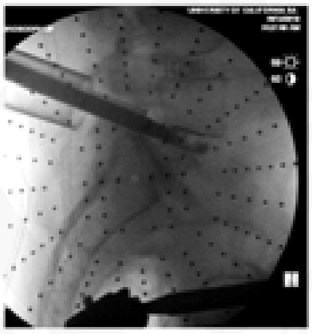
Elevate Expandable TLIF Cage



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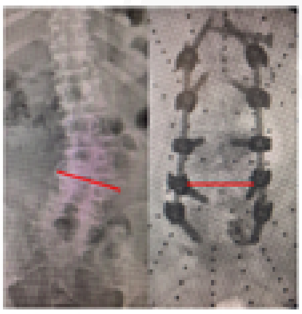
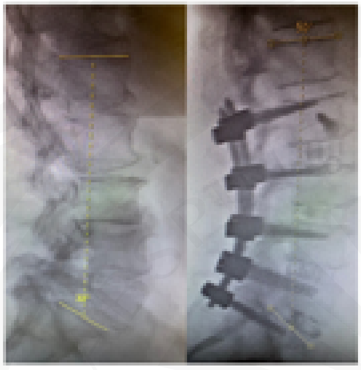
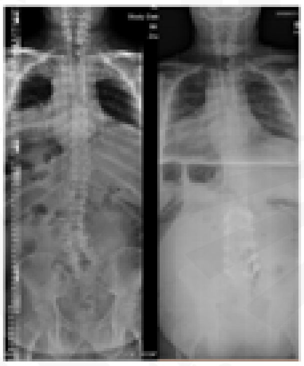
60M Jehovah's witness, severe back and BLE pain



L5 vertebral body horizontalized with eccentric placement of TLIF cage





Post-op course

- AAOx3, MAE 5/5
- Discharged home on POD3

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Case #5

HPI: 68M with severe back and severe bilateral leg pain, BLE weakness, can not ambulate, wheelchair bound due to pain

PMH/PSH:

- HTN, sleep apnea
- Post. Cervical fusion

All: morphine

Meds: oxycodone, lisinopril

PHYSICAL EXAM

- AAOx3
- BUE 5/5
- LLE 4-/5, RLE 4/5
- Sensation grossly full
- Reflexes 1+

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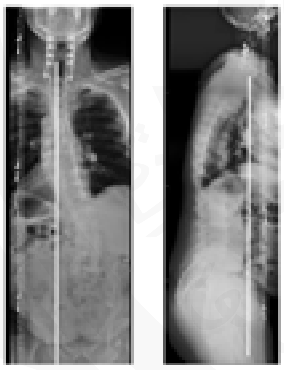

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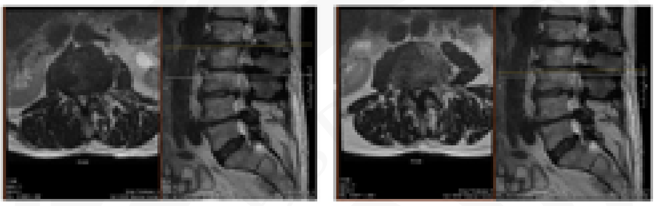
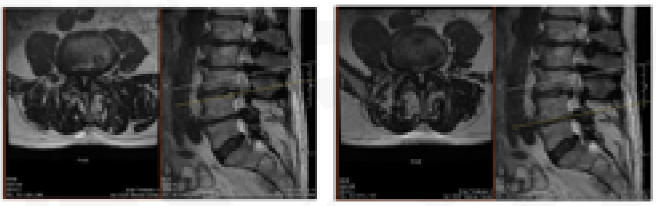
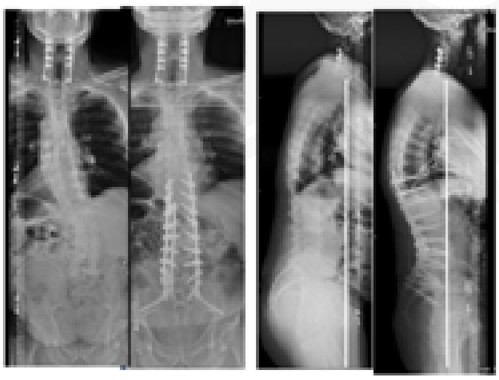
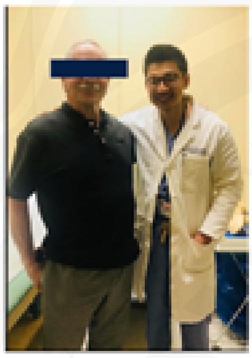








Case #6

HPI: 60F presents with progressively worsening severe LBP and bilateral leg pain, worse on the right.

PMH/PSH:

Anxiety, wrist fracture ORIF

All: NKDA

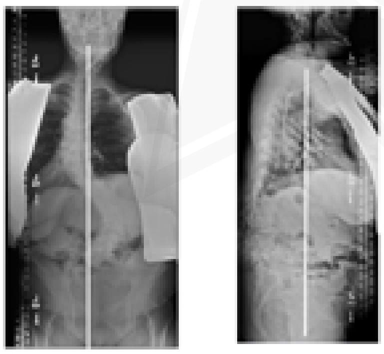
Meds: oxycodone, baclofen

PHYSICAL EXAM

MAE 5/5 except for right EHL 4/5 at least 4+/5

Sensation grossly full

Reflexes 1+

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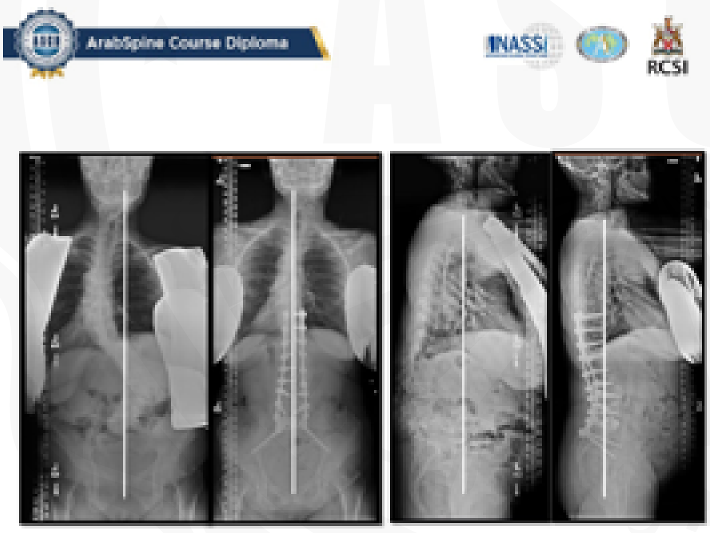
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Case #7

HPI: 42F with prior T10-pelvis fusion presents with increasing low back pain and left leg pain

PMH/PSH:

- Cardiac arrhythmia → defibrillator placement
- T10-pelvis fusion as a teenager

All: none

Meds: oxycodone

PHYSICAL EXAM:

- AAOx3
- MAE 5/5 except LLE 4+/5
- Sensation grossly

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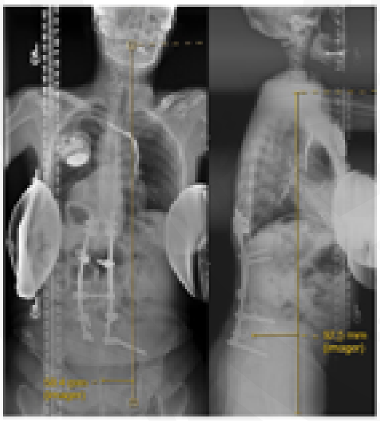

Right trunk shift: 5.84cm
SVA = +9.25cm

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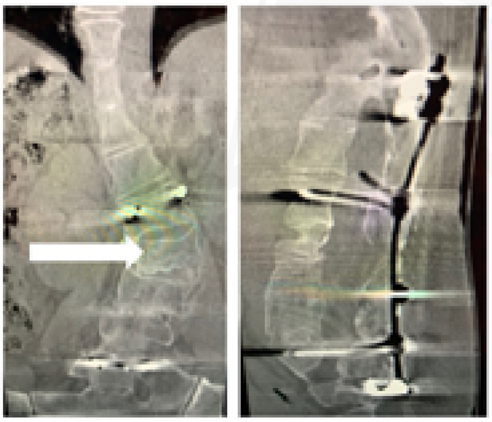

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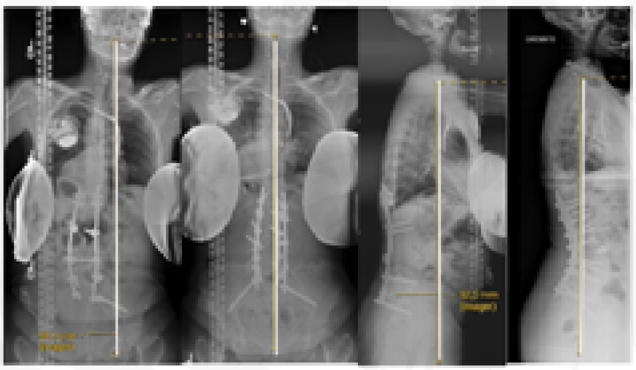

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Case #8

HPI: 73F with multiple prior spinal surgeries presented with fever, bacteremia, severe cervicothraocic kyphosis and skin erosion with exposed hardware

PMH/PSH:

- Anxiety, Depression, SVT, Hypothyroidism, Psoriatic Arthritis, osteoporosis (T-score = -2.9)
- multiple spinal surgeries, with last T4 to S1 with L3 PSO in 2015 at OSH
- bowel perforation with multiple bowel resections

All: amoxicillin, allopurinol

Meds: Vanc, bupropion, diltiazem, neurotin, dilaudid, synthroid

PHYSICAL EXAM

- MAE 4+/5
- Sensation grossly full
- Reflexes 2+
- Able to ambulate
- Open wound in the upper thoracic

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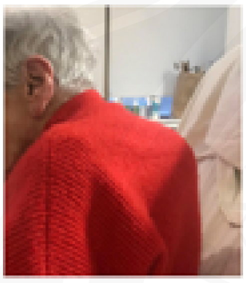

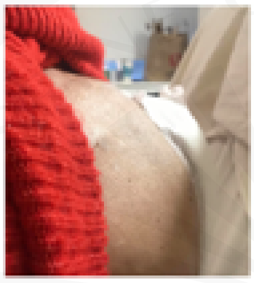

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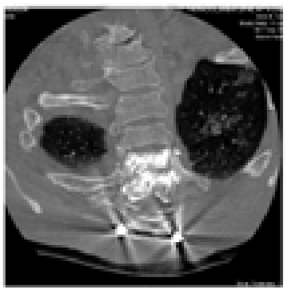

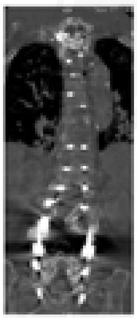

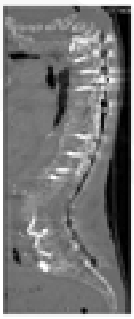

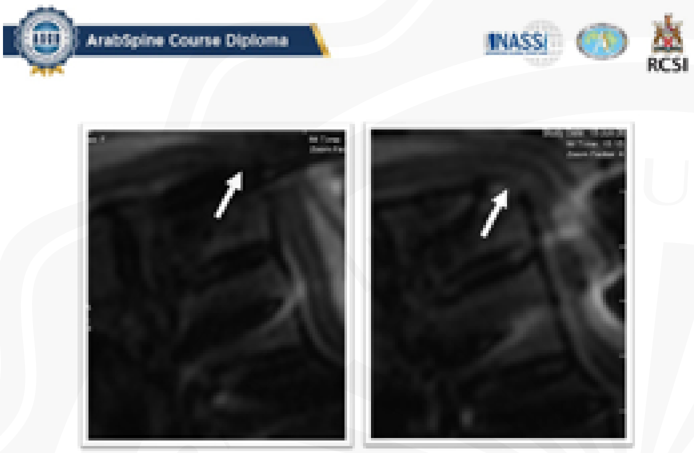
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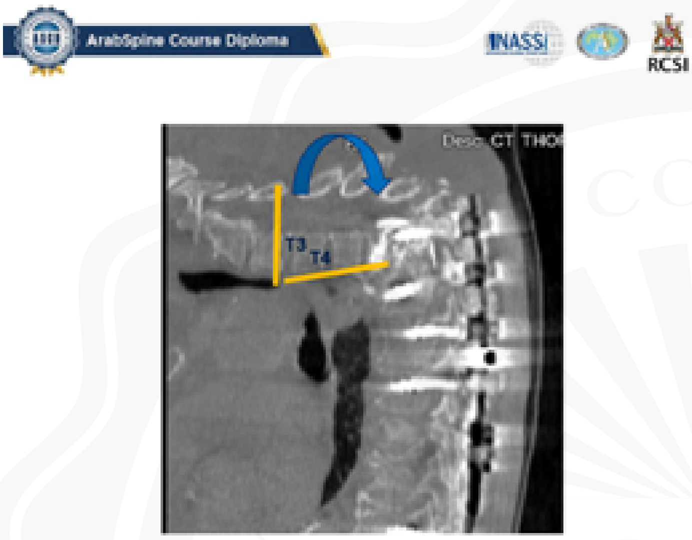
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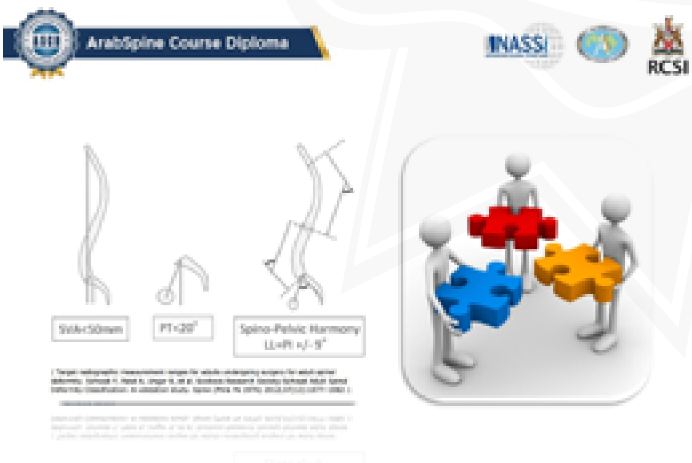
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SVA<50mm
PT<20°
Spino-Pelvic Harmony
LL=PI +/- 9°

Principles in Revision in Scoliosis

Introduction

- Evaluation
- Indications
- Surgical considerations

History

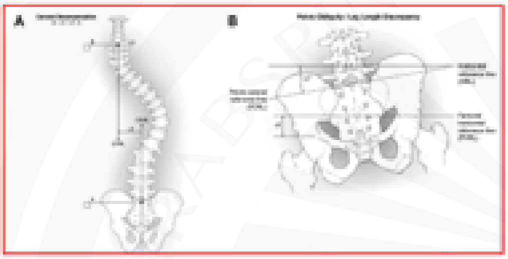
- Main complaint is pain
  - Deformity related, mechanical
  - Radicular / neurogenic claudication
  - Non mechanical
- Main complaint is deformity

Physical Exam

- Posture, alignment
- Neuro exam
- Hip flexors
- SI Joint
- Pulses

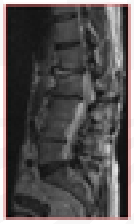
Imaging

- Xray – full length (36") weight bearing films
  - Alignment

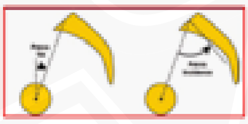


Imaging

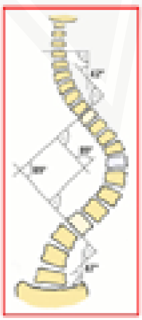
- MRI
  - Stenosis
  - Intraspinal abnormalities
  - Disc disease
- Myelogram with CAT scan
  - Often better assessment of stenosis with deformity
  - Shows bone in more detail
    - Operative planning
    - Ossified soft tissue
- DEXA



Deformity Measurements



- Coronal plane
  - Cobb angle - scoliosis
  - Translation – lateral listhesis
- Sagittal plane
  - Angular – Kyphosis
  - Translation – Spondylolisthesis
  - Pelvic parameters
    - Schwab F. Spine. 2010
    - Bess S. Neurosurg Clin N Am. 2013



Labs

- Infection
- Non union
- Nutrition

Surgical indications

- Failed non op treatment ***
- Deformity with symptomatic stenosis
- L3 or L4 end plate angulation
- Lumbar curve > 30 to 40 degrees
- > 6 degrees lateral listhesis
- Deformity / imbalance related pain

» Silva F. Neurosurg Focus. 2010

Goals to address

- Stenosis
  - Neurological deficit
- Deformity
  - Sagittal
  - Coronal
  - Above the fusion
  - Below the fusion
  - Within the fusion
- Hardware related
  - Symptomatic
  - Failure
- Pseudarthrosis

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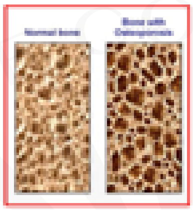
Surgical Evaluation

- Bone Density
- Medical Optimization
- Weight
- Smoking
- Nutrition
- Pain meds



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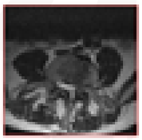
Decompression

- Selective
  - Direct
  - Indirect
    - Weidenbaum M. Spine. 2006.
- Lateral listhesis and deformity increase risk of revision.
    - Keleher M. Spine. 2010.
    - Transfeldt E. Spine. 2010.



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Fusion

- Levels
  - Capture the deformity.
    - Will not compensate (as opposed to kids)
    - Beware potential for decompensation (particularly sagittal)
  - Neutral (rotation) both proximal and distal
  - Stable (vertebra) both proximal and distal
    - Kuklo T. Spine. 2006
- Short fusions can be effective
    - Phan K. JBJS. 2017.

Fusion

- Indications for extension to sacrum
  - Oblique takeoff L5
  - Fractional curve > 15 degrees
  - Spondylolisthesis
  - Disc degeneration ("advanced")
    - Polly D. Spine. 2006.
    - Kuklo T. Spine. 2001
    - Harimaya K. Spine. 2011

Fusion

- Indications for ALIF ± pelvic fixation
  - Improve sagittal alignment
  - Improve potential to correct coronal alignment
  - Reduce pseudarthrosis
    - L-S junction
    - Osteotomy (PSO)
  - Reduce Sacral insufficiency fractures
  - Reduce Hardware failure

Operative Strategies

- Coronal
  - Posterior release
  - LLIF
  - Asymmetric PSO
  - VCR
  - ALIF L5,S1
- Sagittal
  - As above plus
    - SPO
    - ALIF

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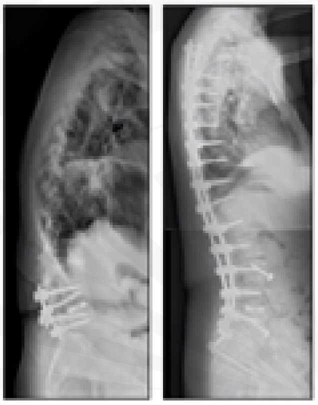
ALIF



- Advantages
  - Large fusion surface area.
  - Thorough discectomy and annular release
  - Restore lordosis
  - Indirect decompression
- Disadvantages
  - Second surgeon
  - Vascular
  - Ileus
  - Hernia
  - Retrograde ejaculation

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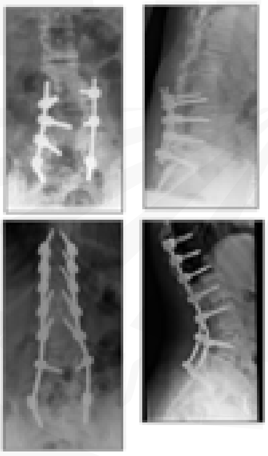
LLIF



- Advantages
  - Large fusion surface area.
  - Can improve segmental alignment
  - Reasonable annular release
  - Indirect decompression
- Disadvantages
  - Subsidence
  - Lumbar plexopathy
  - Vascular

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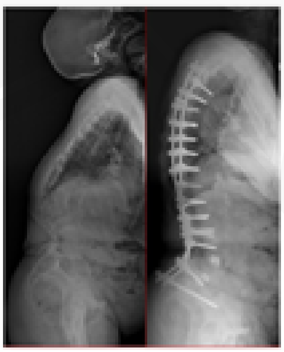
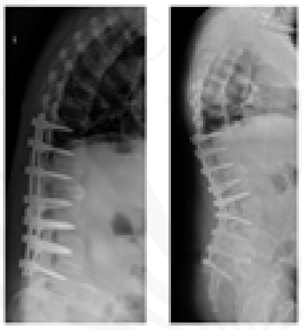
SPO



- Advantages
  - Time and morbidity
- Disadvantages
  - Sagittal plane only
  - Small correction
  - Effectiveness dependent on mobility of disc space

PSO

- Advantages
  - Powerful sagittal correction; coronal more difficult
  - All posterior
- Disadvantages
  - Pseudarthrosis
  - Time, blood loss
  - Neurological injury



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VCR

- Advantages
  - Most powerful correction of sagittal and coronal plane
- Disadvantages
  - May require anterior and posterior
  - Time, blood loss
  - Neurological injury

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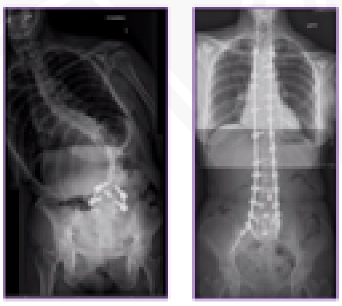
Anterior Release, Traction

- Advantages
  - Powerful correction
  - Gradual, safe
- Disadvantages
  - Two staged
  - Period of immobilization
  - Disadvantages of anterior approach



Summary

- Indications
- Pre op optimization
- Surgical planning
  - Decompression
  - Alignment
- High complication rate, but favorable long term outcomes and HRQoL

Revision CTDR

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NEUROSURGICAL FOCUS

Current practice of cervical disc arthroplasty: a survey among 383 AOSpine International members

- 54% ortho – 46% neuro – 15 years (9.7years)
- 84.3% ACDF standard
- 47.8% occasionally used CDA
- 7.3% used CDA as standard
- Reasons – low evidence for benefits/higher costs, ACDF expected to have highest effectiveness

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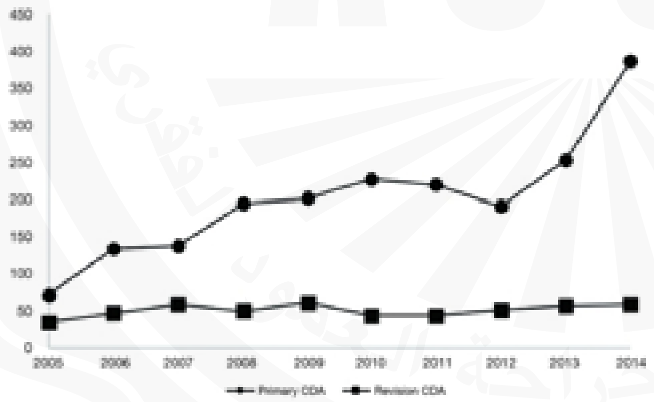

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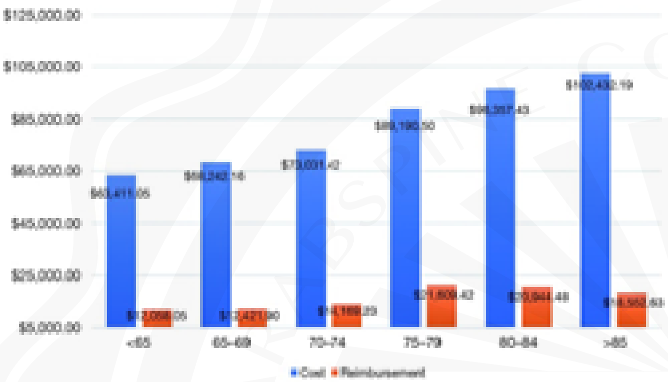

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Long Term Societal Costs of Anterior Discectomy and Fusion (ACDF) versus Cervical Disc Arthroplasty (CDA) for Treatment of Cervical Radiculopathy

Methods

We completed an economic and decision analysis using a Markov model to evaluate the long-term societal costs of ACDF and CDA in a theoretical cohort of 45-65 year old patients with single level cervical disc disease who have failed nonoperative treatment.

Results

The long-term societal costs for a 45-year old patient undergoing ACDF are $33,178 while long-term costs for CDA are $24,119. Long-term costs for CDA remain less expensive throughout the modeled age range of 45 to 65 years old. Sensitivity analysis demonstrated that CDA remains less expensive than ACDF as long as annual reoperation rate remains below 10.5% annually.

Conclusions

Based on current data, CDA has lower long-term societal costs than ACDF for patients 45-65 years old by a substantial margin. Given reported reoperation rates of 2.5% for CDA, it is the preferred treatment for cervical radiculopathy from an economic perspective.

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Cervical Arthroplasty Failures

- Revision strategies
- Failure mode
- Patient symptoms
- Cord compression
- Spinal stability
- Surrounding structures
- Alignment
- Approaches

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Cervical Arthroplasty: Failures

- Poor patient selection
- Inadequate pre-operative planning
- Suboptimal surgical technique
- Malpositioning of implant
- Mechanical implant failure
- Biologic and chemical failure

Indications for cervical disc replacement
Symptomatic cervical disc disease at one or two vertebral levels between C3 and T1 confirmed by imaging (MRI, CT or myelogram) showing herniated nucleus pulposus, spondylosis, or loss of disc height of at least 4 mm
Failed ≥6 weeks of conservative management
Between 20 and 70 years of age
No contraindications

MRI, magnetic resonance imaging; CT, computed tomography.

Contraindications to cervical disc replacement
≥3 Vertebral levels requiring treatment
Cervical fusion adjacent to the level to be treated
Cervical instability (translation >3 mm and/or >11 rotational difference to that of either adjacent level)
Facet joint degeneration
Severe spondylosis (bridging osteophytes, disc height loss >50%, and absence of motion <2)
Known allergy to implant materials (titanium, polyethylene, cobalt, chromium, and molybdenum
Posttraumatic vertebral body deficiency/deformity
Prior surgery at the treated level
Neck or arm pain of unknown etiology
Axial neck pain as the solitary presenting symptom
Osteoporosis/osteopenia
Active malignancy
Any patient with history of invasive malignancy unless treated and asymptomatic for at least 5 years
Systemic disease (AIDS, HIV, hepatitis B or C, and insulin-dependent diabetes)
Metabolic bone disease (i.e., osteomalacia, osteogenesis imperfect, Padget disease)
Active local/systemic infection
Presently on medications that can interfere with bone/soft tissue healing (i.e., steroids)
Autoimmune spondyloarthropaties (i.e., rheumatoid arthritis)
Pregnant or trying to become pregnant in the next 3 years

AIDS, autoimmune deficiency syndrome; HIV, human immunodeficiency virus.

Complications related to the anterior cervical spinal approach
Hematoma Wound Epidural
Wound infection Superficial Deep
Esophageal injury
Laryngeal injury
Dysphagia
Recurrent laryngeal nerve palsy
Thoracic duct injury
Angioedema
Respiratory insufficiency
Pseudo-aneurysm formation
Vascular injury Carotid artery Vertebral artery Jugular vein
Horner syndrome
Dural laceration
Cerebrospinal fluid leak

Arthroplasty related complicatio
Incomplete decompression Persistent radiculopathy Persistent myelopathy
Malposition Kyphotic placement Off-center
Heterotopic ossification/fusion
Improper sizing of implant
Bearing surface wear
Metallosis
Subsidence
Vertebral body fracture
Vertebral body osteolysis
Infection of implant
Neurologic injury

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Table 5. Secondary intervention rates at the target level in cervical disc replacement

Author	Year of publication	Study, duration	Implant type	Total implanted levels	Secondary intervention rate (%)	Revision rate (%)	Removal rate (%)
Goffin et al. [44]	2003	Prospective, MCT	Bryan	189	1.6	0.5	0.0
Pickett et al. [38]	2006	Prospective, MCS	Bryan	96	3.1	0	1.0
Mummaneni et al. [36]	2007	2 yr, RCCT	Prestige ST	276	1.8	0	1.8
Sasso et al. [30]	2007	2 yr, PRCT	Bryan	56	0	0	0
Murrey et al. [35]	2009	FDA IDE, Study	ProDisc-C	103	0	0	1.9
Riew et al. [55]	2008	FDA IDE, Study	Bryan/prestige	47/59	0/0	0/0	2.1/1.7
Heller et al. [22]	2009	2 yr, PRCT	Bryan	242	0.8	0.4	1.2
Sasso et al. [23]	2011	4 yr, PRCT	Bryan	242	1.6	0.4	1.6

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Specific complication	Author	Procedure, study	Implant	Findings
Dysphagia	[illegible]	[illegible]	[illegible]	[illegible]
Persistent radiculopathy	[illegible]	[illegible]	[illegible]	[illegible]
Kyphosis	[illegible]	[illegible]	[illegible]	[illegible]
Malposition	[illegible]	[illegible]	[illegible]	[illegible]
Heterotopic ossification (HO)	[illegible]	[illegible]	[illegible]	[illegible]
Implant sizing	[illegible]	[illegible]	[illegible]	[illegible]
Bearing surface wear	[illegible]	[illegible]	[illegible]	[illegible]
Subsidence	[illegible]	[illegible]	[illegible]	[illegible]
Vertebral body fracture	[illegible]	[illegible]	[illegible]	[illegible]
Osteolysis	[illegible]	[illegible]	[illegible]	[illegible]
Infection	[illegible]	[illegible]	[illegible]	[illegible]

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Table 6. Current reports of procedures performed for revision cervical disc replacement

Author	Study design	Implant	Complication	Revision procedure
Goffin et al. [19]	PMCT (n=143, R=1.5%)	Bryan Bryan Bryan	Persistent myelopathy Persistent radiculopathy Persistent radiculopathy	Posterior laminectomy Posterior foraminotomy Anterior decompression, implant repositioning
Sasso et al. [23]	PRCT (n=242, R=3.7%)	Bryan	Persistent neck/shoulder pain	ACDF
Buchowski et al. [50]	Review of literature	Bryan	Infection	ACDF
Anderson et al. [33]	RCS (n=242, R=2.9%)	Bryan	Device malposition	Repositioning of implant
Pickett et al. [38]	PCT (n=74, R=5.4%)	Bryan Bryan	Segmental kyphosis Persistent radiculopathy	ACDF Posterior foraminotomy
Cavanaugh et al. [45]	Case report	Keel-based	Hyper-reactivity to metallosis	ACDF
Tumialan and Gluf [49]	Case report	ProDisc-C	Vertebral body osteolysis	ACDF
Guyer et al. [48]	Case report	Kineflex-C	Lymphocytic reaction	ACDF
Fan et al. [57]	Case report	Bryan	Device malfunction	ACDF
Nguyen et al. [58]	Case report	Ceramic-on-ceramic	Device malfunction	ACDF
Chen et al. [59]	Case report	Bryan	Neurologic injury	Anterior corpectomy, fusion

Table 1 Summary of cited articles discussing migration of cervical disk arthroplasty devices

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[18]	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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Revision Strategies

- Re-Operation
  - Procedure at same level without altering implant
  - Posterior decompression
  - Posterior fusion
- Revision
  - Adjust or modify implant
  - Anterior decompression
- Removal

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Revision Strategies

- Removal
  - Anterior approach
  - Migration
  - Neural compression
  - Subsidence
  - Alignment
- Removal not necessary
  - Posterior approach

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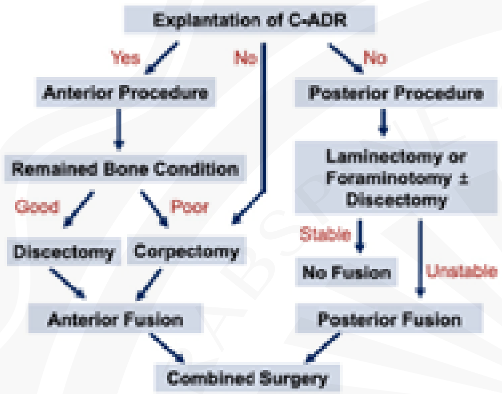

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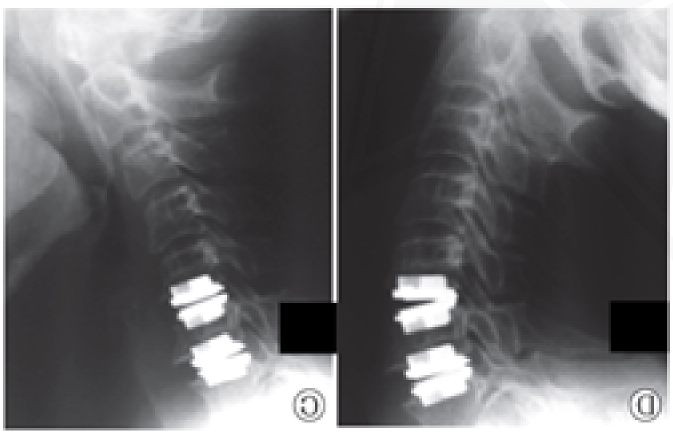


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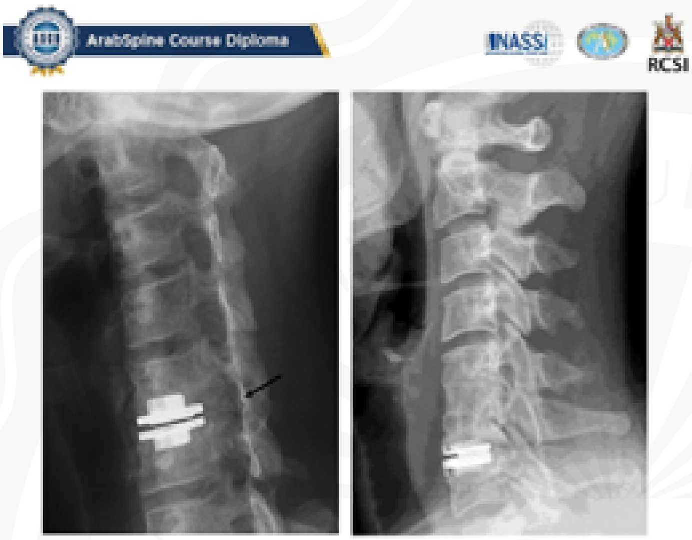
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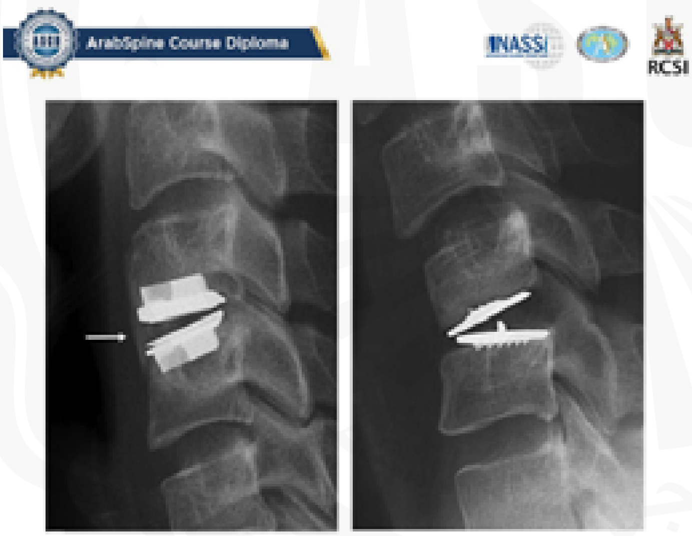
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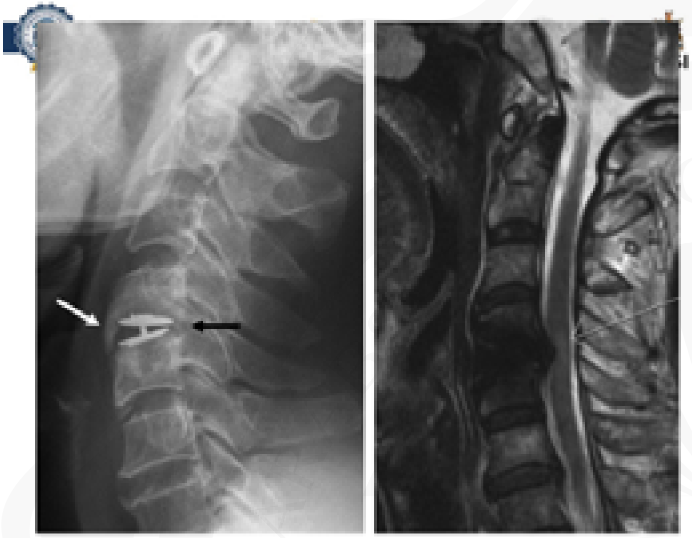

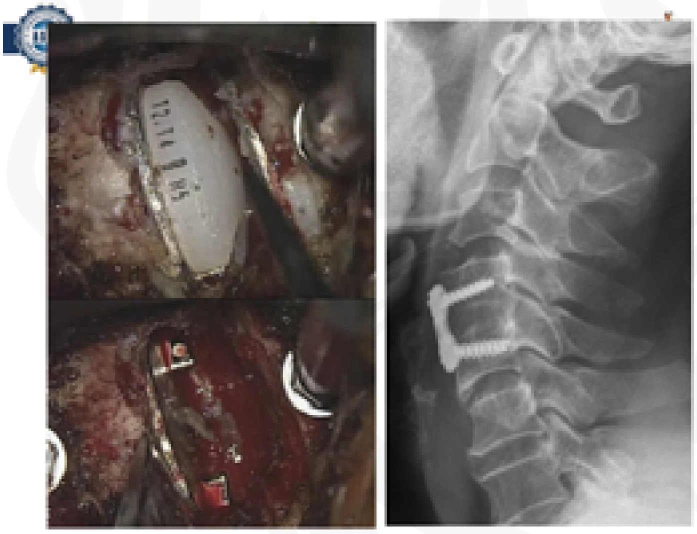

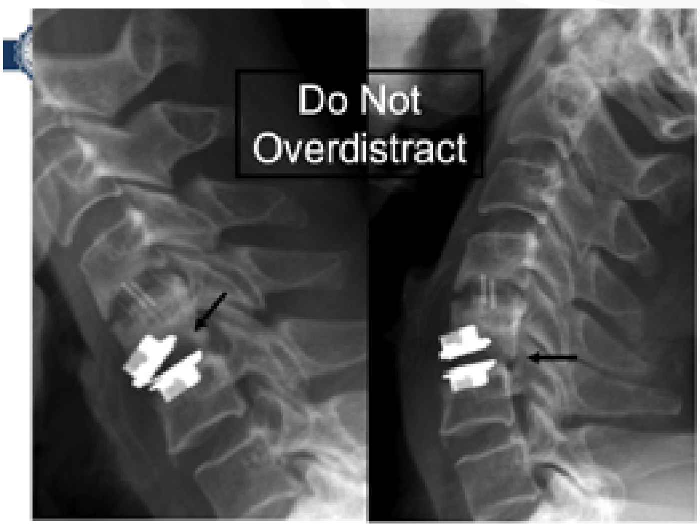
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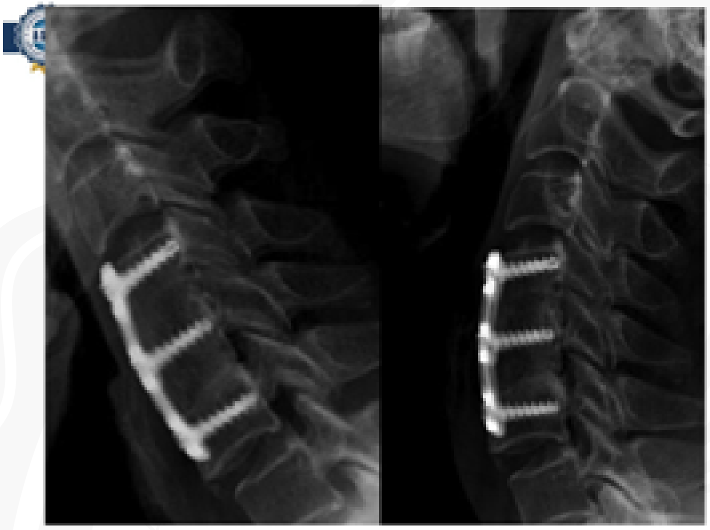

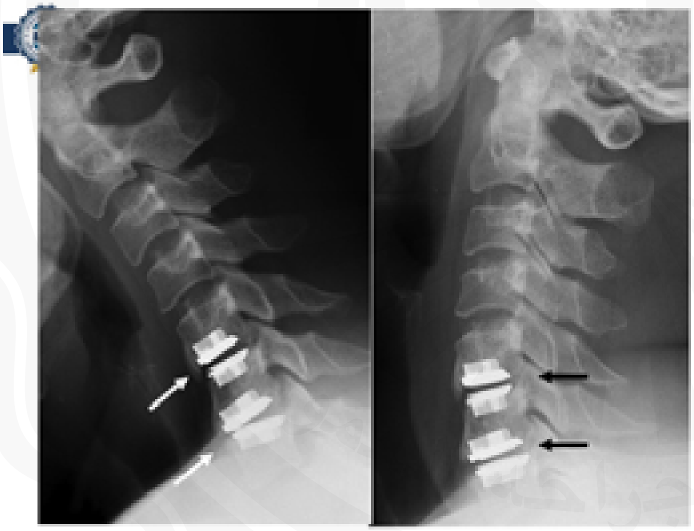

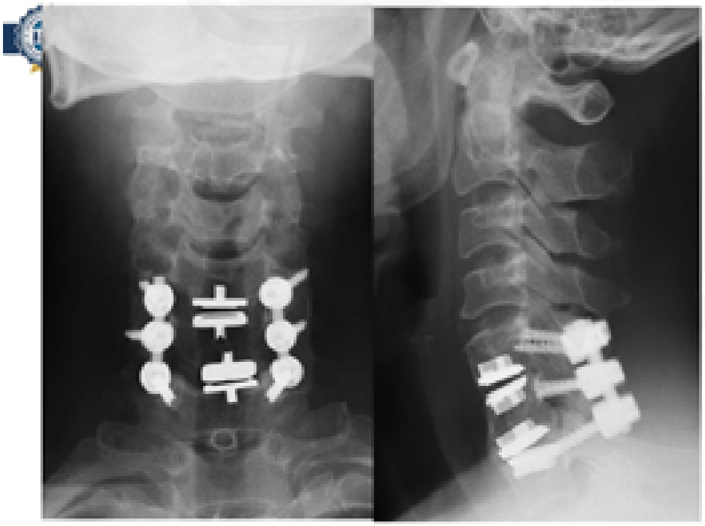

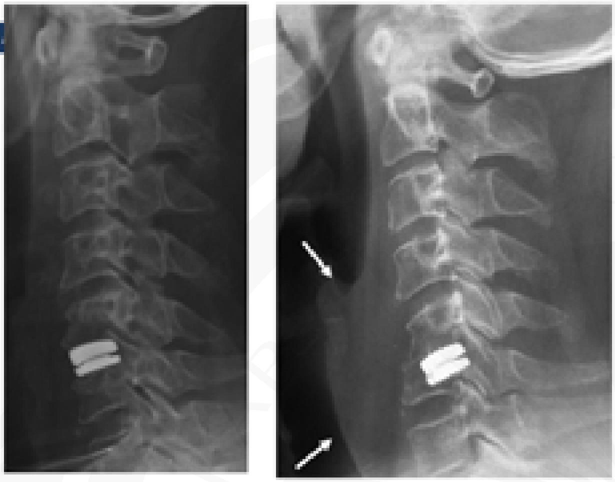

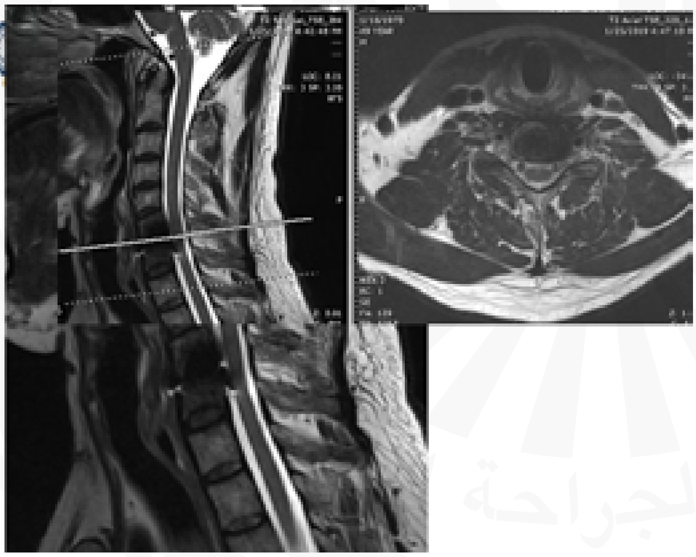

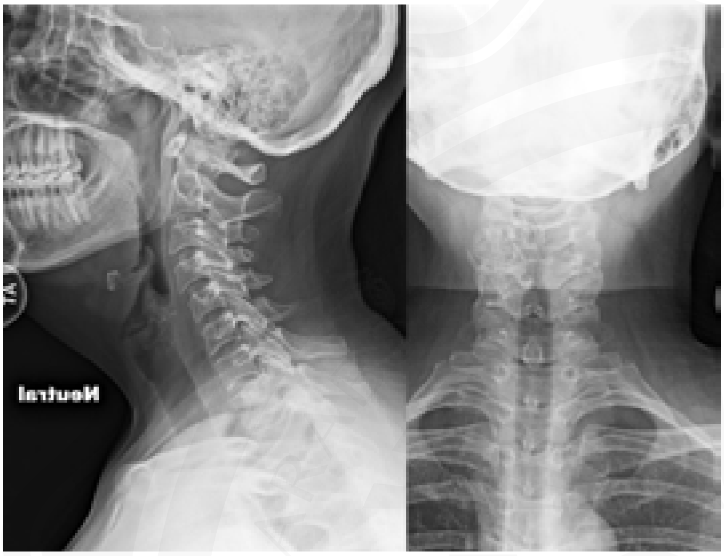

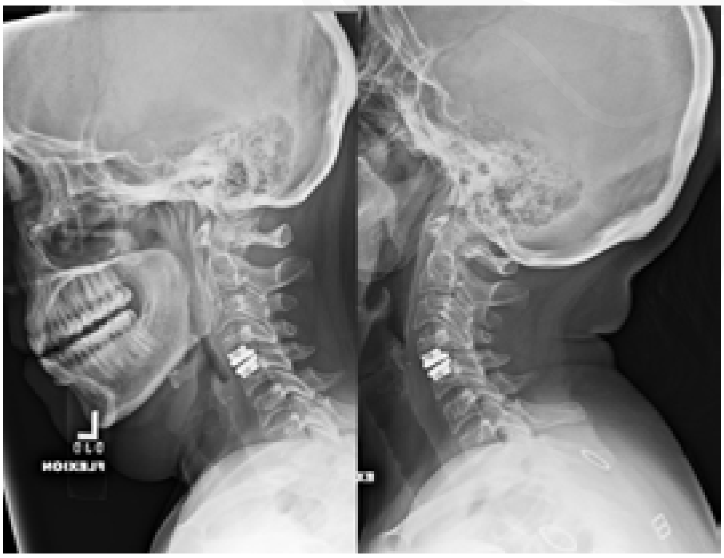

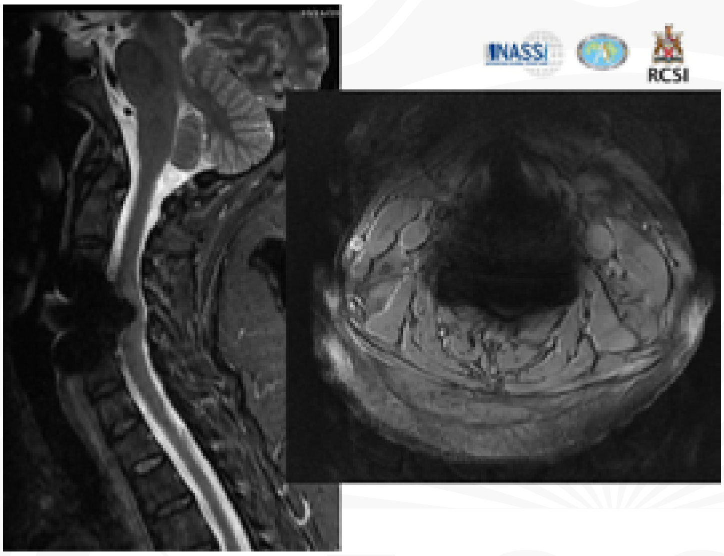
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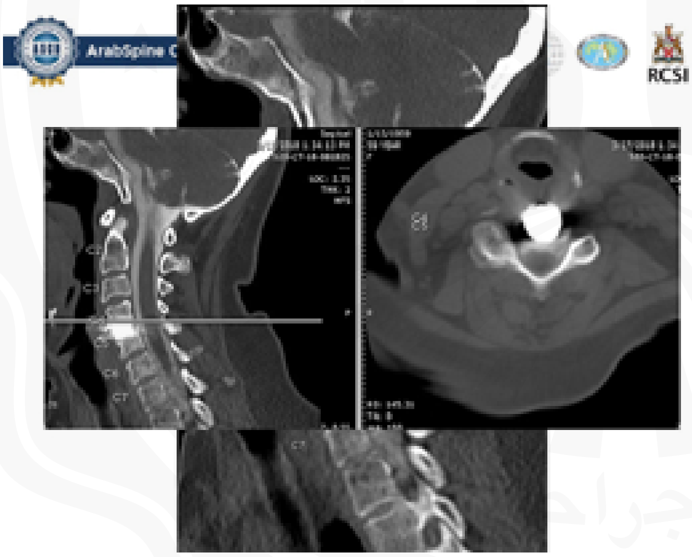
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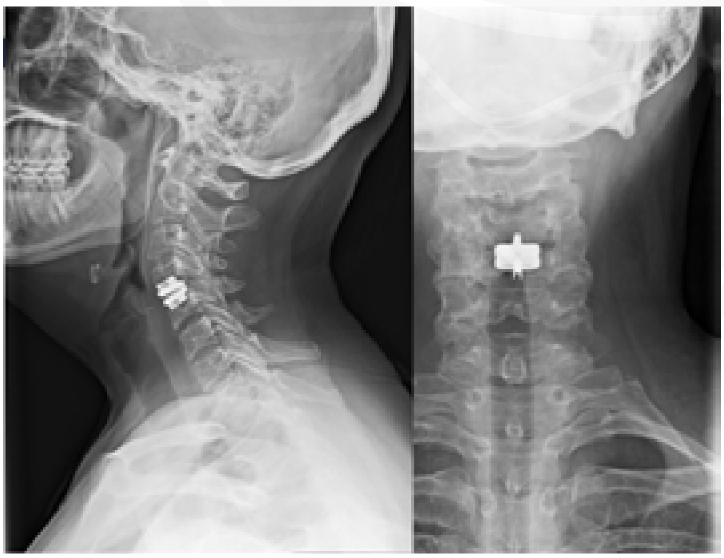

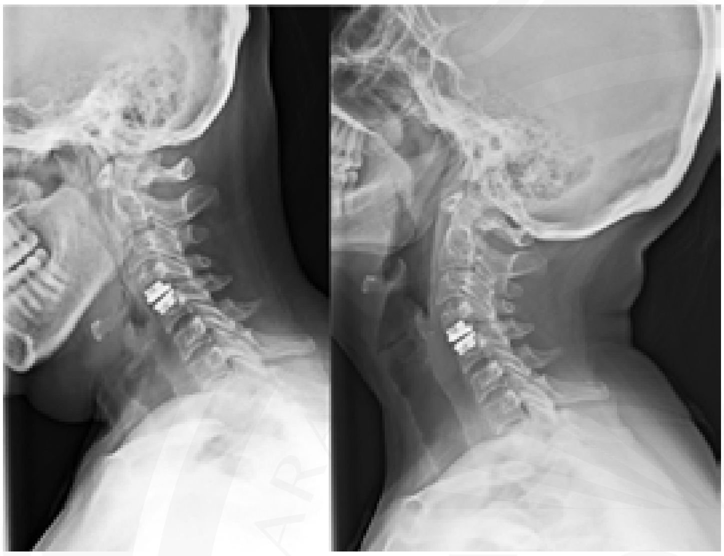

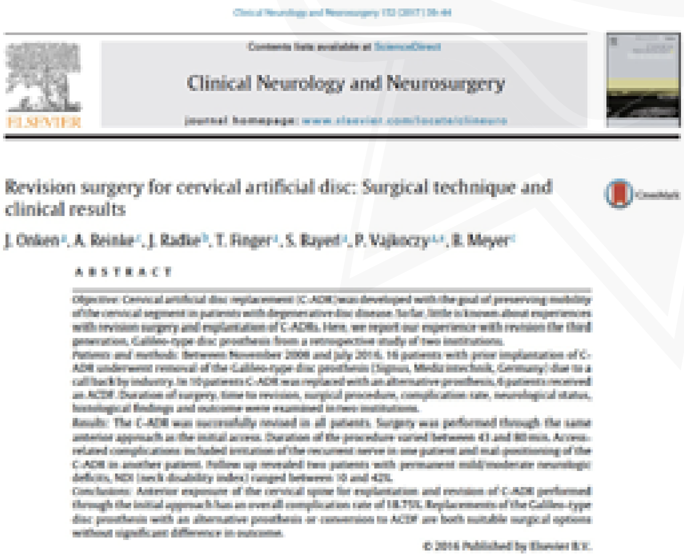

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Revision surgery for cervical artificial disc: Surgical technique and clinical results

J. Onken[a], A. Reinke[a], J. Radke[b], T. Finger[a], S. Bayerl[a], P. Vajkoczy[a,c], B. Meyer[d]

ABSTRACT

Objective: Cervical artificial disc replacement (C-ADR) was developed with the goal of preserving mobility of the cervical segment in patients with degenerative disc disease. So far, little is known about experiences with revision surgery and explantation of C-ADRs. Here, we report our experience with revision the third generation, Galileo-type disc prosthesis from a retrospective study of two institutions.

Patients and methods: Between November 2008 and July 2016, 16 patients with prior implantation of C-ADR underwent removal of the Galileo-type disc prosthesis (Signus, Medizintechnik, Germany) due to a call back by industry. In 10 patients C-ADR was replaced with an alternative prosthesis, 6 patients received an ACDF. Duration of surgery, time to revision, surgical procedure, complication rate, neurological status, histological findings and outcome were examined in two institutions.

Results: The C-ADR was successfully revised in all patients. Surgery was performed through the same anterior approach as the initial access. Duration of the procedure varied between 43 and 80 min. Access-related complications included irritation of the recurrent nerve in one patient and mal-positioning of the C-ADR in another patient. Follow up revealed two patients with permanent mild/moderate neurologic deficits, NDI (neck disability index) ranged between 10 and 42%.

Conclusions: Anterior exposure of the cervical spine for explantation and revision of C-ADR performed through the initial approach has an overall complication rate of 18.75%. Replacements of the Galileo-type disc prosthesis with an alternative prosthesis or conversion to ACDF are both suitable surgical options without significant difference in outcome.

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ASIAN SPINE JOURNAL
Clinical Study

Anterior Bone Loss in Cervical Disc Arthroplasty

David Christopher Kieser, Derek Thomas Cawley, Takeshi Fujishiro, Celeste Tavolaro, Simon Mazas, Louis Boissiere, Ibrahim Obeid, Vincent Pointillart, Jean Marc Vital, Olivier Gille

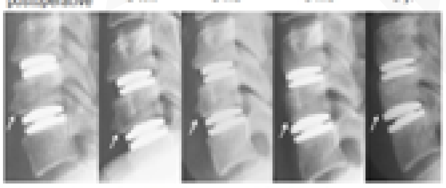

Fig. 4. Radiographs of the lateral cervical spine of a representative case with multi-level cervical disc arthroplasties showing the natural history of mild anterior bone loss (arrow).

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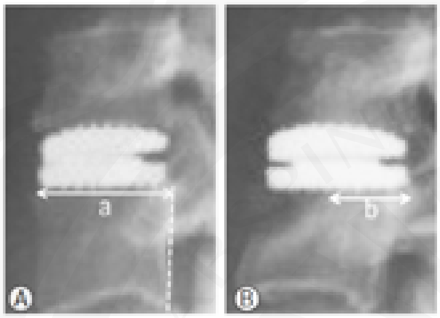

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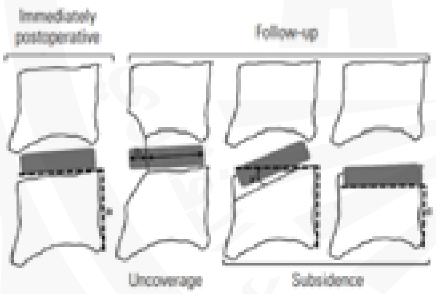
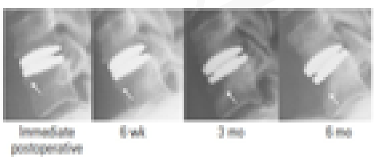


Fig. 2. Illustration of the anterior implant exposure (defined as b >2 mm) and implant subsidence (defined as either: x >5° or a–d >2 mm).

Fig. 5. Radiographs of the lateral cervical spine of a representative case showing the natural history of moderate ABL in the upper endplate and severe ABL with collapse in the lower endplate (arrow). ABL, anterior bone loss.



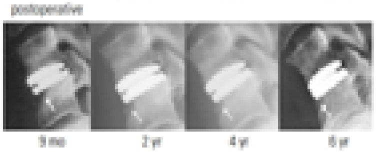


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Table 4. Classification of anterior bone loss

Grade	Anterior bone loss (%)	Cervical disc arthroplasty (%)	Cause	Radiograph	Implant exposure	Endplate compromise	Treatment
0 (None)	0	42.9	-		No	No	Nil
1 (Mild)	1–5	45.5	Direct anterior vertebral injury or resected ALL		No	No	Nil
2 (Moderate)	6–10	4.2	Direct anterior vertebral injury or resected ALL		Potential	No	Nil
3 (Severe without collapse)	>10	5.5	Avascular necrosis		Yes	No	Monitor
4 (Severe with collapse)	>10	2.5	Avascular necrosis		Yes	No	Monitor

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AOTT

Revision surgeries following artificial disc replacement of cervical spine

Jong-Beom Park [a,*], Han Chang [b], Jin S. Yeom [c], Kyung-Soo Suk [d], Dong-Ho Lee [e], Jae Chul Lee [f]

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Objective: We investigated causes and results of revision surgeries after artificial disc replacement of cervical spine (C-ADR).

Methods: Twenty-one patients (mean age: 52.8) who underwent revision surgery after C-ADR and who had a minimum 2-year of follow-up were included into this study. The mean time between the primary and revision surgeries was 21 months. During their primary surgeries, 14 patients underwent single level C-ADR, 2 two-level C-ADR, and 5 two-level hybrid surgery for 16 radiculopathy, 3 myelopathy, and 2 adjacent segment diseases. Causes for revision surgeries were at least one of the followings: 17 poor patient selections, 7 insufficient decompressions, 7 malpositions, 6 subsidences, 3 osteolysis, and 1 postoperative infection.

Results: Sixteen patients underwent anterior removal of C-ADR, one-level discectomy and fusion (N = 11), two-level discectomy (N = 3) or one-level corpectomy (N = 2) and fusion. Three patients of keel type C-ADR with heterotopic ossification underwent posterior laminoforaminotomy and fusion. Two patients underwent combined procedures due to infection or severe subsidence and osteolysis. At the 2-year follow-up, neck (7.3 vs 1.6) and arm (7.0 vs 1.3) visual analog scales and Neck Disability Index score (46.7 vs 16.32) were improved (all, $p < 0.05$). According to Odom's criteria, 86% of the patients were satisfied and 91% achieved solid fusion. No major complications developed except for transient dysphagia in 6 patients (29%).

Conclusions: In this small case series, revision surgeries provided successful outcomes in failed C-ADR without major complications. Careful patient selection and meticulous surgical techniques are important to avoid disappointing clinical outcome or even failure of C-ADR.

Level of evidence: Level IV, Therapeutic study.

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No.	Sex	Age	C-ADR device	Failure level(s)	Time to revision surgery (months)	Revision surgery approach	Overall satisfaction (Odom's criteria)	Fusion status
1	F	43	Prodisc-C	C5-6, C6-7	20	Posterior	Good	Fusion
2	F	48	Prodisc-C	C5-6, C6-7	34	Posterior	Good	Fusion
3	F	58	Mobi-C	C5-6	27	Anterior	Fair	Pseudarthrosis
4	M	55	Bryan	C4-5, C5-6	18	Anterior	Good	Fusion
5	M	57	Discover	C5-6, C6-7	5	Anterior	Good	Fusion
6	F	53	Prodisc-C	C4-5, C5-6	6	Anterior	Good	Fusion
7	M	43	Mobi-C	C5-6, C6-7	6	Anterior	Good	Fusion
8	M	63	Prestige LP	C5-6, C6-7	13	Posterior	Fair	Fusion
9	M	61	Discover	C5-6	18	Combined	Good	Fusion
10	M	53	Mobi-C	C4-5	84	Anterior	Excellent	Fusion
11	M	48	Mobi-C	C5-6	25	Anterior	Good	Fusion
12	M	55	Discover	C5-6, C6-7	21	Anterior	Good	Fusion
13	F	52	Prestige LP	C6-7	8	Anterior	Excellent	Fusion
14	M	55	Discover	C6-7	4	Combined	Fair	Fusion
15	M	53	Mobi-C	C4-5	20	Anterior	Good	Fusion
16	F	59	Mobi-C	C5-6	17	Anterior	Good	Fusion
17	M	50	Bryan	C6-7	32	Anterior	Good	Fusion
18	M	48	Discover	C5-6	22	Anterior	Good	Pseudarthrosis
19	F	55	Mobi-C	C5-6	10	Anterior	Good	Fusion
20	M	51	Mobi-C	C6-7	16	Anterior	Excellent	Fusion
21	F	49	Discover	C5-6	23	Anterior	Good	Fusion

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Summary

- CDA is a viable option
- May have advantages as we gain longer followup
- Patient selection is critical
- Operative technique
- Need revision strategies to deal with complications

Revision for Pseudoarthrosis

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Reasons for failure

- Host factors
  - Bone density
  - Nutrition
  - Smoking
  - Biology
  - Metabolic
  - Drugs
- Infection
- Junctional areas
- Technical
  - Alignment
  - Grafting / decortication
  - Implants – biomechanics of reconstruction
    - Multiple levels
    - Corpectomy vs. Discectomies
    - Anterior approaches with anterior support decrease the rate by 30%
    - Long fusions, osteotomies and pelvic fixation increase its rate.

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Evaluation

- PMH
  - Endocrine
  - Autoimmune disorders
  - Hepatic
  - Renal
- Medications
- Labs
  - Infection
  - Metabolic
  - nutrition
- Imaging
  - Xray: Flexion and extension, 36 inch alignment films
  - CT
  - MRI
  - DEXA
  - PET scan
- Biopsy?

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Lumbar

- Optimize host
- Replace / optimize hardware
  - Convert to screws
  - Increase diameter of screws
  - Increase diameter of rods
  - Rod material
  - Dual rods
  - Extension to pelvis
  - Circumferential fusion

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Multi-Rod Constructs

- Primary rods
- Secondary rods
- Satellite rods
- Accessory rods
- Delta rods

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FBSS (Failed Back Surgery Syndrome)

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Failed Back Surgery Syndrome

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

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FBSS after 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 (5-15%)
- Overlooked LDH
- Epidural scar
- Iatrogenic instability

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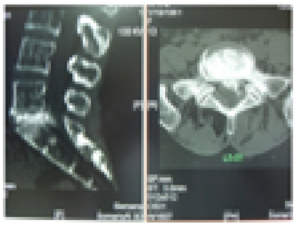
FBSS-Multifactorial

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

Clinical Evaluation Utmost importance

Detailed history and meticulous physical examination

Spinal imaging: don't hesitate if invasive tests are needed: myelography or discography



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Clinical Evaluation

- Neurophysiology testing (SSEP, EMG/NCS, etc.)
- Interventional testing (Nerve root block, facet injection, provocative discography)
- Psychological, social and economic testing

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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

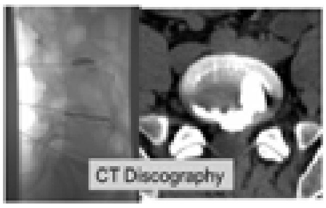
Surgical Treatment

1- Decompression of compressed neural elements (look for residual stenosis, missing disc fragment…compressing nerve root, cauda equina)

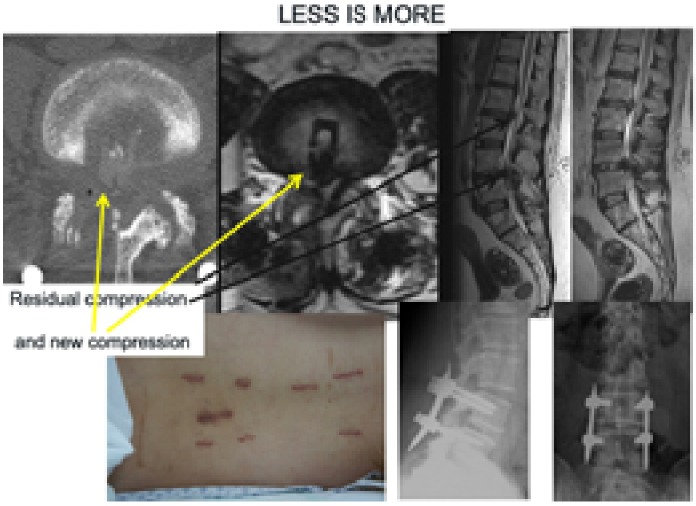
Re-operation with adequate microsurgical decompression particularly when combined with a low back rehabilitation program results in substantial relief and improvement.

Recurrent DH

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



MISS? Experienced hands +++
LESS IS MORE



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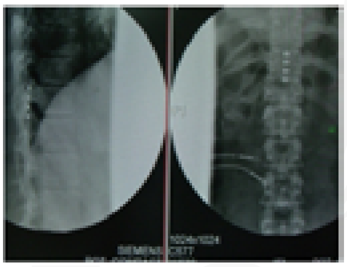
Missing treatable cause: Persisting DH

- 47y. Old GM
- 2001 L5-S1 discectomy, no improvement, resisting sciatic pain, SCS inserted by pain physician, displacement of the percut. lead
- Change to surgical lead done in Dubai,



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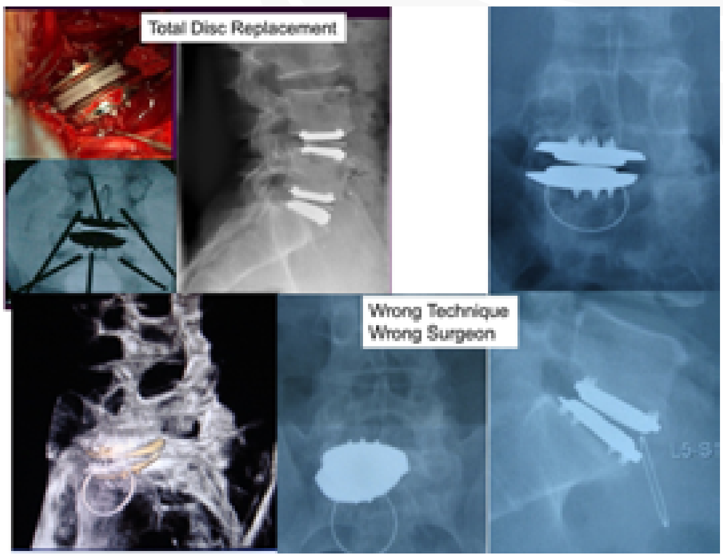
Missing treatable cause: Persisting DH

- Mechanical type pain++, Investigated: CT discography showed residual DH,
- Microdiscectomy and neurolysis done: Improved,

  Removal of SCS



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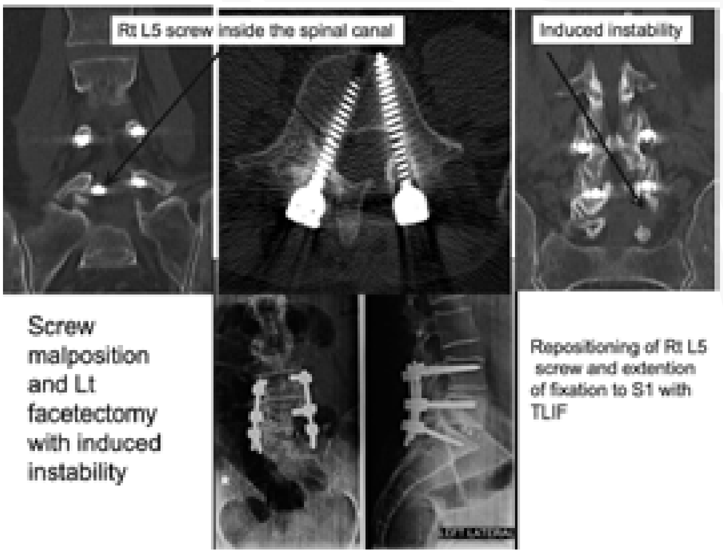
Surgical Treatment

2- Stabilization of vertebral motion segments

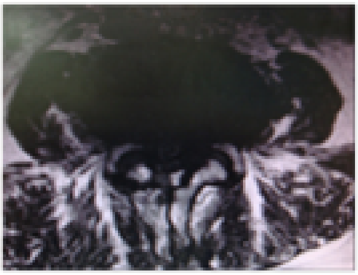
Dynamic Imaging studies helps localizing the segments: Spondylolisthesis, retrolisthesis

Hypermobility in 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.



WRONG ASSESSMENT & TREATMENT:
missing instability, osteoporotic patient



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

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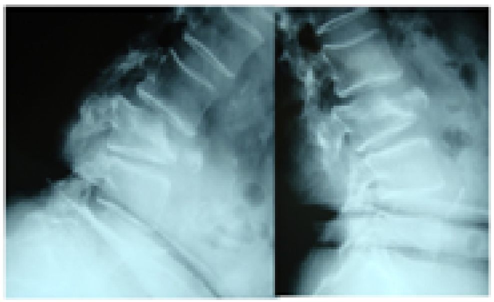
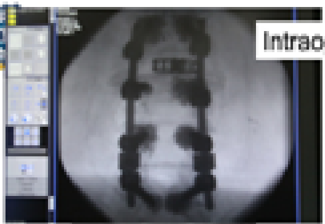
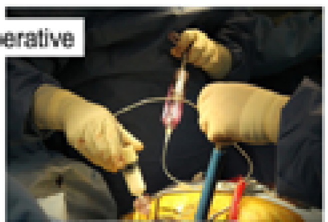
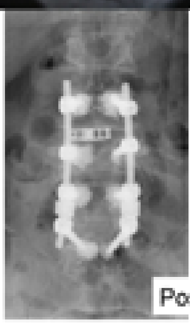
Missing Instability









FBSS in Endoscopic Techniques

Endoscopy is relatively popular and attractive to patients, but indications are limited, they have:

Long learning curve

Lower success rate

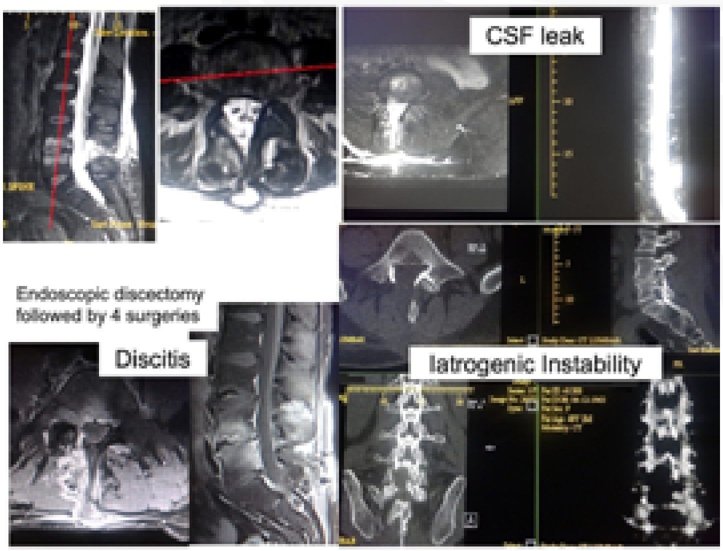
Difficult to manage complications(open surgery required)

Chains of complications

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

↓

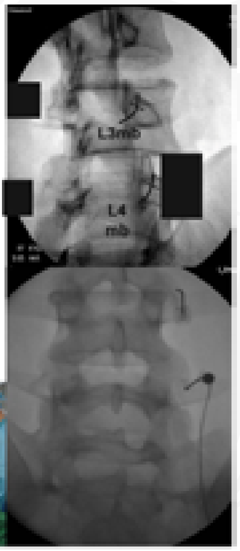
- Admitted to NSH: treatment of infection followed by surgical stabilization

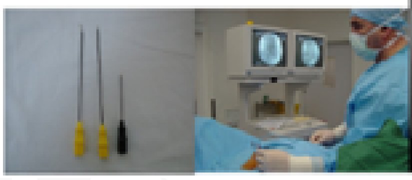


Surgical Treatment

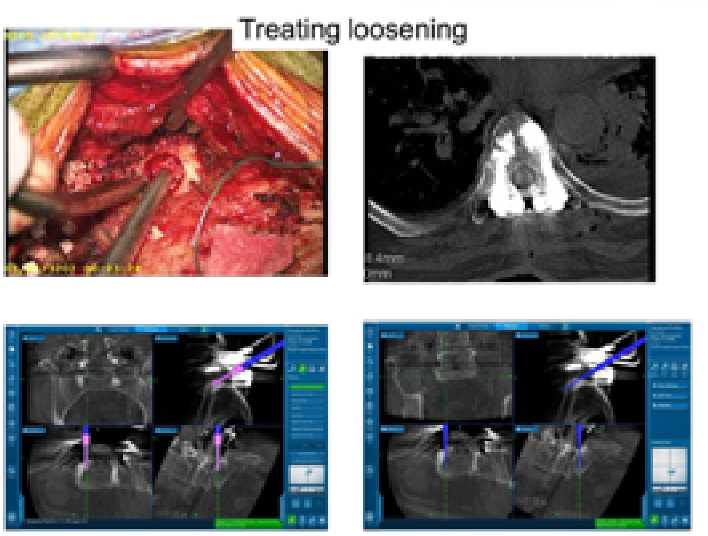
3- Destruction of neural elements thought to be involved in the pathogenesis of pain:

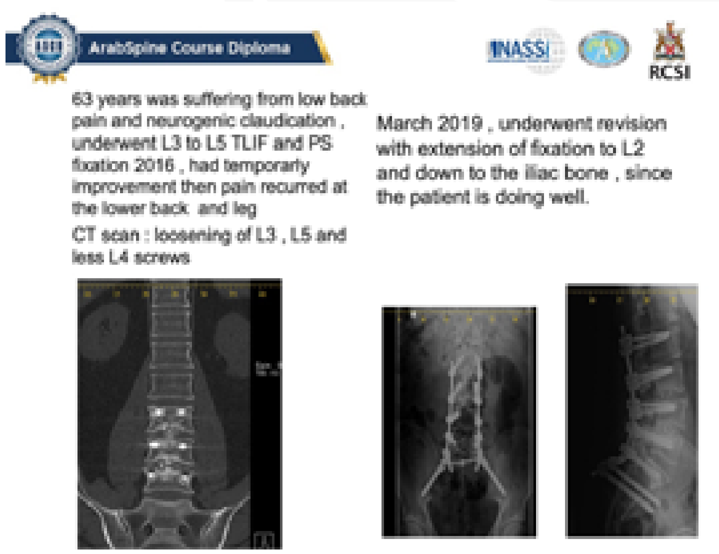
RF medial branches ablation





SCREWS LOOSENING AND PSEUDOARTYHROSIS


Treating loosening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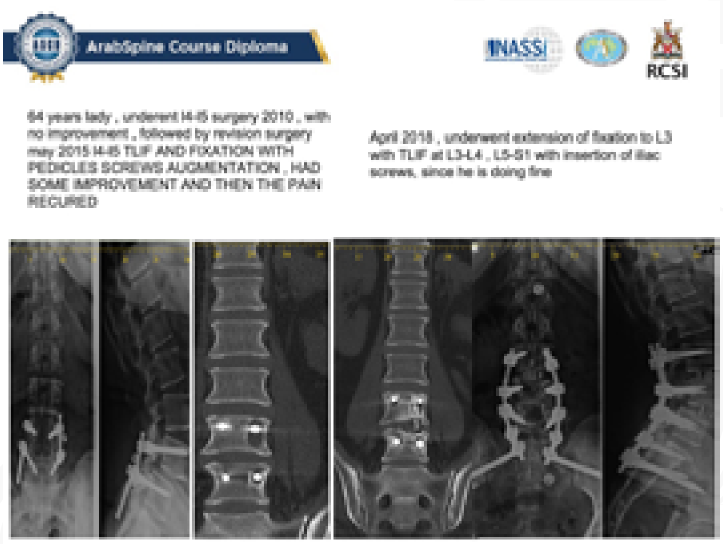
63 years was suffering from low back pain and neurogenic claudication , underwent L3 to L5 TLIF and PS fixation 2016 , had temporarly improvement then pain recurred at the lower back and leg
CT scan : loosening of L3 , L5 and less L4 screws
March 2019 , underwent revision with extension of fixation to L2 and down to the iliac bone , since the patient is doing well.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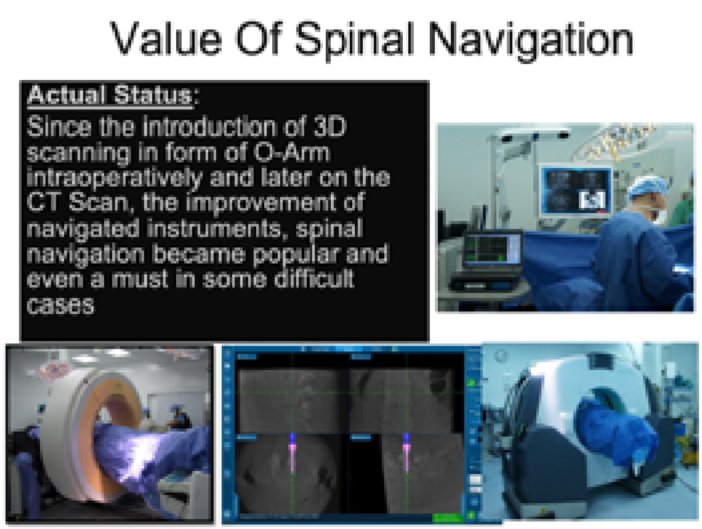
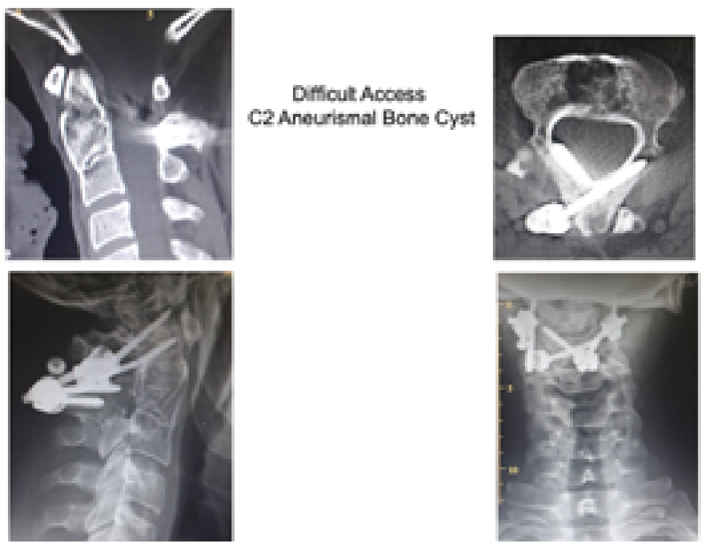
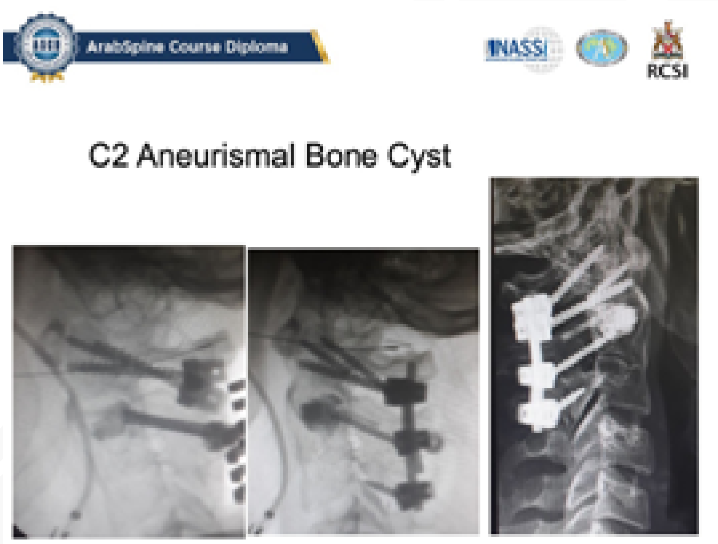
64 years lady , underent l4-l5 surgery 2010 , with no improvement , followed by revision surgery may 2015 l4-l5 TLIF AND FIXATION WITH PEDICLES SCREWS AUGMENTATION , HAD SOME IMPROVEMENT AND THEN THE PAIN RECURED
April 2018 , underwent extension of fixation to L3 with TLIF at L3-L4 , L5-S1 with insertion of iliac screws, since he is doing fine


Value Of Spinal Navigation
Actual Status:
Since the introduction of 3D scanning in form of O-Arm intraoperatively and later on the CT Scan, the improvement of navigated instruments, spinal navigation became popular and even a must in some difficult cases


Difficult Access
C2 Aneurismal Bone Cyst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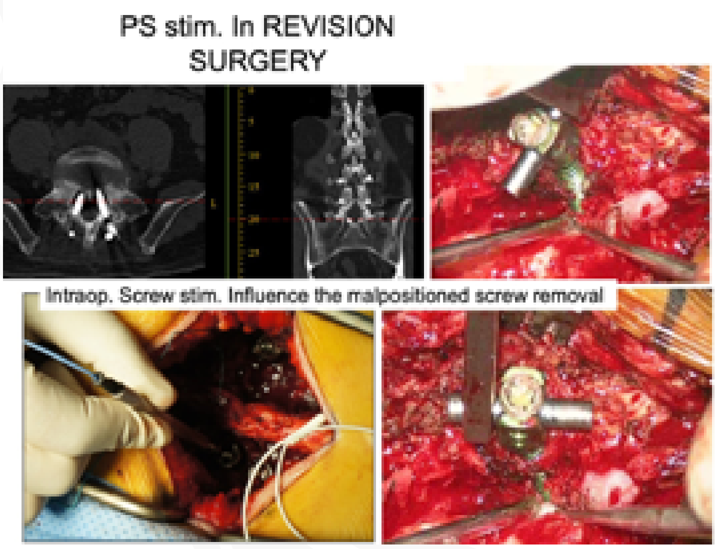
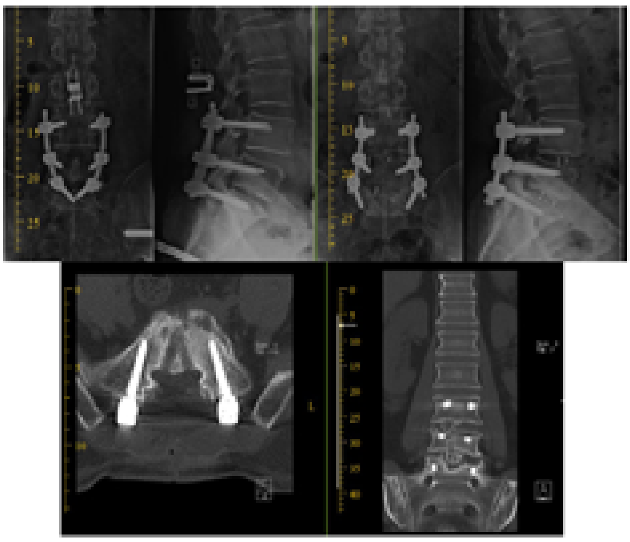
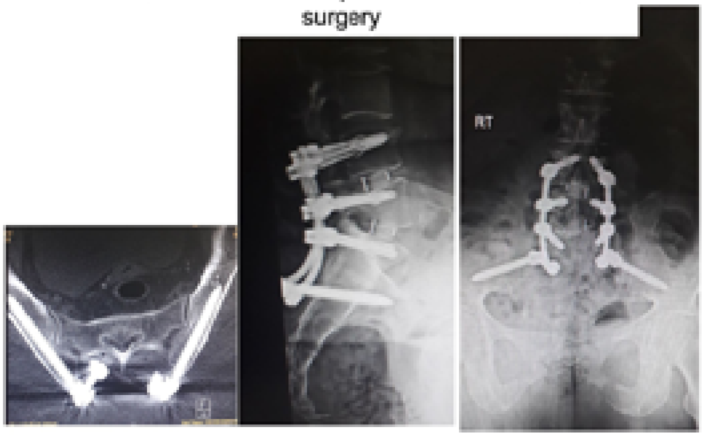
C2 Aneurismal Bone Cyst


PS stim. In REVISION SURGERY
Intraop. Screw stim. Influence the malpositioned screw removal



Degenerative Pathologies
The majority of our spine cases
Oseo screws and nav. Improve outcome in revision surgery



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Surgical Treatment

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

Spinal Cord Stimulation

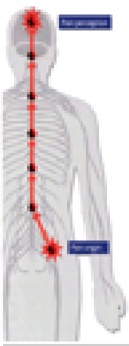
Peripheral Nerve Stimulation

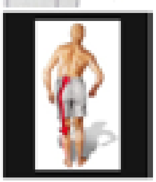
Subcutaneous Small Nerves Stimulation

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***:

<u>Intractable chronic LBP with leg pain is the most frequent indication for SCS</u>





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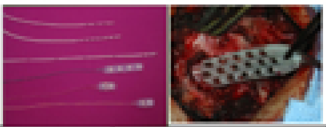
Patient Selection For SCS

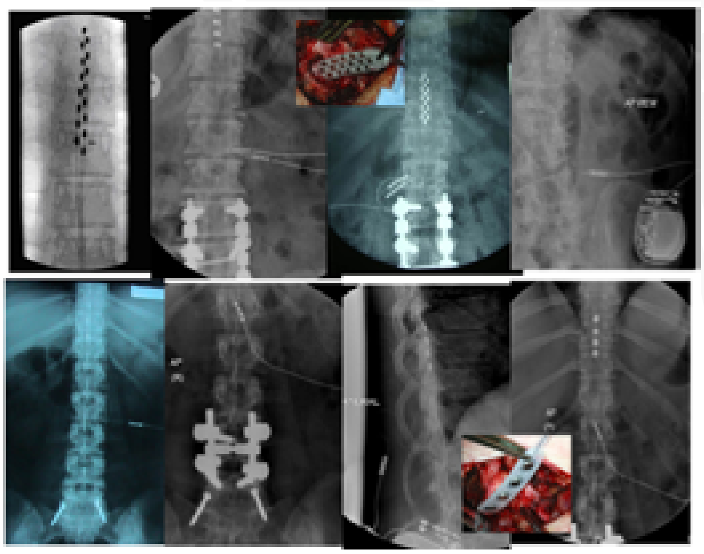
1. Pain not associated with malignancy.
2. Poor response to conservative treatment
3. No treatable cause.
4. No major active psychiatric disorder.
5. Willingness to stop inapropriate drug use.
6. No secondary gain or litigation involved.
7. Ability to give informed consent for the procedure.

Surgical plate vs.percutaneous

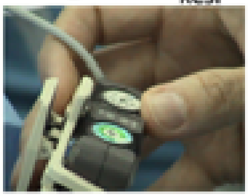


	Percutaneous	Surgical
Minimal invasiveness reversibility	X	
Overlap of pain by paresthesias	X	XX
Stability •Postural effects •Migration, Malposition		X
Reliability		X

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

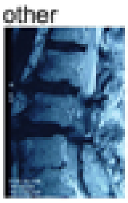
  Ensure maximal coverage of painful territory by painless paresthesias/tingling.

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. preference).

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.

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Rechargeable Stimulator

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When Pain Is Not Reachable By SCS

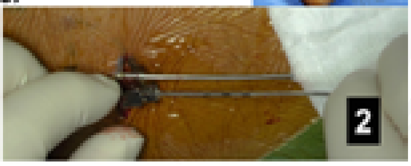
SPNS is a Minimally Invasive Surgical Technique

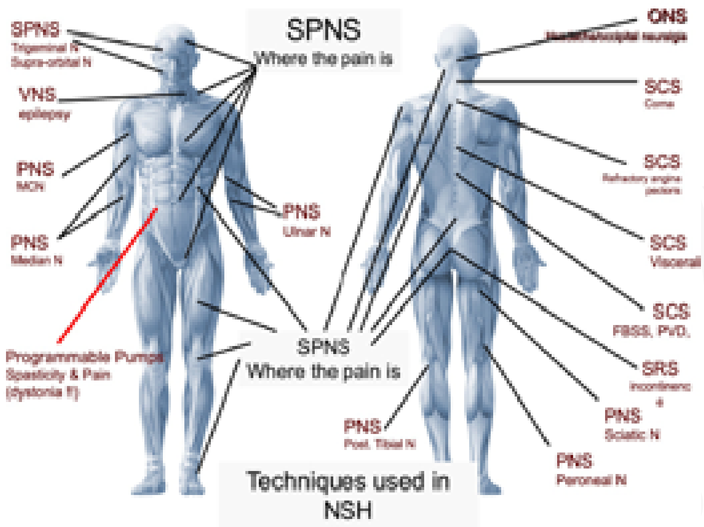
1- Precise ***marking of the painful area*** in fully awake patient.

***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***





Intractable Back Pain
3y. duration not accessible by SCS

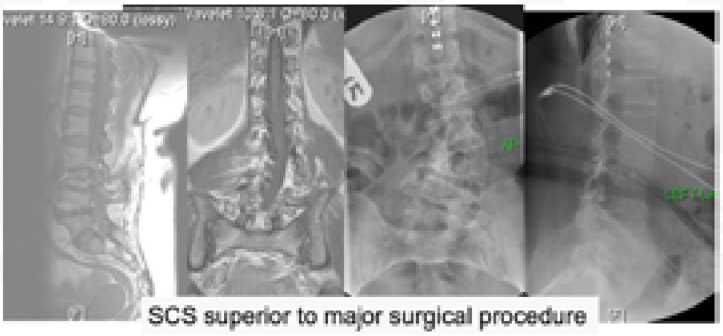
SCS was found to be superior to:

-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 residual permanent LBP and both legs pain, Degenerative Scoliosis

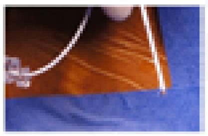
SCS was the less invasive efficient solution

SCS

- SCS Improves the quality of life, the functional capacity with the tendency to return to work. Oral pain medication however was not significantly modified.

Taylor R., Edgaston, Birmingham Dept. of Health and Epidemiology, Univ. of Birmingham 2002, pp 22-27

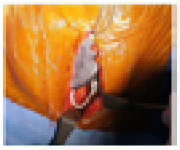
Surgical Treatment



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

Paice JA, Penn R D, Shotts I. Intraspinal Morphine for chronic pain: Retrospective, Multicentre Study. J Pain Symptom Manage 1996;11:71-80



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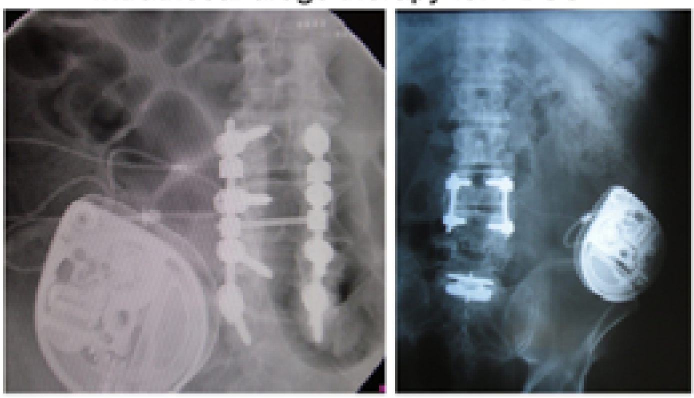
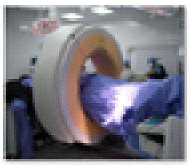
Intrathecal drugs therapy for FBSS



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

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INASS RCSI

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***

ASCD

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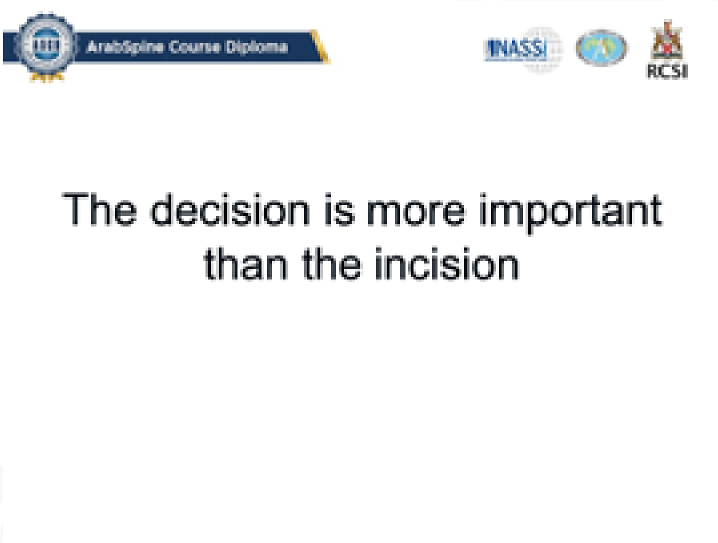

- END OF THE PROGRAM -

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Who are we?

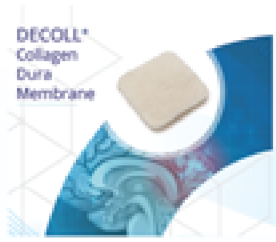
We do take care of implants and surgical consumables for various fields of application, in top quality materials manufactured by specialists.

We offer a comprehensive line of innovative, top quality products also provided peerless clinical support to post-acute facilities. We do an exceptional job of articulating the value of our products and solutions; we position ourselves in a clear, powerful, and memorable way in the marketplace.

Injectable Putty

We Cater to

- Spine Surgery
- Neurosurgery
- Pain Management
- Medical Consumables
- Ultrasonic Bone Scalpel System

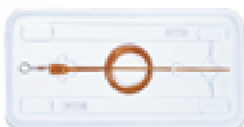


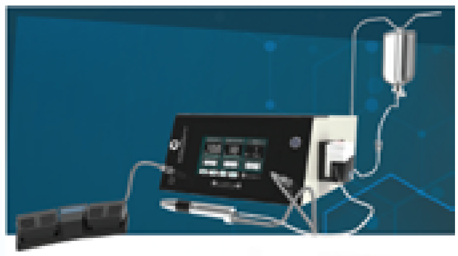
Our Mission

Our mission is to improve the well being of our patients and community. Also by delivering innovative, compassionate and family centered health care enriched by science, education and technology.

Technical Support

Our experts are available round the clock to rapidly diagnose and resolve technical problems, as well as proactively plan for your needs.





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