Gloves Off: Complications & Costs of MIS vs. Open Spine Surgery

Chairperson:

Chadi Tannoury, MD, FAOA, FAAOS

Associate Professor, Orthopedics

Medical Director, Orthopedic Clinic

Director of Spine Research

Boston University Medical Center

Tuesday, March 26th, 2024

3:15-3:45pm

MISS: What, Why, How?

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2024
Work Related Injuries Workshop

Key Points

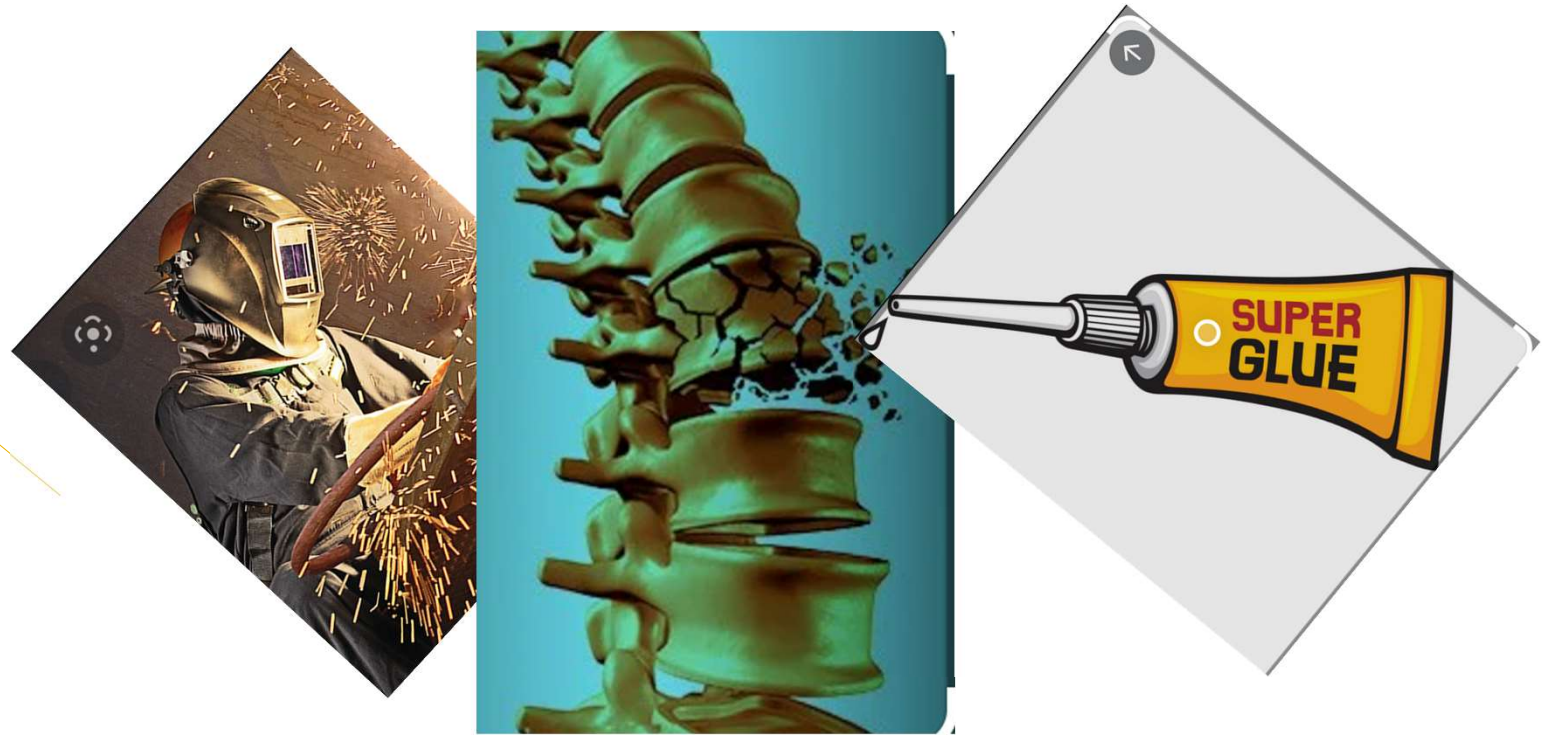
- WHAT?
- WHY?
- HOW?

Key Points

- WHAT?
  - Define anterior + posterior fixation - fusion
- WHY?
  - Utility - applications
- HOW?
  - Technique – MISS vs Open Standard

WHAT is Fusion?

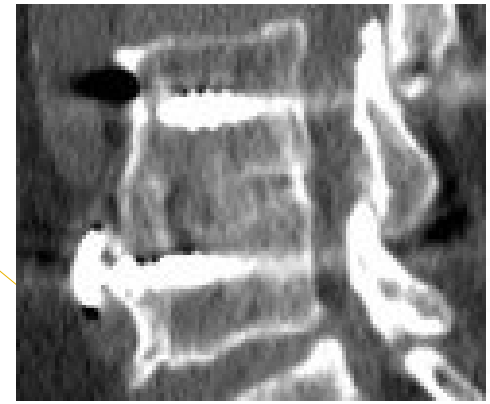
- Spinal Fusion: “weld-glue” the bone = Biologic process (evolving process)

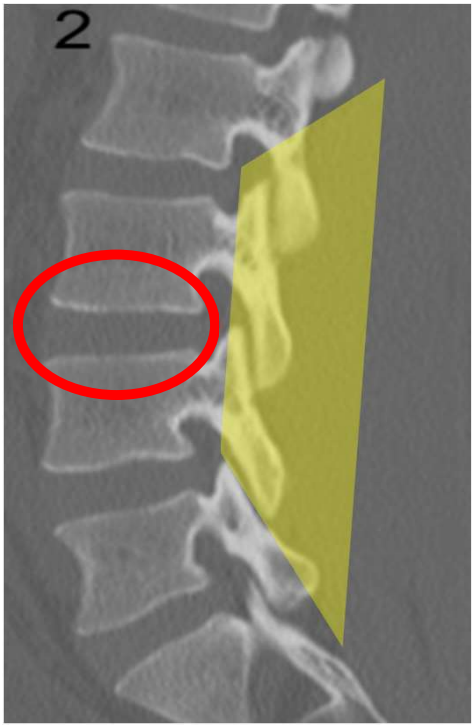


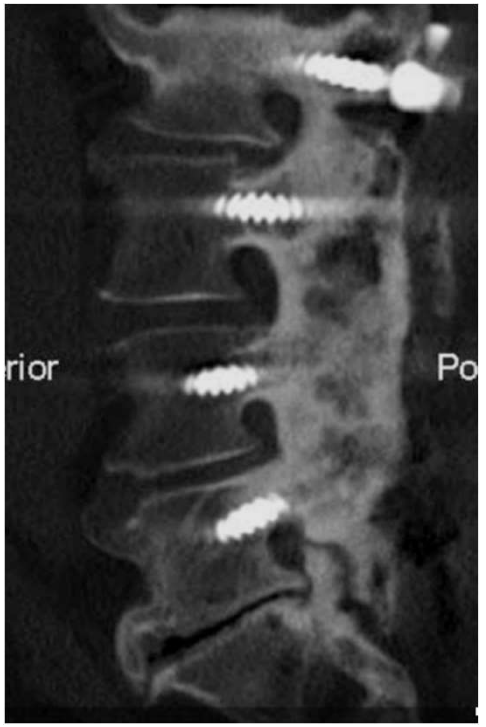
WHAT are the main players - Fusion?

- Spinal Fusion:

Diabetes, Smoking, Immune↓, Malnutrition, Motion (instability)





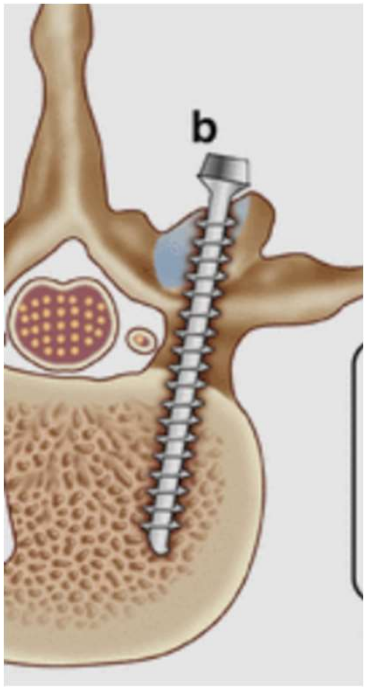


WHAT is Fixation?

- Spinal Fixation: Braces & stabilizes the spine until the Biology succeeds in healing

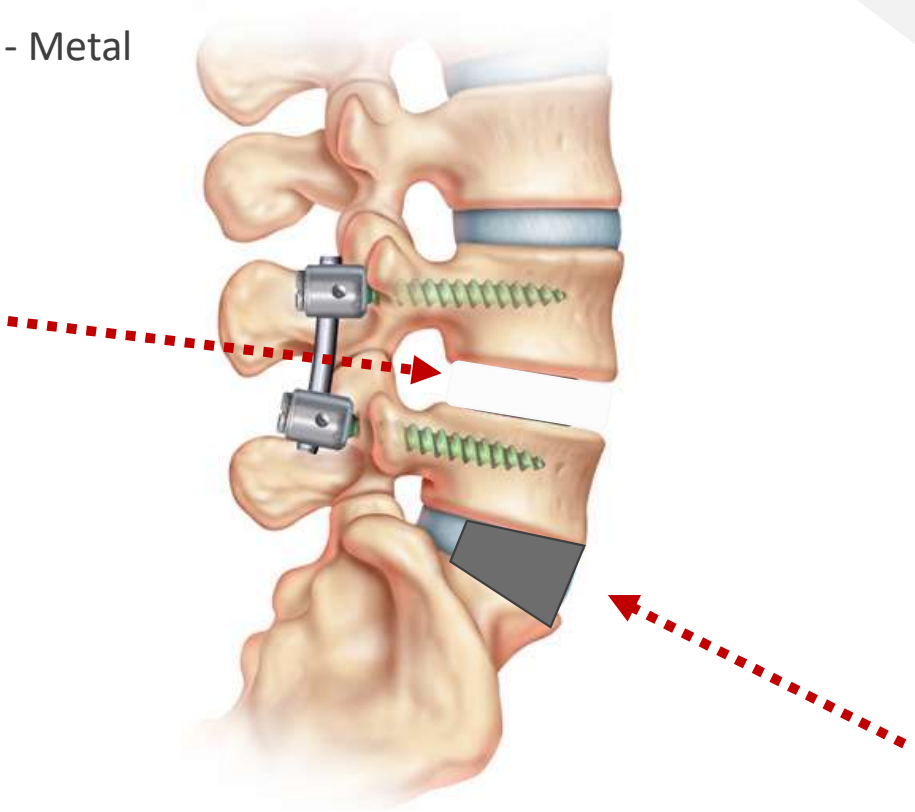
WHAT are the main players - Fixation?

- Spinal Fixation: “Internal Brace”
  - Various Systems BUT similar concepts - Metal
    - Screws
    - Screw caps
    - Rods



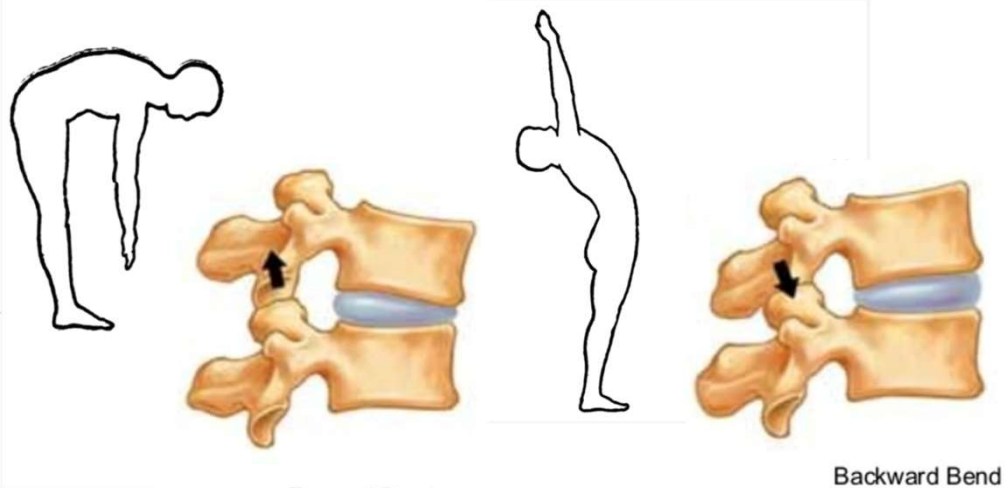
WHAT are the main players - Fixation?

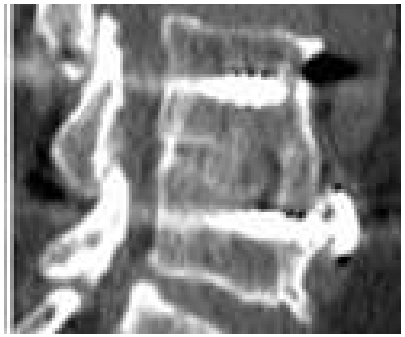
- Spinal Fixation: “Internal Brace”
  - Various Systems BUT similar concepts - Metal
    - Screws
    - Screw caps
    - Rods
    - Anterior support
      - Cages / spacers / implants



WHY we do Fusion?

- Spinal Fusion: Eliminates motion across
  - A diseased painful joint (Degen disc-facet disease)
  - An unstable spinal segment

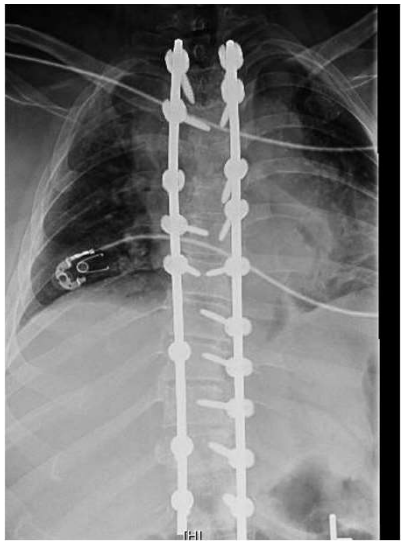




WHY we do Fixation?

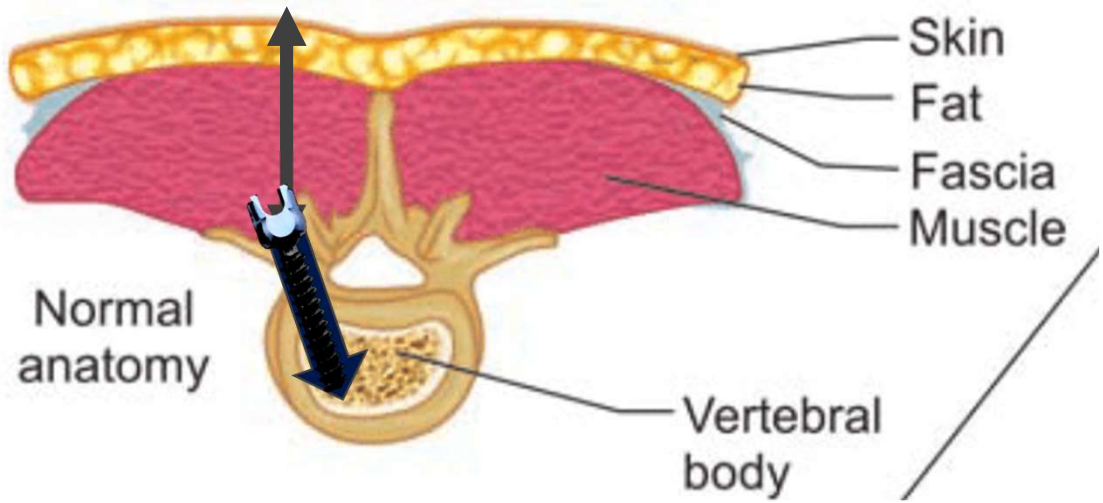
- Posterior Spinal Fixation:
  - Add stability: fractured spine – Frx healing
  - Correct deformity & maintain corrected alignment
  - Stabilize spine intended to fuse



HOW?

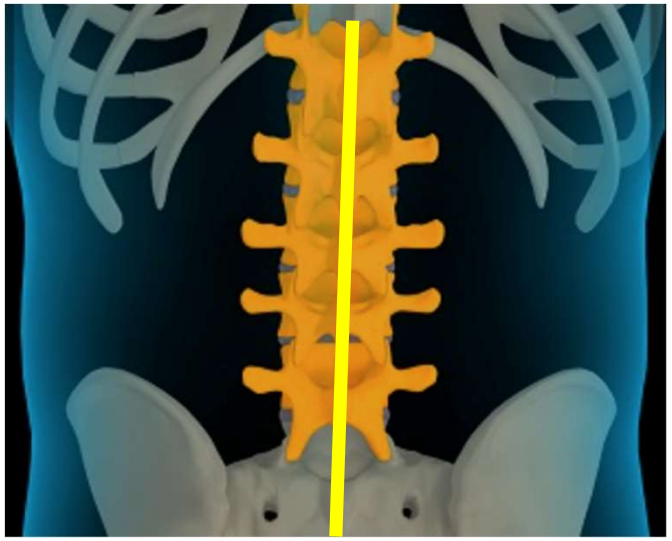
- Posterior Spinal Fixation - Fusion:
  - Soft tissue exposure ⟷



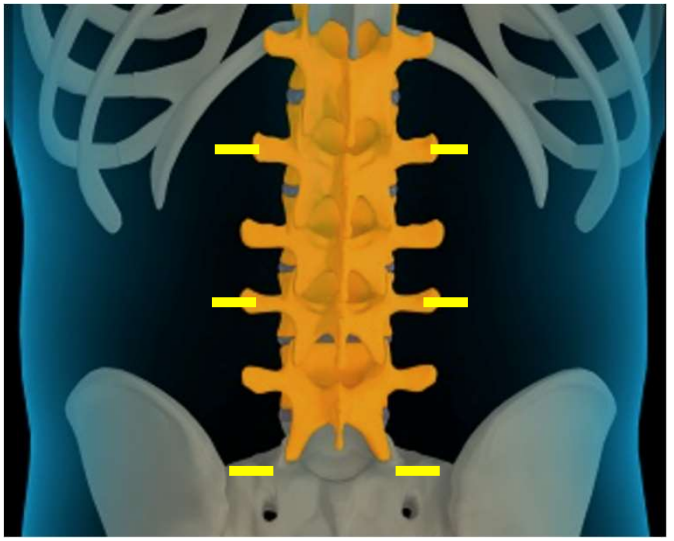
HOW – Exposure?

- Posterior Spinal Fixation - Fusion:
  - Skin incision
  - Soft tissue exposure

OPEN

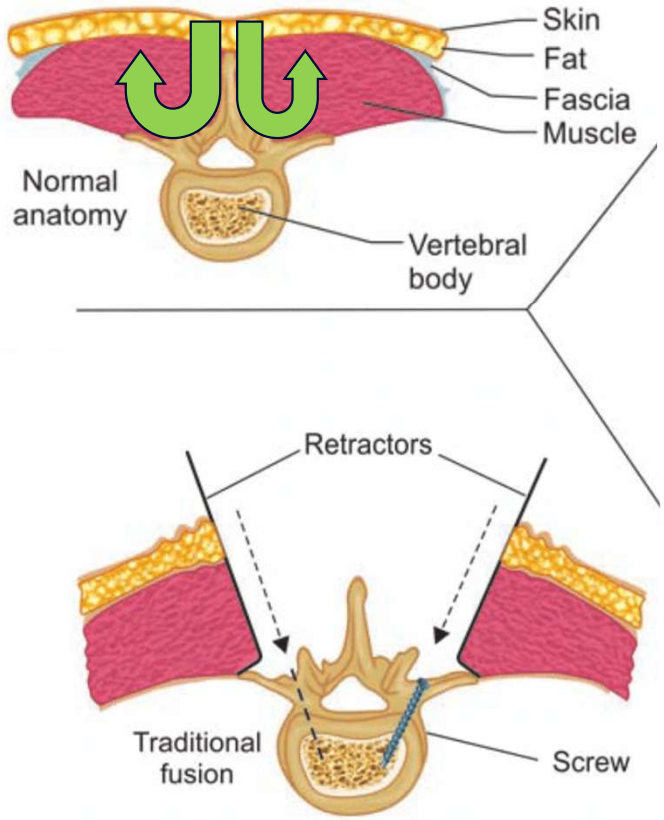


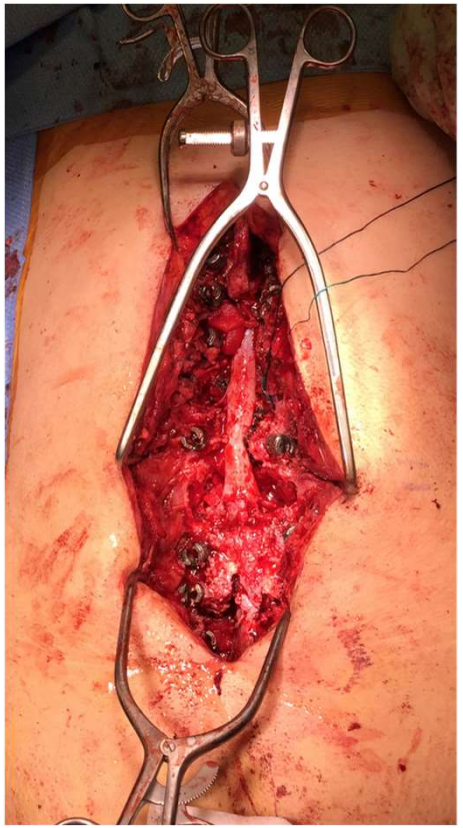
MIS



HOW – Open Exposure?

- Posterior Spinal Fixation - Fusion: Open

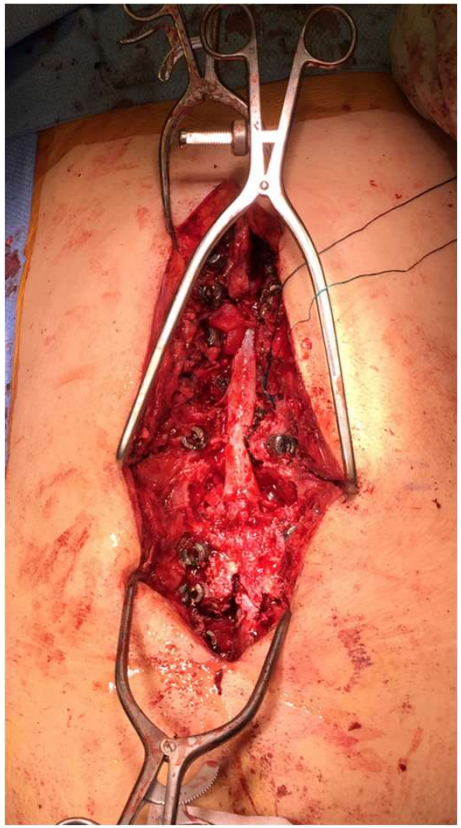




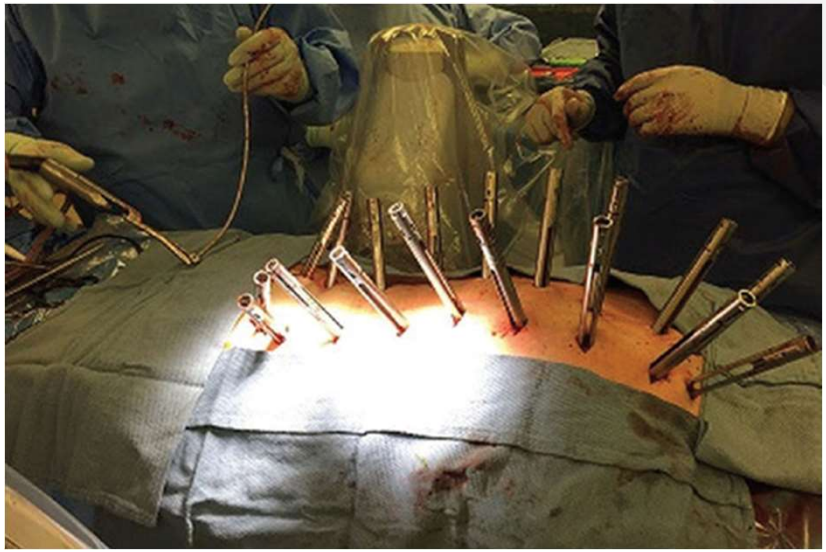
HOW – MISS?

- Posterior Spinal Fixation: MIS

OPEN

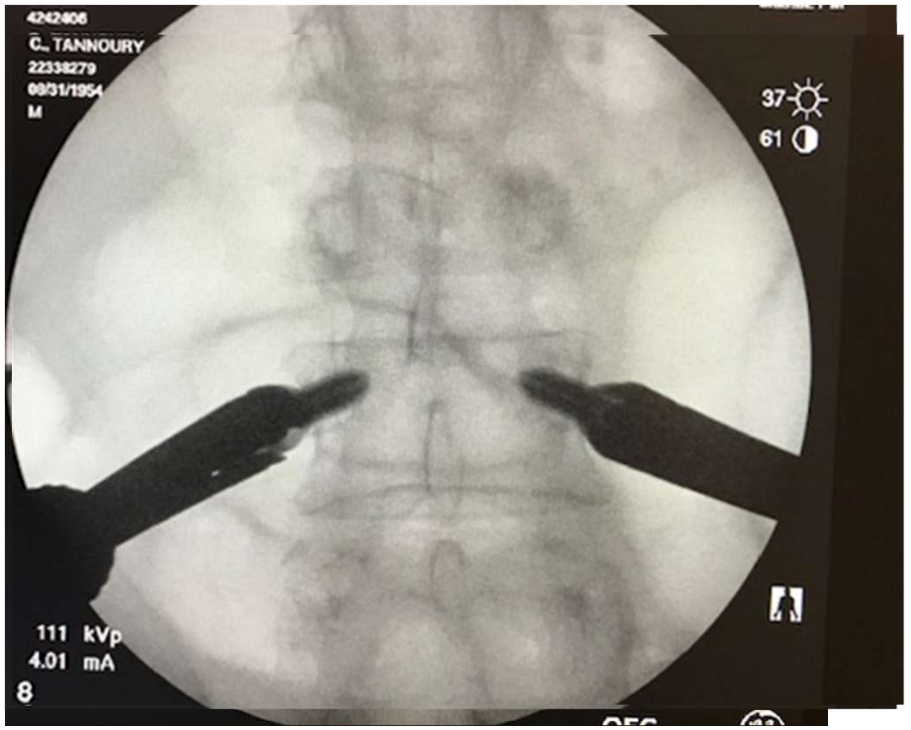


MIS



2024

Work Related Injuries Workshop



2024

Work Related Injuries Workshop

2024

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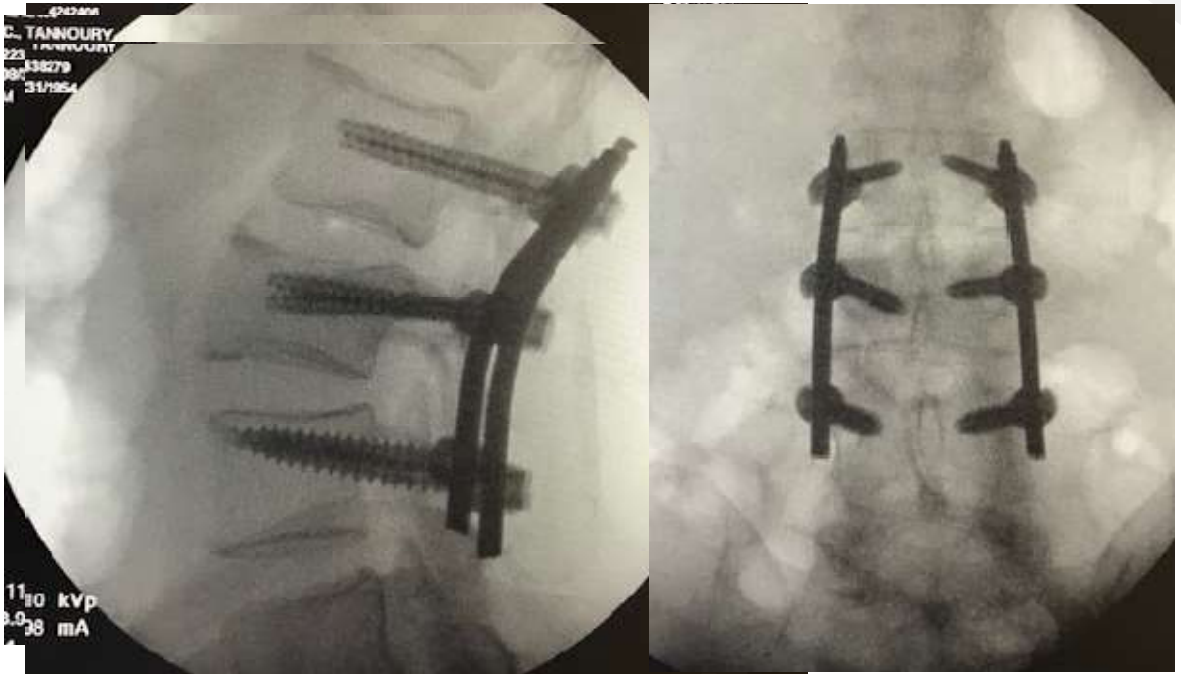
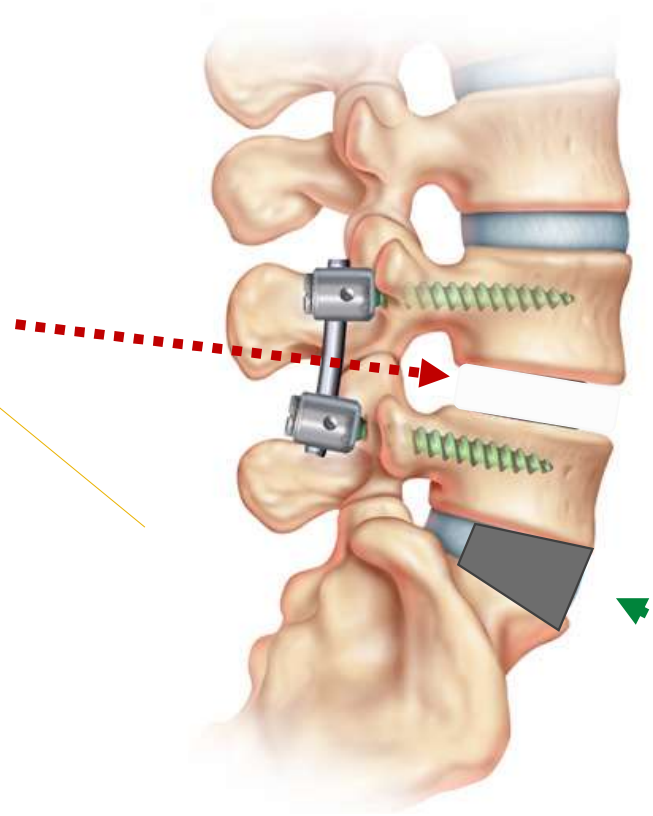
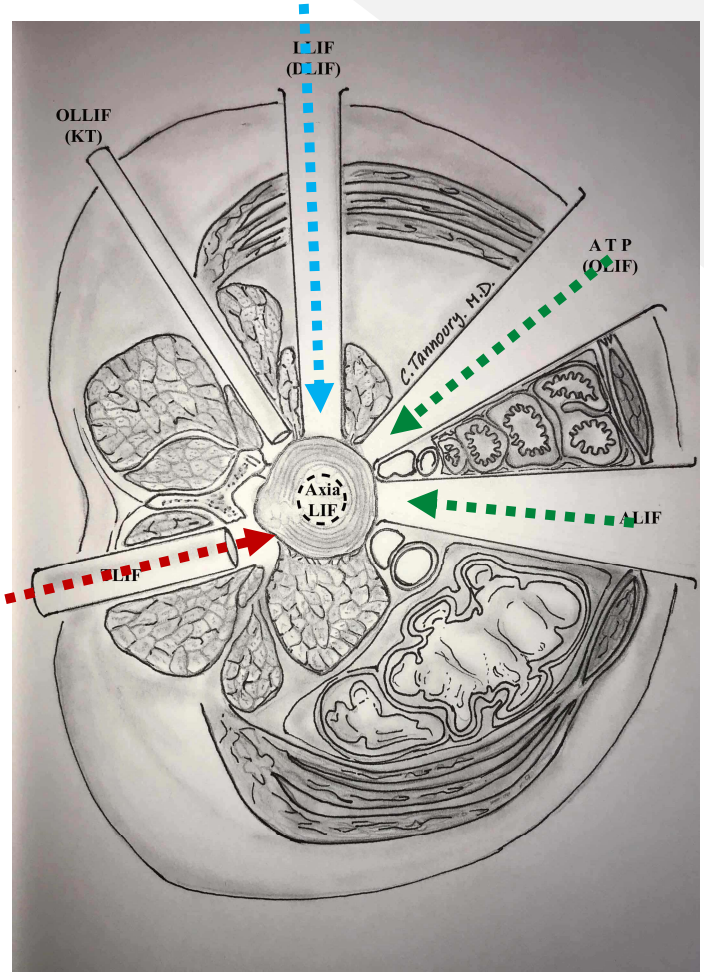
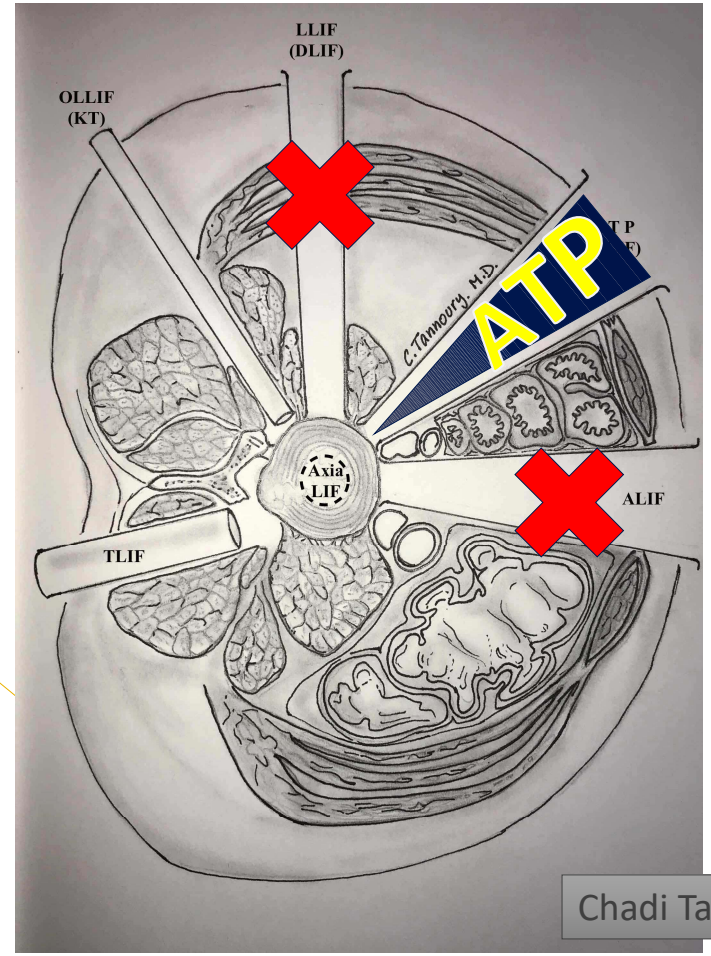


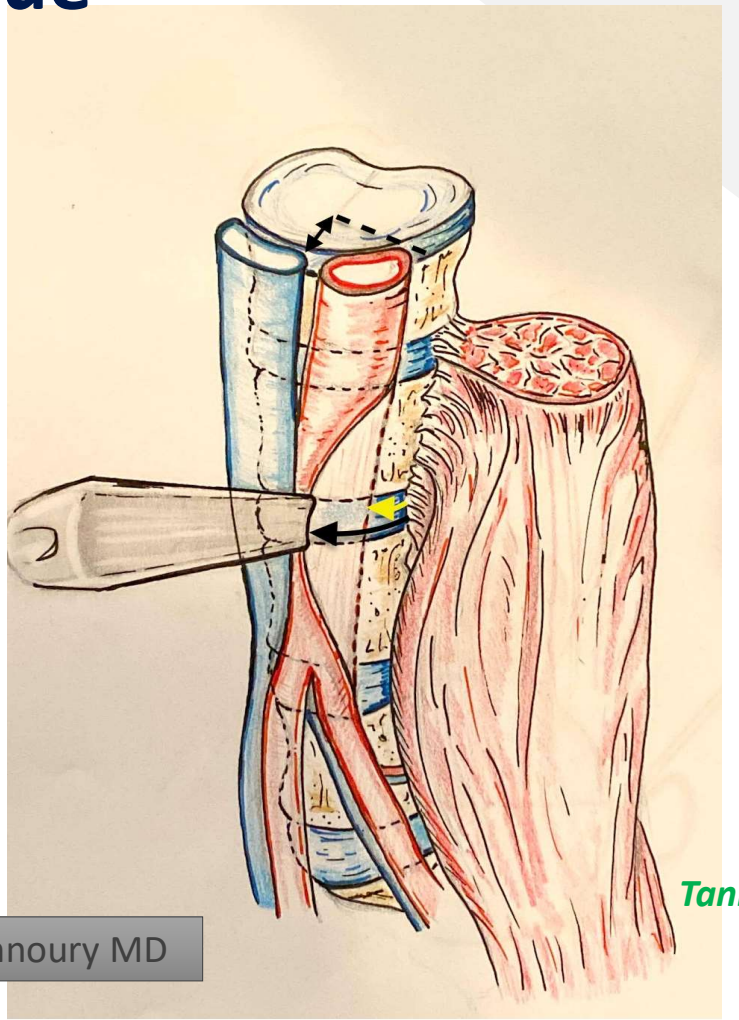
How? Fusion (interbody)





ATP (AntePsoas) Technique





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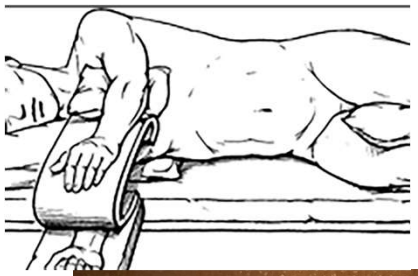
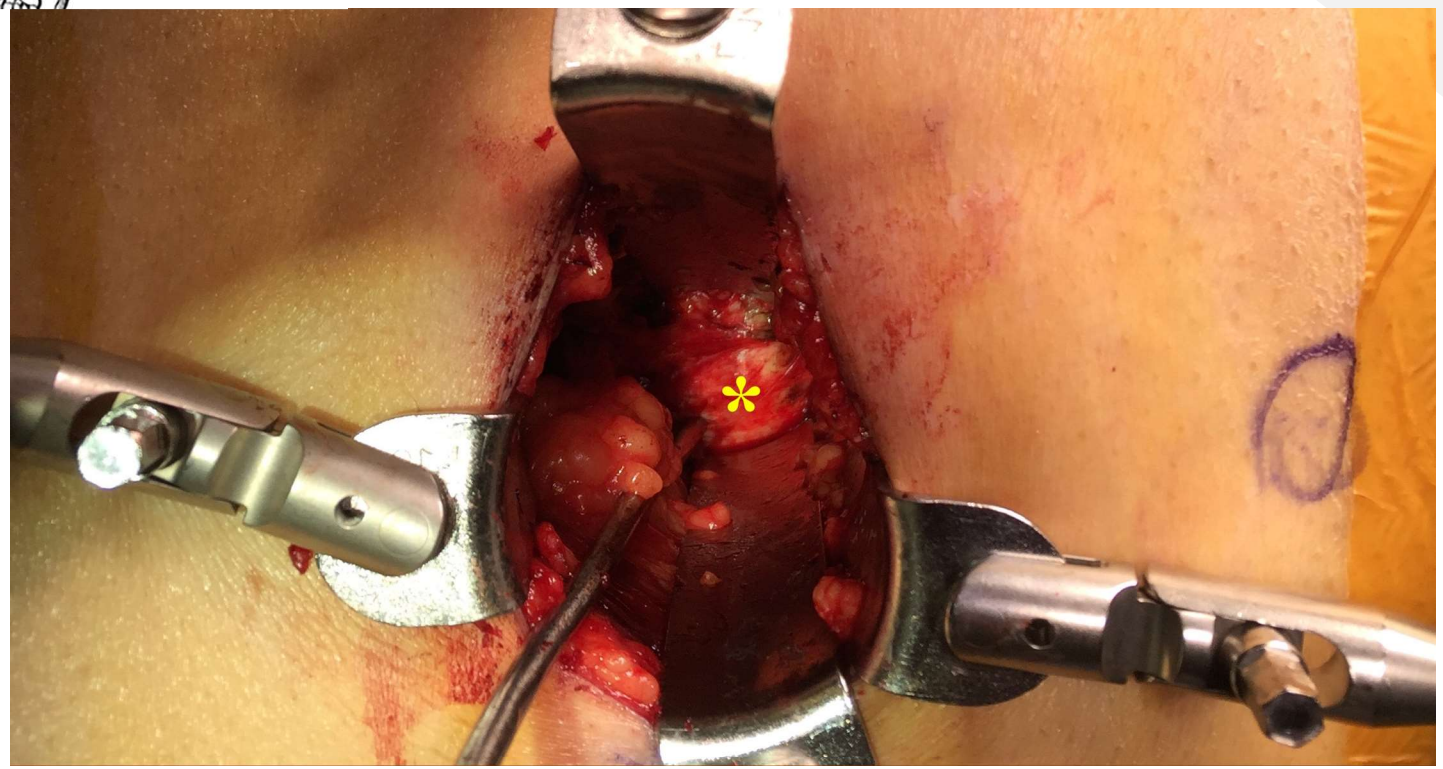
Tannoury et al, LSRS 2017
Tannoury et al 2018
Tannoury et al 2022



Wide Exposure=Safe Visualization!



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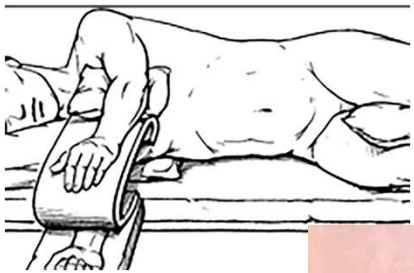
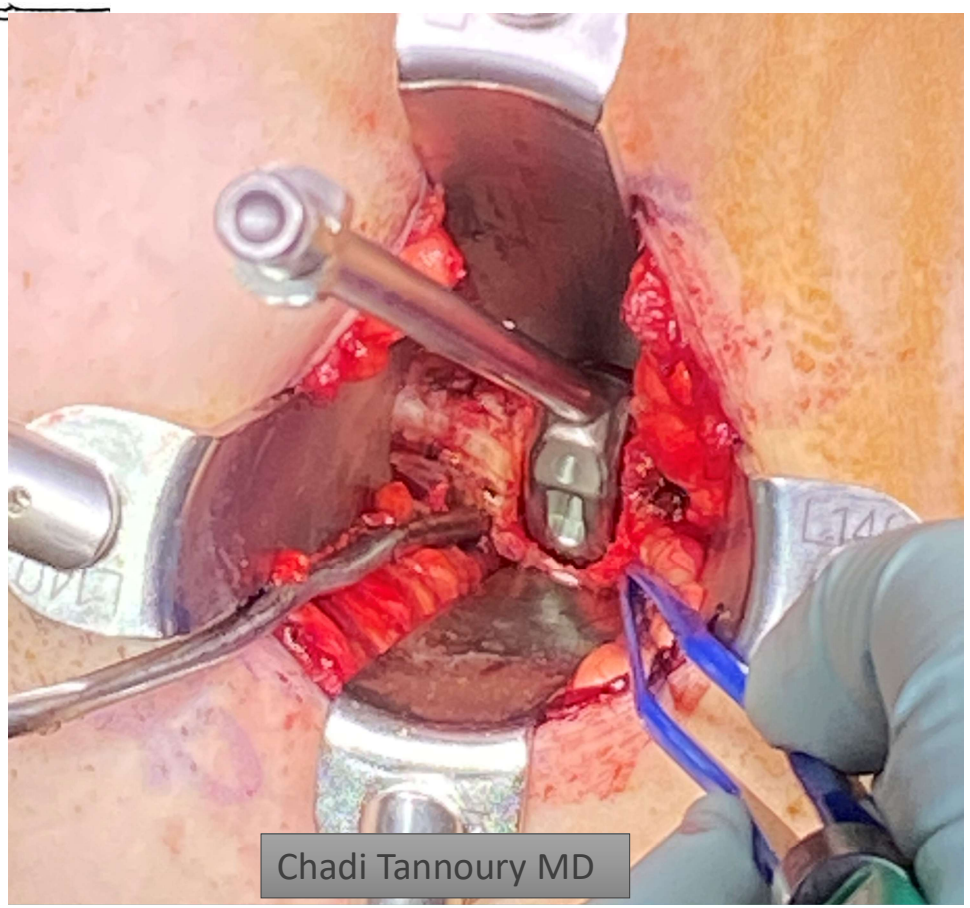
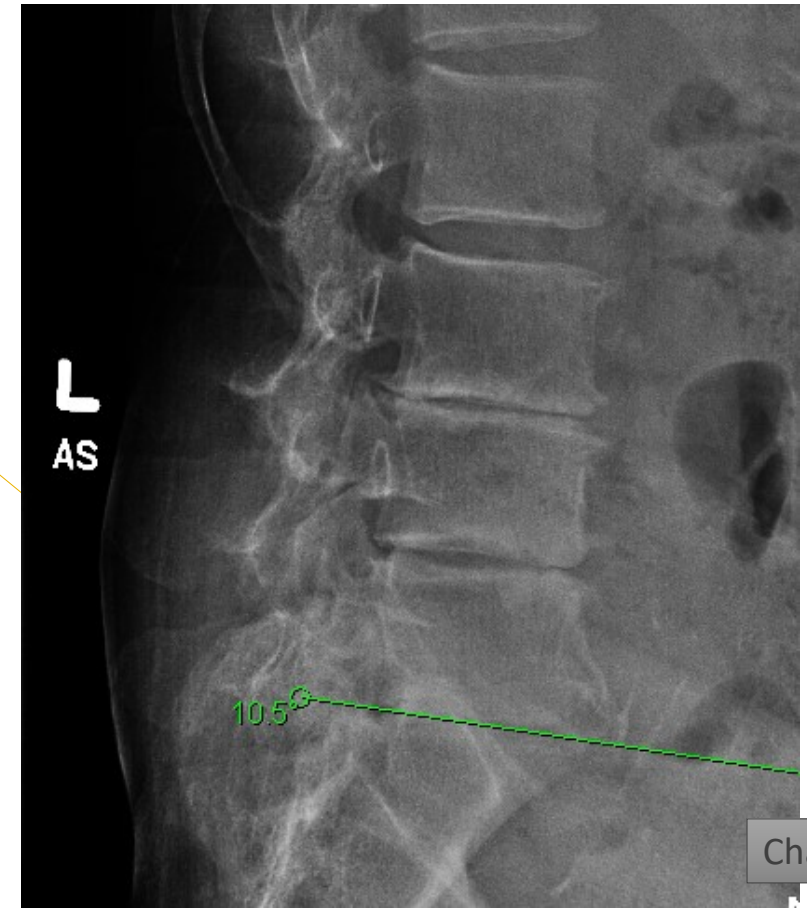


Full Discectomy & Safe ACR





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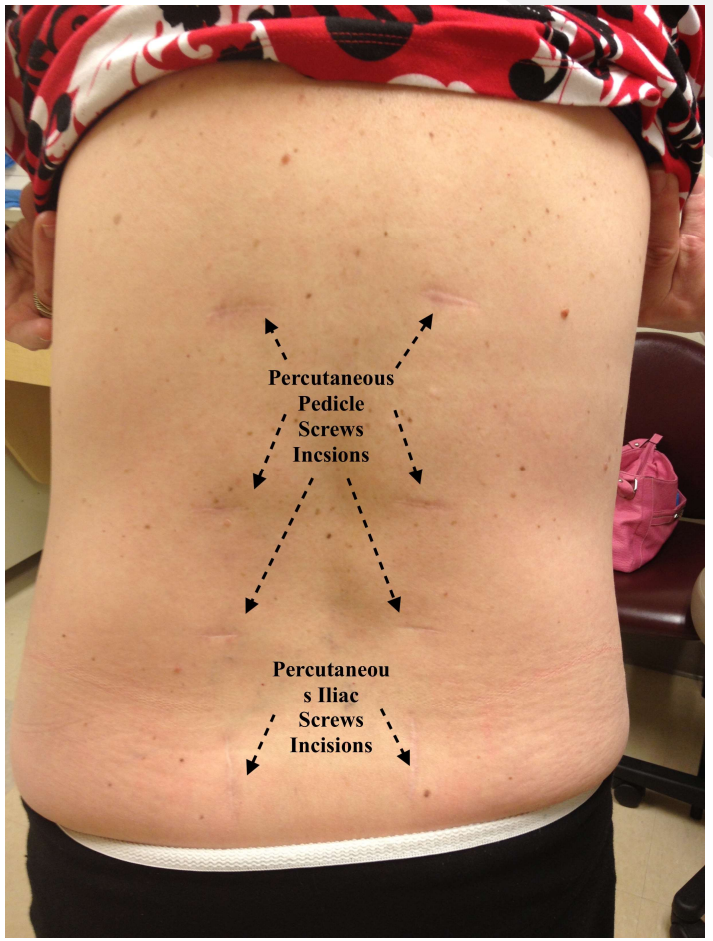
Outcomes?
MIS vs Open Spine Surgery

- MISS: LESS
  - Soft tissue dissection
  - Blood loss
  - Complications (infections, nerve injury, etc.)
  - Postoperative Pain
  - Opiates use

  - Faster Recovery
  - Faster return to activity: Productivity



References

- Tannoury, Chadi. *Minimally Invasive Spine Surgery*. Lippincott Williams & Wilkins, 2017.
- Kerr SM, Tannoury C, White AP, Hannallah D, Mendel RC, Anderson DG. The role of minimally invasive surgery in the lumbar spine. Operative Techniques in Orthopaedics. 2007 Jul 1;17(3):183-9.
- Poelstra KA, Tannoury C, Srinivasan S, Anderson DG. Minimally invasive exposure techniques in spine surgery. Current Opinion in Orthopaedics. 2006 Jun 1;17(3):208-13.
- Tannoury, Chadi, et al. "The antepsoas (ATP) surgical corridor for lumbar and lumbosacral arthrodesis: a radiographic, anatomic, and surgical investigation." *Spine* 47.15 (2022): 1084-1092.

Thank You!

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Is MIS Applicable for Revision Surgeries & Where It Can Go Wrong

Tony Tannoury, MD

Is MIS Applicable for Revision Surgery & Where It Can Go Wrong

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Disclosures

- DePuy:
  - Royalty
  - Consultant
  - Technology evaluation
  - Research grants
- HillRom:
  - Royalty

Presentation Overview
Questions Re MIS surgery

- What is MIS?
- Effectiveness
- Safety
- Cost

67 yo. Fall of a height. NV Intact

Classic surgery

Spinal fixation + fusion

Fracture reduction + fixation

MIS:

Spinal fixation without fusion:

Fracture reduction and fixation

Comparison: Direct cost RVUs

Open Classic Surgery

- Fracture Rx:
- Laminectomy
- Fusion: at least 7 levels:
- Fixation Implant:
  - 14-16 screws
  - Two cages
  - Fusion graft

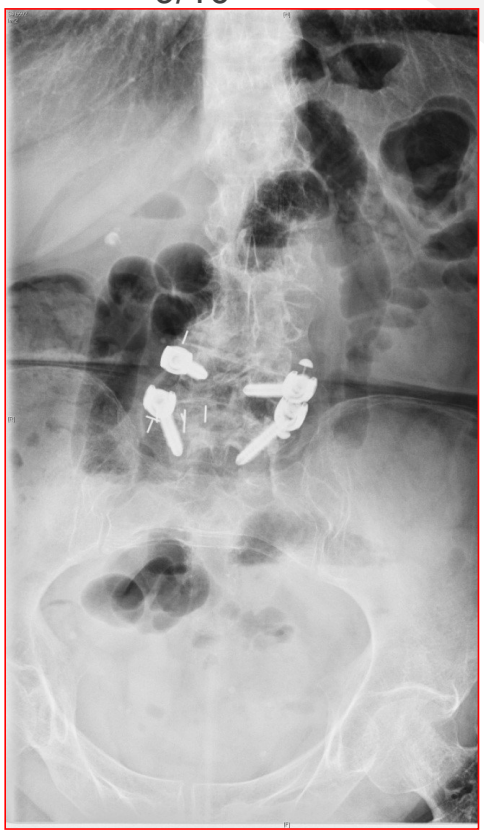
MIS option

- Fracture Rx:
- Laminectomy=None
- Fusion=None
- Fixation Implants:
  - 8 screws
- ROH (staged procedure)
- Fusion Graft: None

MS- 73F with severe back and left leg pain

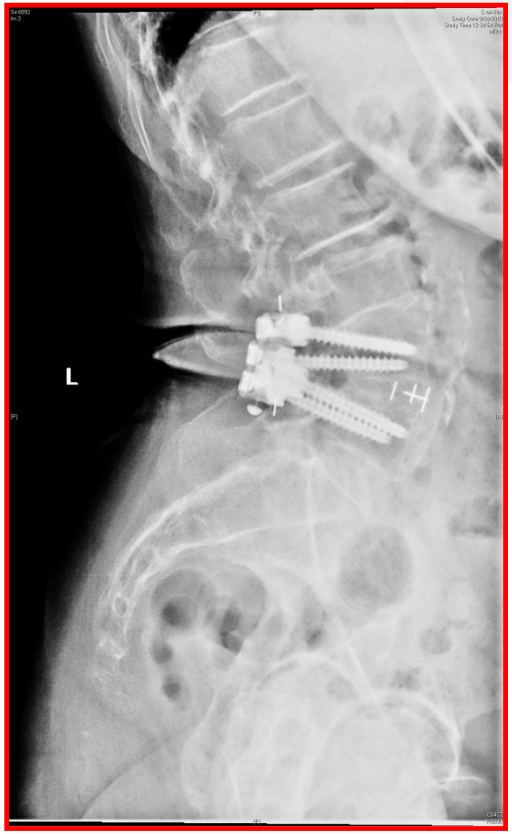
- PMH
  - Osteopenia
  - Lumbar disk disease
- PSH
  - Spine x3
  - L hip DHS, ROH
- Soc. Hx
  - 5 cig/day smoker
  - 1-2 drinks/day
  - Community ambulator
    - Uses a cane secondary to back and L leg pain

9/10

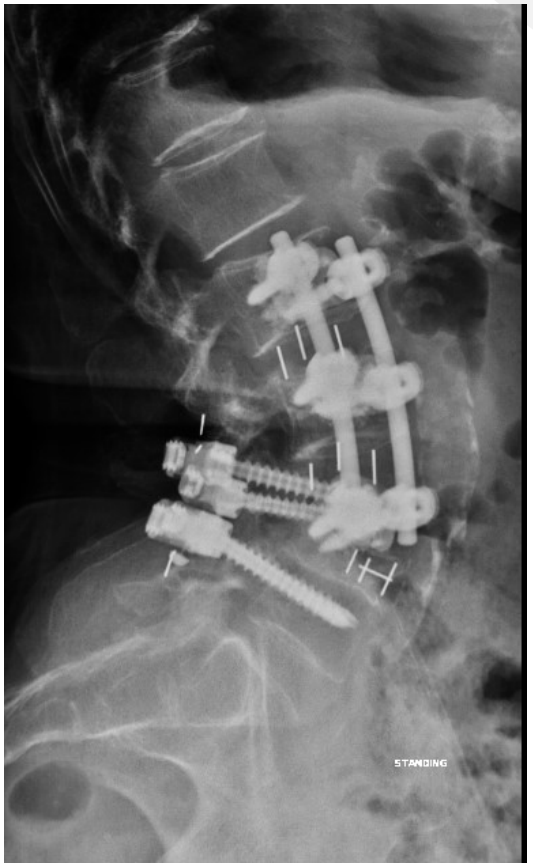


History

- **Exam**
  - Thin female in apparent discomfort
  - Antalgic Gait
  - Loss of lordosis on standing
  - Flex to knee, 20* extension
  - No sensory deficits
  - Complains of painful sensation down anterior and medial side of L leg
  - Strength 5/5 and symmetric IP/Q/H/TA/EHL/GS
  - No clonus, Babinski's down going, (-) straight leg raise and cross straight leg raise, (-) Hoffman.



MIS Rx:
No need to ROH or Posterior surgery



Comparison: Direct cost RVUs

Open Classic Surgery

- Laminectomy x 3
- Fusion: at least 3 levels:
- ROH
- EOF

- Fixation Implants:
  - 8 screws
  - Two cages
  - Two Rods
  - Fusion graft

MIS option

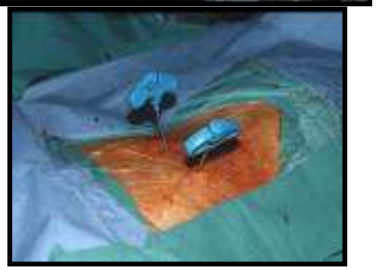
- Laminectomy= None
- Fixation: 2 levels
- ROH=None
- EOF: None
- Fixation Implants:
  - 3 screws
  - Two cages
  - One Rod
  - Fusion graft

Minimally Invasive Spinal Surgery!!

Endoscopic

Mini open

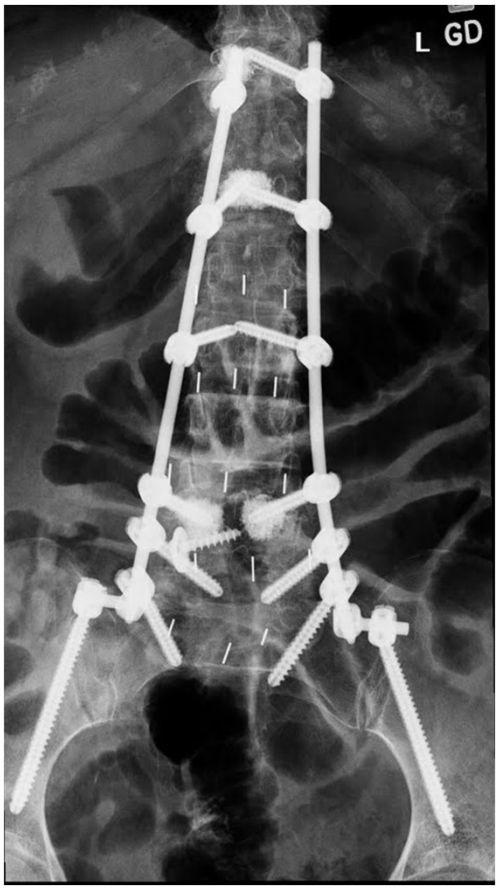
Image Guided
Percutaneous



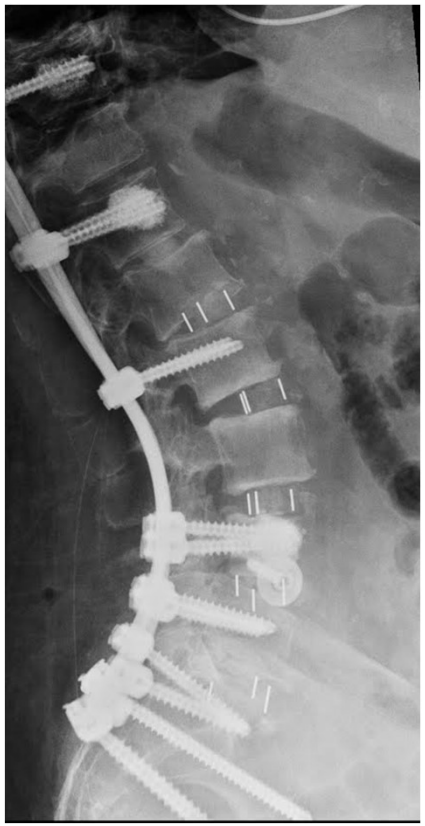
Promises of Minimaly Access Spine Surgery...

- Less:
  - muscle damage (fusion disease)
  - denervation
  - blood loss
  - hospitalization
  - time off work

Challenges of MIS



- Surgery too long
- Too many complications
- Radiation exposure
- Inadequate decompression
- Inadequate fusion
- Inadequate deformity correction
- Suboptimal fixation



How about when it hits your family?
Cost Vs Quality!!

Clinical Presentation

- My Dad, 79 yo, very healthy, severe left buttock pain and leg pain and weakness
- Started developing Drop foot on left.
- Right calf pain

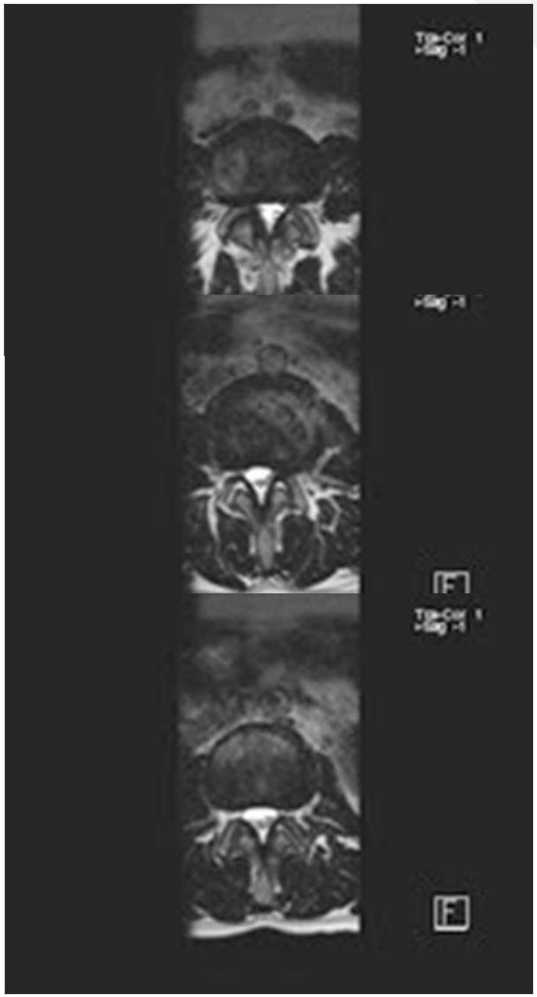
X-Rays

AP

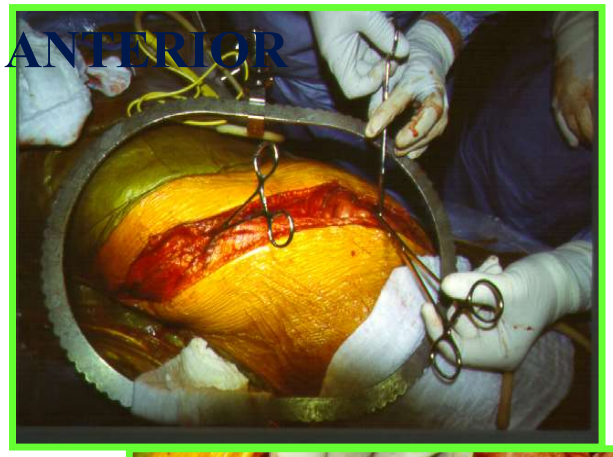
Flexion

Extension

MRI



Current “Standard of Care”of Spine Surgery



Adult Idiopathic Scoliosis
SURGICAL TREATMENT
Risk/Benefit

- Residual Pain 3 to 15%
- Pseudarthrosis 5 to 30%
- Mortality 1 to 5%
- Neurologic 1 to 5%
- Infection 0.5 to 5%
- PEs 1 to 20%

Complications of Open Surgery SRS Data, 2010

- Spondylolisthesis: 10,242 cases
  - 9.2% major complication rate.
  - Infection 2%
  - Neurologic injury: 2%
- Degenerative scoliosis: 5,980 cases
  - Major complication: 10.5
  - Infection: 1.5%
  - Neurological injury: 1% (immediate) +0.5% (delayed)

So Dad and I decided to Stay Away from surgery

2024
Work Related Injuries Workshop

What we did:

- PT
- Time
- Reduce activity
- Steroid injections!!
- Pain medicine

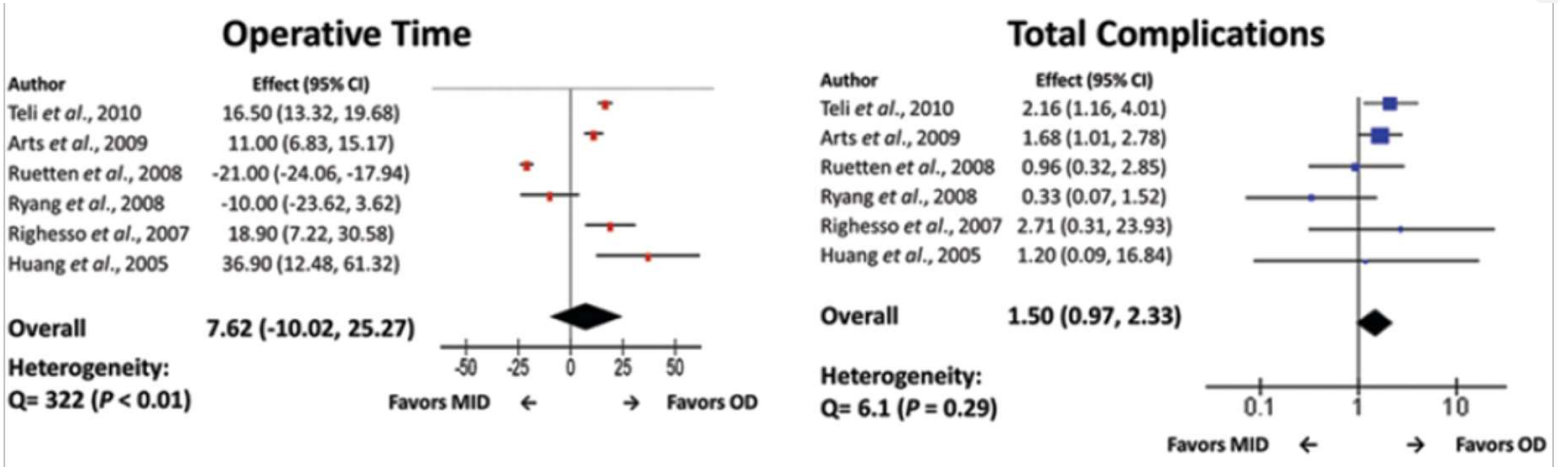
4 moths later

- My dad leg got weaker
- Pain increased

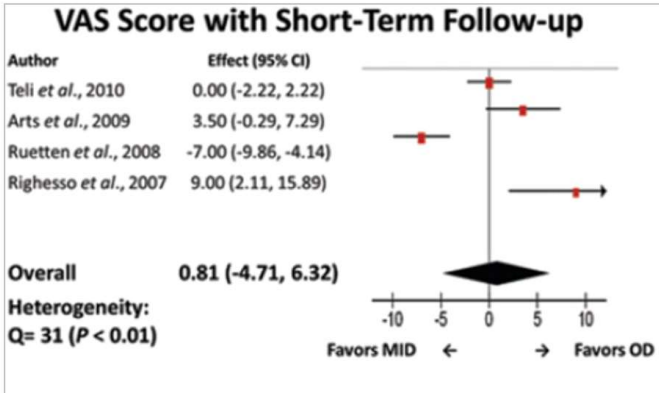
WE HAD TO DO SOMETHING

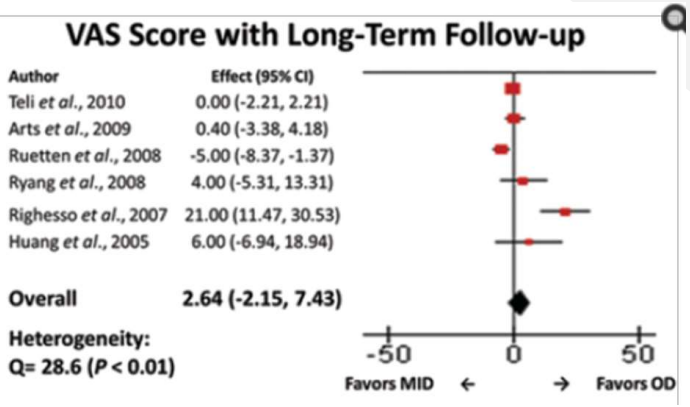
SO I DECIDED TO RESEARCH LESS
Invasive Options

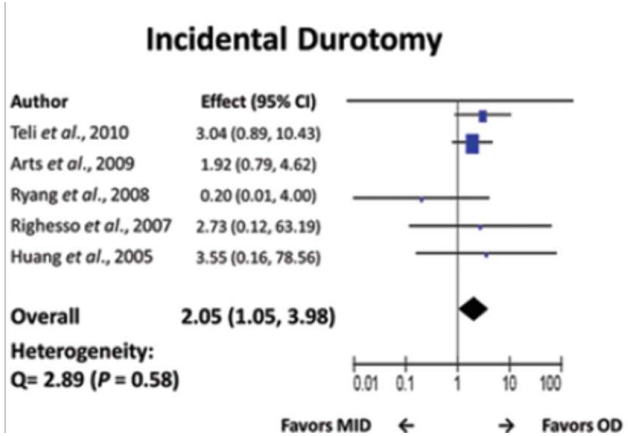
Meta-analysis MIS discectomy vs Open, Bydon et al

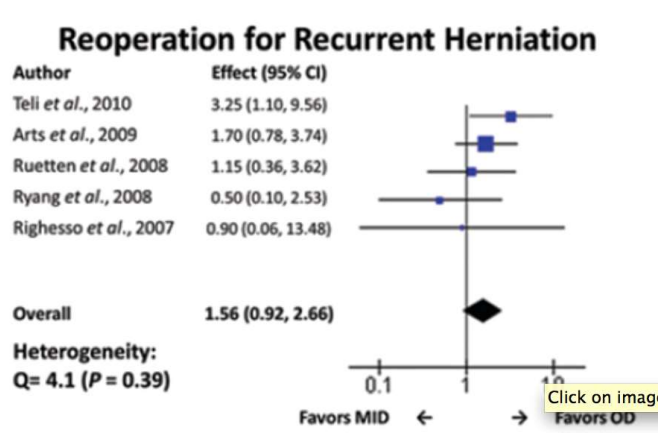


Meta-analysis MIS discectomy vs Open, Bydon et al









Cost of MIS discectomy vs Open

World Neurosurg. 2013 Jul-Aug;80(1-2):208-12. doi: 10.1016/j.wneu.2012.08.015. Epub 2012 Sep 25.

A comparison of acute hospital charges after tubular versus open microdiskectomy.

Cahill KS[1], Levi AD, Cummock MD, Liao W, Wang MY.

Author information

Abstract

OBJECTIVE: To determine if tubular microdiskectomy is associated with differences in hospital charges compared with open microdiskectomy.

METHODS: A retrospective review of patients who underwent tubular microdiskectomy or open microdiskectomy performed by the senior authors from 2007-2010 was performed. The primary outcome was inflation-adjusted total hospital charges for each procedure using itemized charge data obtained from the hospital finance department. Secondary outcomes included length of stay, complications, and operative times.

RESULTS: There were 76 eligible patients (33 open microdiskectomy and 48 tubular microdiskectomy) identified during the study period. The mean total charge was $27,811 (standard deviation $11,198) in the open group compared with $22,358 (standard deviation $8695) in the tubular group. Total charges in the tubular group were on average $5453 less than in the open group (P = 0.02). There were no significant differences in operative times or complications. Length of stay was significantly shorter in the tubular group (mean 1.5 days open vs. 0.9 days tubular, P = 0.01).

CONCLUSIONS: This analysis revealed significantly lower acute hospital charges associated with tubular microdiskectomy versus open microdiskectomy at an academic tertiary care hospital. These differences appear to the related to decreased use of postoperative resources in the tubular group.

KEYWORDS: Cost-effectiveness analysis, Hospital charges, Lumbar disk herniation, MIS, Minimally invasive spine surgery, Minimally invasive surgery, SD, SPORT, Spine Patient Outcomes Research Trial, Standard deviation, Tubular microdiskectomy

Comment in

Cost of multilevel decompression

J Spinal Disord Tech. 2013 Feb;26(1):42-7. doi: 10.1097/BSD.0b013e318232313d.

Cost-utility analysis of minimally invasive versus open multilevel hemilaminectomy for lumbar stenosis.

Parker SL[1], Adogwa O, Davis BJ, Fulchiero E, Aaronson O, Cheng J, Devin CJ, McGirt MJ.

Author information

Abstract

STUDY DESIGN: Two-year cost-utility study comparing minimally invasive (MIS) versus open multilevel hemilaminectomy in patients with degenerative lumbar spinal stenosis.

OBJECTIVE: The objective of the study was to determine whether MIS versus open multilevel hemilaminectomy for degenerative lumbar spinal stenosis is a cost-effective advancement in lumbar decompression surgery.

SUMMARY OF BACKGROUND DATA: MIS-multilevel hemilaminectomy for degenerative lumbar spinal stenosis allows for effective treatment of back and leg pain while theoretically minimizing blood loss, tissue injury, and postoperative recovery. No studies have evaluated comprehensive healthcare costs associated with multilevel hemilaminectomy procedures, nor assessed cost-effectiveness of MIS versus open multilevel hemilaminectomy.

METHODS: Fifty-four consecutive patients with lumbar stenosis undergoing multilevel hemilaminectomy through an MIS paramedian tubular approach (n=27) versus midline open approach (n=27) were included. Total back-related medical resource utilization, missed work, and health state values [quality adjusted life years (QALYs), calculated from EuroQuol-5D with US valuation] were assessed after 2-year follow-up. Two-year resource use was multiplied by unit costs based on Medicare national allowable payment amounts (direct cost) and work-day losses were multiplied by the self-reported gross-of-tax wage rate (indirect cost). Difference in mean total cost per QALY gained for MIS versus open hemilaminectomy was assessed as incremental cost-effectiveness ratio (ICER: COST(MIS)-COST(OPEN)/QALY(MIS)-QALY(OPEN)).

RESULTS: MIS versus open cohorts were similar at baseline. MIS and open hemilaminectomy were associated with an equivalent cumulative gain of 0.72 QALYs 2 years after surgery. Mean direct medical costs, indirect societal costs, and total 2-year cost ($23,109 vs. $25,420; P=0.21) were similar between MIS and open hemilaminectomy. MIS versus open approach was associated with similar total costs and utility, making it a cost equivalent technology compared with the traditional open approach.

CONCLUSIONS: MIS versus open multilevel hemilaminectomy was associated with similar cost over 2 years while providing equivalent improvement in QALYs. In our experience, MIS versus open multilevel hemilaminectomy is a cost equivalent technology for patients with lumbar stenosis-associated radicular pain.

Hybrid Anterior plus Posterior Fusion: Open vs MIS fixation

Spine J. 2013 May;13(5):489-97. doi: 10.1016/j.spinee.2012.10.034. Epub 2012 Dec 5.

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

Kepler CK[1], Yu AL, Gruskay JA, Delasotta LA, Radcliff KE, Rihn JA, Hilibrand AS, Anderson DG, Vaccaro AR.

Author information

Abstract

BACKGROUND CONTEXT: Minimally invasive techniques for spinal fusion have theoretical advantages for the reduction of iatrogenic injury. Although this topic has been investigated previously for posterior-only interbody surgery, such as transforaminal lumbar interbody fusion, similar studies have not evaluated these techniques after anteroposterior spinal fusion, a study design that can more accurately determine the effect of pedicle screw placement and decompression via a minimally invasive technique without the confounding effect of simultaneous interbody cage placement.

PURPOSE: To compare process measures that provide insight into the morbidity of surgery, such as surgical time and the length of postoperative hospital stay between open and minimally invasive anteroposterior lumbar fusion; and to compare the complications during the intraoperative and early postoperative period between open and minimally invasive anteroposterior lumbar fusion.

STUDY DESIGN: Retrospective case-control study.

PATIENT SAMPLE: One hundred sixty-two patients.

OUTCOME MEASURES: Estimated blood loss, length of surgery, intraoperative fluoroscopy time, length of postoperative hospital stay, malpositioned instrumentation on postoperative imaging, and postoperative complications, including pulmonary embolus and surgical site infection.

METHODS: Patients who underwent open anterior lumbar interbody fusion followed by either traditional open posterior fusion (Open group) or minimally invasive posterior fusion (minimally invasive surgery [MIS] group) were matched by the number of surgical levels. A chart review was performed to document the intraoperative and postoperative process measures and associated complications in the two groups. Secondary analyses were performed to compare the subgroups of patients, who did and did not undergo a posterior decompression at the time of posterior instrumentation to determine the effect of decompression.

RESULTS: Baseline characteristics were similar between the Open and MIS groups. Estimated blood loss and postoperative transfusion rate were significantly higher in the Open group, differences that the subanalyses suggested were largely because of those patients who underwent concomitant decompression. Length of stay was not significantly different between the groups but was significantly shorter for MIS patients treated without decompression than for Open patients treated without decompression. Intraoperative fluoroscopy time was significantly longer in the MIS group. There was no difference in the infection or complication rates between the groups.

CONCLUSIONS: Our case-control study comparing patients who underwent anterior lumbar interbody fusion followed by open posterior instrumentation with those who underwent anterior lumbar interbody fusion followed by minimally invasive posterior instrumentation demonstrated that patients undergoing MIS fusion without decompression had less blood loss, less need for transfusion in the perioperative period, and a shorter hospital stay. In contrast, most outcome measures were similar between MIS and Open groups for patients who underwent decompression.

MIS vs Open complications 1-2 level TLIFs

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

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

Bagan B[1], Patel N, Deutsch H, Harrop J, Sharan A, Vaccaro AR, Ratliff JK.

Author information

Abstract

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

Complications and efficacy of MIS vs Open Rx of DDD

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

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

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

Author information

Abstract

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

Cost of Spinal fusion, W/C population: MIS vs Open TLIF

Spine (Phila Pa 1976). 2012 Oct 15;37(22):1914-9. doi: 10.1097/BRS.0b013e318257d490.

A comparison of perioperative costs and outcomes in patients with and without workers' compensation claims treated with minimally invasive or open transforaminal lumbar interbody fusion.

Pelton MA[1], Phillips FM, Singh K.

Author information

Abstract

STUDY DESIGN: A nonrandomized, nonblinded prospective review.

OBJECTIVE: To analyze intraoperative, immediate postoperative, and financial outcomes in worker's compensation (WC) and non-WC patients undergoing either an open or a minimally invasive surgery (MIS) transforaminal lumbar interbody fusion (TLIF).

SUMMARY OF BACKGROUND DATA: Few studies have analyzed outcomes in a WC population of MIS TLIFs.

METHODS: A total of 66 consecutive patients undergoing a single-level TLIF (open/MIS) were analyzed (33 open and 33 MIS). Twenty-four total WC patients were identified (11 MIS and 13 open). Patients in either cohort (MIS/open) were matched according to insurance status (WC) and medical comorbidities (Charleston disability index). Every patient in this study had a diagnosis of either degenerative disc disease or spondylolisthesis and stenosis. Operative time (min), length of stay (d), estimated blood loss (mL), anesthesia time (min), visual analogue scale scores, and hospital cost/payment amount were assessed (MIS/open and work-comp versus non-work comp).

RESULTS: There were no statistically significant differences between MIS WC and non-WC TLIFs with respect to surgical time, length of stay, estimated blood loss, visual analogue scale scores, and anesthesia time. There were no statistically significant differences between open WC and non-WC TLIF patients in all of the same above-mentioned parameters. There were significant differences between MIS (WC and non-WC) and open (WC and non-WC) TLIFs in clinical outcomes. There were statistically significant differences in total costs amounts between WC MIS TLIF and WC open TLIF ($28,060 vs. $33,862, respectively; P = 0.0311) and non-WC MIS TLIF versus non-WC open TLIF groups ($29,429 vs. $32,998, respectively; P = 0.0001).

CONCLUSION: Contrary to popular belief, immediate outcomes and hospitalizations between non-WC and WC populations did not differ regardless of surgical technique (MIS/open). Differences occurred in improved outcomes with an MIS TLIF versus an open TLIF even in a WC environment. MIS TLIF WC and non-WC patient hospital costs were lower than their open TLIF counterparts.

PMID: 22487713 [PubMed - indexed for MEDLINE]

Cost MIS vs Open TLIF, 2 Yrs

World Neurosurg. 2012 Jul;78(1-2):178-84. doi: 10.1016/j.wneu.2011.09.013. Epub 2011 Nov 7.

Cost-effectiveness of minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis associated low-back and leg pain over two years.

Parker SL[1], Adogwa O, Bydon A, Cheng J, McGirt MJ.

Author information

Abstract

OBJECTIVE: Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) for lumbar spondylolisthesis allows for surgical treatment of back and leg pain while theoretically minimizing tissue injury and accelerating overall recovery. Although the authors of previous studies have demonstrated shorter length of hospital stay and reduced blood loss with MIS versus open-TLIF, short- and long-term outcomes have been similar. No studies to date have evaluated the comprehensive health care costs associated with TLIF procedures or assessed the cost-utility of MIS- versus open-TLIF. As such, we set out to assess previously unstudied end points of health care cost and cost-utility associated with MIS- versus open-TLIF.

METHODS: Thirty patients undergoing MIS-TLIF (n=15) or open-TLIF (n=15) for grade I degenerative spondylolisthesis associated back and leg pain were prospectively studied. Total back-related medical resource use, missed work, and health-state values (quality-adjusted life years [QALYs], calculated from EQ-5D with U.S. valuation) were assessed after two-year follow-up. Two-year resource use was multiplied by unit costs on the basis of Medicare national allowable payment amounts (direct cost) and work-day losses were multiplied by the self-reported gross-of-tax wage rate (indirect cost). Difference in mean total cost per QALY gained for MIS- versus open-TLIF was assessed as incremental cost-effectiveness ratio (ICER: COSTmis-COSTopen/QALYmis-QALYopen).

RESULTS: MIS versus open-TLIF cohorts were similar at baseline. By two years postoperatively, patients undergoing MIS- versus open-TLIF reported similar mean QALYs gained (0.50 vs. 0.41, P=0.17). Mean total two-year cost of MIS- and open-TLIF was $35,996 and $44,727, respectively. The $8,731 two-year cost savings of MIS- versus open-TLIF did not reach statistical significance (P=0.18) for this sample size.

CONCLUSIONS: Although our limited sample size prevented statistical significance, MIS- versus open-TLIF was associated with reduced costs over two years while providing equivalent improvement in QALYs. MIS-TLIF allows patients to leave the hospital sooner, achieve narcotic independence sooner, and return to work sooner than open-TLIF. In our experience, MIS- versus open-TLIF is a cost reducing technology in the surgical treatment of medically refractory low-back and leg pain from grade I lumbar spondylolisthesis.

Cost, US Database, 6106 pts

J Spinal Disord Tech. 2012 Aug;25(6):324-8. doi: 10.1097/BSD.0b013e318220be32.

Acute hospital costs after minimally invasive versus open lumbar interbody fusion: data from a US national database with 6106 patients.

Wang MY[1], Lerner J, Lesko J, McGirt MJ.

Author information

Abstract

STUDY DESIGN: Retrospective multi-institutional database review.

OBJECTIVE: To determine if minimally invasive interbody fusion is associated with cost savings when compared with open surgery.

SUMMARY OF BACKGROUND DATA: Minimally invasive spine (MIS) surgeries are increasingly recognized as equivalent to open procedures. Although these techniques have been advocated for reducing pain, disability, and length of hospitalization, to date there has been little data demonstrating these benefits.

METHODS: This study analyzed inpatient hospital records from the Premier Perspective database (2002 to 2009), including patients who underwent a posterior lumbar fusion with interbody cage placement by ICD-9 code, and had implant charge codes that allowed determination if MIS pedicle screws were utilized. Exclusion criteria included a refusion surgery, deformity, >2 levels, and anterior fusion. Total costs were adjusted for covariates (age, sex, race, hospital geography and setting, payor, and comorbidities) using an analysis of covariance model.

RESULTS: A total of 6106 patients were identified (1667 MIS and 4439 open). Length of stay (LOS) for 1-level MIS surgery averaged of 3.35 days versus 3.6 days for open surgery (P≤0.006). For 2-level MIS surgery LOS averaged of 3.4 days versus 4.03 days for open surgery (P≤0.001). Total inflation-adjusted acute hospitalization cost averaged $29,187 for 1-level MIS procedures versus $29,947 for open surgery, a nonsignificant difference (P=0.55). Total inflation-adjusted acute hospitalization cost averaged $2106 lower for 2-level MIS surgery (total costs of $33,879 for MIS vs. $35,984 for open surgery, P=0.0023). Cost savings were attributable primarily to lower room and board ($857), operating room ($359), pharmacy ($304), and laboratory ($166) costs in the MIS group. High variances in the 2-level open surgery with prolonged hospital stay also accounted for overall cost differences.

CONCLUSIONS: This data from a large nationwide sample of hospitalizations demonstrates that MIS lumbar interbody fusion results in a statistically significant reduction in hospital LOS and a reduction in total hospital costs with 2-level surgery after adjusting for significant covariates. The majority of cost savings from MIS surgery were due to more rapid mobilization and discharge, as well as a reduction in outliers with extended hospitalizations.

Infection & Cost

J Neurosurg Spine. 2011 Jun;14(6):771-8. doi: 10.3171/2011.1.SPINE10571. Epub 2011 Mar 18.

Comparative analysis of perioperative surgical site infection after minimally invasive versus open posterior/transforaminal lumbar interbody fusion: analysis of hospital billing and discharge data from 5170 patients.

McGirt MJ[1], Parker SL, Lerner J, Engelhart L, Knight T, Wang MY.

Author information

Abstract

OBJECT: Surgical site infection (SSI) after lumbar fusion results in significant patient morbidity and associated medical resource utilization. Minimally invasive (MI) techniques for posterior/transforaminal lumbar interbody fusion (P/TLIF) were introduced with the goals of smaller wounds, less tissue trauma, reduced blood loss, and quicker postoperative recovery, while maintaining comparable surgical results. Studies with sufficient power to directly compare the incidence of SSI following MI versus open P/TLIF procedures have been lacking. Furthermore, the direct medical cost associated with the treatment of SSI following the P/TLIF procedure is poorly understood and has not been adequately assessed. Thus, the aim in the present study was to determine the incidence of perioperative SSI in patients undergoing MI versus open P/TLIF and the direct hospital cost associated with the diagnosis and management of SSI after P/TLIF as reported in a large administrative database.

METHODS: The authors retrospectively reviewed hospital discharge and billing records from the Premier Perspective Database for 2003 to 2009 to identify patients undergoing 1- or 2-level MI or open P/TLIF for lumbar spondylotic disease, disc degeneration, or spondylolisthesis. The ICD-9-CM procedure codes were used to identify patients undergoing P/TLIF and those experiencing SSI. Infection-related costs were obtained from the total costs incurred by the hospital for SSI-related care provided during inpatient or hospital outpatient encounters.

RESULTS: Five thousand one hundred seventy patients undergoing P/TLIF were identified. Demographic profiles, including the Charlson Comorbidity Index, were similar between MI and open cohorts. Overall, 292 patients (5.6%) experienced an SSI with a mean direct cost of $15,817 per SSI. For 1-level MI versus open P/TLIF, the incidence of SSI (38 [4.5%] vs 77 [4.8%], p = 0.77) and the mean SSI-associated cost per P/TLIF ($684 vs $724, p = 0.680) were similar. For 2-level MI versus open P/TLIF, the incidence of SSI (27 [4.6%] vs 150 [7.0%], p = 0.037) and mean SSI-associated cost per P/TLIF ($756 vs $1140, p = 0.030) were both significantly lower among MI-treated patients. In a multivariate model that accounted for differences in demographics and patient severity, open fusion was associated with a strong trend of increased incidence of SSI as compared with MI fusion (OR 1.469, 95% CI 0.959-2.250).

CONCLUSIONS: In this multihospital study, the MI technique was associated with a decreased incidence of perioperative SSI and a direct cost savings of $38,400 per 100 P/TLIF procedure when used in 2-level fusion. There was no significant difference in the incidence of SSIs between the open and MI cohorts for 1-level fusion procedures. The results of this study provide further evidence of the reduced patient morbidity and health care costs associated with MI P/TLIF.

Cost Infection MIS vs Open

Minim Invasive Neurosurg. 2011 Feb;54(1):33-7. doi: 10.1055/s-0030-1269904. Epub 2011 Apr 19.

Post-operative infection after minimally invasive versus open transforaminal lumbar interbody fusion (TLIF): literature review and cost analysis.

Parker SL[1], Adogwa O, Witham TF, Aaronson OS, Cheng J, McGirt MJ.

Author information

Abstract

INTRODUCTION: Surgical site infection (SSI) in the setting of lumbar fusion is associated with significant morbidity and medical resource utilization. To date, there have been no studies conducted with sufficient power to directly compare the incidence of SSI following minimally invasive (MIS) vs. open TLIF procedures. Furthermore, studies are lacking that quantify the direct medical cost of SSI following fusion procedures. We set out to determine the incidence of SSI in patients undergoing MIS vs. open TLIF reported in the literature and to determine the direct hospital cost associated with the treatment of SSI following TLIF at our institution.

METHODS: A systematic Medline search was performed to identify all published studies assessing SSI after MIS or open TLIF. The cumulative incidence of SSI was calculated from all reported cohorts and compared between MIS vs. open TLIF. In order to determine the direct hospital costs associated with the treatment of SSI following TLIF, we retrospectively reviewed 120 consecutive TLIFs performed at our institution, assessed the incidence of SSI, and calculated the SSI-related hospital costs from accounting and billing records.

RESULTS: To date, there have been 10 MIS-TLIF cohorts (362 patients) and 20 open-TLIF cohorts (1 133 patients) reporting incidences of SSI. The cumulative incidence of reported SSI was significantly lower for MIS vs. open-TLIF (0.6% vs. 4.0%, p=0.0005). In our experience with 120 open TLIF procedures, SSI occurred in 6 (5.0%) patients. The mean hospital cost associated with the treatment of SSI following TLIF was $ 29,110 in these 6 cases. The 3.4% decrease in reported incidence of SSI for MIS vs. open-TLIF corresponds to a direct cost savings of $ 98,974 per 100 MIS-TLIF procedures performed.

CONCLUSIONS: Post-operative wound infections following TLIF are costly complications. MIS vs. open TLIF is associated with a decreased reported incidence of SSI in the literature and may be a valuable tool in reducing hospital costs associated with spine care.

Infection, SRS database

Spine (Phila Pa 1976). 2011 Apr 1;36(7):556-63. doi: 10.1097/BRS.0b013e3181eadd41.

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

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

Author information

Abstract

STUDY DESIGN: Retrospective review of a prospectively collected database.

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

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

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

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

Fusion Rate

Spine (Phila Pa 1976). 2010 Dec 15;35(26):2273-81. doi: 10.1097/BRS.0b013e3181cd42cc.

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

Wu RH[1], Fraser JF, Härtl R.

Author information

Abstract

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

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

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

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

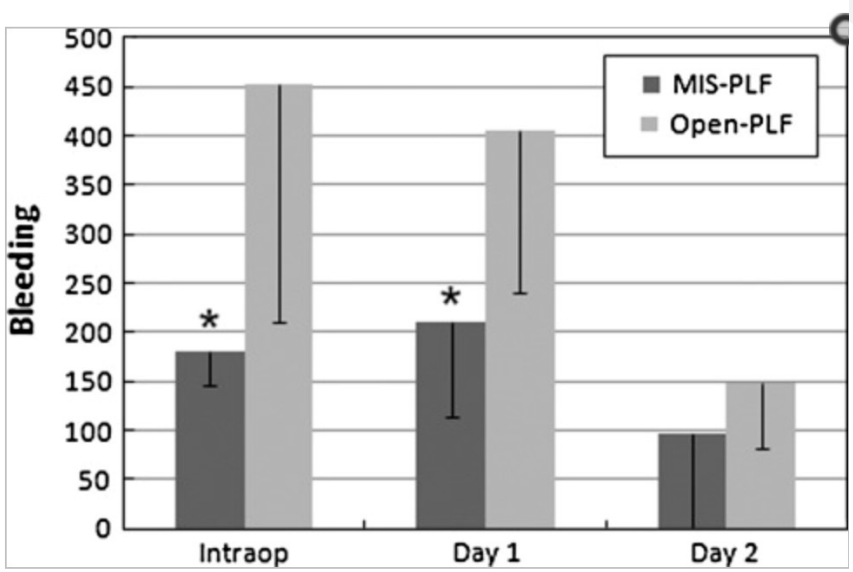
RESULTS: Twenty-three articles were identified that fit inclusion criteria. In each of the 23 studies, TLIF was performed with pedicle fixation and fusion was evaluated using radiograph or computed tomography scan at minimum 6-month follow-up. Overall, the studies included 1028 patients, 46.8% of which were female. The mean age of all patients was 49.7 (range, 38-64.9), and mean follow-up interval for assessment of fusion was 26.6 months (range, 6-46 months). The usage of recombinant bone morphologic protein was higher in the mTLIF group (50% vs. 12%). Mean fusion rate from 16 studies (716 patients) of open TLIF was 90.9%, whereas mean fusion rate from 8 studies (312 patients) of mTLIF was 94.8%. Complication rate was 12.6% and 7.5% for open and mTLIF, respectively.

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

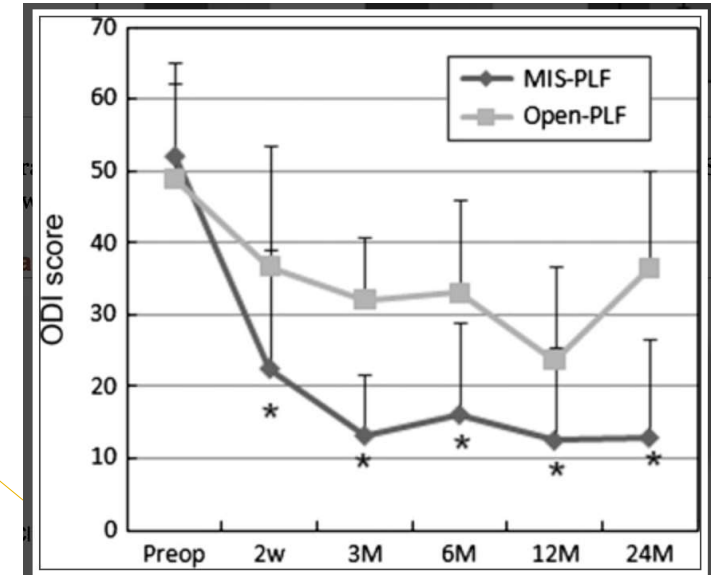
MIS PLF vs Open

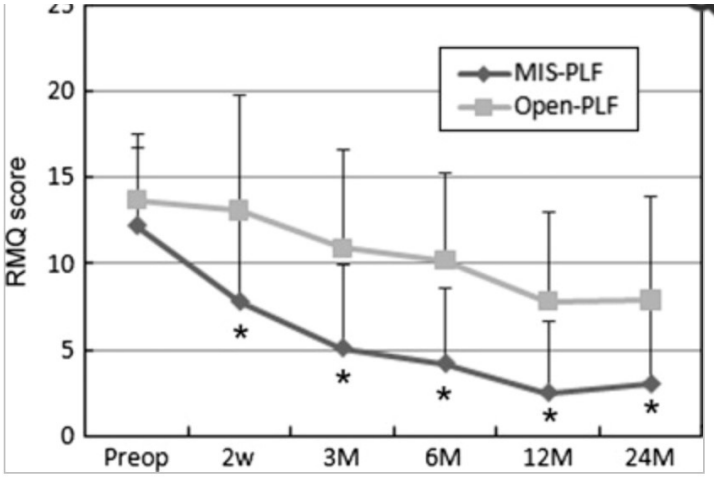
Kotani et al

- 80 patients
  - 43 MIS
  - 37 Open
- Midterm F/U



Kotani et al. MIS vs Open PLF ODI & RMQ





Degenerative Scoliosis via Transpsoas and Percutaneous Screws:2-5 yr review

Spine (Phila Pa 1976). 2013 Aug 15;38(18):1566-75. doi: 10.1097/BRS.0b013e31829cb67a.

Long-term 2- to 5-year clinical and functional outcomes of minimally invasive surgery for adult scoliosis.

Anand N[1], Baron EM, Khandehroo B, Kahwaty S.

Author information

Abstract

STUDY DESIGN: A retrospective study.

OBJECTIVE: We assess MIS technique's clinical and functional outcomes during a 2- to 5-year period.

SUMMARY OF BACKGROUND DATA: Traditional surgical approaches for adult scoliosis are associated with significant blood loss and morbidity, in a population that is often elderly with multiple medical comorbidities. Minimally invasive surgery (MIS) represents a newer method of achieving similar long-term outcomes but considerably lower morbidity and complication rates.

METHODS: We reviewed 71 patients who underwent MIS correction of spinal deformity with fusion of 2 or more levels including: degenerative scoliosis (54), idiopathic scoliosis (11), and iatrogenic scoliosis (6). All underwent a combination of 3 MIS techniques: direct lateral interbody fusion (66), axial lumbar interbody fusion (34), and posterior instrumentation (67). Thirty-six patients were staged with direct lateral interbody fusion done first followed by the posterior instrumentation and fusion including axial lumbar interbody fusion done 3 days later.

RESULTS: Mean age was 64 years (20-84 yr). Mean follow-up was 39 months (24-60 mo). Patients with 1-stage same-day surgery had a mean blood loss of 412 mL and a mean surgical time of 291 minutes. Patients with 2-stage surgery had a mean blood loss of 314 mL and surgical time of 183 minutes for direct lateral interbody fusion and 357 mL and 243 minutes, respectively for posterior instrumentation and axial lumbar interbody fusion. Mean hospital stay was 7.6 days (2-26 d). The mean preoperative Cobb angle was 24.7° (8.3°-65°), which corrected to 9.5° (0.6°-28.8°). Mean preoperative Coronal balance was 25.5 mm, which corrected to 11 mm. Mean preoperative sagittal balance was 31.7 mm and corrected to 10.7 mm. The mean preoperative lumbar apical vertebral translation was 24 mm and corrected to 12 mm. Fourteen patients had adverse events requiring intervention: 4 pseudarthrosis, 4 persistent stenosis, 1 osteomyelitis, 1 adjacent segment discitis, 1 late wound infection, 1 proximal junctional kyphosis, 1 screw prominence, 1 idiopathic cerebellar hemorrhage, and 2 wound dehiscence.

CONCLUSION: A combination of 3 novel MIS techniques allows comparable correction of adult spinal deformity, with low pseudarthrosis rates, significantly improved functional outcomes, and excellent clinical and radiological improvement, but considerably lowers morbidity and complication rates at early and long-term follow-up.

2024
Work Related Injuries Workshop

MIS Rx for Degenerative Deformity

Minimally invasive surgery for thoracolumbar spinal deformity: initial clinical experience with clinical and radiographic outcomes.

Wang MY[1], Mummaneni PV.

Author information

Abstract

OBJECT: Adult degenerative scoliosis can be a cause of intractable pain, decreased mobility, and reduced quality of life. Surgical correction of this problem frequently leads to substantial clinical improvement, but advanced age, medical comorbidities, osteoporosis, and the rigidity of the spine result in high surgical complication rates. Minimally invasive surgery is being applied to this patient population in an effort to reduce the high complication rates associated with adult deformity surgery.

METHODS: A retrospective study of 23 patients was undertaken to assess the clinical and radiographic results with minimally invasive surgery for adult thoracolumbar deformity surgery. All patients underwent a lateral interbody fusion followed by posterior percutaneous screw fixation and possible minimally invasive surgical transforaminal lumbar interbody fusion if fusion near the lumbosacral junction was necessary. A mean of 3.7 intersegmental levels were treated (range 2-7 levels). The mean follow-up was 13.4 months.

RESULTS: The mean preoperative Cobb angle was 31.4 degrees , and it was corrected to 11.5 degrees at follow-up. The mean blood loss was 477 ml, and the operative time was 401 minutes. The mean visual analog scale score improvement for axial pain was 3.96. Clear evidence of fusion was seen on radiographs at 84 of 86 treated levels, with no interbody pseudarthroses. Complications included 2 returns to the operating room, one for CSF leakage and the other for hardware pullout. There were no wound infections, pneumonia, deep venous thrombosis, or new neurological deficits. However, of all patients, 30.4% experienced new thigh numbness, dysesthesias, pain, or weakness, and in one patient these new symptoms were persistent.

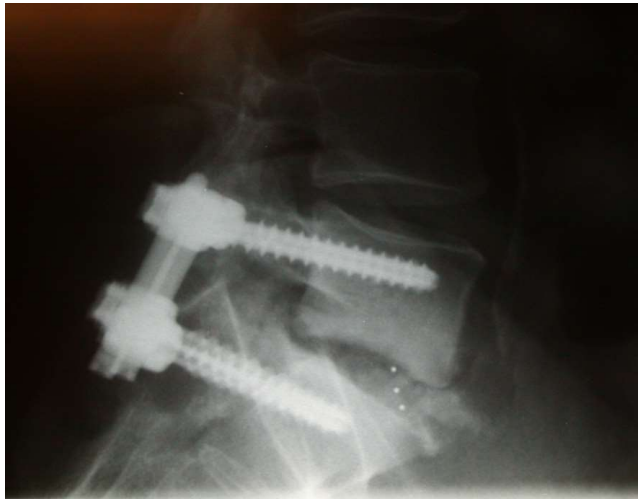
CONCLUSIONS: The minimally invasive surgical treatment of adult deformities is a promising method for reducing surgical morbidity. Numerous challenges exist, as the surgical technique does not yet allow for all correction maneuvers used in open surgery. However, as the techniques are advanced, the applicability of minimally invasive surgery for this population will likely be expanded and will afford the opportunity for reduced complications.

Case Analysis: 48 yo coalminer

- Severe LBP
- Intermittent radiculopathy with walking and standing
- Legs pain disappears with flexion and forward bend

Intaop. X-rays

2 wks postop. Returned to work 2mos po



Comparison: Direct cost RVUs

Open Classic Surgery

- Laminectomy
- Fusion: 1 level

- Fixation Implant:
  - 4 screws
  - 2 rods
  - one cages
  - Fusion graft

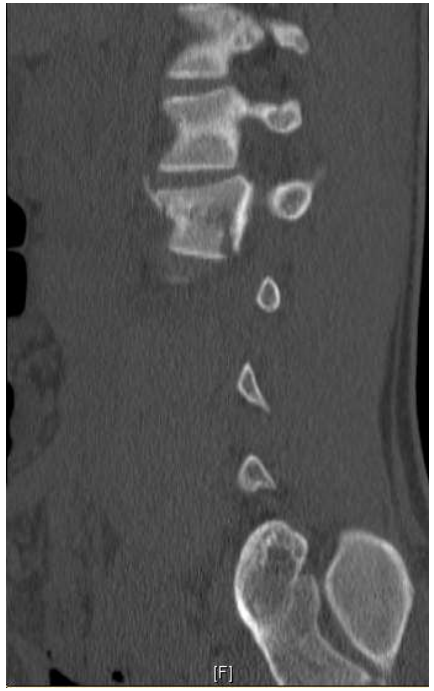
MIS option

- Laminectomy
- Fusion: 1 level:

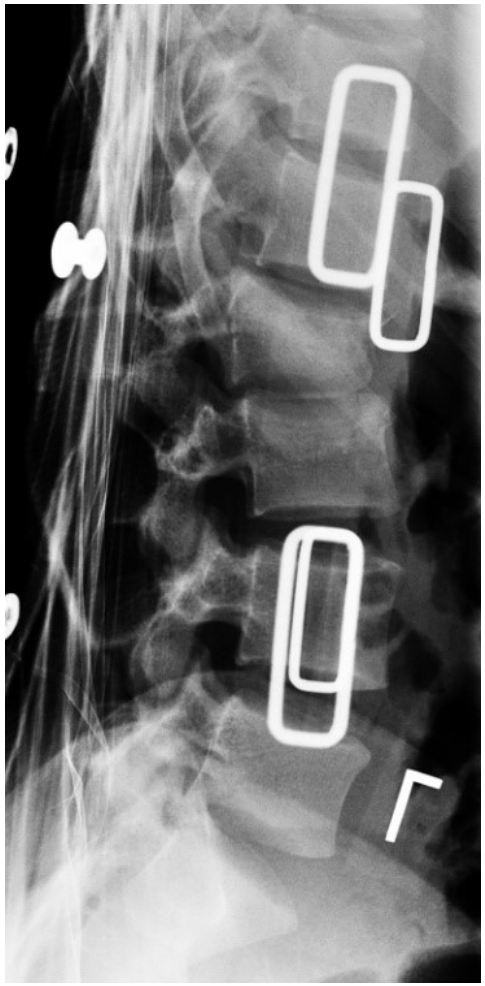
- Fixation Implant:
  - 4 screws
  - Two rods
  - one cages
  - Fusion graft

24 yo male, s/p fall of the roof
Was being treated with TLSO Bracing

CT scan.



3 week post op



Doing well.

Comparison: Direct cost RVUs

Open Classic Surgery

- Fracture Rx
- Laminectomy x 3
- Fusion: at least 7 levels:

- Fixation Implant:
  - 14 screws
  - Fusion graft

MIS option

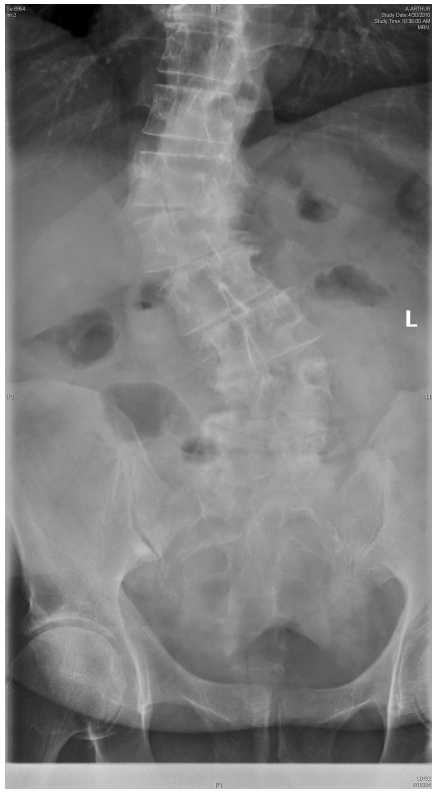
- Fracture Rx
- Laminectomy: None
- Fusion: None

- Fixation Implants:
  - 8 screws
- Removal of hardware (staged procedure)

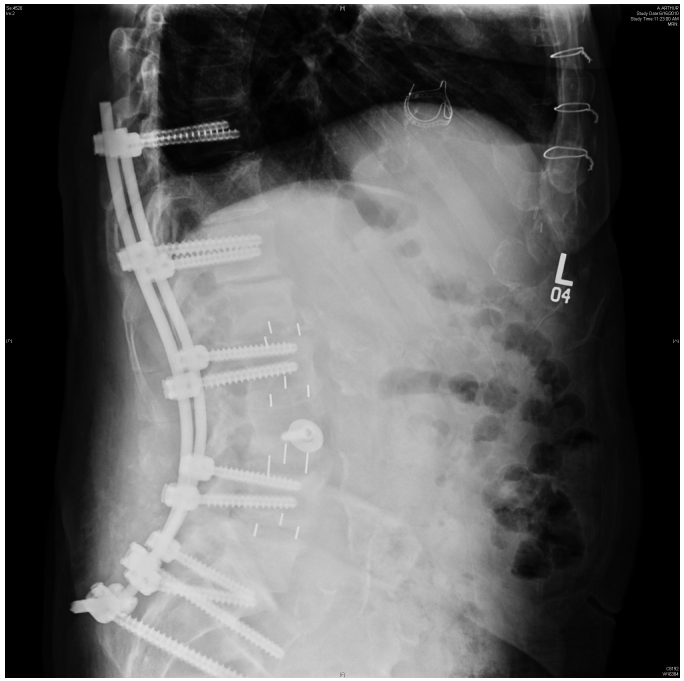
Complex SPINE: MIS vs Open

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

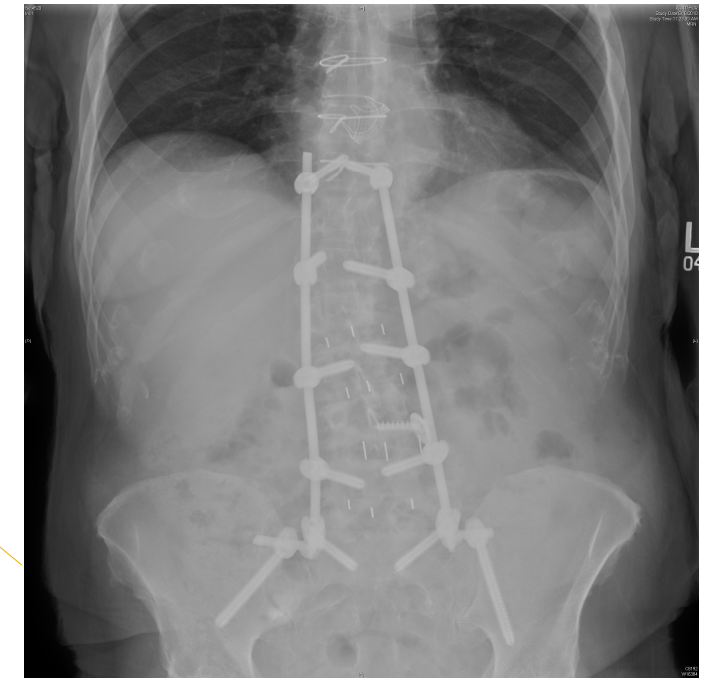
84 yo, Severe back and leg pain. Unable to stand straight

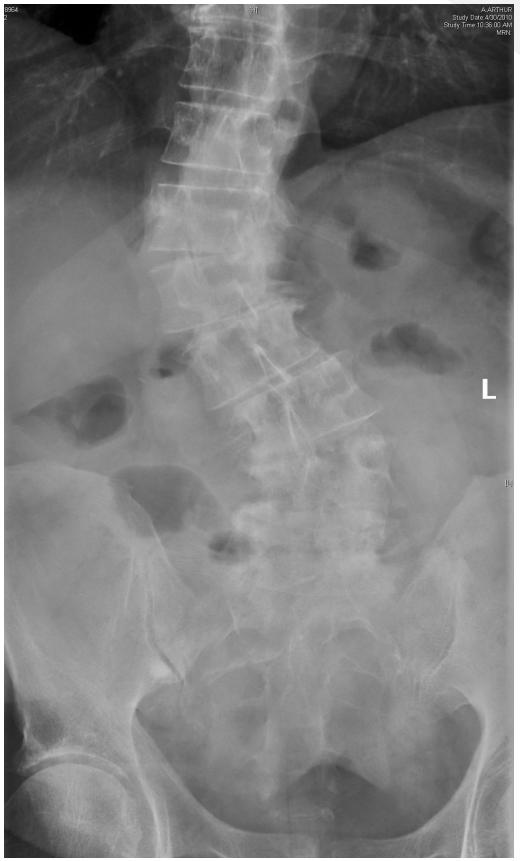


Anterior T12-L5 + Posterior T10-Iliac



anterior T12-L5 + Posterior T10-Iliac





Clinical presentation

- 56 YO M. back + both legs Pain going down the posterior aspect of the thigh and the dorsum of the feet
- Previous spinal surgery in the lumbar spine eleven years ago which was complicated by infection followed by removal of the hardware
- Cervical fusion from C4 to C7 in the past complicated by a postoperative hematoma

Physical examination

- Decreased sensation in his small finger, middle finger, and ring finger on the left side.
- Decreased sensation in the right anterolateral aspect of the thigh. He has intact sensation in the rest of the lower extremities.
- Motor: 5/5 in bilateral upper and lower extremities.
- Hyperreflexic, especially in his upper extremities, 3+ triceps, biceps, and brachioradialis bilaterally.
- Sustained clonus bilaterally

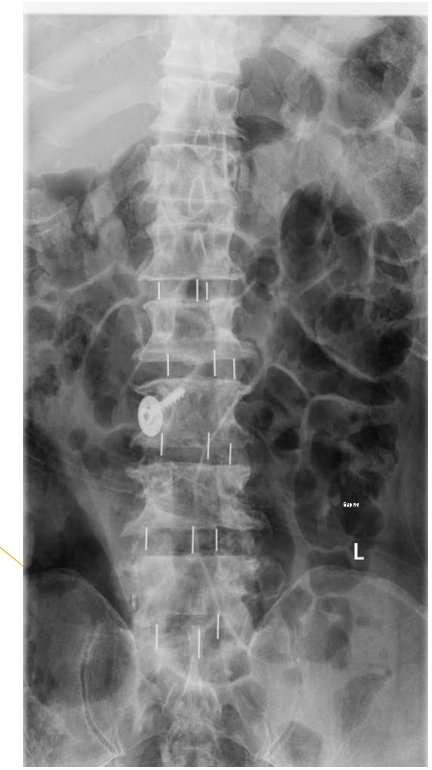
Post-L1-S1 Laminectomy kyphosis

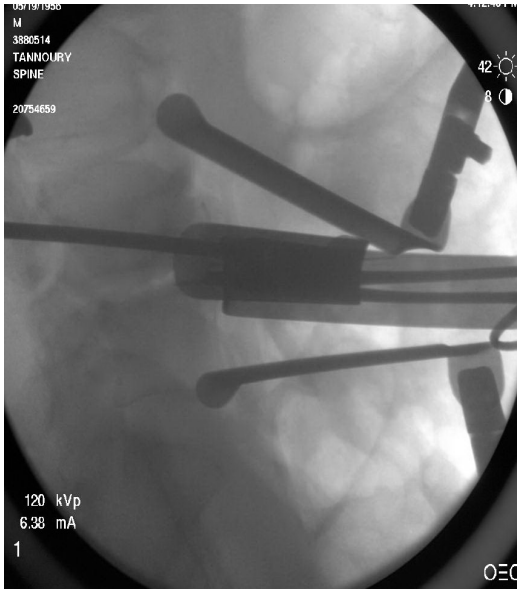
MRI and CT sagittal

MRI T2 saggital L5-S1

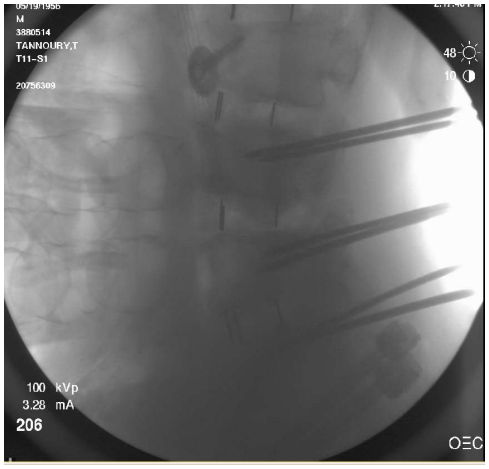
CT scan 3D reconstruction

T12-S1 ATP Fusion. stage 1





stage 2


M
3880514
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T11-S1
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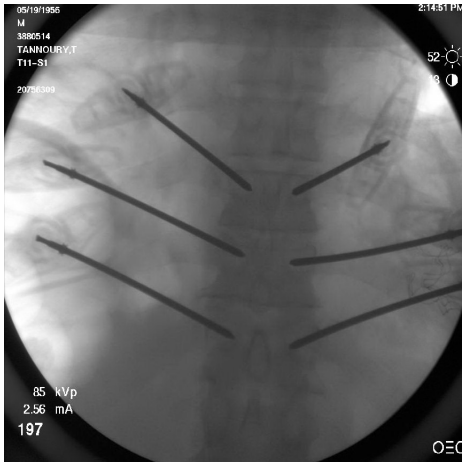
48
10
100 kVp
3.28 mA
206


05/19/1956
M
3880514
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T11-S1
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52
85 kVp
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197


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M
3880514
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49
17
90 kVp
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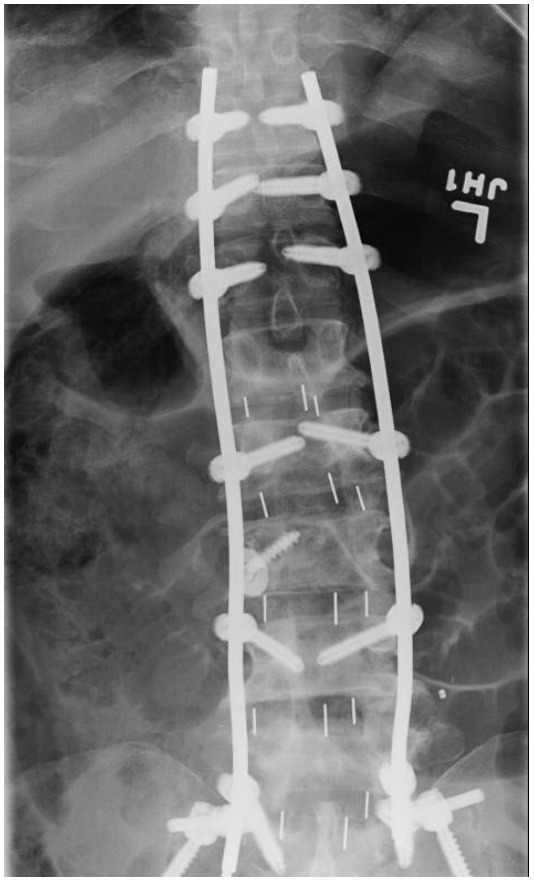
504

Post op radiograph

Post op radiograph



54 Yo. Lady Cab driver, Severe Scoliosis and Rotational deformity

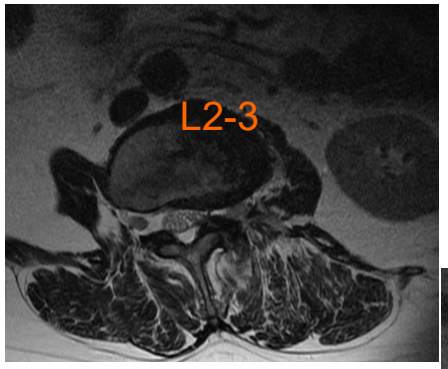
Clinical presentation

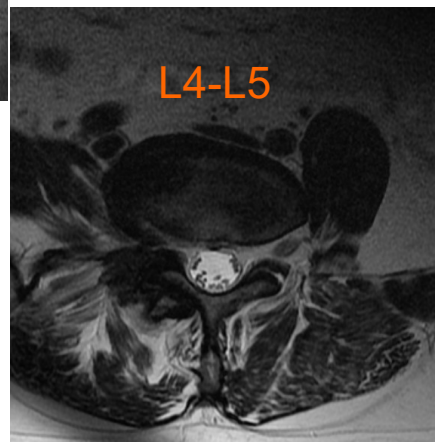
- severe lower back pain
- Bilateral radiculopathy, right more than left
- Prolonged course of physical therapy with no improvement.
- 9 cortisone injections with only temporary relief of symptoms
- Narcotic medication daily

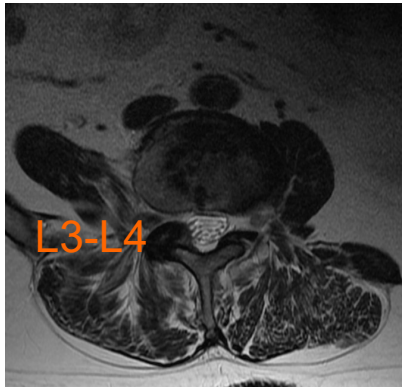
Physical Exam

- Decreased sensation on the right over the lateral aspect of the calf and the top of the foot
- Motor : grade 5/5 in all muscle groups
- Positive SLR on the right with pain at about 45 degrees
- Long tract signs: Negative

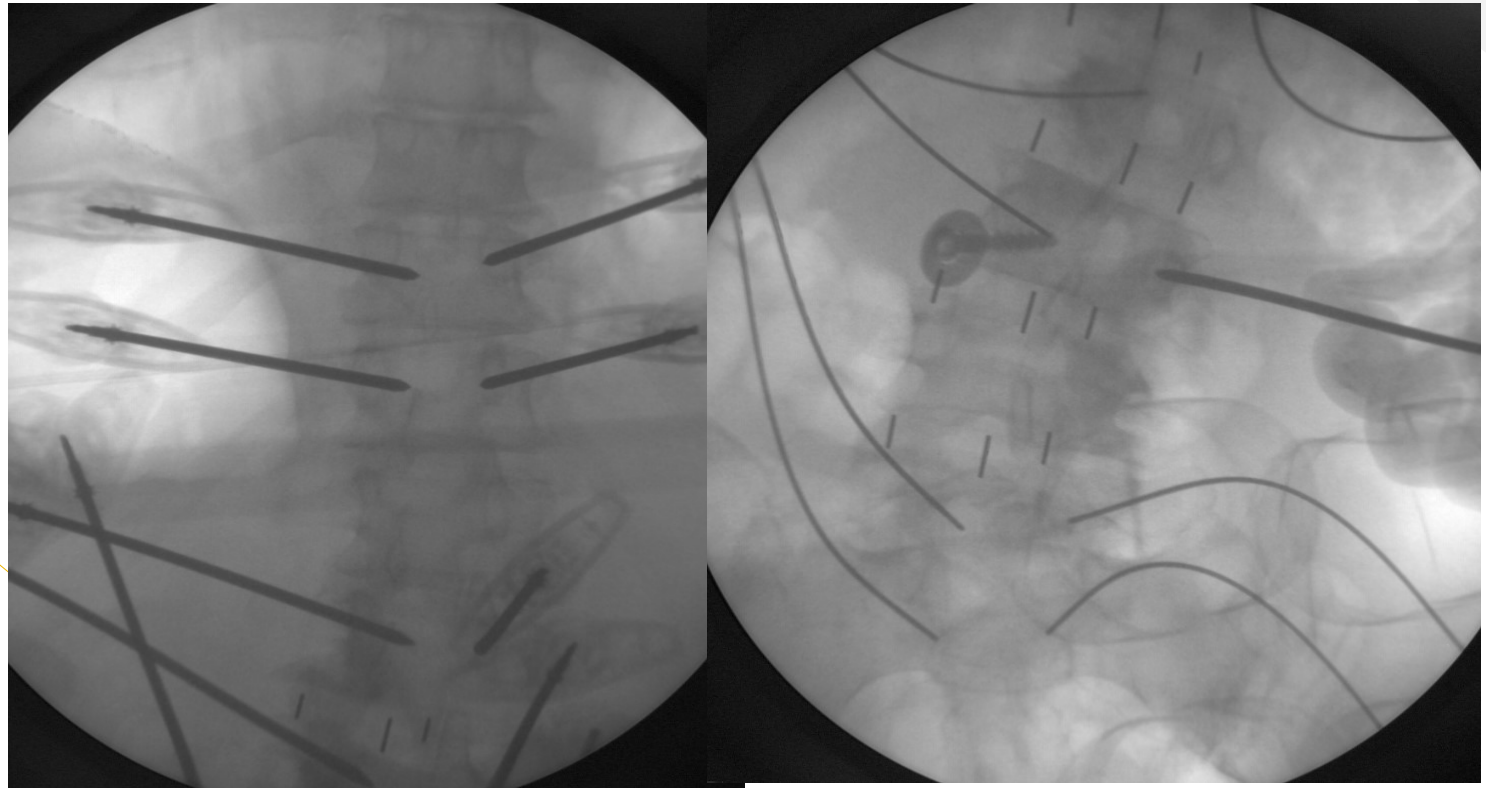
Preop T2 MRI saggital



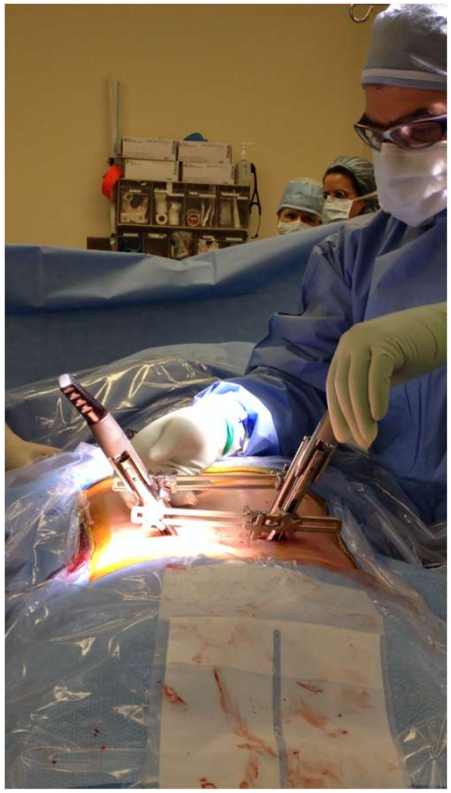


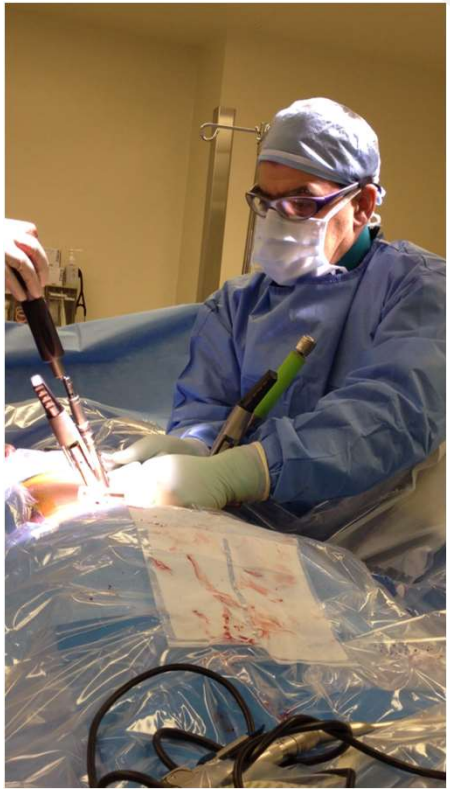


Intraop imaging

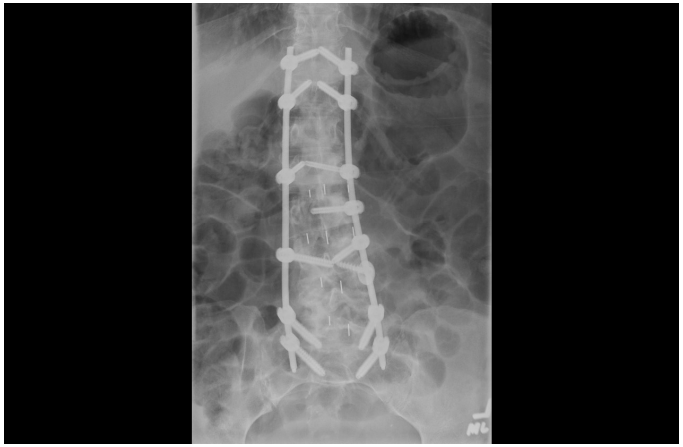


Derotation

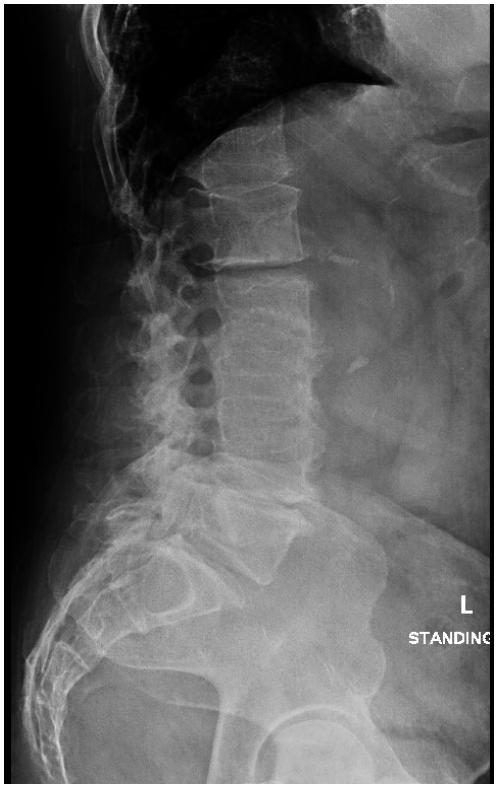


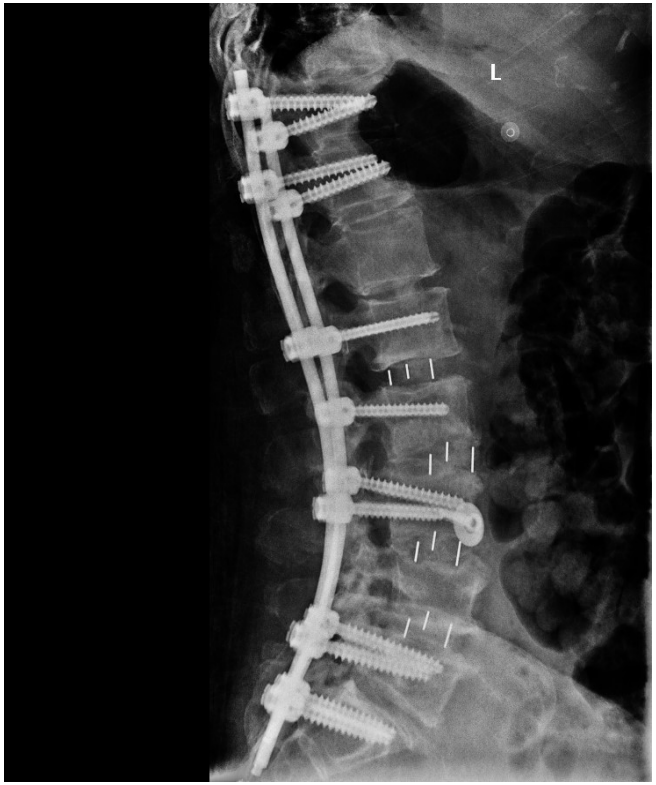


Derotation: Before & After



Lateral Views





78 yo Severe back and leg pain.
Severe Lumbar rotational deformity

C7 Plumb line: +12.5cm
Left body shift: 2.5 cm

PHYSICAL EXAMINATION

- Body shift to the Left
- Unable to stand straight
- Diffuse tenderness in lumbar spine
- Motor:

	IP	Quads	Hams	TA	EHL	GS
R	3	3	4	5	5	5
L	4	5	3	3	4	4

- Sensory: intact
- Reflexes 2+ symmetrically
- (+) SLR, left

Degenerated Idiopathic Scoliosis
T12-L3:73° , L4-S1:35°
Severe Rotational deformity

2 weeks s/p staged ALIF & PSIF

2 months post-op

doing very well, no back pain and leg pain. Minimal Right anterior groin pain 2/10, ambulatory without assistive device

4 weeks Post op.

Comparison: Direct cost RVUs

Open Classic Surgery

- Laminectomy x 5
- Post Fusion: 9 levels:
- Anterior fusion: 2 levels

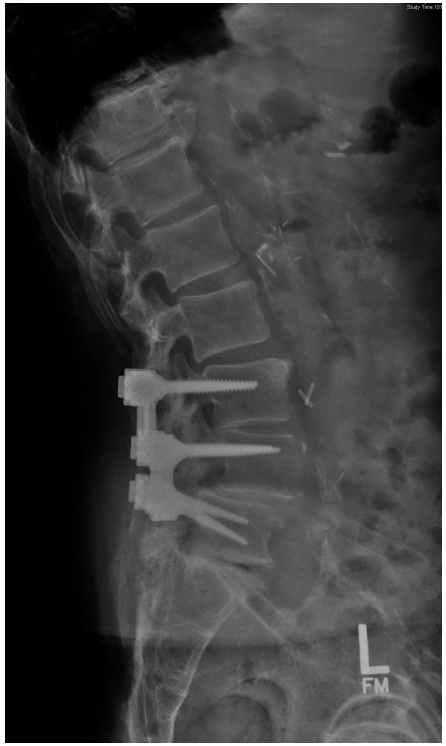
- Fixation:
- Implant:
  - 22 screws
  - 2-3 cages
  - Fusion graft

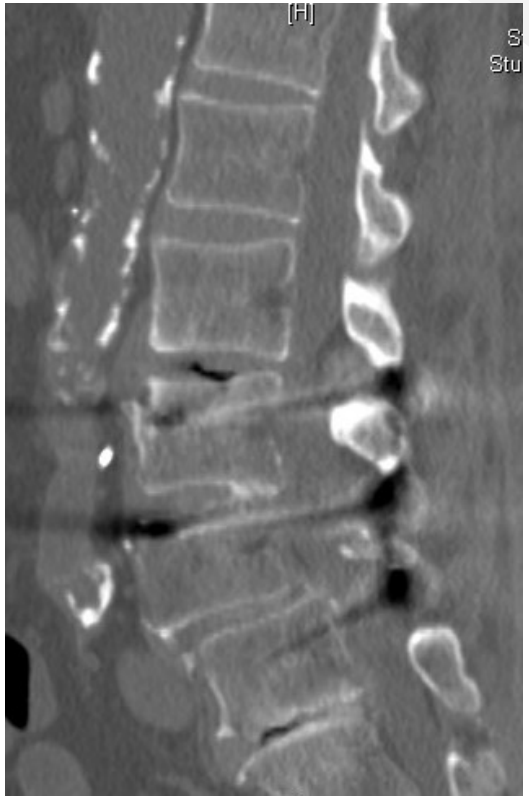
MIS option

- Laminectomy: none
- Post. Fusion: 8 level:
- Ant fusion: 5 levels

- Fixation:
- Implant:
  - 18 screws
  - 5 cages
  - Fusion graft

Revision Surgery
80 yo with severe back and B/L leg weakness, vascular bypass x2





MRIs


Se:501
Im:25
[A]
S.ALFRED
Study Date:7/...
Study Time:11...
MRN:
[R]
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C691
W1335


Se:201
Im:8
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S.ALFRED
Study Date:7/27/2012
Study Time:11:06:03 AM
MRN:
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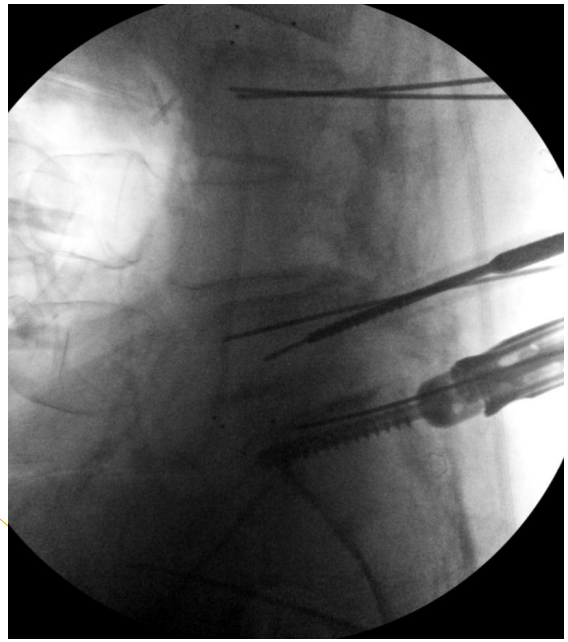
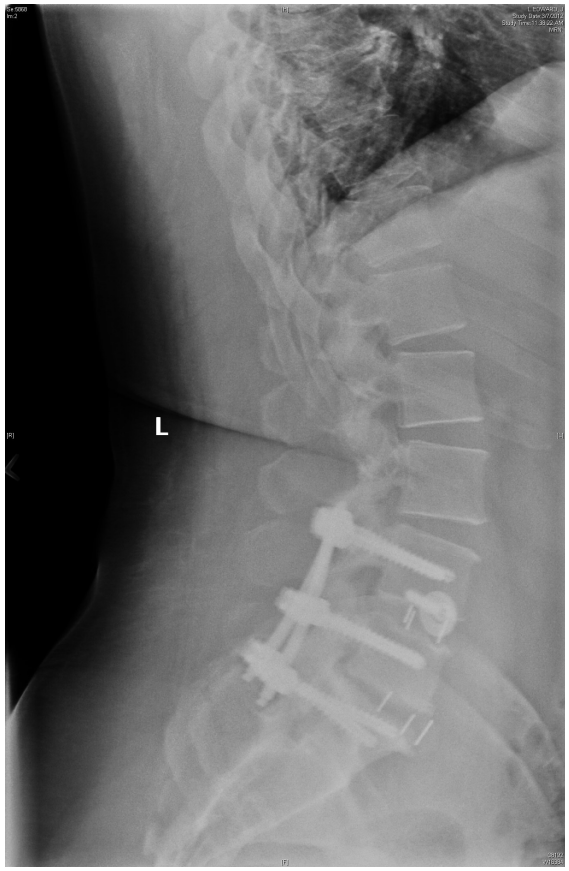
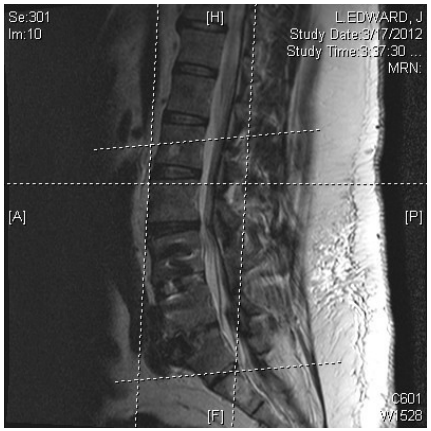
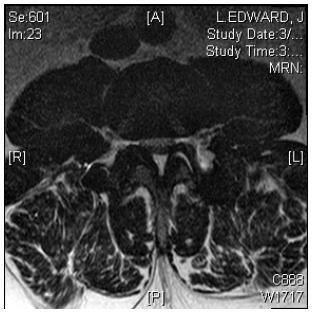
[F]
C625
W1470

ROH, L2-3, L5-S1 SPOs + TLIF





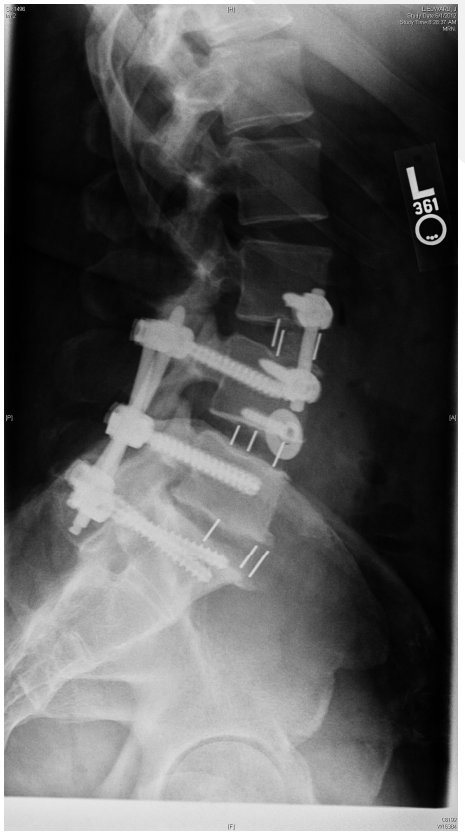




Adj. segment disease

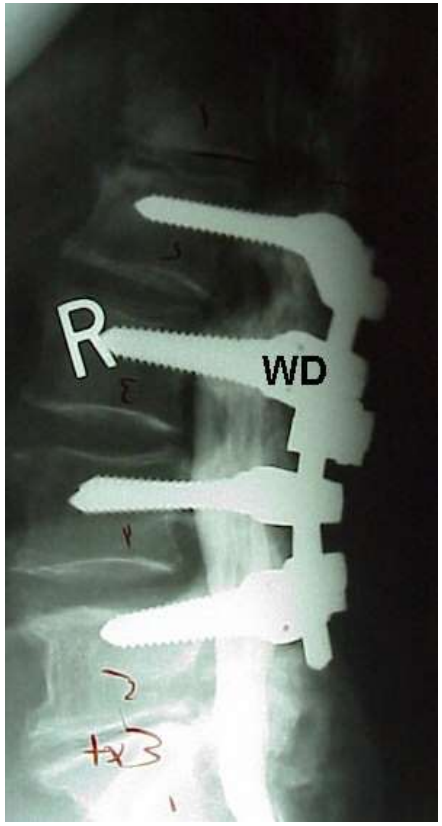
2024

Work Related Injuries Workshop

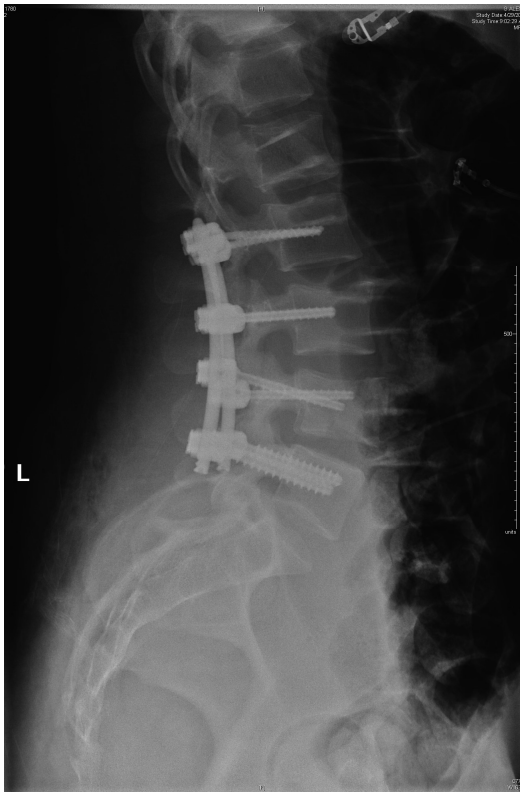


Conclusion:
Two different patients.

4 level fusion

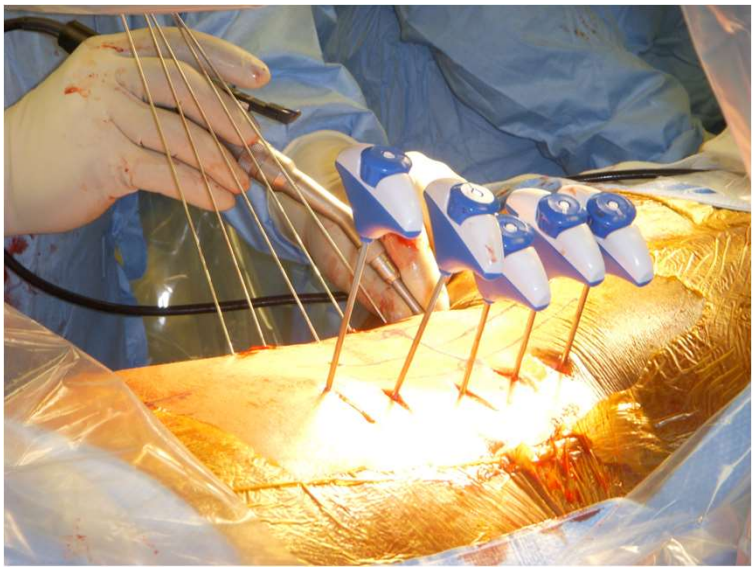


4 level fixation

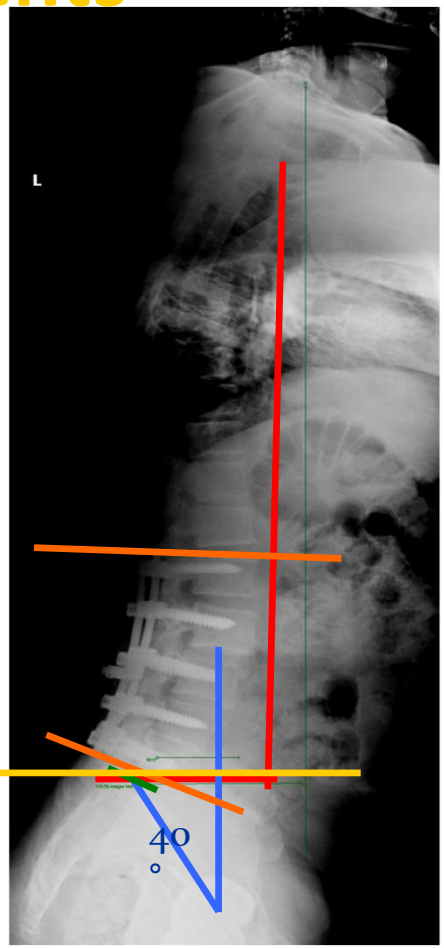


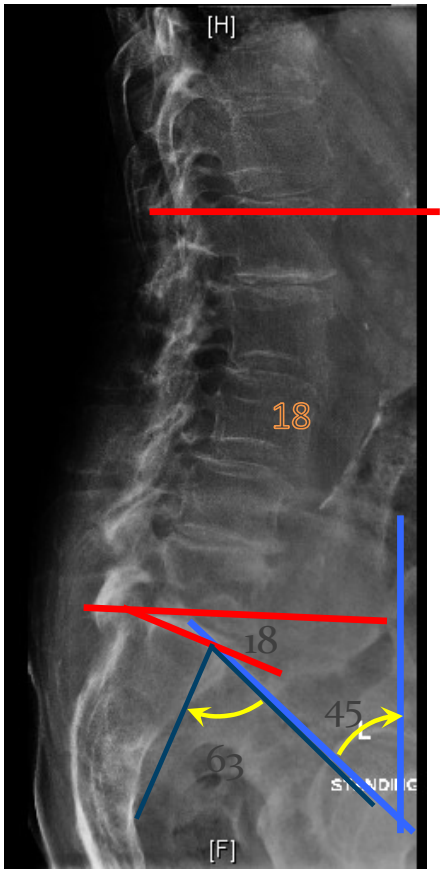
Which patient should return to work earlier?

Two patients, same disease
which one returns to work earlier?



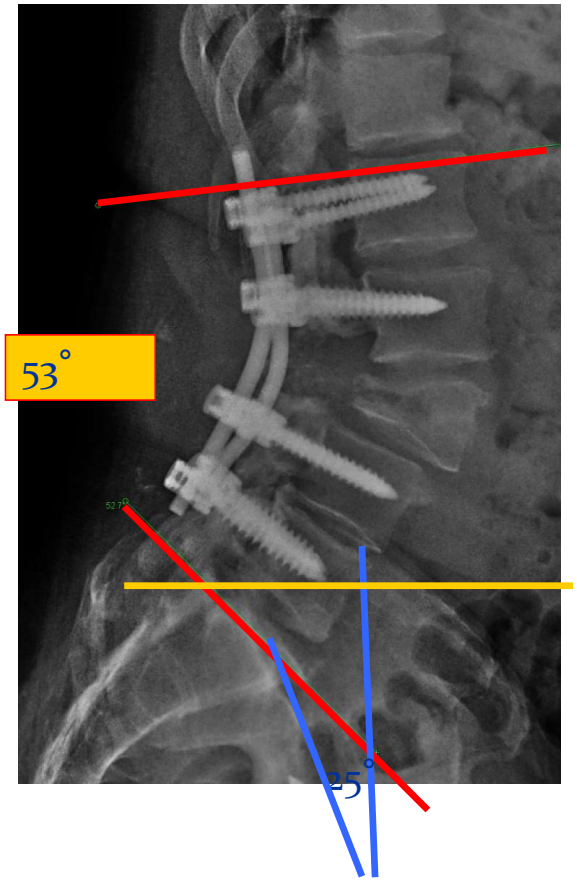
Sagittal Imbalance: two different patients



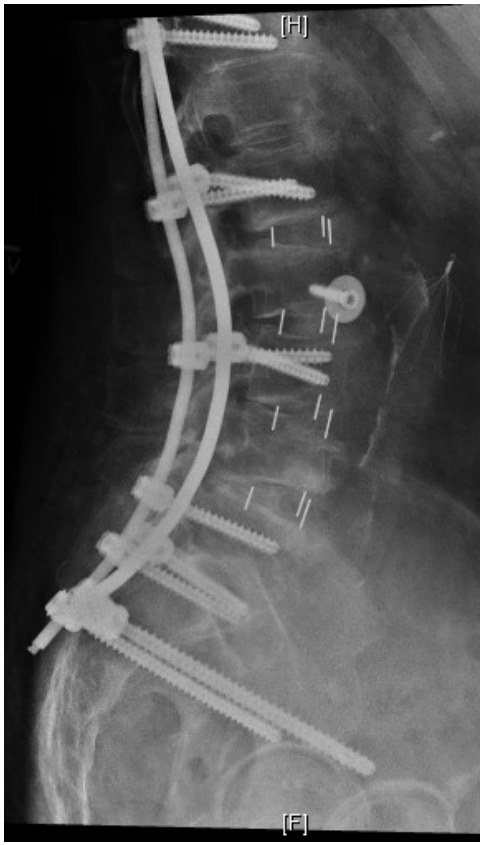


Two different patients: Lateral X-rays

L3 OSTEOTOMY & SPINAL RECONSTRUCTION



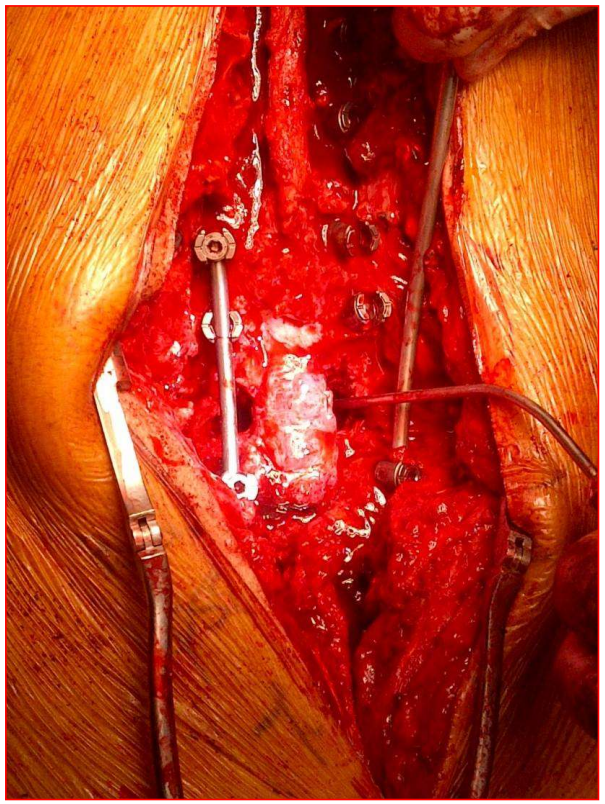
Spinal reconstruction



Anterior posterior X-rays

Two Different patients

Post-PSO with new instrumentation



Which patient should return to work earlier?

- Postoperative pain?
- Hospital stay?
- Post-operative rehab?
- Return to work?
- Disability?

4 weeks Post Op.

4 weeks post op

Learning Curve, difficult, but all worth it!

Jim Wittacker, the first American
who climbed the Mt Everest, Alpes, Kilimanjaro,

THANKS FOR YOUR ATTENTION