JOHNS HOPKINS MEDICINE

Spine Surgery
Overview and Key Principles

Amit Jain, MD
Associate Professor

30 September 2021

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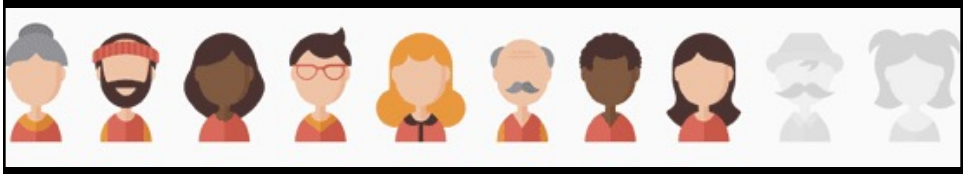

8 out of 10 Americans Have back problems *Sometime* in their lifetime

2


8 out of 10
Americans who suffer from low back pain experience recurrence of low back pain within two years
80%

3


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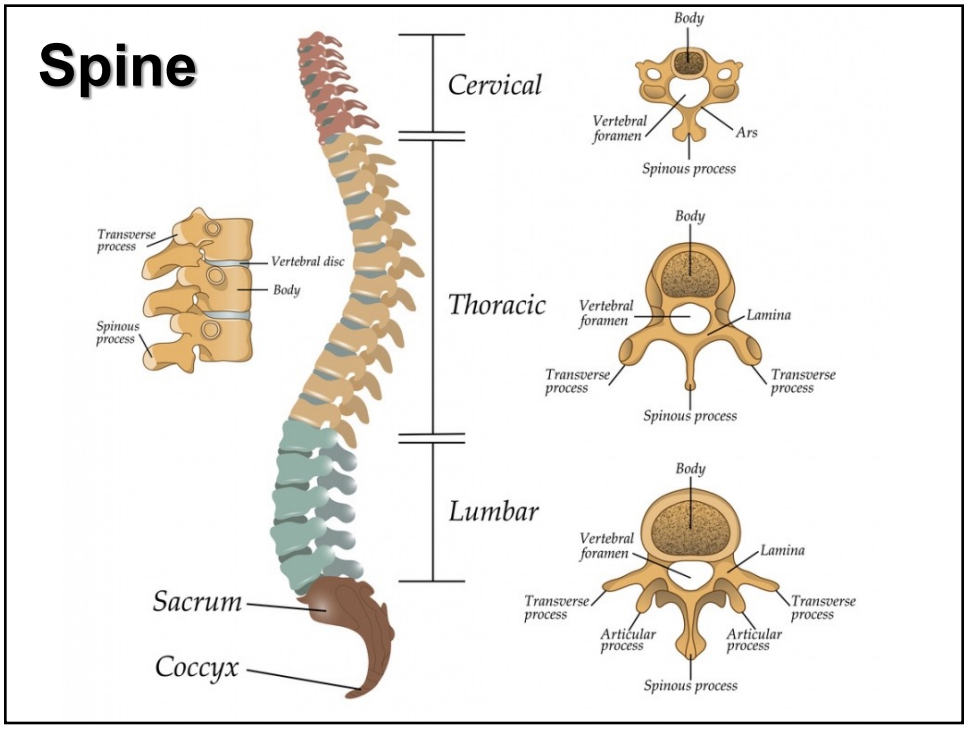
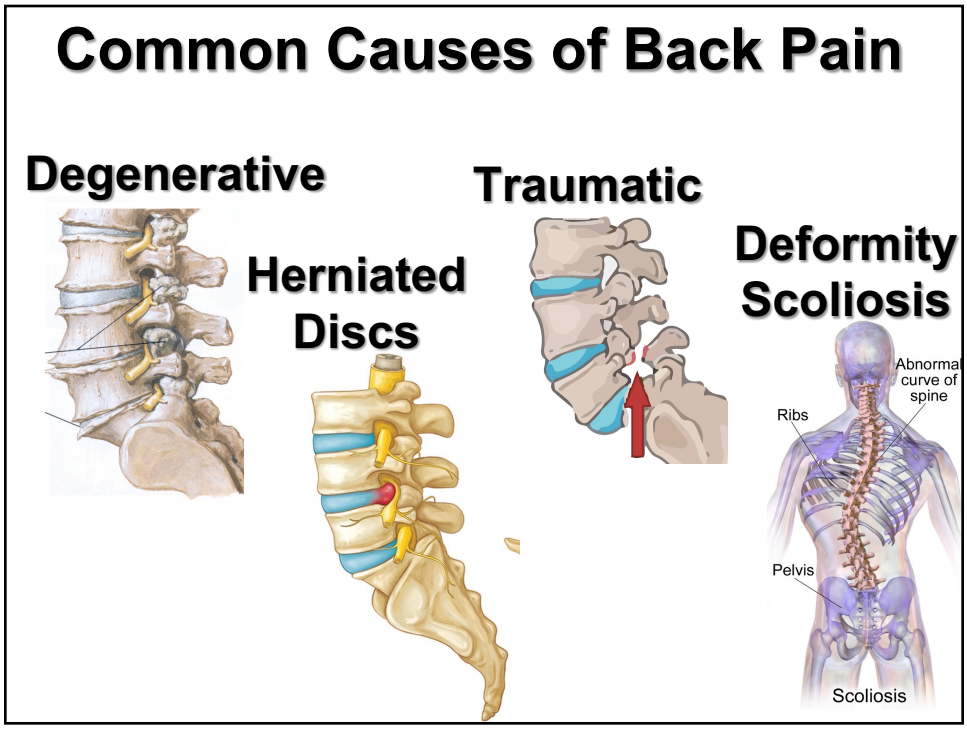
People Miss Nearly
150 Million
Days of Work
a Year
as a Result of
Chronic Lower
Back Pain

4


Spine
Cervical
Thoracic
Lumbar
Sacrum
Coccyx
Transverse process
Vertebral disc
Body
Spinous process
Body
Vertebral foramen
Ars
Spinous process
Body
Vertebral foramen
Lamina
Transverse process
Transverse process
Spinous process
Body
Vertebral foramen
Lamina
Transverse process
Transverse process
Articular process
Articular process
Spinous process

5


Common Causes of Back Pain
Degenerative
Herniated Discs
Traumatic
Deformity Scoliosis
Abnormal curve of spine
Ribs
Pelvis
Scoliosis

6

Lumbar Spinal Stenosis

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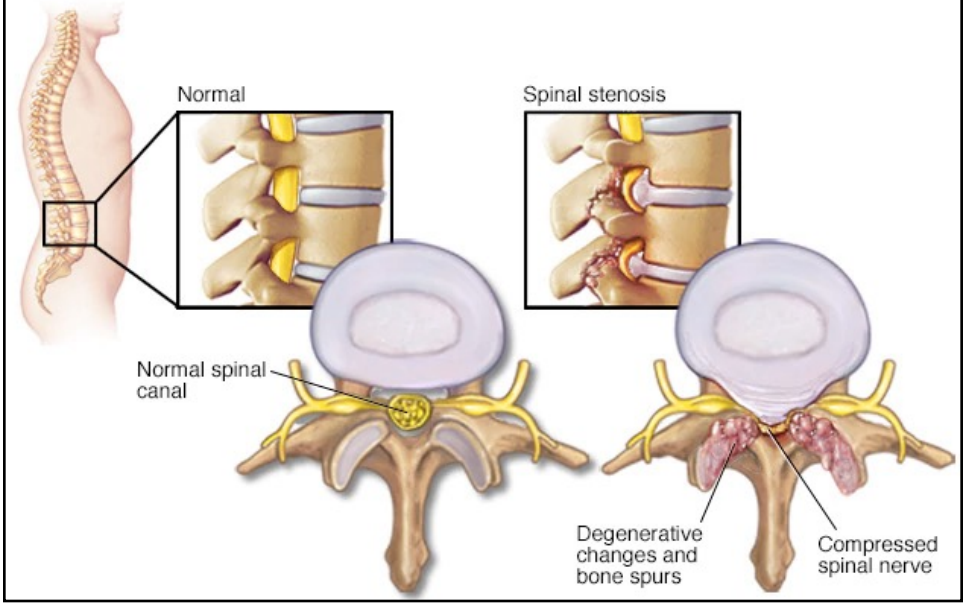

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Non Surgical Treatment

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- Oral Medications
  - NSAIDS, Neuroleptics, Corticosteroids
- Physical Therapy, Chiropractic, Acupuncture
- Steroid Injections (epidural vs. transforaminal)



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Outline

- Definition
- General Principles
- Specific "Minimally Invasive" Techniques
  - Robotic Spinal Instrumentation
  - XLIF
  - OLIF
  - MIS TLIF

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Quick Walk Through the Past…

10

History of Back Treatment

3000 BC Text: *Srimad Bhagwat Mahapuranam*
Lord Krishna's chin traction method

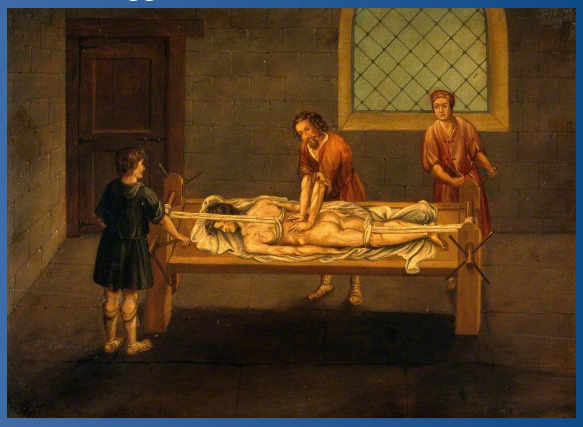
Kumar. 1996. Spine 21(5):653-655

11

11

History of Back Treatment

400 BC *De Articulaciones in Corpus Hippocraticum*
Hippocrates's "Scamnum" traction table method



Marketos. 1999. Spine 24(13):1381-7

12

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History of Back Treatment

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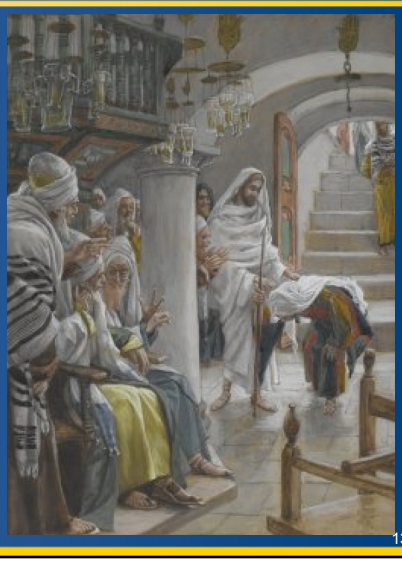
30 AD
Gospel of Luke 13:10-17

Jesus heals a woman with "sunkupto" (bent forward)



"Christ Healing an Infirm Woman"
Artist: James Tissot, 1886-1896

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ORTHO-PEDICS

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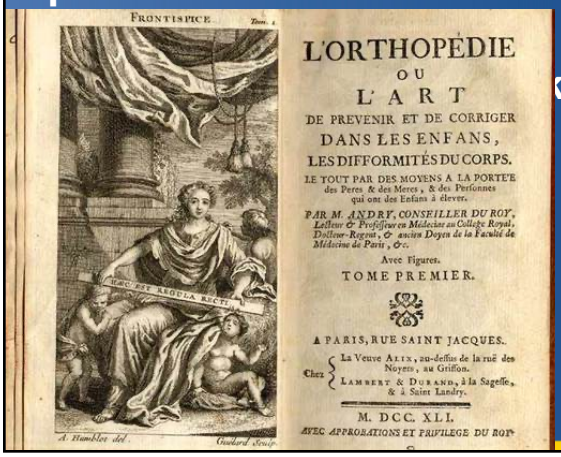
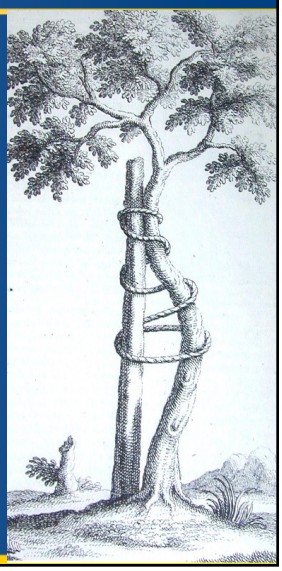
"orthos" = straighten
"pedi" = children


FRONTISPICE

L'ORTHOPÉDIE
OU
L'ART
DE PREVENIR ET DE CORRIGER
DANS LES ENFANS,
LES DIFFORMITÉS DU CORPS.
LE TOUT PAR DES MOYENS A LA PORTE'E des Peres & des Meres, & des Perſonnes qui ont des Enfans à élever.
PAR M. ANDRY, CONSEILLER DU ROY, Lecteur & Profeſſeur en Médecine au Collège Royal, Docteur-Regent, & ancien Doyen de la Faculté de Médecine de Paris, &c.
Avec Figures.
TOME PREMIER.
A PARIS, RUE SAINT JACQUES.
Chez { La Veuve ALIX, au-deſſus de la rue des Noyers, au Griffon. / LAMBERT & DURAND, à la Sageſſe, & à Saint Landry.
M. DCC. XLI.
AVEC APPROBATIONS ET PRIVILEGE DU ROI.



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History of Back Treatment

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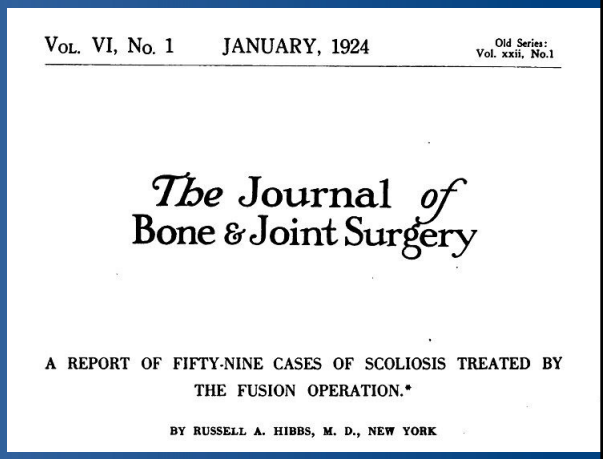
Russell A. Hibbs, surgeon-in-chief New York Orthopedic Hospital Described a new operation "spinal fusion"



VOL. VI, NO. 1 JANUARY, 1924 Old Series: Vol. xxii, No.1

The Journal of Bone & Joint Surgery

A REPORT OF FIFTY-NINE CASES OF SCOLIOSIS TREATED BY THE FUSION OPERATION.*

BY RUSSELL A. HIBBS, M. D., NEW YORK

Hibbs. 1924. JBJS 6(1): 3-34

15

15

1911 Fred Albee described grafting tibial strut to the spine

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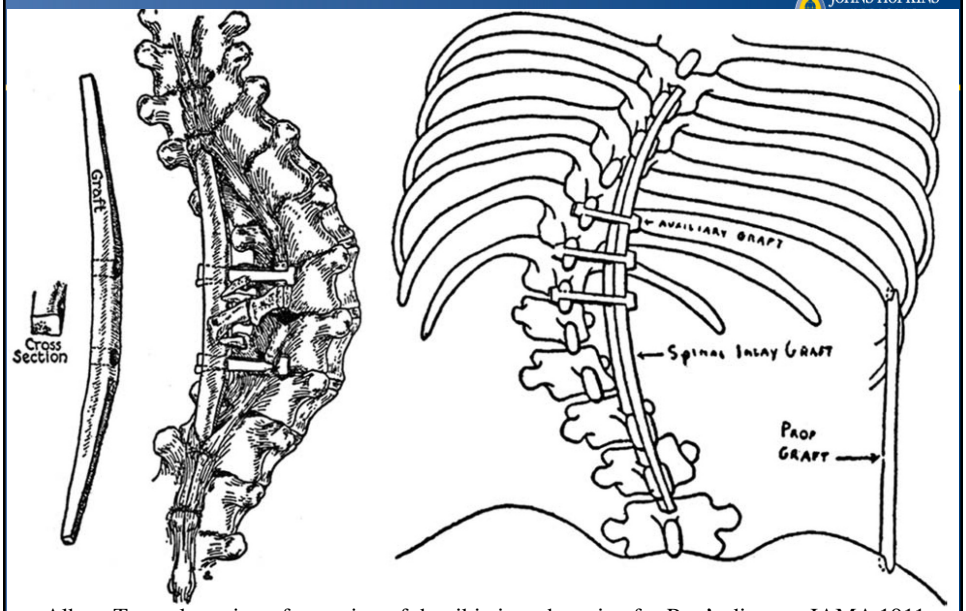

Albee. Transplantation of a portion of the tibia into the spine for Pott's disease. JAMA 1911

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1936 Spinal Fusion Surgery

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What Does the Future Hold?

- Minimally Invasive and Robotics-based Spine Surgery

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Goals of Minimally Invasive Spine Surgery

- Same as open surgery!
  - **Decompress**
  - **Stabilize and Fuse**
  - **Avoid creation of deformity**
- Additional Goal:
  - **Reduce collateral damage**

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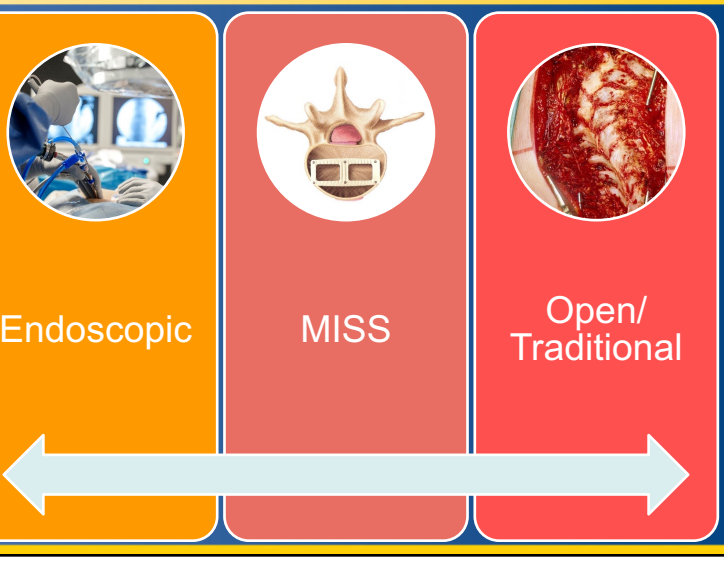
Spectrum



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Key Principles

- Appropriate patient selection and indications
- Choosing the optimal technique
- Minimizing collateral damage
- Understanding limitations

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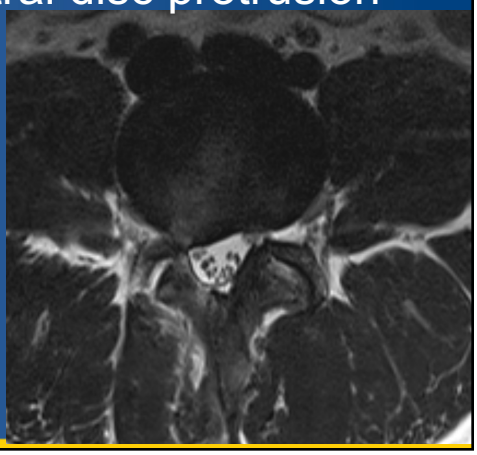
True MISS = Endoscopic

- 28 yo with recurrent R L4-5 paracentral disc protrusion



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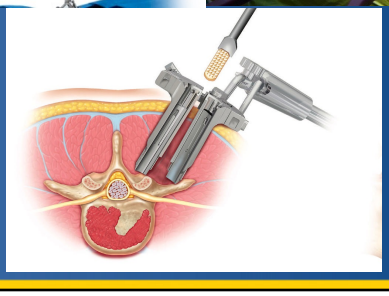
"MISS" = Robotic screws, (X,O)LIF, MIS-TLIF



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Robotic Spine Surgery

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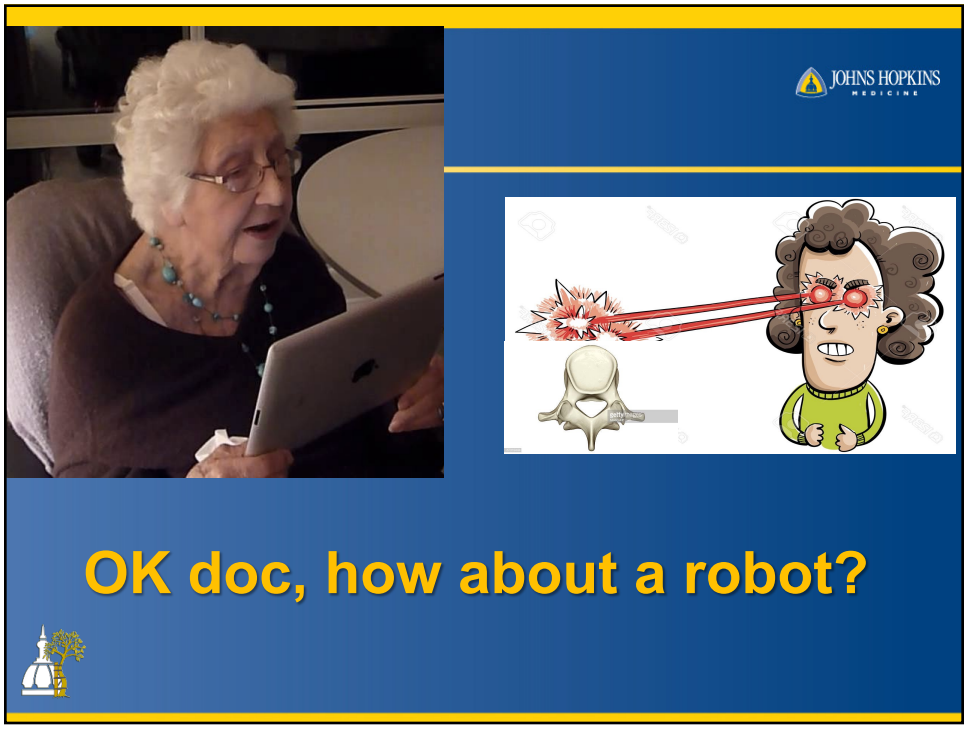
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OK doc, how about a robot?

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Sure, Why Not?
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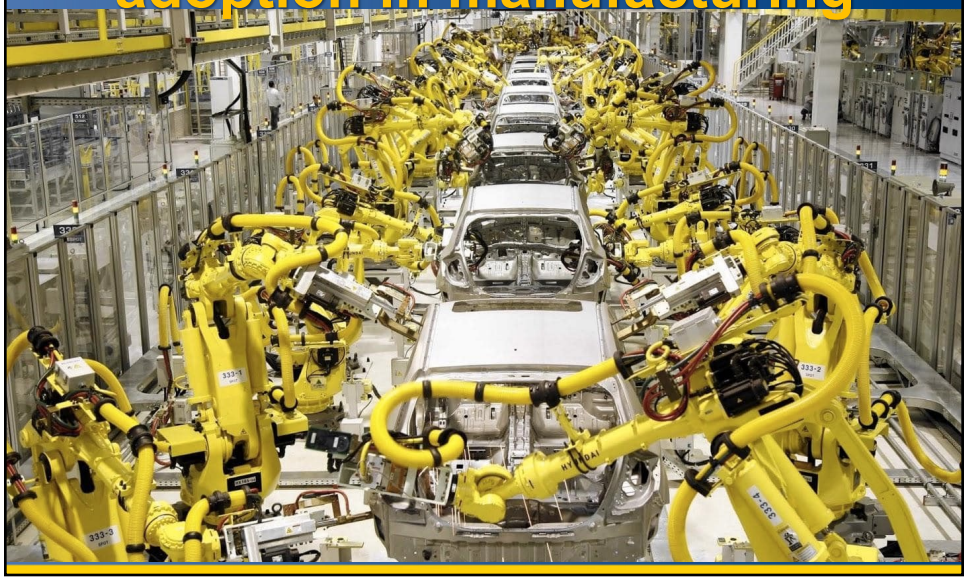
Robotics has gained wide spread adoption in manufacturing



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Public's Perception

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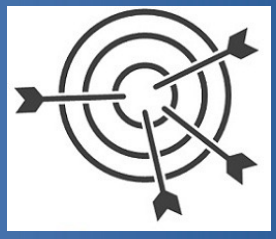
Advantages of Robotics

1. Accuracy



2. Precision

3. Untiring (no fatigue)

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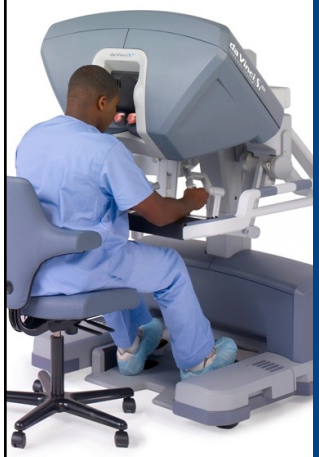
In Urology and ObGyn Robotic surgery is increasingly performed



1. Better visualization
2. Increased DOF
3. Improved dexterity
4. Fatigue avoidance

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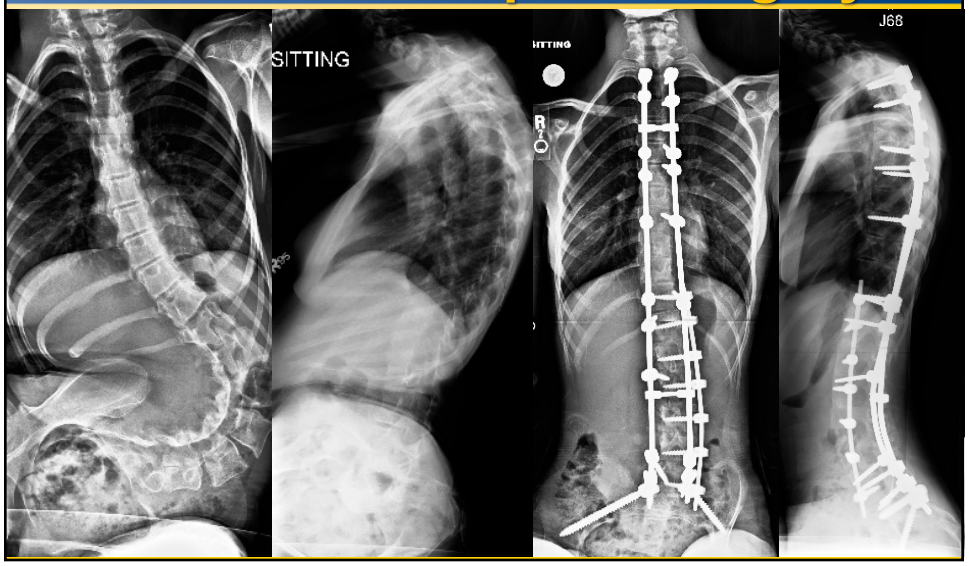
Pedicle screws are the workhorse in spinal surgery



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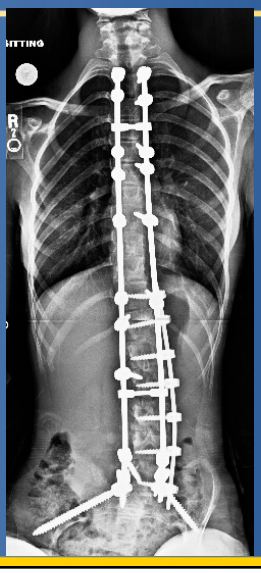
Use the Force…



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Key Principles in Pedicle Screw Placement

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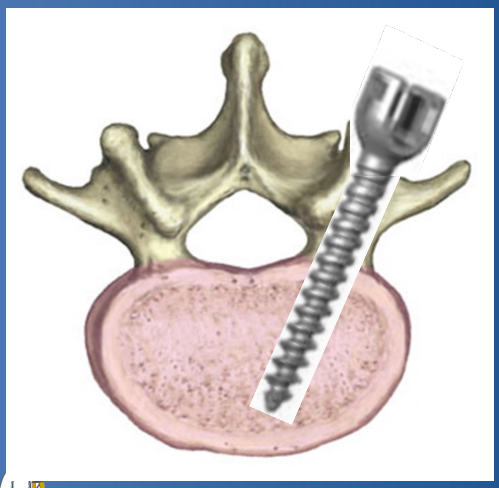

1. Safety
2. Safety
3. Safety
4. Efficiency

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Reality vs. Self-Rating

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Lot of Examples of What NOT to Do…

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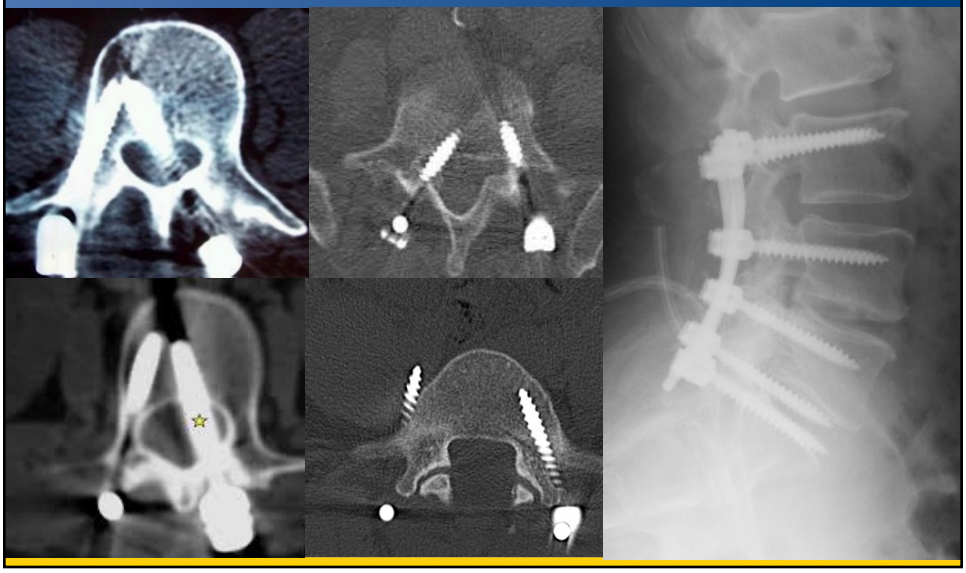

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Case Report

Pneumomediastinum, Subcutaneous Emphysema, and Tracheal Tear in the Early Postoperative Period of Spinal Surgery in a Paraplegic Achondroplastic Dwarf

Sinan Kahraman,[1] Meriç Enercan,[1] Özkan Demirhan,[2] Türker Şengül,[3] Levent Dalar,[4] and Azmi Hamzaoğlu[1]

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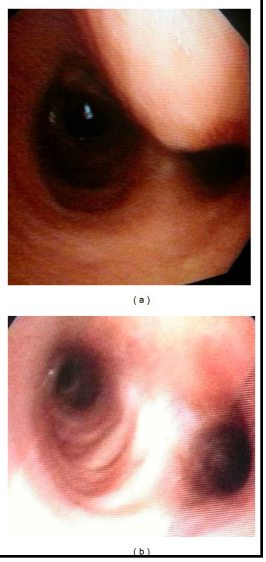

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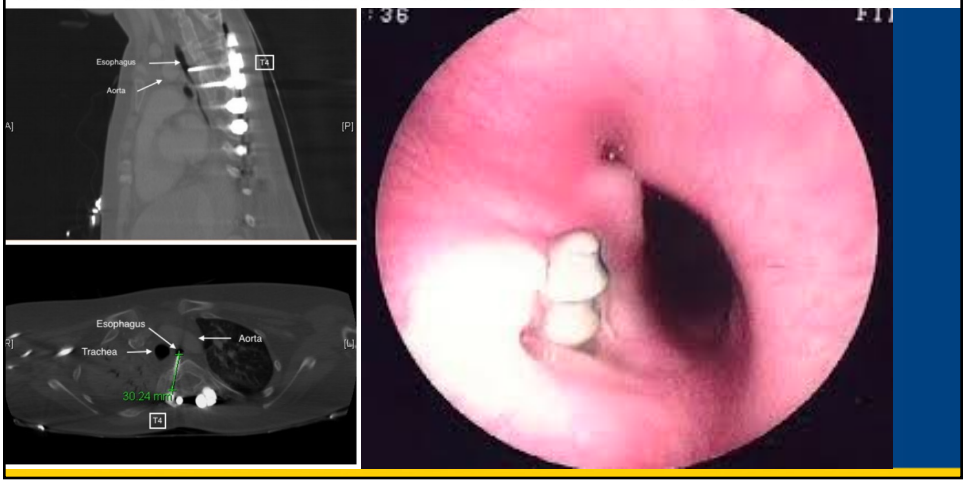
European Spine Journal
https://doi.org/10.1007/s00586-018-5611-3

GRAND ROUNDS

Esophageal perforation caused by a thoracic pedicle screw

Stanislas Marouby[1] · Clément Jeandel[1] · Djamel Louahem M'Sabah[1] · Marion Delpont[1] · Jérôme Cottalorda[1,2]



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Could these complications have been *avoided* if modern technology (navigation, robotics, etc.) was used?

Maybe…

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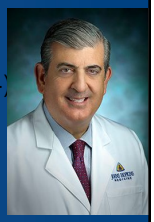
History of Robotic Spine Surgery

Moshe Shoham , PhD
(Technion, Israel)

Mazor - Founded 2001
- Spine Assist (1st)
- Renaissance (2nd gen)
- Mazor X (3rd gen)
- Acquired by Medtronic for 1.64 billion

Zimmer Biomet ROSA (2014)

- Excelsius GPS (2017)



Nicholas Theodore, MD
Johns Hopkins

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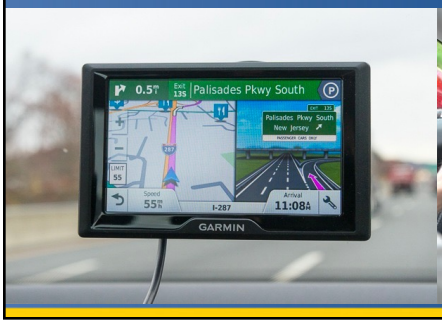
Navigation vs. Robotics

- Surgeon has a "GPS" which displays the current location of the surgical tools and the ***expected trajectory***
- Surgeon plans trajectory either preop or intraop
- Robot ***directs the tools*** in the pre-planned trajectories



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Step 1: Image Acquisition

- Medtronic O-Arm (portable)
- Brainlab Airo CT
- Siemens Cios/Arcadis
- Ziehm RFD 3D

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Step 2: Referencing

- Medtronic Stealth
- Brainlab Curve
- Stryker NAV3i
- 7D Surgical

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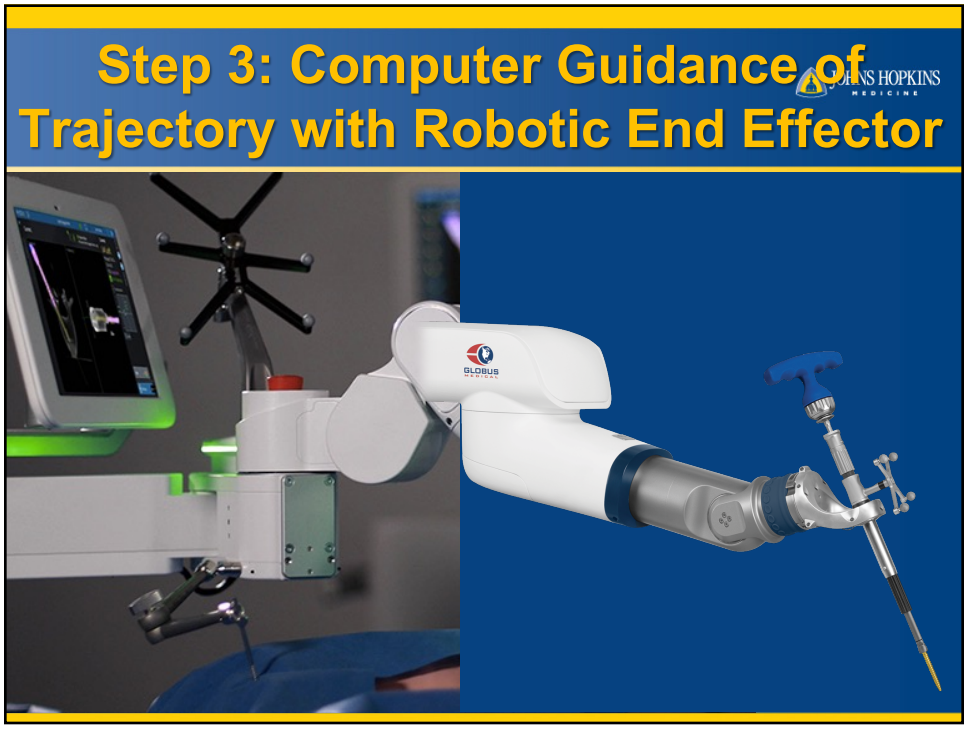
Step 3: Computer Guidance of Trajectory with Robotic End Effector
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GLOBUS

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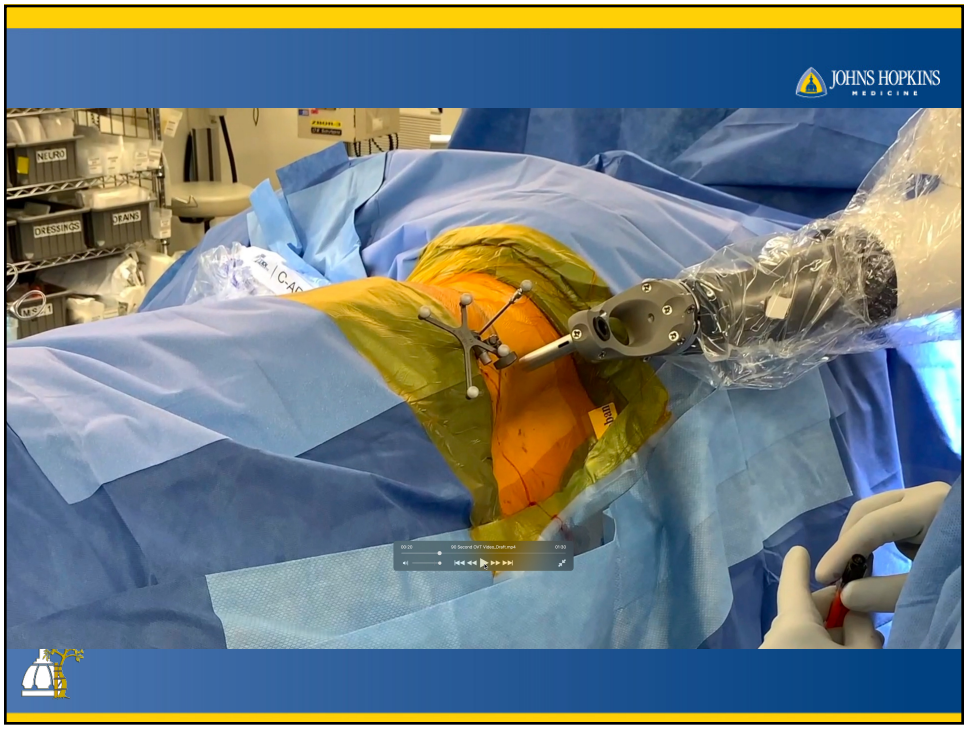
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NEURO
DRESSINGS

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How does robotics *HELP ME* minimize complications?

SHOW ME THE EVIDENCE!

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Accuracy of Free-Hand Pedicle Screws in the Thoracic and Lumbar Spine: Analysis of 6816 Consecutive Screws

BACKGROUND: Pedicle screws are used to stabilize all 3 columns of the spine, but can be technically demanding to place. Although intraoperative fluoroscopy and stereotactic-guided techniques slightly increase placement accuracy, they are also associated with increased radiation exposure to patient and surgeon as well as increased operative time.

OBJECTIVE: To describe and critically evaluate our 7-year institutional experience with placement of pedicle screws in the thoracic and lumbar spine using a free-hand technique.

METHODS: We retrospectively reviewed records of all patients undergoing free-hand pedicle screw placement without fluoroscopy in the thoracic or lumbar spine between June 2002 and June 2009. Incidence and extent of cortical breach by misplaced pedicle screw was determined by review of postoperative computed tomography scans. We defined breach as more than 25% of the screw diameter residing outside of the pedicle or vertebral body cortex.

RESULTS: A total of 964 patients received 6816 free-hand placed pedicle screws in the thoracic or lumbar spine. Indications for hardware placement were degenerative/deformity disease (51.2%), spondylolisthesis (23.7%), tumor (22.7%), trauma (11.3%), infection (7.6%), and congenital (0.9%). A total of 115 screws (1.7%) were identified as breaching the pedicle in 87 patients (9.0%). Breach occurred more frequently in the thoracic than the lumbar spine (2.5% and 0.9%, respectively; $P < .0001$) and was more often lateral (61.3%) than medial (32.8%) or superior (2.5%). T4 (4.1%) and T6 (4.0%) experienced the highest breach rate, whereas L5 and S1 had the lowest breach rate. Eight patients (0.8%) underwent revision surgery to correct malpositioned screws.

CONCLUSION: Free-hand pedicle screw placement based on external anatomy alone can be performed with acceptable safety and accuracy and allows avoidance of radiation exposure encountered in fluoroscopic techniques. Image-guided assistance may be most valuable when placing screws between T4 and T6, where breach rates are highest.

KEY WORDS: Accuracy, Lumbar, Pedicle screw, Thoracic

Neurosurgery 68:170–178, 2011 DOI: 10.1227/NEU.0b013e3181fdfaf4 www.neurosurgery-online.com

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- 2010 study: 6,816 Free-hand pedicle screws
- **1.5%** screws were breached
- **0.8%** reoperation rate

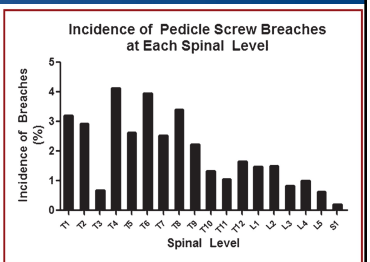

FIGURE 7. *Bar graph depicting the incidence of pedicle screw breaches at each spinal level. The most common sites for breach included T4 (4.1%) and T6 (4.0%).*

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Eur Spine J (2012) 21:247–255
DOI 10.1007/s00586-011-2011-3

ORIGINAL ARTICLE

Accuracy of pedicle screw placement: a systematic review of prospective in vivo studies comparing free hand, fluoroscopy guidance and navigation techniques

- 2012 Systematic Review of 26 prospective studies
- Freehand – **69% to 94%** accuracy
- 2D Fluoro – **28% to 85%** accuracy
- 3D Nav – **89% to 100%** accuracy

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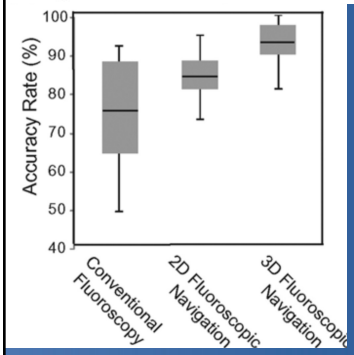
J Neurosurg Spine 20:196–203, 2014

The accuracy of pedicle screw placement using intraoperative image guidance systems

A systematic review



- 2014 Systematic Review of 30 studies
- 1973 patients - 9310 pedicle screws
- Accuracy:
  - 2D fluoroscopic navigation: **84.3%**
  - 3D fluoroscopic navigation: **95.5%**

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Authors and Year	Type of Robot	Approach	Study Type	Time, s/screw	Time, min	Accuracy (%)	Complication
Kim *et al*, 2016[7]	Renaissance	Open and percutaneous	Prospective RCT	4.8	Freehand: 189.8; robotic: 220.1	Freehand: 99.4; robotic: 99.4	None
Tsai *et al*, 2016[8]	Renaissance	Percutaneous	Retrospective	Not listed	Not listed	98.9	2
Hyun *et al*, 2016[9]	Renaissance	Open and percutaneous	Prospective RCT	Freehand: 13.3; robotic: 3.5	Freehand: 208.5; robotic: 208.5	Freehand: 98.6; robotic: 100	2
Onen *et al*, 2013 *I*[10]	Renaissance	Open and percutaneous	Prospective	1.3	298.4	98.5	None
Kuo *et al*, 2016[11]	Renaissance	Percutaneous	Retrospective	Not listed	190.4	98.74	None
Hu and Lieberman, 2014[12]	Renaissance	Open and percutaneous	Prospective	Not listed	Not listed	Group 1: 82; group 2: 93; group 3: 91; group 4: 95; group 5: 93	None
					Freehand: 218.9;	Freehand: 73.5;	Freehand: 3;

Operative Time, min	Accuracy (%)	Complications
35	98.3	4
Not listed	97.2	1
Freehand: 132; robotic: 151	Freehand: 93; robotic: 85	1
Freehand: 189; robotic-guided open: 210; robotic-guided percutaneous: 201	Freehand: 87.1; robotic-guided open: 90.4; robotic-guided percutaneous: 91.9	1
Not listed	96.2	None
161	Not listed	None
Freehand: 264.1; robotic: 226.1	Freehand: 83.6; robotic: 84.4	None
Not listed	Freehand: 88.9; robotic: 93.4	None
244	98.9	None
Freehand: 209; robotic: 336	Freehand: 92; robotic: 97.3	3
Not listed	98.9	7
Freehand: 14.2; robotic: 16.7	Freehand: 92.2; robotic: 95.3	None

RCT indicates randomized controlled trial.

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Amit, Why don't you use a robot in every case?

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Ideal Robotics Uses (Currently)

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- Percutaneous cases (minimize surgical team fluoro exposure) (eg: MIS TLIF)
- Unusual anatomy/ guidance helpful (eg: ? single position lateral)

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Is Robotics A Fad or Is it Here to Stay?

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4 big devicemakers rival Intuitive Surgical in robotics — Medtronic, Stryker & more

Written by Angie Stewart | January 13, 2020 | Print | Email

Robotics pioneer Intuitive Surgical is facing increased market competition as Johnson & Johnson, Medtronic and others gain traction through major mergers and acquisitions, S&P Global reports.

The surgical robot market is expected to reach $275 billion by 2025, almost tripling in size from 2018, according to analytics firm GlobalData. Intuitive has maintained a tight hold on the market since its da Vinci system gained FDA approval for urology in 2000.

However, during an earnings call in October 2019, Intuitive CEO Gary Guthart acknowledged increasing competition from opportunistic market entrants. While Intuitive has grown organically, four competitors have gained market share by acquiring smaller companies with key offerings:

1. **Johnson & Johnson.** In 2018, Johnson & Johnson purchased Orthotaxy SAS and its orthopedic surgery system prototype. The company more recently became involved in Google's joint venture to develop a general surgery robot and acquired the project's remaining stake in late 2019. And in April 2019, Johnson & Johnson acquired surgical robot-maker Auris Health for $3.4 billion, gaining a platform that can compete with Intuitive's Ion system for lung biopsies.

2. **Medtronic.** In 2018, Medtronic entered the orthopedic robotic surgery space by acquiring Mazor Robotics. Expected to boost future revenues, the Mazor robot has driven growth in equipment sales and spine implants. Medtronic has placed more systems than its competitors in the past several quarters, according to President Geoffrey Martha.

3. **Zimmer Biomet.** Zimmer acquired MedTech SA and its Rosa robotic surgery system for orthopedic surgery in 2016. The number of Rosa systems installed in hospitals is expected to rise significantly in the next few years. SVB Leerink analyst Richard Newitter estimates 66 units will be installed for $56 million in 2020.

4. **Stryker.** Stryker acquired Mako and its robot in 2013, becoming a leader in robotic knee replacement alongside Smith & Nephew. Stryker sold 51 Mako robots globally in the third quarter of 2019. It also embarked on a strategy to improve the robot by buying Mobius Imaging and Cardan Robotics for $370 million.

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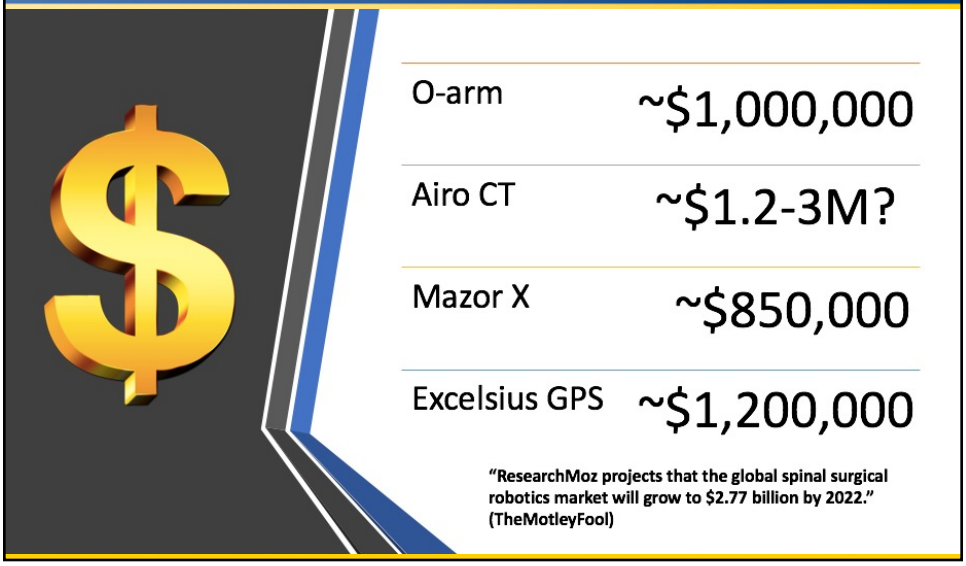
Nothing is Free!



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Lateral Access Spine Surgery

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Key Principles of LLIF

JOHNS HOPKINS MEDICINE

- Retroperitoneal trans-psoas (XLIF) vs. ante-psoas (OLIF/ATP) approach
- Indirect decompression of neural elements
- Wide surface area for fusion

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XLIF Positioning

JOHNS HOPKINS MEDICINE

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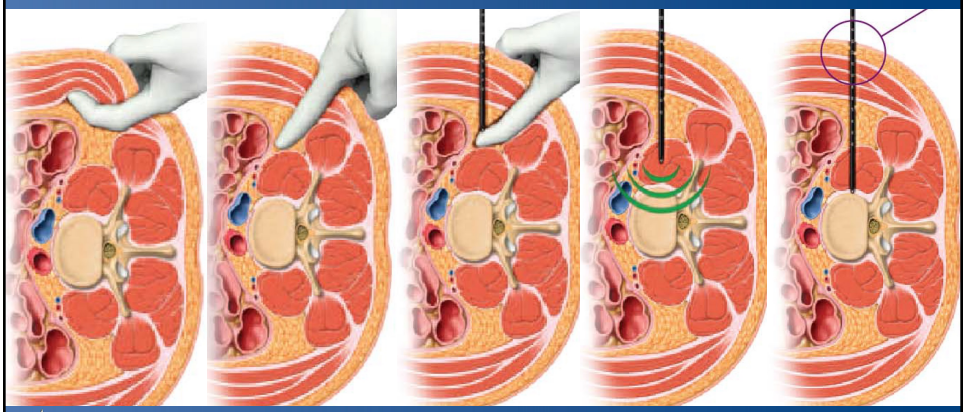
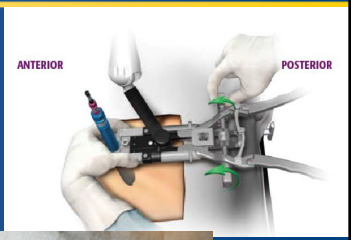
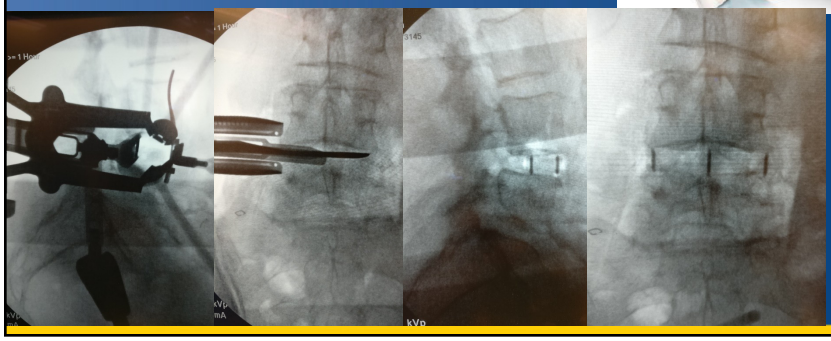
XLIF Retroperitoneal Access



57

Image Guidance Critical!

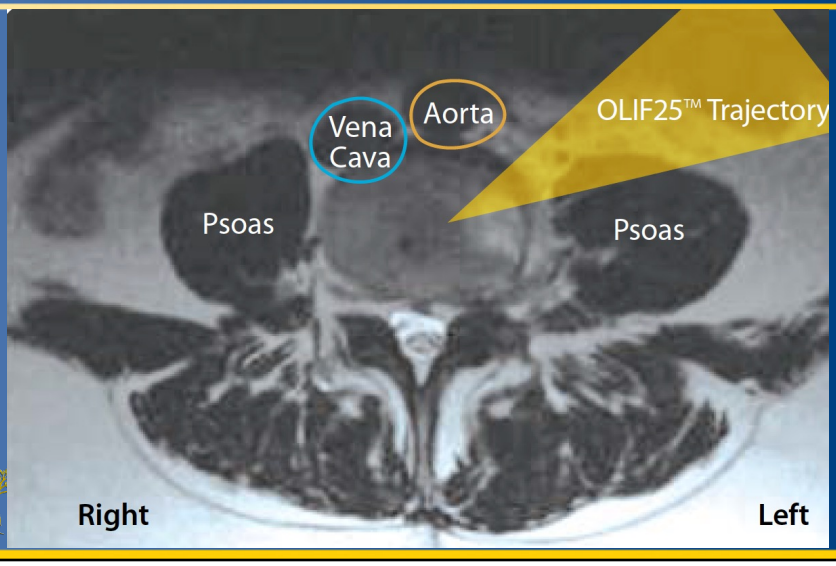




58

OLIF Trajectory

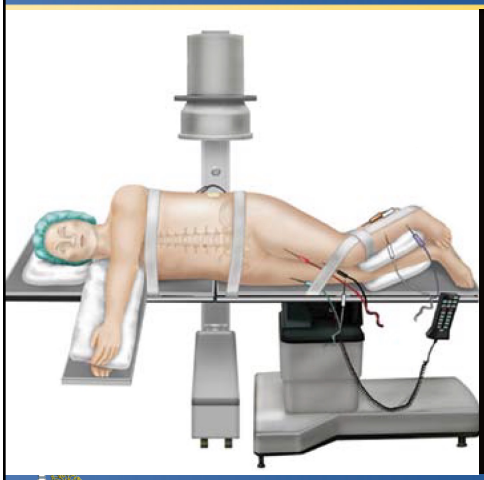
JOHNS HOPKINS MEDICINE

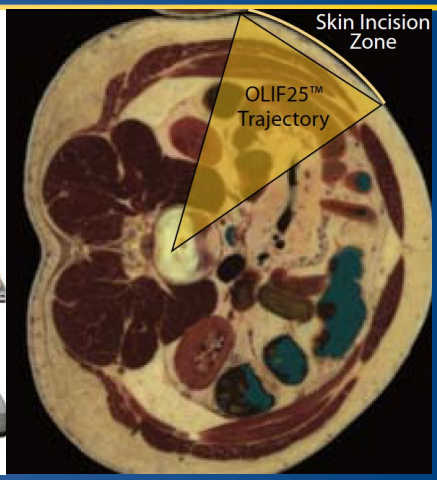


59

OLIF Positioning

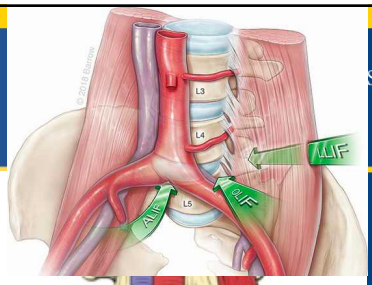
JOHNS HOPKINS MEDICINE

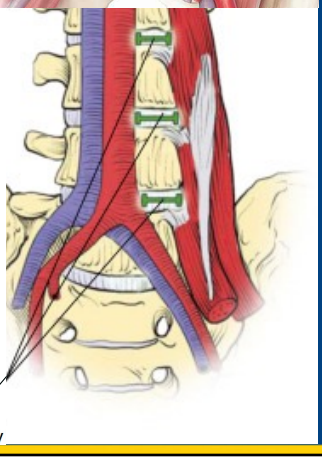




60

OLIF Access





DLIF Trajectory

OLIF25™ Trajectory

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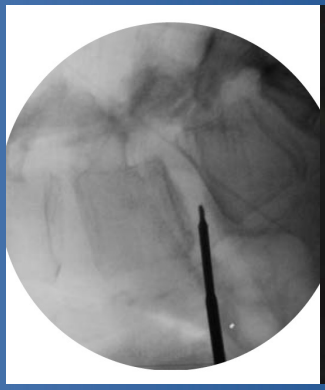
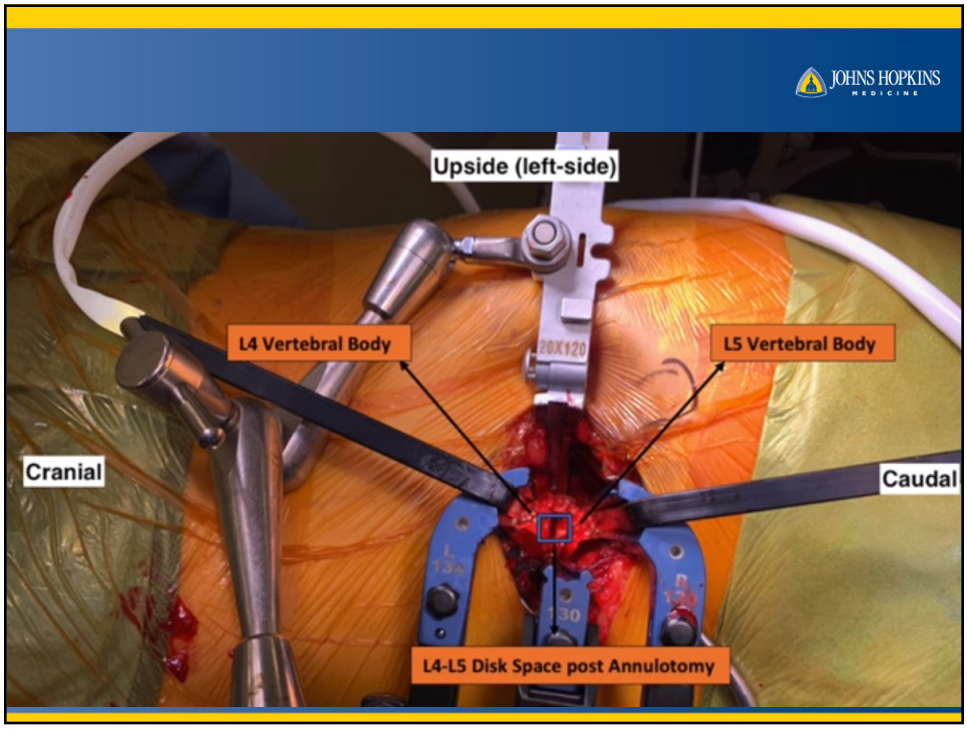
Oblique Docking

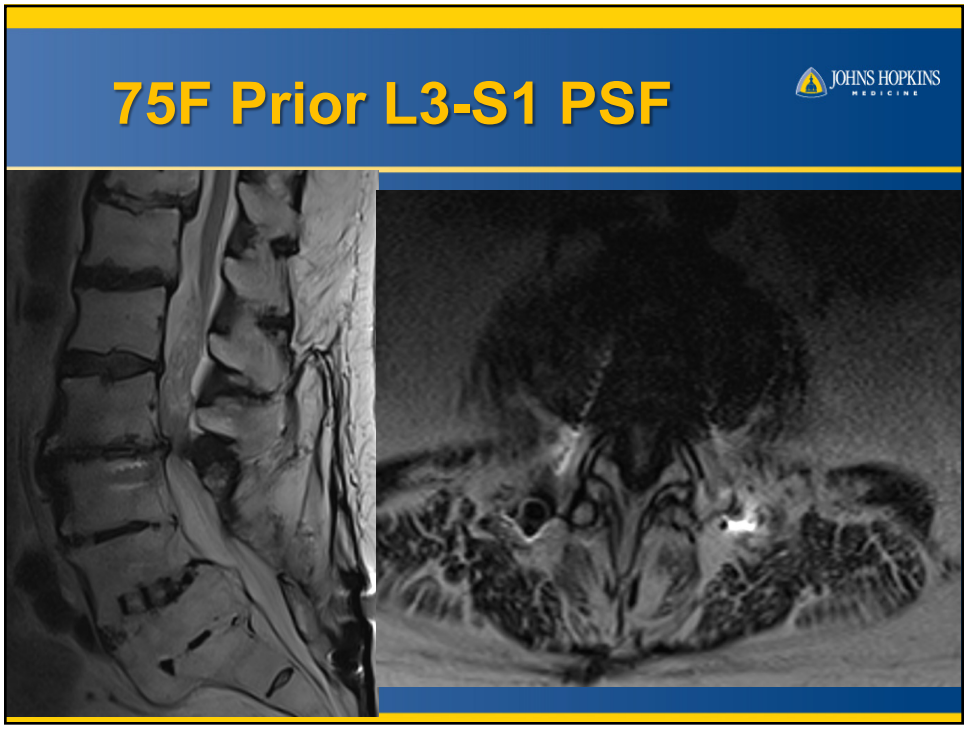
JOHNS HOPKINS MEDICINE



62


JOHNS HOPKINS
MEDICINE
Upside (left-side)
L4 Vertebral Body
L5 Vertebral Body
Cranial
Caudal
L4-L5 Disk Space post Annulotomy

63


75F Prior L3-S1 PSF
JOHNS HOPKINS
MEDICINE

64

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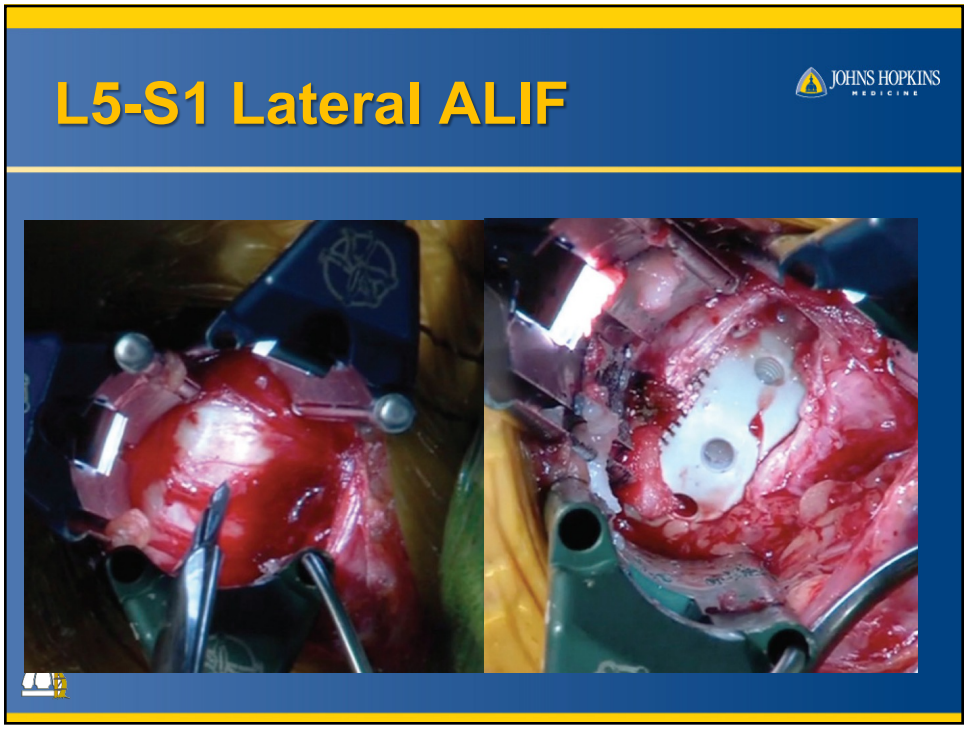

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MIS TLIF

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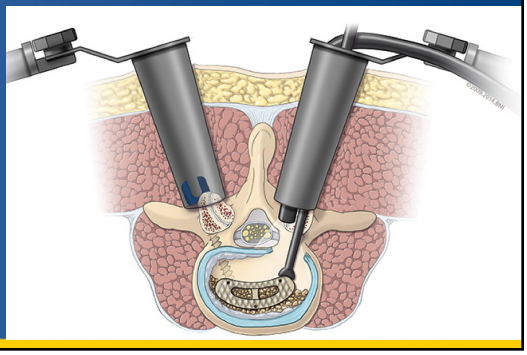
Key Principles of MIS TLIF

- Wiltse muscle splitting technique
- Direct decompression
- Interbody to enhance fusion



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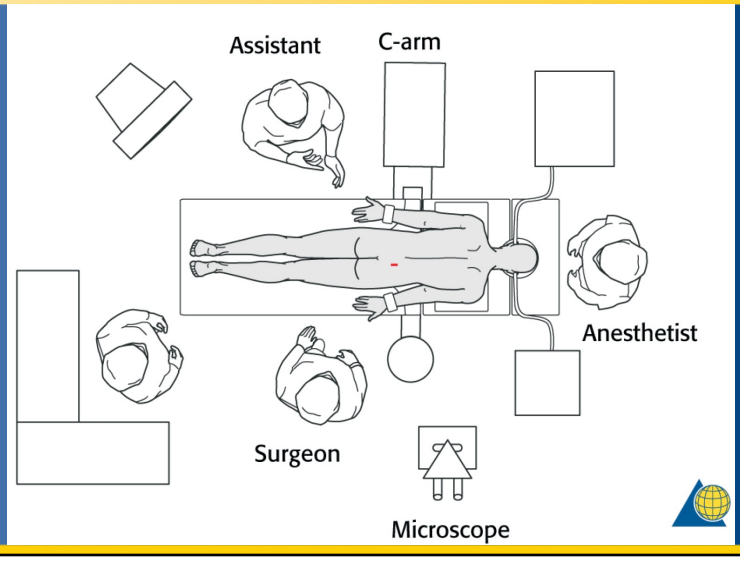
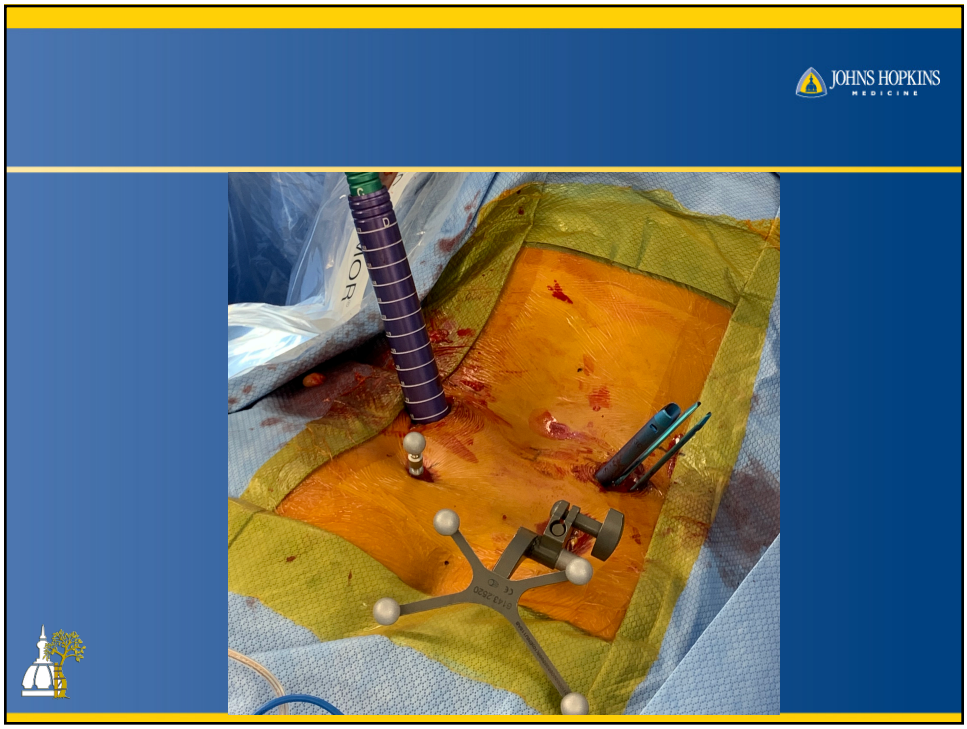
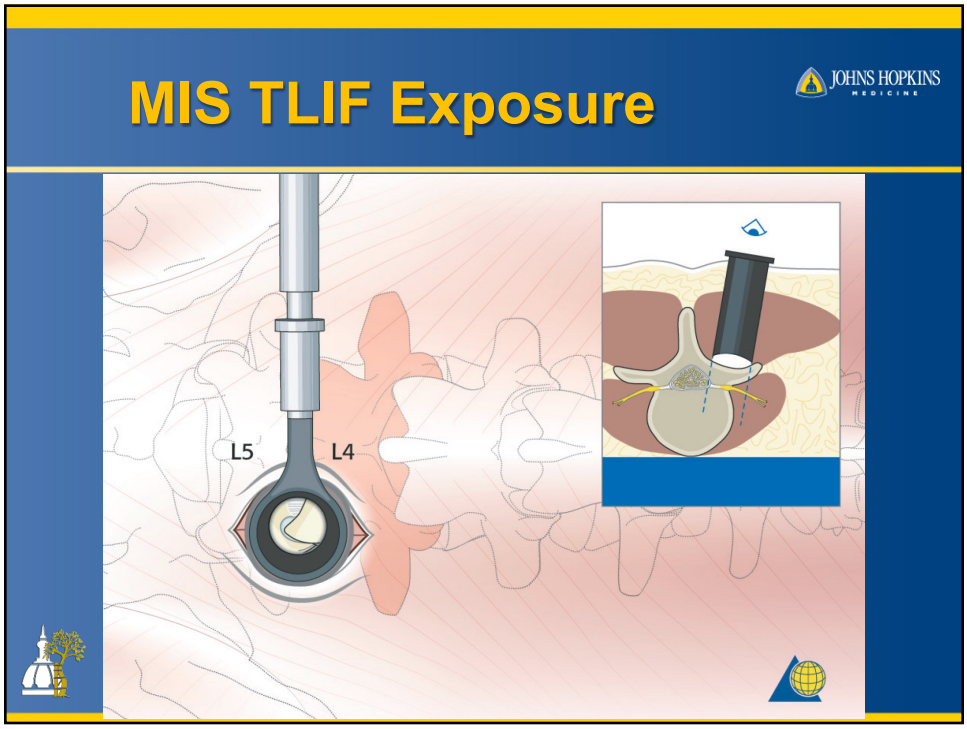
MIS TLIF Set Up



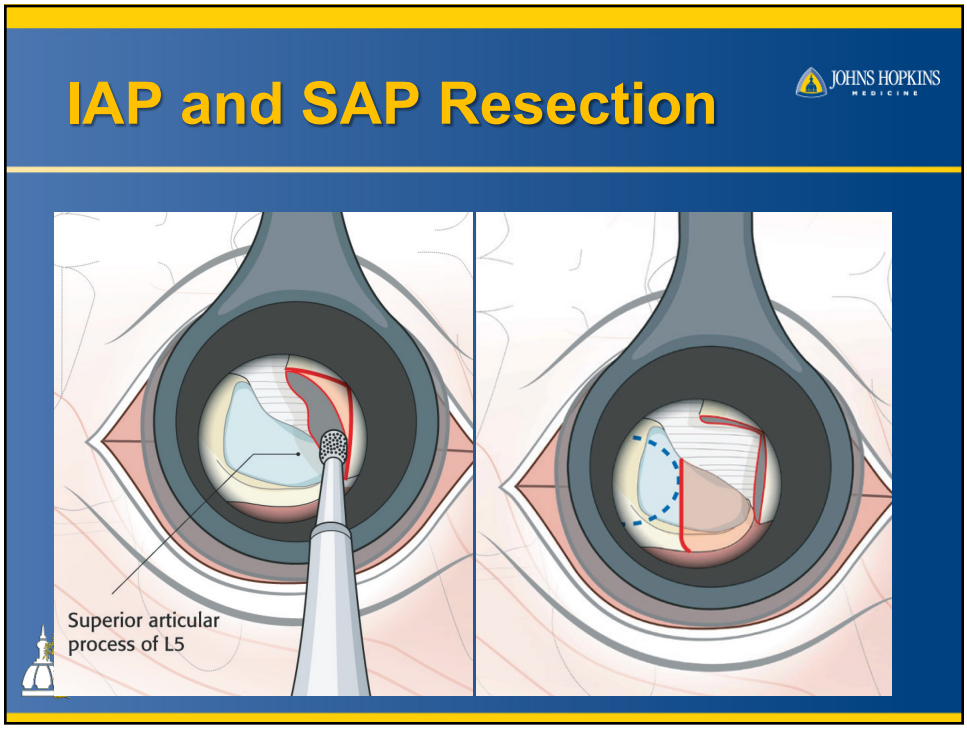
69



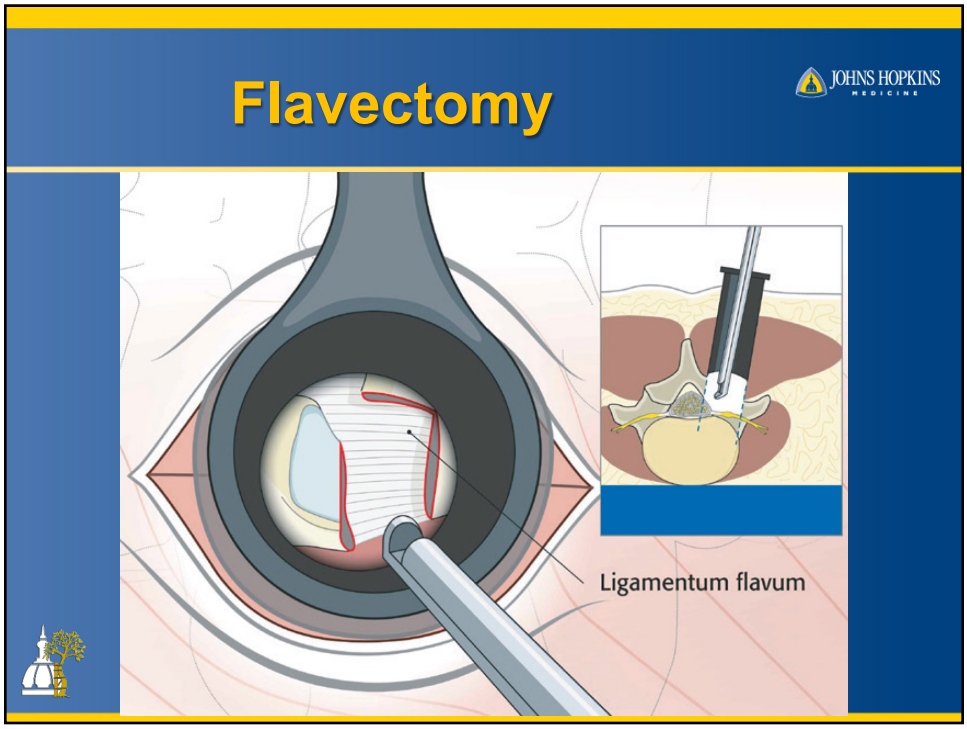
70


MIS TLIF Exposure
JOHNS HOPKINS
MEDICINE
L5
L4

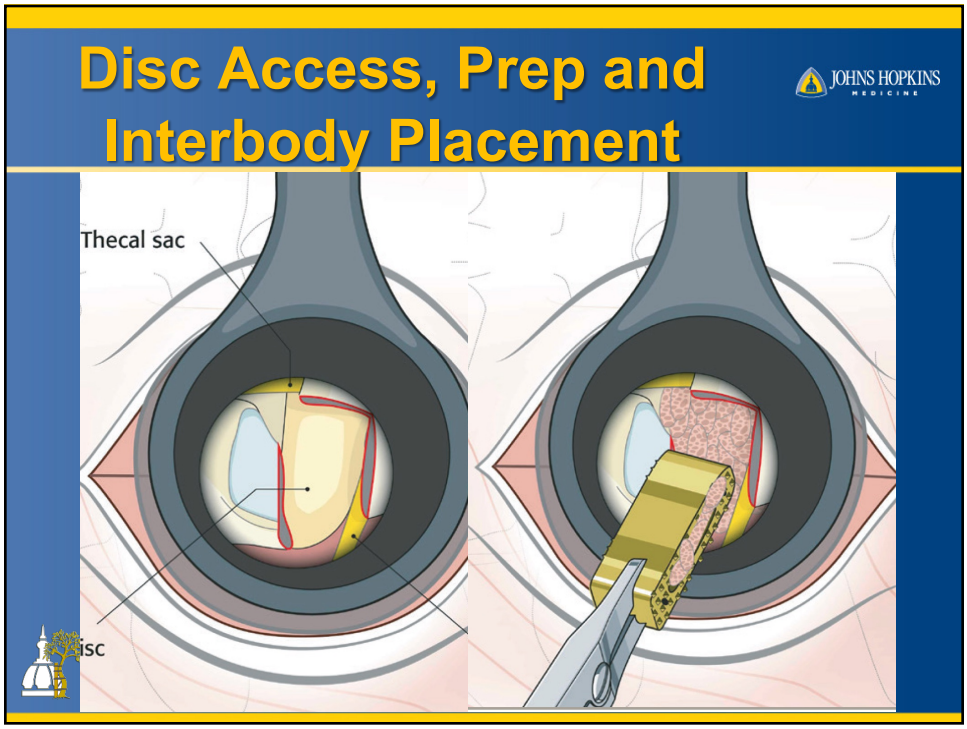
71


IAP and SAP Resection
JOHNS HOPKINS
MEDICINE
Superior articular process of L5

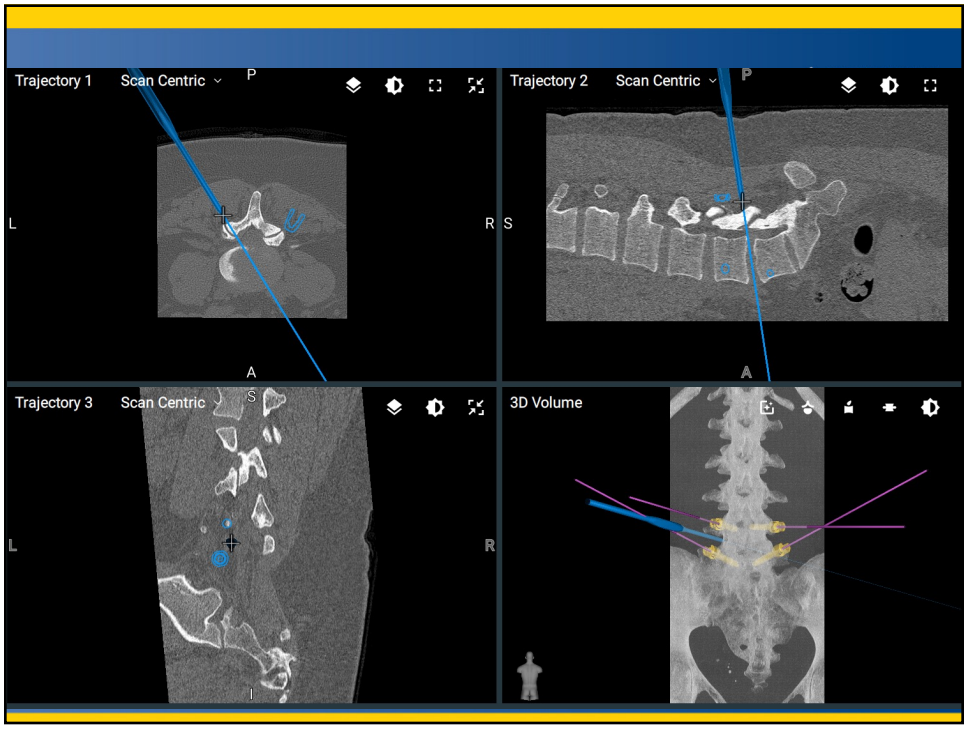
72


Flavectomy
JOHNS HOPKINS
MEDICINE
Ligamentum flavum

73


Disc Access, Prep and Interbody Placement
JOHNS HOPKINS
MEDICINE
Thecal sac
isc

74


Trajectory 1
Scan Centric
Trajectory 2
Scan Centric
Trajectory 3
Scan Centric
3D Volume

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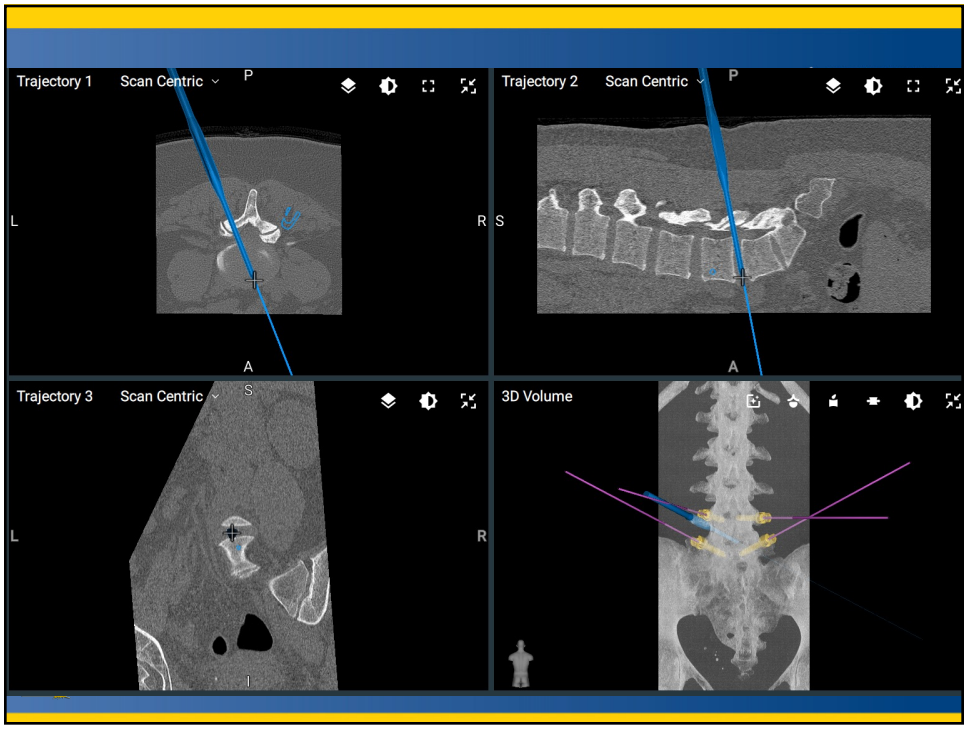
Trajectory 1
Scan Centric
Trajectory 2
Scan Centric
Trajectory 3
Scan Centric
3D Volume

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Putting It All Together

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Conclusions

- Goals of MISS are ***same*** as that of traditional open surgery
  - **Decompress**
  - **Stabilize and Fuse**
  - **Avoid creation of deformity**
- MISS ≱ Open Surgery
- Proficiency takes thought and practice!

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