Robotic Spine Surgery
Introduction and Literature Review

Christopher R. Good, MD, FACS
Director of Research
Director of Scoliosis and Spinal Deformity Surgery

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Advancements in Robotic Spine Surgery
Agenda

- History of Robotic Surgery and Literature Review
  - Christopher R, Good MD, FACS
- Minimally Invasive Robotic Spine Surgery
  - Michael Wang, MD, FACS
- Robotic Spinal Deformity Surgery
  - Ronald Lehman, Jr, MD
- Robotic Assisted Spinal Tumor Resection
  - Samuel Bederman, MD
- Robotic Sacroiliac Joint Fusion
  - Bernard Guiot, MD
- The Future of Robotic Spine Surgery
  - Christopher R, Good MD, FACS

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Disclosures

- Consultant Mazor Robotics
  - Consultant /Travel Reimbursement
    - MOI: $1000-$10,000
- I use “guidance” in ~ 30% of my cases
  - First Robot Experience - 2005
  - First Navigation Experience - 2007
  - Regular use Navigation -2010
  - Regular use Robot- 2012

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Robotic Spine Surgery
History and Literature Review
Agenda

- Robotic Surgery Background
- "How it Works" for Spine surgery
- Case Examples
  - Open Deformity
  - MIS Deformity
- Literature
- Potential advantages
- Potential Weaknesses

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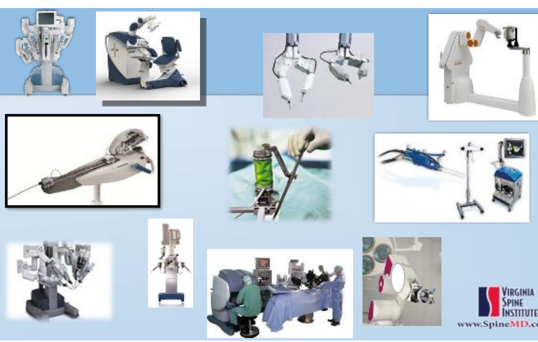

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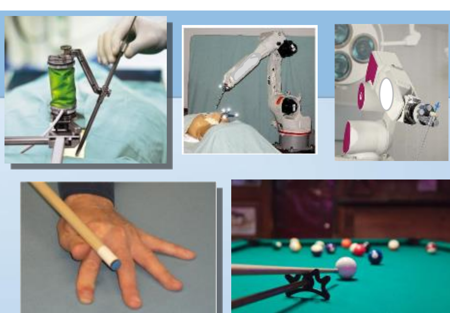

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Robotic-Guided Spine Surgery
Posterior approaches (Open, MIS, Percutaneous)

- Spinal fixation
  - Pedicle screws
  - Transfacet, translaminar-facet screws
  - Sacroiliac screws
- Spinal deformities
  - Scoliosis posterior spinal instrumentation
- Cement augmentations
  - Kyphoplasty and vertebroplasty
- Oncological applications
  - Biopsies, tumor resections
- Revision Surgery

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Robotic-Guided Spine Surgery

Planning Software

Workstation

Guidance Unit

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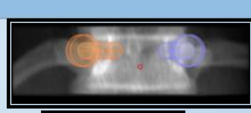
Robotic-Guided Spine Surgery
Pre-op 3D planning



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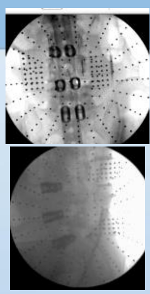
Robot Registration Process



Pre-op CT vs intra-op CT "scan and plan"

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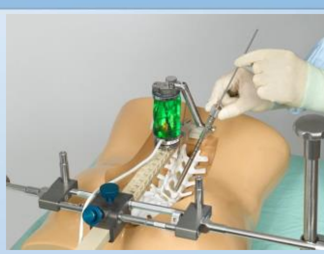
Robot mounted to patient via bone



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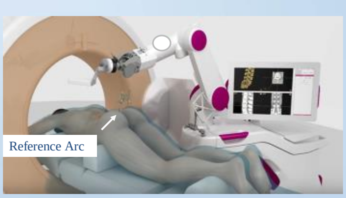
Robot Positioning Near Patient



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Robotic-Guided Scoliosis Correction

Cortical Pedicles, Severe Osteoporosis
Progressive Deformity, PFTs 47% predicted

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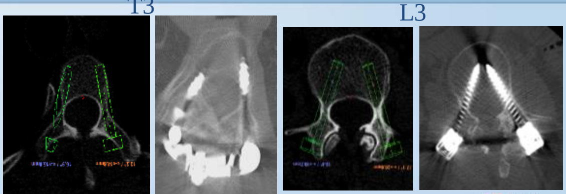

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Robotic-Guided Scoliosis Correction

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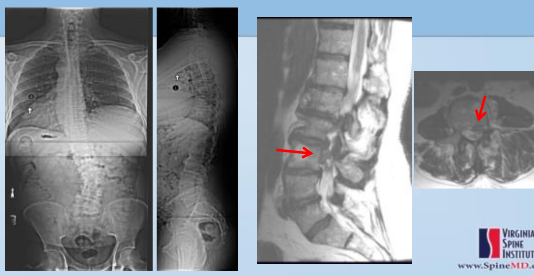
MIS Deformity



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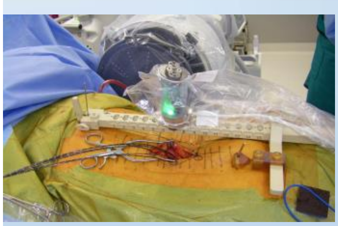
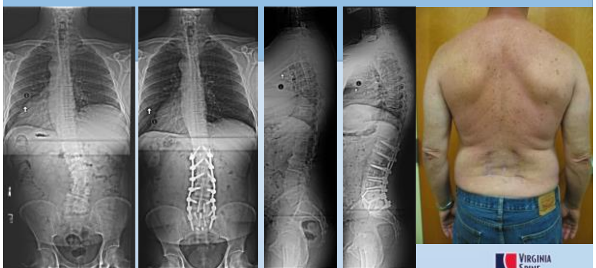
Template skin incisions





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SPINE Volume 32, Number 5, pp E111–E120
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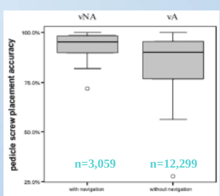
Pedicle Screw Placement Accuracy

A Meta-analysis

Victor Kosmopoulos, PhD, and Constantin Schizas, MD, PD, FRCS

- 130 studies – 37,337 pedicle screws (cadaver and in vivo)
  - 91% accuracy overall
  - Navigation – 95.2%
  - No Navigation – 90.3%



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Journal of Neurosurgery: Spine
Feb 2014 / Vol. 20 / No. 2 / Pages 196-203

ARTICLE

The accuracy of pedicle screw placement using intraoperative image guidance systems
A systematic review

Alexander Mason, M.D.[1,2], Renee Paulsen, Ph.D.[1], Jason M. Babuska, B.A.[1], Sharad Rajpal, M.D.[2], Sigita Burneikiene, M.D.[1,2], E. Lee Nelson, M.D.[1,2], and Alan T. Villavicencio, M.D.[1,2]

- **30 studies**
- 1973 patients - **9310 pedicle screws**
- Results consistent throughout all spinal levels

Type	Data sets	Total screws	Accurate screws	% accurate
Conventional fluoroscopy	12	3719	2532	**68.1**
2D fluoroscopic navigation	8	1223	1031	**84.3**
3D fluoroscopic navigation	20	4368	4170	**95.5**

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SPINE Volume 35, Number 24, pp 2109–2115
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Clinical Acceptance and Accuracy Assessment of Spinal Implants Guided With SpineAssist Surgical Robot

Retrospective Study

Dennis P. Devito, MD,* Leon Kaplan, MD,† Rupert Dietl, MD,‡ Michael Pfeiffer, MD,§

- Retrospective review
  - Radiographs (all) and CTs (646 screws)
- 635 cases in 14 medical centers
- 49% of implants placed percutaneously

- 98.3% Accuracy of 3,271 implants
- CT data
  - 98% safe (<2mm)
  - 89% contained

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Eur Spine J
DOI 10.1007/s00586-011-1729-2

ORIGINAL ARTICLE

Perioperative course and accuracy of screw positioning in conventional, open robotic-guided and percutaneous robotic-guided, pedicle screw placement

Sven Rainer Kantelhardt · Ramon Martinez ·

Retrospective: 112 cases Robot vs freehand

- Improved implant accuracy
  - 94% vs 91%
- Reduced fluoroscopy by 56%
  - 34 sec vs 77 sec
- Reduced complication rates by 48%
- Reduced re-operations 46%
  - 1% vs 12%
- Reduced average length of stay 27%
  - 10.6 days vs 14.6 days

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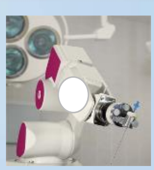
J Robotic Surg (2015) 9:331–338

ORIGINAL ARTICLE

Accuracy of thoracolumbar transpedicular and vertebral body percutaneous screw placement: coupling the Rosa® Spine robot with intraoperative flat-panel CT guidance—a cadaver study

M. Lefranc · J. Peltier

- Cadaveric Study
  - New robotic device
  - Coupled with flat panel CT guidance
  - 38 cadaver screws
    - 37 (97.4%) fully contained
    - 1 screw ,1mm lateral breach



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Eur Spine J
DOI 10.1007/s00586-015-3758-8

IDEAS AND TECHNICAL INNOVATIONS

Robot-assisted spine surgery: feasibility study through a prospective case-matched analysis

Nicolas Lonjon · Emilie Chan-Seng ·

- 20 patients , 1 surgeon
  - 10 robot (40 screws)
  - 10 freehand (50 screws)
- Operating time
  - Robot 187 min
  - Freehand 119 min
- Accuracy
  - Robot
    - 36/40 successfully placed (4 manually placed)
      - 97% accurate
  - Freehand
    - 50/50 successfully placed
      - 92% accurate

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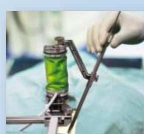
First Report from MIS ReFRESH - a Prospective, Comparative Study of Robotic- Guidance vs. Freehand Pedicle Screw Placement in Minimally Invasive Lumbar Surgery
IMAST 2016
Zahrawi F., Schroerlucke SR., Good CR., Wang MY.

- Prospective, comparative multi-center study – Robot vs Freehand
  - Lumbar instrumented fusions: 1-3 levels
  - Complications
  - Accuracy
  - Rate of revision surgery
  - 143 cases
    - 118 robot, 25 freehand
  - Fluoro time
    - 3.2 sec/screw robot
    - 12.5 sec/screw freehand ($p<0.001$)
  - Complications
    - Robot – no complications
    - Freehand – 1 neuro deficit, 1 infection ($p=0.03$)



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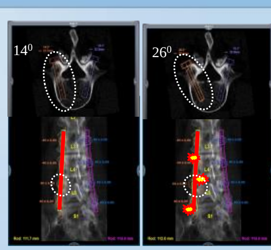
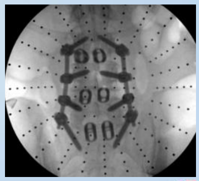
Robotic-Guided Spine Surgery
Potential Advantages

- Improved Accuracy
- Less Intra-op Radiation
- Complex procedure / anatomy
  - DOES change my usual technique
- MIS
- Screw cadence facilitates rod placement
- Plan skin incision



Robotic Weaknesses

- Maximum ~ 5 levels per scan
- Lack of live intra-op feedback
- Cost / availability
- Learning curve
- Registration issues



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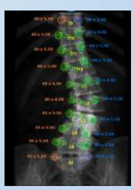
Robotic Spine Surgery Conclusions

- Many robots in development, FDA approval/studies ongoing and growing
- First FDA approved robot
  - 120 systems worldwide, 80 USA
  - >18,000 cases
  - >120,000 Implants



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Time when Robot is most beneficial:

- Complicated anatomy
  - Severe deformity
  - Congenital anomaly
  - Previous surgery
- Osteoporosis
- Morbid Obesity
- Minimal visualization

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Thank You!

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Advances in Robotics and Navigation for MIS Spinal Surgery

Michael Y. Wang, MD
Professor & Spine Director
Departments of Neurological Surgery & Rehab Medicine
The Miller School of Medicine at the
University of Miami

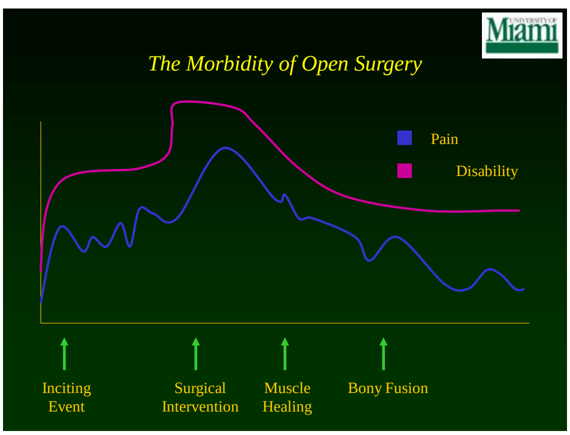
Disclosures

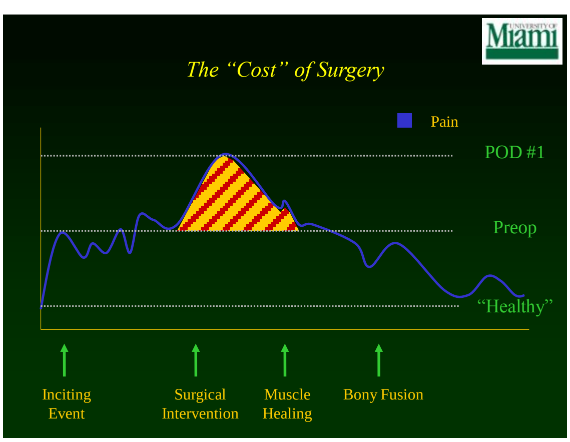
Consultant:	Depuy Spine
	Aesculap Spine
	JoiMax
	K2M
Royalties:	Children's Hospital of Los Angeles
	Depuy Spine
	Springer Publishing
	Quality Medical Publishing
Stock:	Innovative Surgical Devices
	Spinicity
Grants:	Department of Defense

Disclaimer

New does <u>not</u> mean better !


Miami
Surgical Obsolescence

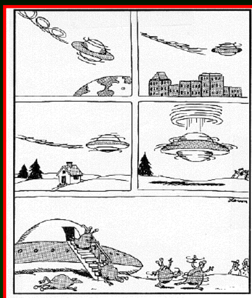

Miami
The Morbidity of Open Surgery
Pain
Disability
Inciting Event
Surgical Intervention
Muscle Healing
Bony Fusion


Miami
The "Cost" of Surgery
Pain
POD #1
Preop
"Healthy"
Inciting Event
Surgical Intervention
Muscle Healing
Bony Fusion

Disadvantages of Minimally Invasive Spine Surgery

› Technically challenging
› Inadequate visualization
› Disorienting
› Difficult to manipulate instruments & structures
› ? Iatrogenic neural injury ?

High Complication Rates Resulted in a previous generation of spine surgeons being disabused of MIS

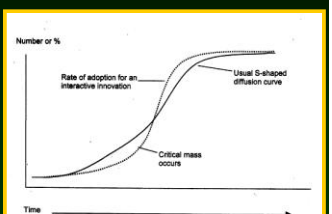


The “Disconnect”

MIS Adoption remains at less than 20% of lumbar fusion surgeries

Reasons:

- Safety concerns
- Lack of familiarity
- Limited applications
- Increased work effort
- Financial disincentive



So what is the role of Robotics & Navigation?

ro·bot
/ˈrōˌbät,ˈrōbət/

noun

a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.
synonyms: automaton, android, golem; More

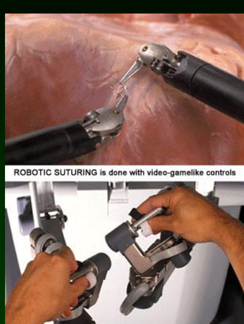
- (especially in science fiction) a machine resembling a human being and able to replicate certain human movements and functions automatically.

co·bot
/ˈkōˌbät,-bət/

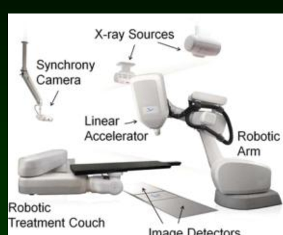
noun

a computer-controlled robotic device designed to assist a person.

Different Surgical Robots



Da Vinci®

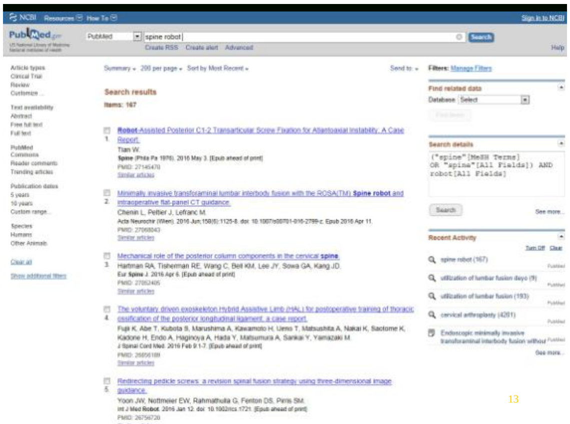


Cyberknife®

Who Needs Robotics?

- Too expensive
- It will slow me down
- I'm doing just fine
- Don't fix what isn't broken
- Just helps place K-wires
- Marketing ploy

"Maybe it's good for other surgeons, but I don't need it"



Doesn’t technology add to cost?

Complication Avoidance

Pedicle Screw Misplacement

Problem:

The radiographic breach rate is > 5% in open surgeries

Solutions:

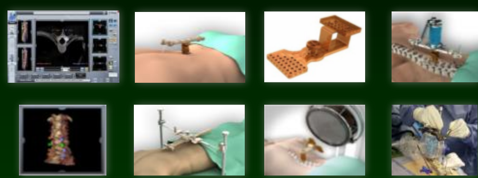
1. Experience
2. Intra-operative visualization/palpation
3. Proper X-ray guidance
4. Neuronavigation
5. Neuromonitoring

Good judgment comes from experience, and experience comes from bad judgment

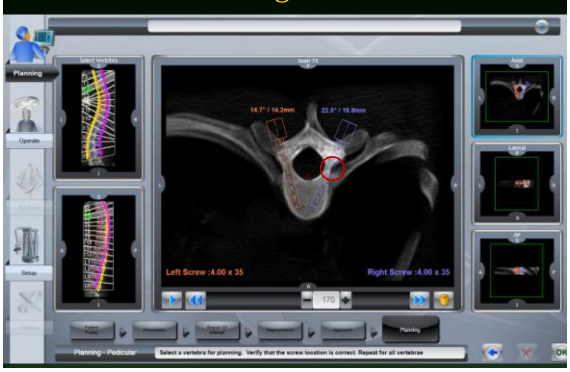
Can MIS Techniques Get You There?

Renaissance 4-Step Workflow

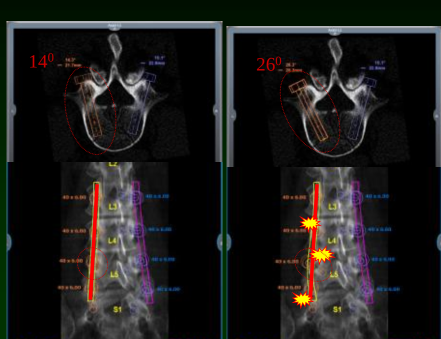
Pre-Operative Blueprint → Hardware Attachment → 3D Synchro-nization → Surgical Execution

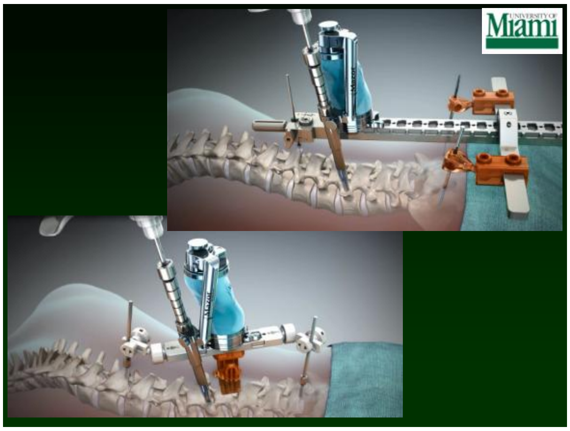


Planning Software



Enabling MIS





Bed Mount

Original

Received: 29.07.2013 / Accepted: 05.11.2013
DOI: 10.5137/1019-5149.JTN.8951-13.1

Author	System	Application	Percutaneous/ Open	Number of Patients	Comments
Sukovicz W (2006) (30)	SpineAssist	TPS	Not stated	14	93% successful
Barzilay Y (2006) (1)	SpineAssist	TPS	0/9	9	Software- and patient-induced technical problems were encountered in 4 patients
Pechlivanis I (2009) (23)	SpineAssist	TPS	31/31	31	93.5% successful
Kantelhard SR (2011) (11)	SpineAssist	TPS	35/20	55	94.5% successful, 55% decrease in using x-ray
Zaulan Y (33)	SpineAssist	VP	23	23	65% decrease in using fluoroscopy
Hu X (2012) (10)	Renaissance	TPS	16/96	102	98.9% successful
Roser (2013) (25)	SpineAssist	TPS	30/46	46	Surgical comparison performed by Freehand and navigation: 40% decrease in radiation, 99% accuracy in screws
Togawa (2007) (32)	SpineAssist	TPS–translaminar screw	24 percutaneous, 43 screw, 19 level percutaneous translaminar	10 cadavers	TPS 95.3% in cadaver study, 100% success in translaminar, excluding two levels where the k-wire was broken

YÖNTEM ve GEREÇLER: Torakolomber stabilizasyon operasyonu yapılan 27 hasta preoperatif, intraoperatif ve postoperatif verileri kaydedildi. Öğrenme eğrisinine göre hastalar; grup A ve grup B olmak üzere ikiye ayrıldı, klinik ve radyolojik veriler, preoperatif ve postoperatif sonuçlarla karşılaştırıldı.

Review of evidence on Renaissance accuracy

Author	Year	Study type	# screws	Safe Screws
Hu	2013	Retrospective	960	98.9%
Onen	2014	Prospective	136	98.5%
Kim	2015	RCT**	80	100%
Fujishiro	2015	Cadaveric study	216	100%
Kuo	2016	Retrospective	317	98.7%
Weighted average				99.0%

* Fully within the pedicle or breaching <2mm
** RCT = Randomized Control Trial

ClinicalTrials.gov
A service of the U.S. National Institutes of Health

Example: "Heart attack" AND "Los Angeles"
Search for studies:
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Home > Find Studies > Search Results > Study Record Detail   Text Size

Trial record **1 of 1** for: mis refresh
Previous Study | Return to List | Next Study

MIS ReFRESH: Robotic vs. Freehand Minimally Invasive Spinal Surgeries

This study is currently recruiting participants. (see Contacts and Locations)
Verified January 2016 by Mazor Robotics

Sponsor:
Mazor Robotics

Information provided by (Responsible Party):
Mazor Robotics

ClinicalTrials.gov Identifier:
NCT02057744

First received: February 5, 2014
Last updated: February 8, 2016
Last verified: January 2016
History of Changes

Full Text View | Tabular View | No Study Results Posted | Disclaimer | How to Read a Study Record

Purpose

To quantify potential short- and long-term benefits of robotically-guided minimally invasive spine surgery (MIS) for adult patients with lower back degeneration, in comparison a matching group of control patients operated in a minimally invasive approach whether freehand or with image guidance or navigation techniques.

Condition
Degenerative Disc Disease Spinal Stenosis Spondylolisthesis Spondylosis

Study Type: Observational
Study Design: Observational Model: Case Control
Time Perspective: Prospective

Official Title: Multi-center, Partially Randomized, Controlled Trial of MIS Robotic vs. Freehand in Short Adult Degenerative Spinal Fusion Surgeries

MIS ReFRESH

- Prospective
- Multi-center (currently 6 sites)
- Controlled, partially randomized study
- Adult degenerative lumbar disease
- Fusion surgery of 1 to 3 levels

Outcome Measures

- Surgical complications
- Revision surgeries
- Intra-operative fluoroscopy

MIS ReFRESH - Surgical Outcomes

- No significant differences in:
  - Charleson comorbidity Index (0.5)
  - Gender (60% female)
  - Age (58)
  - BMI (30.8)

	Robotic	Freehand	P-value
Sites*	3	2	
Patients	118	25	
# levels	1.4 (1-3)	1.1 (1-2)	0.006
Fluoro/screw	3.2±2.8	12.5±7.9	**<0.001**
Complications	0	2	**0.034**
Revisions	0	2	**0.034**

*1 surgeon randomized patients to both arms

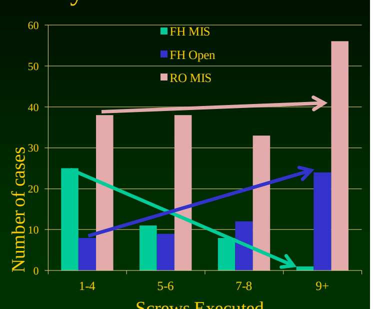
Retrospective Comparative Analysis Sweeney *et al.*

- Robotics MIS vs. Freehand MIS & Open
  - Doctor's Hospital, Sarasota, FL
  - 268 patients
  - Adults, thoracolumbar degenerative spine disease

Parameter	Robot MIS	Total Freehand		Freehand MIS		Freehand Open	
# of patients	167	99	p vs. robot	46	p vs. robot	53	p vs. robot
% female	48.5	42.4	>0.05	50.0	>0.05	35.8	>0.05
Age	68.3	62.6	<0.001	60.5	0.001	64.6	0.093
BMI	31.4	31.2	>0.05	30.3	>0.05	31.7	>0.05
Screws per case	8.2	7.2	<0.001	5.6	<0.001	8.7	>0.05
% complications	4.8	10.1	>0.05	6.5	>0.05	13.2	0.034

Case Mix by Surgical Approach Sweeney *et al.*

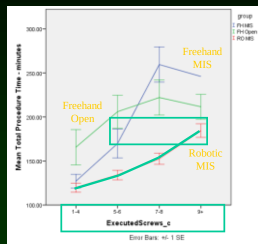
- Clear preference for Freehand MIS in short fusions
  - Freehand MIS performed mainly in 1 level cases
  - Single case of 4 levels Freehand MIS
- Robotics enables MIS in all types of cases



Procedure Time by Technique – Sweeney *et al.*

	Skin-to-skin (min)		
Levels	FH Open	FH MIS	RO MIS
1	166	127	120
2	206	170	134
3	222	260	153
4+	212	246	185

- Robotics MIS is significantly faster than freehand MIS or open



Multi-level Robotic MIS case takes about as long as a 2-level freehand case

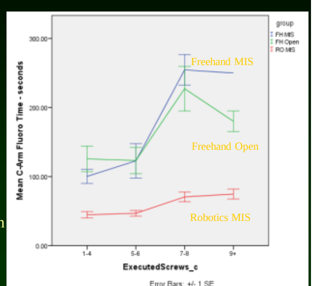
Fluoro Exposure by Technique – Sweeney *et al.*

- Robotics reduces fluoro by:

	Fluoro time - seconds			Reductions in %	
Levels	FH Open	FH MIS	RO MIS	vs. open	vs. MIS
1	126	100	45	64%	55%
2	123	123	47	62%	62%
3	227	255	71	69%	72%
4+	180	250	75	58%	70%

All results are statistically significant

Robotics MIS requires significantly less fluoro than freehand MIS or open



Pros

- Improved planning
- Implant management
- Enables surgeons to do complex surgery
- Axial rotation & deformity are no longer a challenge
- Stepping-stone technology

Cons

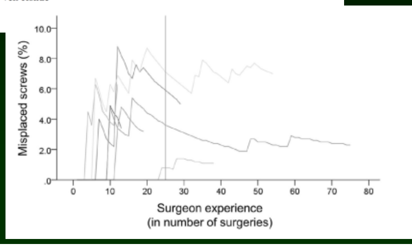
- Requires one mm CT scan
- Capital equipment costs
- Learning curve
- Attachment to the patient or bed
- Dependence on technology
- Unrecognized screw misplacement

Acta Neurochir (2015) 157:1819–1823
DOI 10.1007/s00701-015-2535-0

CLINICAL ARTICLE - SPINE

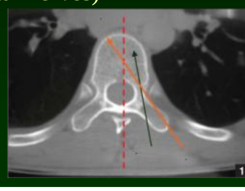
Unskilled unawareness and the learning curve in robotic spine surgery

Bawarjan Schatlo[1] · Ramon Martinez[1] · Awad Alaid[1] · Kajetan von Eckardstein[1] · Reza Akhavan-Sigari[1] · Anina Hahn[1] · Florian Stockhammer[1] · Veit Rohde[1]

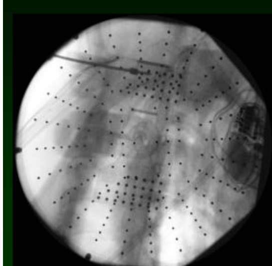


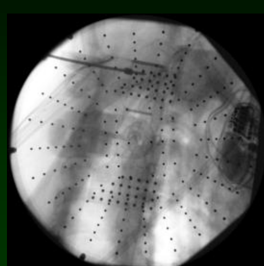
Challenges in this case

- Obesity
- Level localization (T4)
- Surrounding structures (blood vessels, lung, spinal cord, ribs, intercostal nerves)
- Access trajectory
- Medical co-mobidities

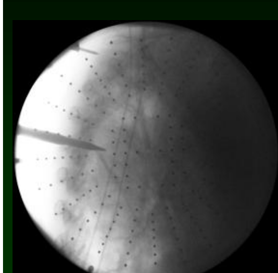


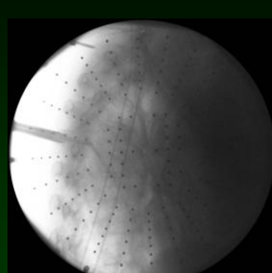
Robot Registraiton



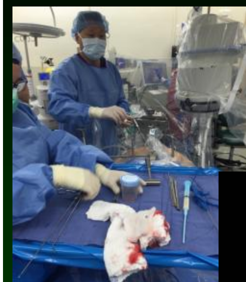


Access at T4





Endoscopic Debridement



A Marriage of Technologies

Robotic localization, trajectory, & access

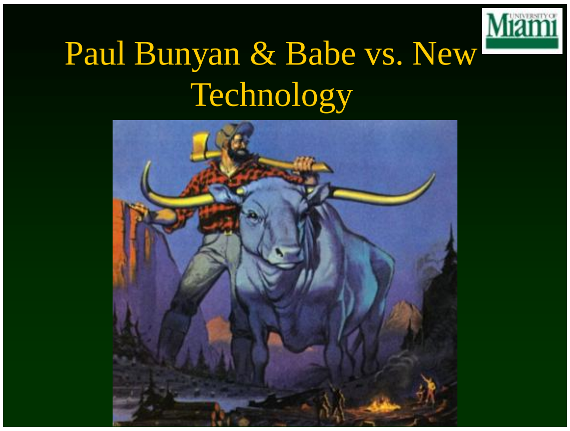
+

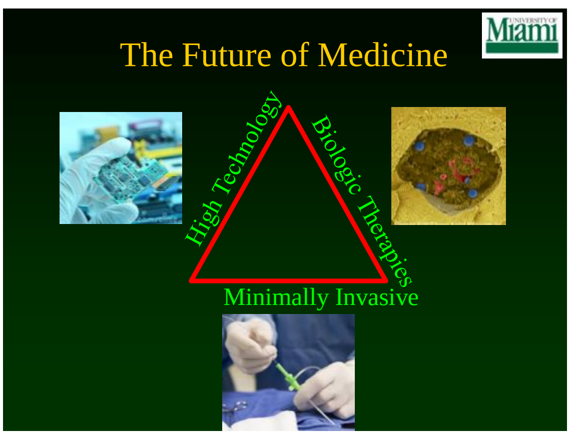
Endoscopic debridement

Who likes the robot?

7th year resident
Performed > 500 spine surgeries
From Missouri
Married w/ two dogs
IQ ~ 145

1st year resident (intern)
Performed < 10 spine surgeries
Worked at Blackrock in NYC
Single (but monogamous)
IQ ~ 154


Paul Bunyan & Babe vs. New Technology
Miami


The Future of Medicine
Miami
High Technology
Biologic Therapies
Minimally Invasive

Robotic Assisted Spine Surgery (RASS) Use in Deformity

Ronald A. Lehman, Jr., MD
Professor of Orthopedic Surgery, Tenure
Chief, Degenerative, Minimally Invasive and Robotic Spine Surgery
Director, Robotic Spine Surgery
Complex Pediatric and Adult Scoliosis Service
Co-Director, Spine Fellowship
Director, Clinical Spine Research
Co-Director, Orthopaedic Clinical Research

The Spine Hospital
ColumbiaDoctors New York – Presbyterian The Allen Hospital

Why Surgical Guidance

- Surgical Planning
  - Create total 3D custom plan for patient
  - Consider challenging anatomy
  - Optimize implant size and placement
  - Accommodate MIS (proximal facet joint, tulip head alignment, rod passage)
- Intra-op Guidance
  - Allows OR staff to be in sync with surgical plan
  - Streamline implant sizing and sequence to OR staff
  - Execute surgical plan
  - Lock trajectory any point, regardless of patient position

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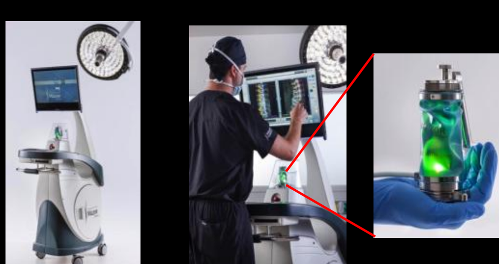
Robotic Assisted Spine Surgery



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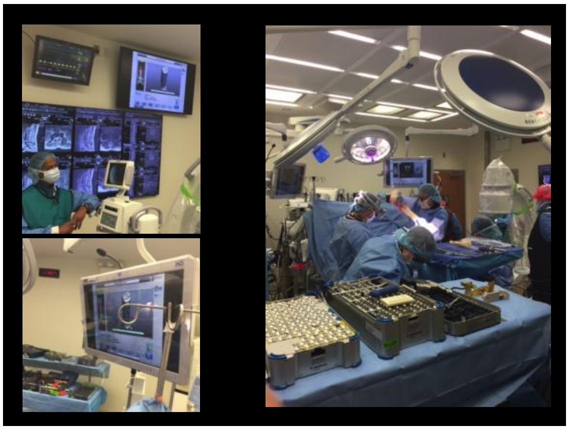
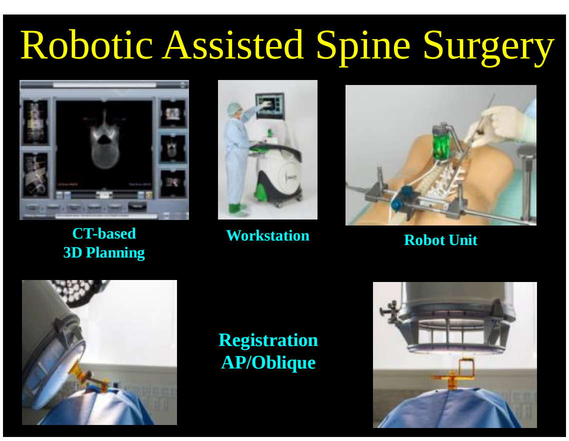



Mazor
Left Screw :7.00 x 50
Right Screw :7.00 x 50


Robotic Assisted Spine Surgery
CT-based
3D Planning
Workstation
Robot Unit
Registration
AP/Oblique

How Does it Work?

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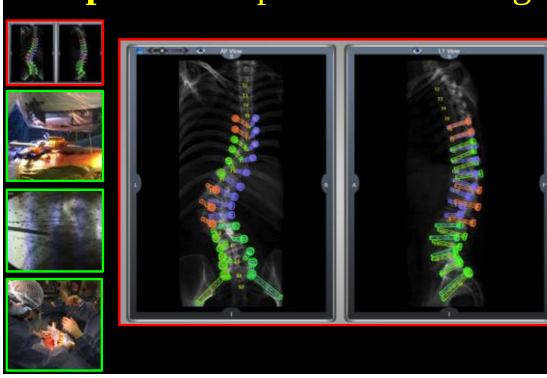
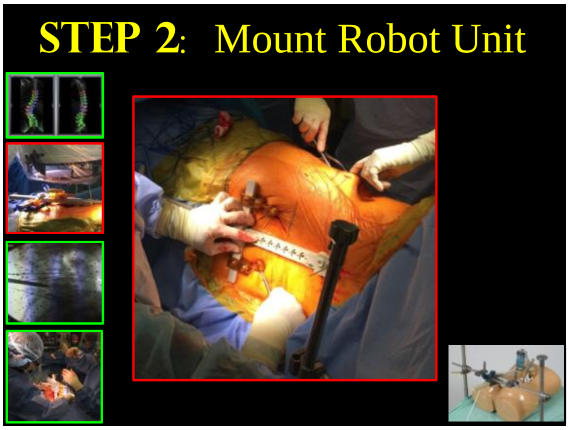
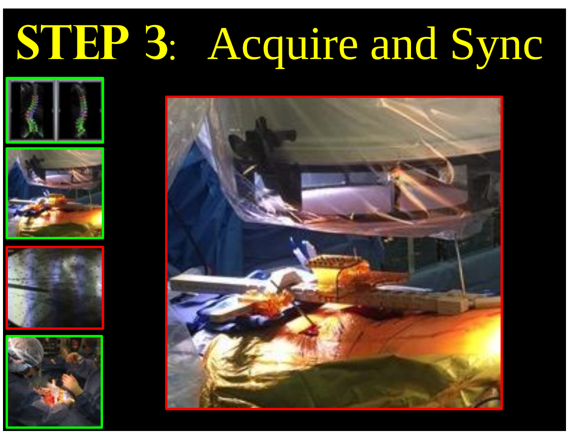
Registration

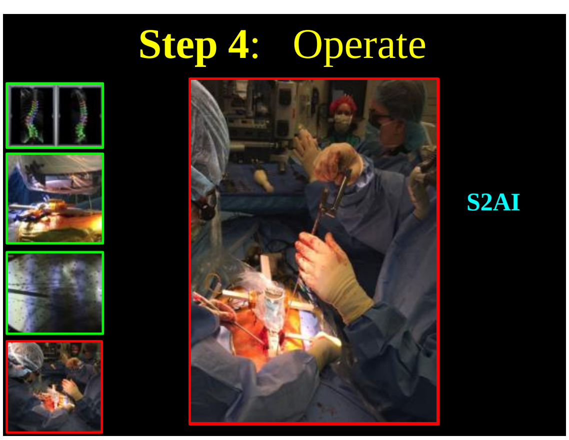
NewYork-Presbyterian Orthopedics | The Spine Hospital | Columbia University Department of Orthopedic Surgery

Step 1: Pre Operative Planning




STEP 2: Mount Robot Unit


STEP 3: Acquire and Sync


Step 4: Operate
S2AI

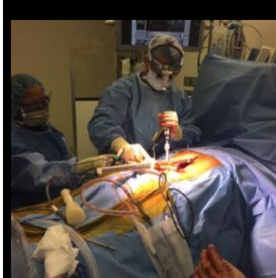
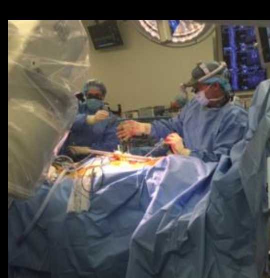
Potential Advantages

- Less radiation
  - Surgical Team vs. MISS with Flouroscopic Assist
  - ? Patient (requires preop or intraop CT scan (similar to navigation)
- Less exposure
  - If employed in MISS or MAST Setting
- Accuracy = Big Question
  - Freehand?
  - Navigation?
  - Flouro Assist?
- Based on "segmentation" vs Navigation (alignment)

Work Flow

Freehand	Robotic Assistance
1. Exposure	1. Exposure
2. Facetectomies	2. Wires/Tap +/- Screws
3. Decompression(s)	3. Facetectomies
4. PCOs	4. Decompressions
5. Screws (benefit open canal)	5. PCOs
6. TLIFs	6. TLIFs
7. Correction	7. Correction

Screw Placement

Adult Deformity

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HISTORY OF PRESENT ILLNESS:

57 yo F with several years of back and leg pain with scoliosis

- Low back pain 70%
- Leg pain 30%. right hip and right calf pain
- Has right calf weakness and numbness
- Had an injection 3 months ago, which helped her for a little it.

PHYSICAL EXAMINATION:

- Right EHL 4/5, gastroc 4/5
- Decreased sensation on the lateral aspect of right leg and right foot

IMAGING:

- **Xray:** scoliosis of approximately 50 degrees, fractional concavity on the right hand side. She has overall good sagittal balance.
- **MRI:** disc desiccation most prevalent at L4-L5 and L5-S1. She also has spondylosis and degenerative disc disease as well as facet hypertrophy.

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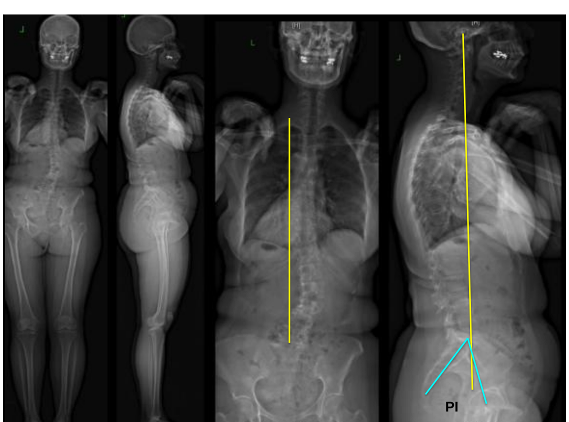
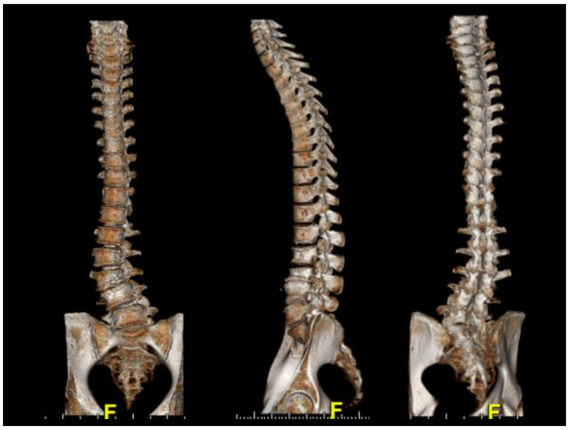
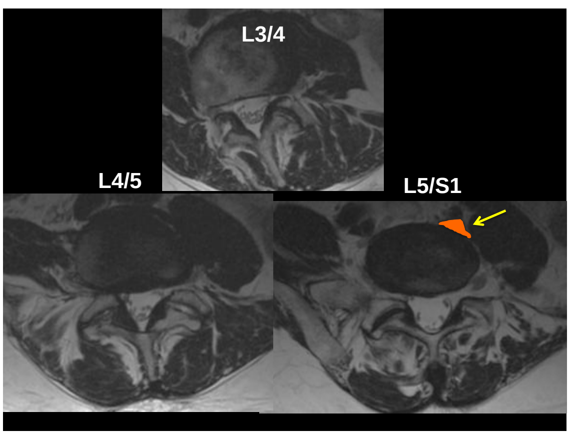
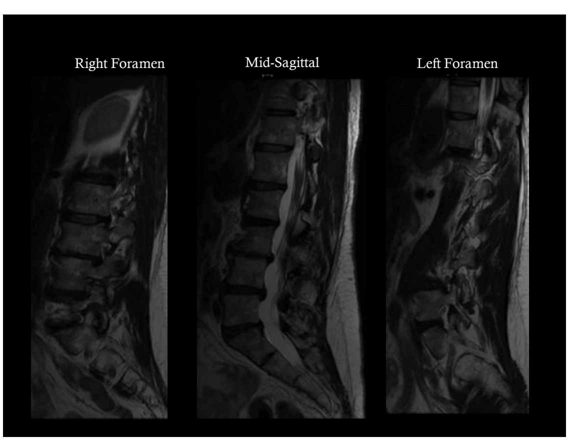



F
F
F


L3/4
L4/5
L5/S1


Right Foramen
Mid-Sagittal
Left Foramen

ASSESSMENT:
57 yo F with degenerative scoliosis and olisthesis, radiculopathy

PLAN:
OLIF vs TLIF at L5/S1
PSF T10 to ilium
Decompression R L4/5 and L5/S1
Robotic Assistance – Left; Freehand on the Right

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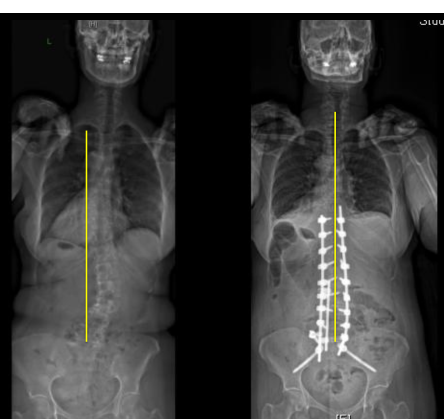
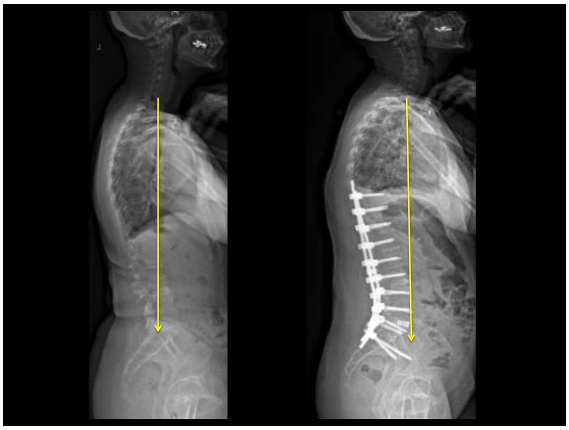
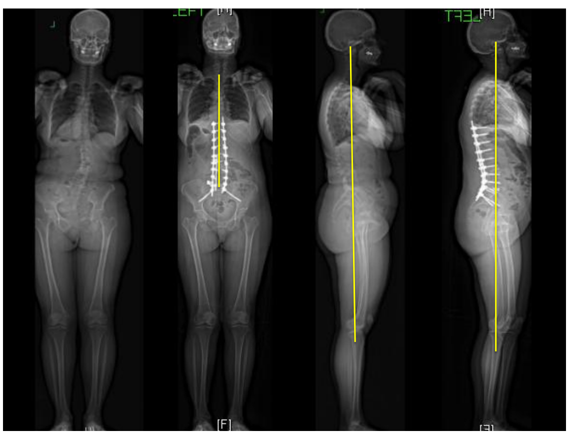
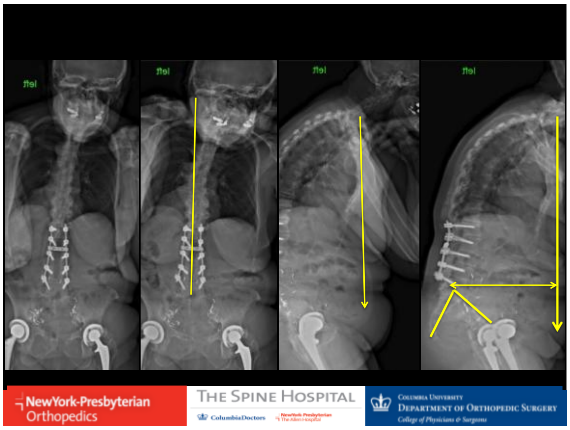






Three Column Osteotomies (3CO)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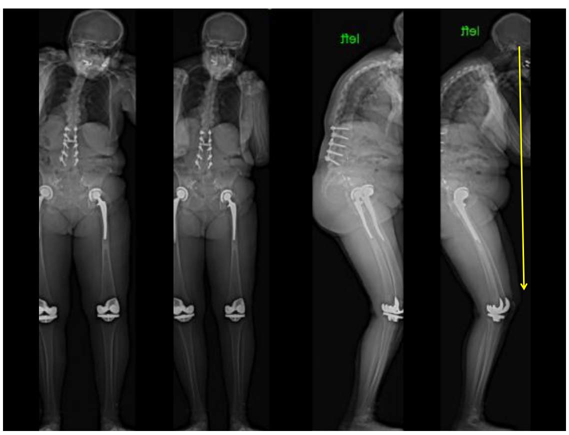
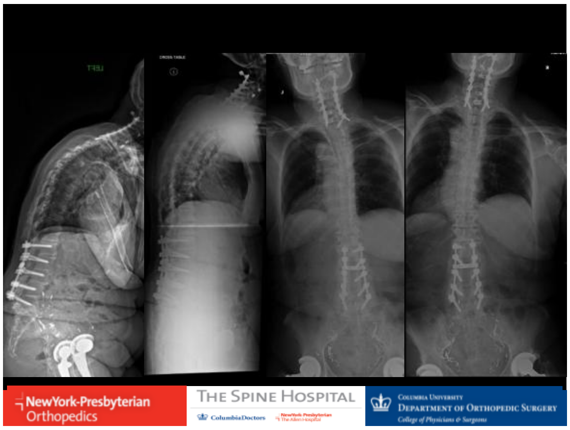
Orthopedics
The Spine Hospital
Columbia University
Department of Orthopedic Surgery
College of Physicians & Surgeons

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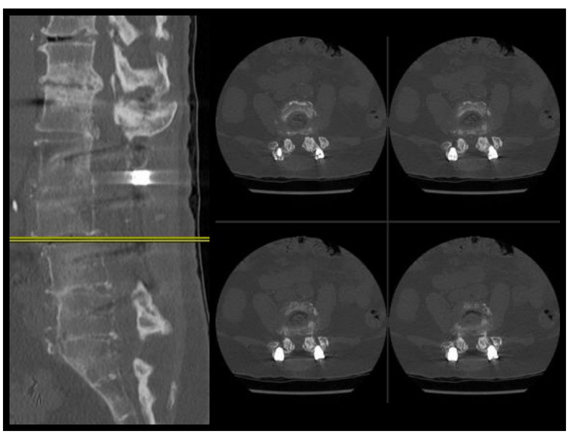

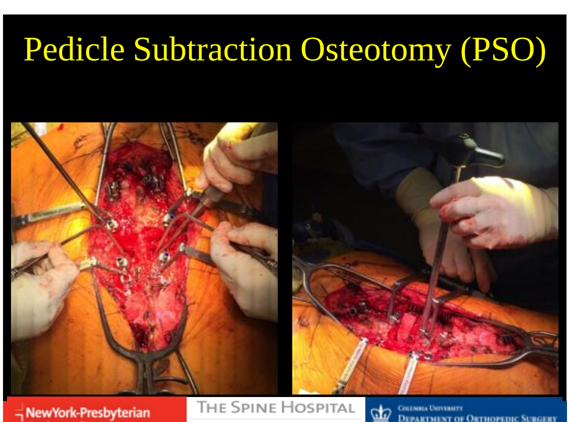
Pedicle Subtraction Osteotomy (PSO)
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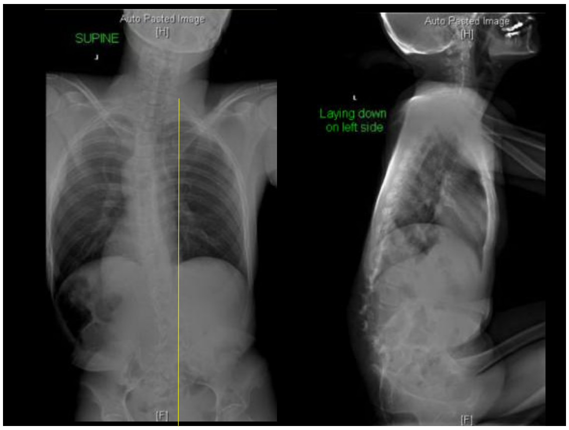
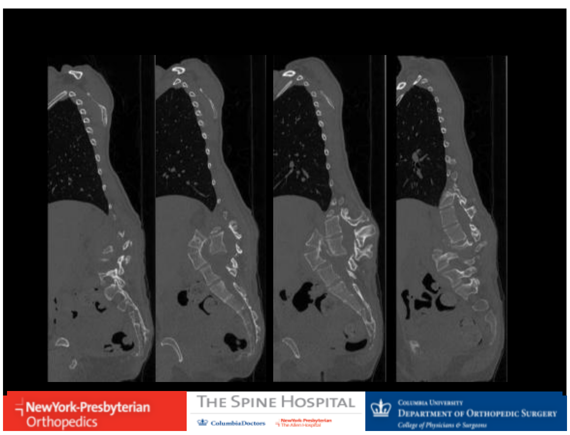
COMPLEX CASES


Auto Pasted Image
[H]
SUPINE
[F]
Auto Pasted Image
[H]
Laying down on left side
[F]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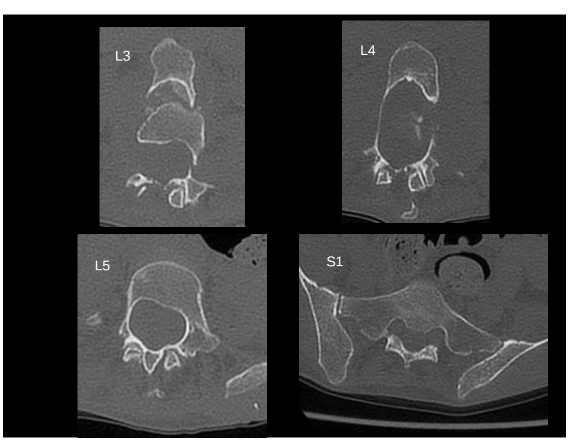
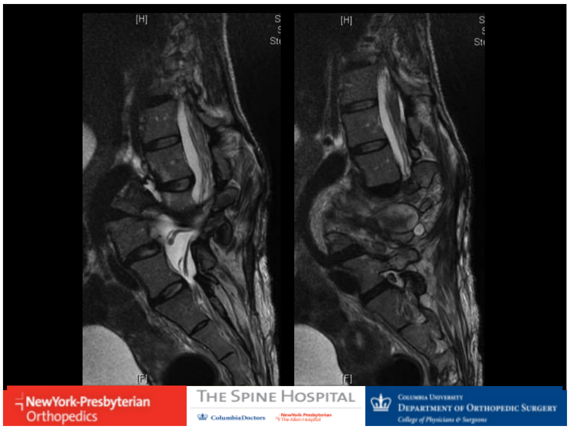
College of Physicians & Surgeons


L3
L4
L5
S1


[H]
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NewYork-Presbyterian Orthopedics
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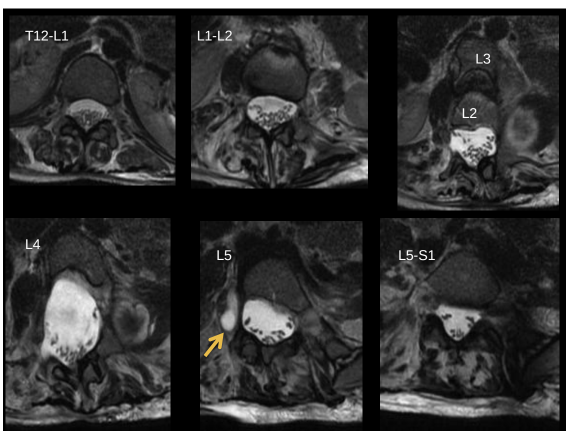
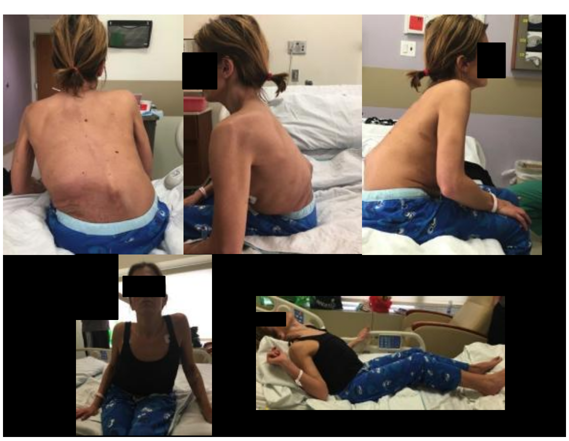
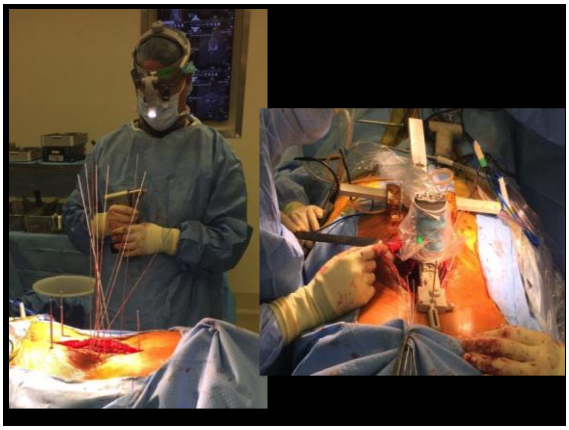
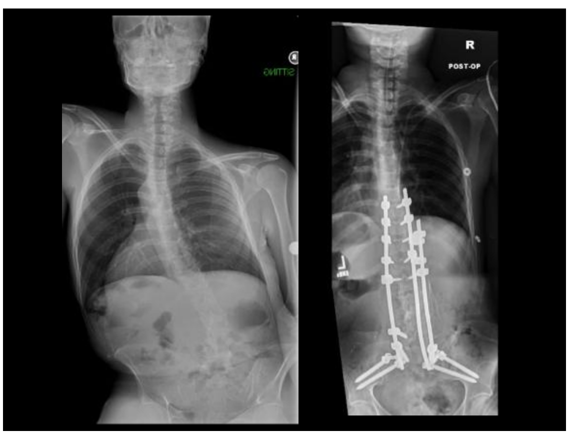
Department of Orthopedic Surgery


T12-L1
L1-L2
L3
L2
L4
L5
L5-S1






R
POST-OP


SITTING
X-Table
INTRA-OP
OR PORTABLE
L

Current Limitations

1. Work Flow Changes
   1. Requires screw preparation first
   2. Cannot remove bone
2. Mandates CT scan (pre or intraop)
   1. Less radiation for OR Team (vs. flouro)
   2. More radiation for patient (vs Freehand or flouro)
3. Time
   1. More than Freehand Technique
   2. </= Flouro and Navigation
4. Accuracy
5. Unable to negotiate difficult deformities

All Adult Deformity is NOT the same

adult deformity

ADULT DEFORMITY

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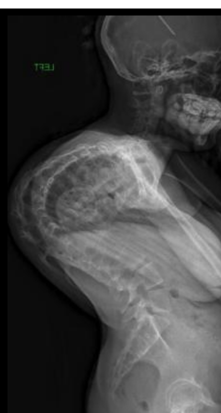


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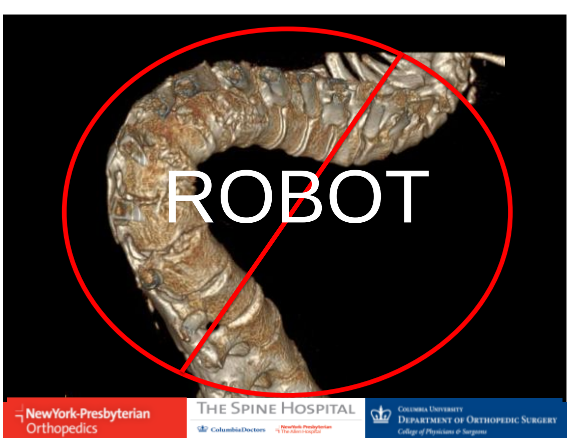
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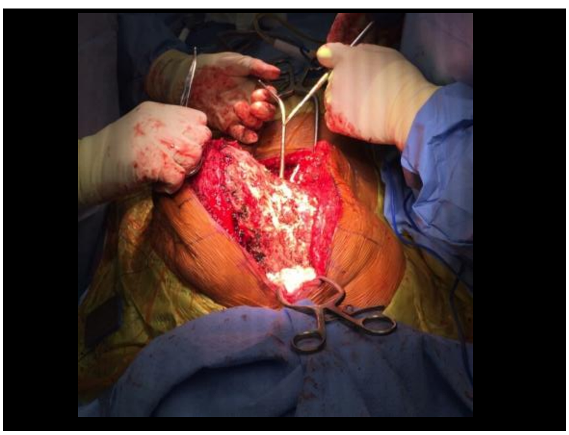
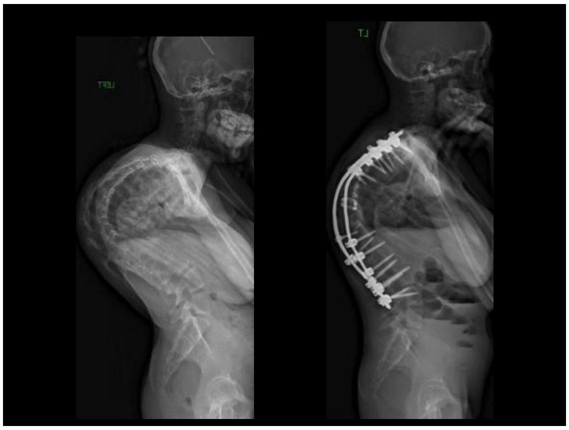
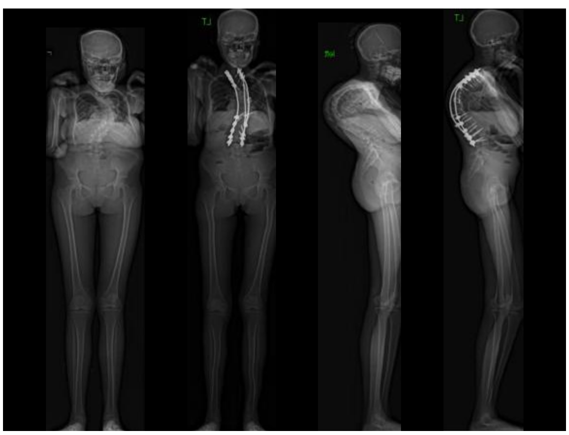
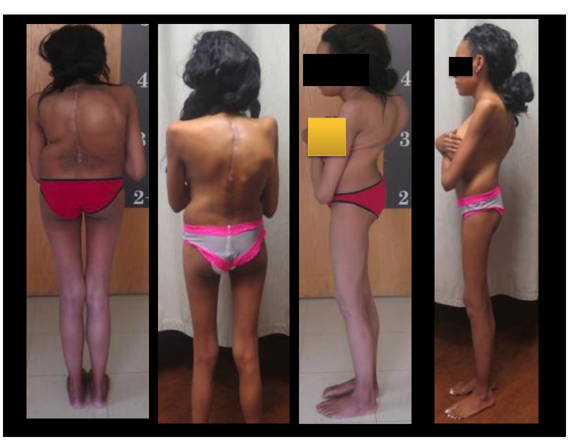




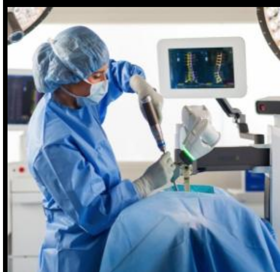


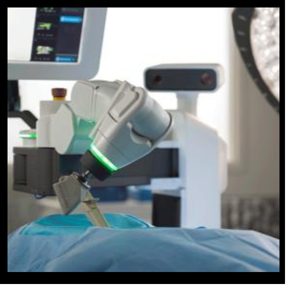


Future and Now

Intraoperative Alignment Correction

Improved DOF / Less Constraint





Thank You!

Ronald A. Lehman, Jr., MD
Professor of Orthopedic Surgery, Columbia University
Chief, Degenerative, Minimally Invasive & Robotic Spine
Complex Pediatric and Adult Scoliosis Service
Co-Director, Spine Fellowship
Director, Clinical Spine Research
Co-Director, Orthopaedic Clinical Research

www.spinesurgeonlehman.com

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CASE REPORT: ROBOTIC-ASSISTED EN BLOC SACRAL OSTEOSARCOMA RESECTION

restore
ORTHOPEDICS AND SPINE CENTER

S. SAMUEL BEDERMAN
MD PhD
FRCSC

SCOLIOSIS AND SPINE SURGEON

RESTORE ORTHOPEDICS AND SPINE CENTER

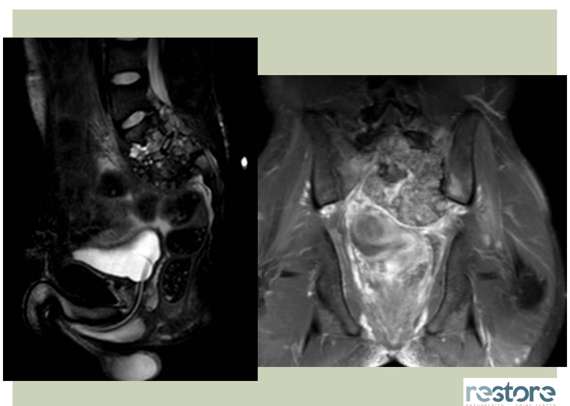
ORANGE COUNTY CALIFORNIA

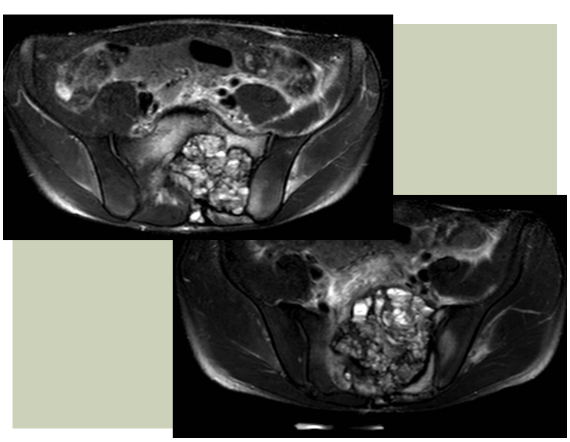
DISCLOSURES

- MAZOR ROBOTICS
  - Consulting/Surgeon Education
- SPINEART
  - Royalties
  - Consulting
  - Stock Options

HISTORY

- 22M with one year history of progressive low back pain followed by bilateral leg pain.
- Developed urinary retention, scrotal numbness, and progressive difficulty ambulating secondary to pain
- Examination:
  - saddle anesthesia and S1 numbness
  - Full motor strength in bilateral lower extremities with normal patellar and Achilles reflexes



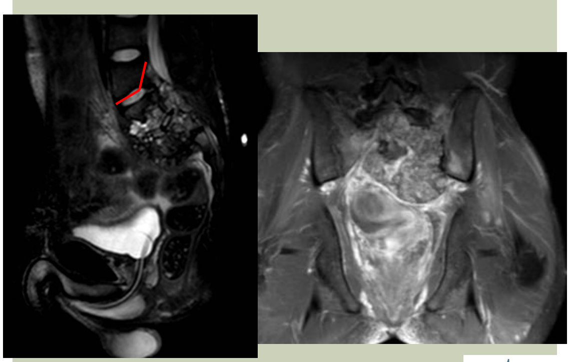


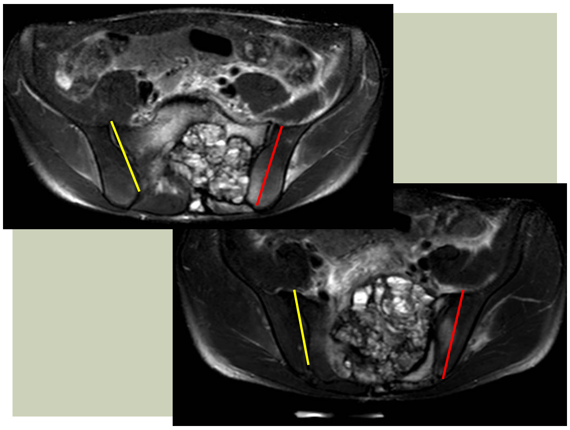
DIAGNOSIS BY OPEN BIOPSY

SACRAL TELANGIECTATIC OSTEOSARCOMA

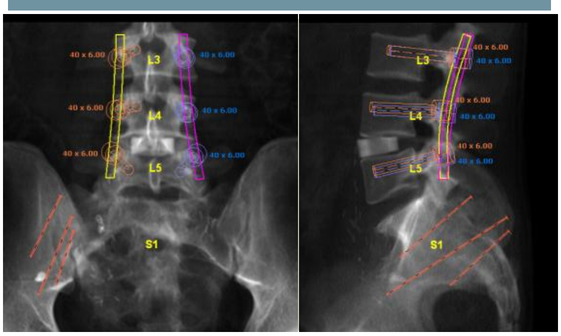
TREATMENT

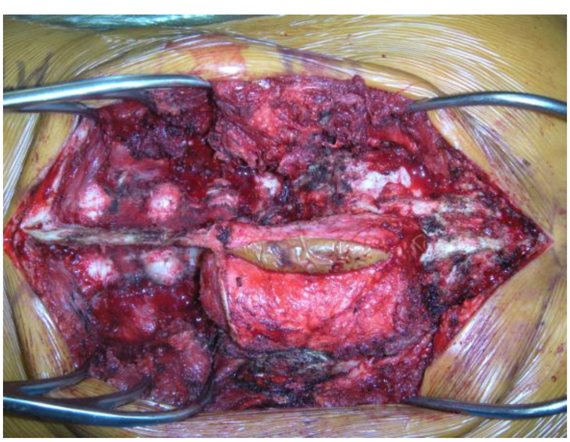
- Pre-op chemo
- Wide en-bloc sacrectomy with L3-Pelvis PSIF
  - Stage 1 (anterior)
    - L5-S1 disc release with anterior dissection
    - L4-L5 ALIF
  - Stage 2 (posterior)
    - En bloc sacrectomy
      - Trans-articular margin on right
      - Trans-iliac margin on left (ROBOTIC-ASSISTED)
      - Partial L5 corpectomy
      - L3 to Pelvis instrumentation with anterior cage
- Post-op chemo

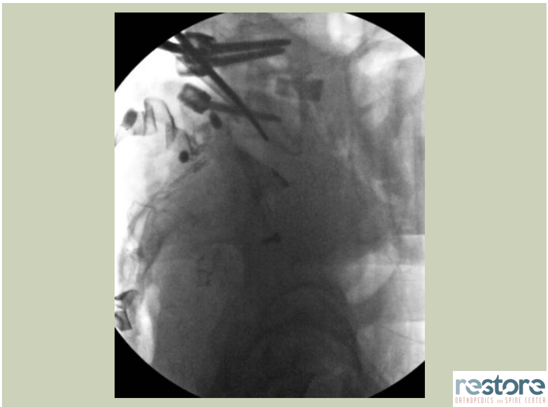




OSTEOTOMY PLANNING



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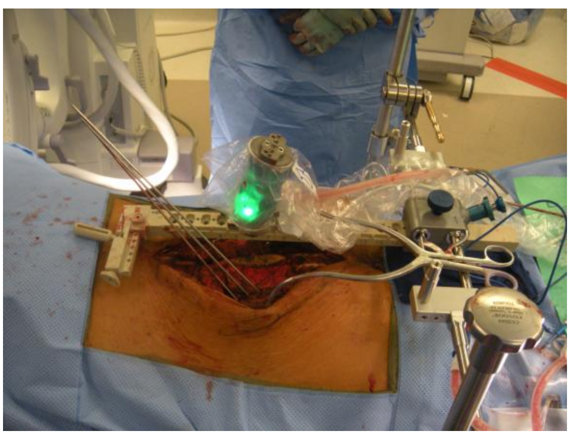
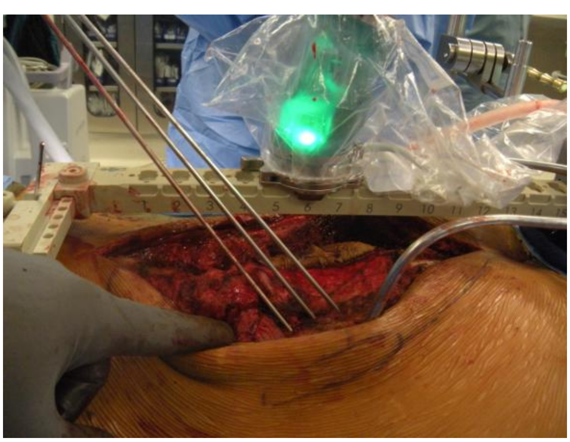
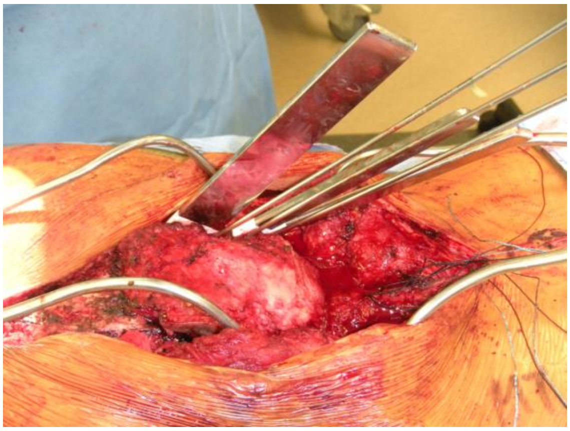
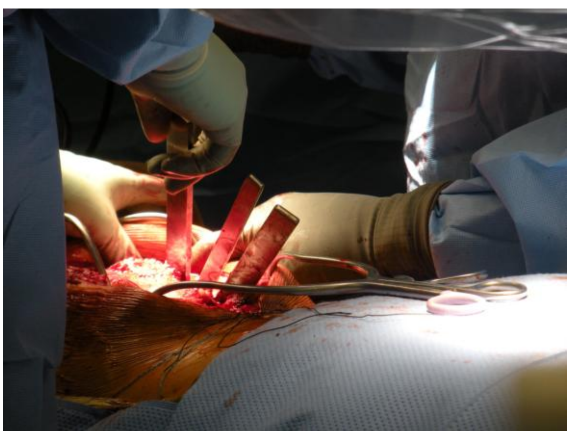
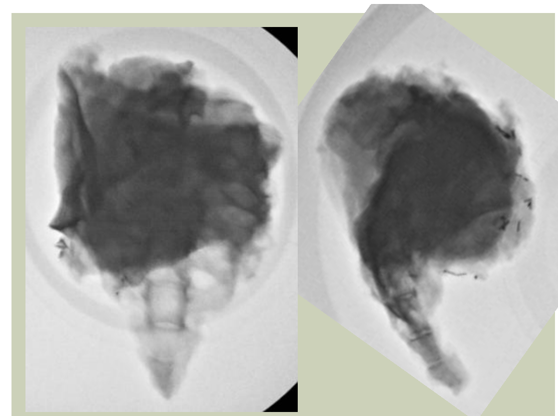
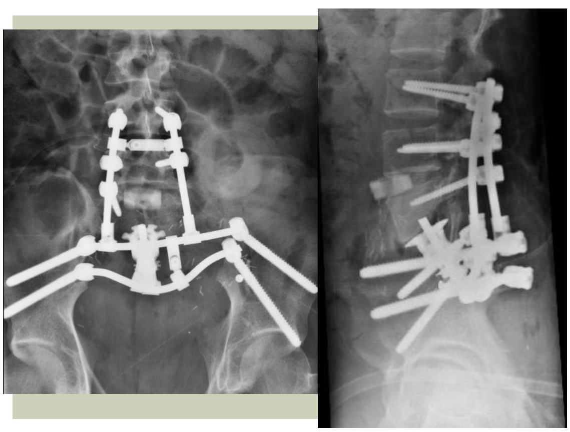


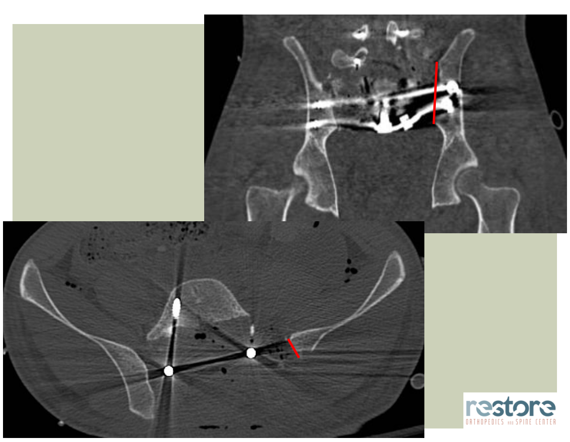











restore

THANK YOU

RESTORE ORTHOPEDICS AND SPINE CENTER

ORANGE COUNTY CALIFORNIA

SI Joint Fusion with Mazor Renaissance

Ben Guiot, MD, FRCSC

December 2016

1

Case Presentation

- 58 year old male
- Sharp stabbing pain overlying the L SI joint
  - 24/7. Worse with activity
  - non radiating
  - no radicular symptoms or signs

Case Presentation - continued

- Imaging:
  - Plain x-rays reveal normal alignment
  - CT scan – DDD and facet arthropathy. Vacuum phenomenon in L SI joint.
  - MRI – DDD and facet arthropathy. No focal compression

Case Presentation - continued

- Non operative management:
  - PT
  - SI joint injections – 100% pain relief in the anesthetic phase. No long term relief
  - RFA – no long term relief

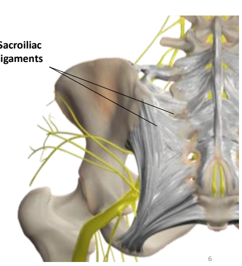
SI Joint: Symptom Presentation

- Low back pain
- Buttock pain
- Thigh pain
- Sciatic-like symptoms
- Difficulty sitting in one place for too long due to pain
- Poor sleep habits

5

Anatomy – Ligaments

- Strong ligaments encase each joint
- Ligaments affect stability
- If damaged, may have excessive motion
- Excessive motion may inflame and disrupt the joint and surrounding nerves



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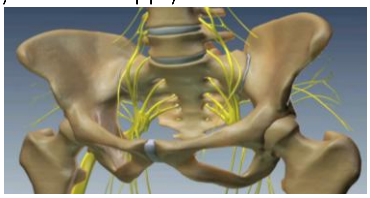
Anatomy – Nerve Supply of Pelvis



Diagnosing: Provocative Tests



Distraction Test

- The sacroiliac joint is stressed by the examiner, attempting to pull the joint apart

Compression Test

- The two sides of the joint are forced together. Pain may indicate that the sacroiliac joint is involved.

Gaenslen's Test

- Lay on a table, one leg drops over the edge and the supported leg is flexed. In this position, sacroiliac joint problems will cause pain because of stress to the joint.

FABER Test

- The leg is brought up to the knee, and the knee is pressed on to test for hip mobility.

Diagnosis

- Clinical
- Imaging – limited benefit
- Injections

Treatment Options

- Non operative
  - NSAIDs
  - Analgesics
  - PT
  - SI belt
  - Injections
  - RFA
- Operative

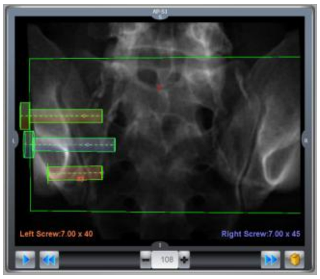
Surgery

- Why use navigation?
  - Poor visualization of relevant anatomy on fluoroscopy
    - Superior aspect of the sacral ala
    - Anterior aspect of sacrum – ala and body
    - S1 neural foramina
  - Percutaneous

Surgery

- Robotic guided SI joint immobilization:
  - Pre operative CT scan of lower lumbar spine, sacrum and pelvis
  - Pre operative planning for placement of device across the joint
  - GPS speaks to robot

Planning in Coronal View



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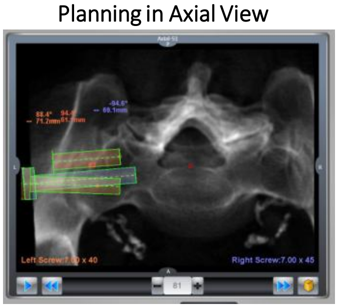
Planning in Axial View



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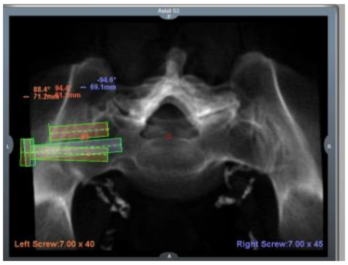
Planning in Sagittal View

15

Planning in Axial Video



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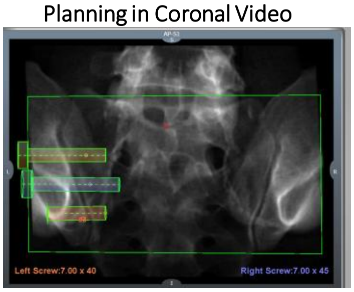
Planning in Coronal Video



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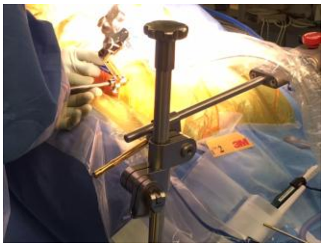
Mounting Multi Directional Bridge

18

Operating



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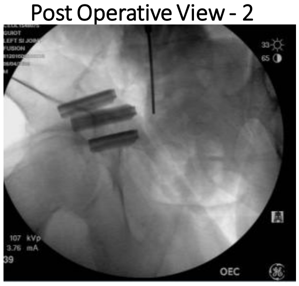
Post Operative View - 1

20

Post Operative View - 2



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Post Op Lateral View

22

Case Information and Data Points

- Start Time: 1:56pm
- End Time: 2:38pm
- Registration Fluoro Time: Seven Seconds
- Total Fluoro: 41 seconds

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Questions?

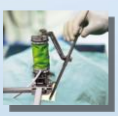
Thank You

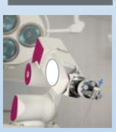
The Future of Robotic Spine Surgery

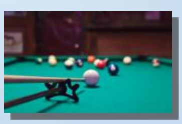
Christopher R. Good, MD, FACS
Director of Research
Director of Scoliosis and Spinal Deformity Surgery

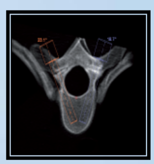
Virginia Spine Institute
www.SpineMD.com

Robotic Spine Surgery – The Past
Trajectory Guidance









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Robotic Spine Surgery – The Past
Trajectory Guidance

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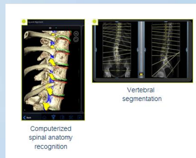
Robotic Spine Surgery – The Future
Current or developing technical advancements:

- Improved 3D pre-op anatomy
  - Merging pre-op imaging studies
    - CT, Scoli X-rays, Flexibility X-rays
  - Incorporate developing planning software
- Stronger Robotic Arms
  - More accurate trajectories
  - More tools available
    - Drills, burrs, bone cutters
- Merge with Navigation
  - Real-time feedback
- Merge with implants
  - Contour/cuts rods
  - Assist in Correction



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Robotic Spine Surgery – The Future
Pre-operative Assessment

- Pre-op
  - Spinal Alignment Assessment
    - Combine X-ray / CT / MRI
    - Global parameters
    - 3D rotation assessment
    - Segmental analysis
  - Pre-op Planning
    - Implant Positioning
    - Deformity Correction
    - Osteotomy Planning
    - Decompressions

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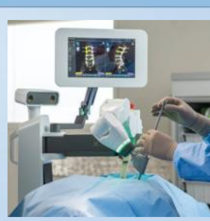
Robotic Spine Surgery – The Future
Intra-op

- Intra-op
  - Trajectory Guidance
  - Improved Reachability
    - Implants
      - Screws
      - SI fusion
      - Tumor
    - Osteotomy
    - Decompression
  - Live intra-op Feedback
  - Rob bend based on robot plan
  - Deformity Correction



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Robotic Spine Surgery – The Future
Conclusions

- Many robots in development, FDA approval/studies ongoing and growing
- Growing Literature
  - >30 Studies
  - Increased accuracy
  - Decreased radiation
  - Decreased complications
- First FDA approved robot
  - 120 systems worldwide, 80 USA
  - >18,000 cases
  - >120,000 Implants
- 2 systems currently FDA approved
  - More to follow

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