# Intraoperative Imaging for Patient Safety and OR Quality Assurance

**Jeff Siewerdsen, PhD**
John C. Malone Professor of Biomedical Engineering
Vice-Chair for BME Clinical and Industry Programs
Computer Science, Radiology, and Neurosurgery
Johns Hopkins University

The I-STAR Lab / istar.jhu.edu
Carnegie Center for Surgical Innovation / carnegie.jhu.edu

# Disclosures

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Siemens Healthineers
- Mobile and Robotic C-Arms

Medtronic
- Intraoperative Imaging and Registration

Carestream Health
- CBCT of the Extremities
- CBCT of Head Trauma

## Advisory and Licensing

Siemens Healthineers
Carestream Health
Elekta Oncology
Precision X-Ray

*This presentation includes research systems and off-label use.

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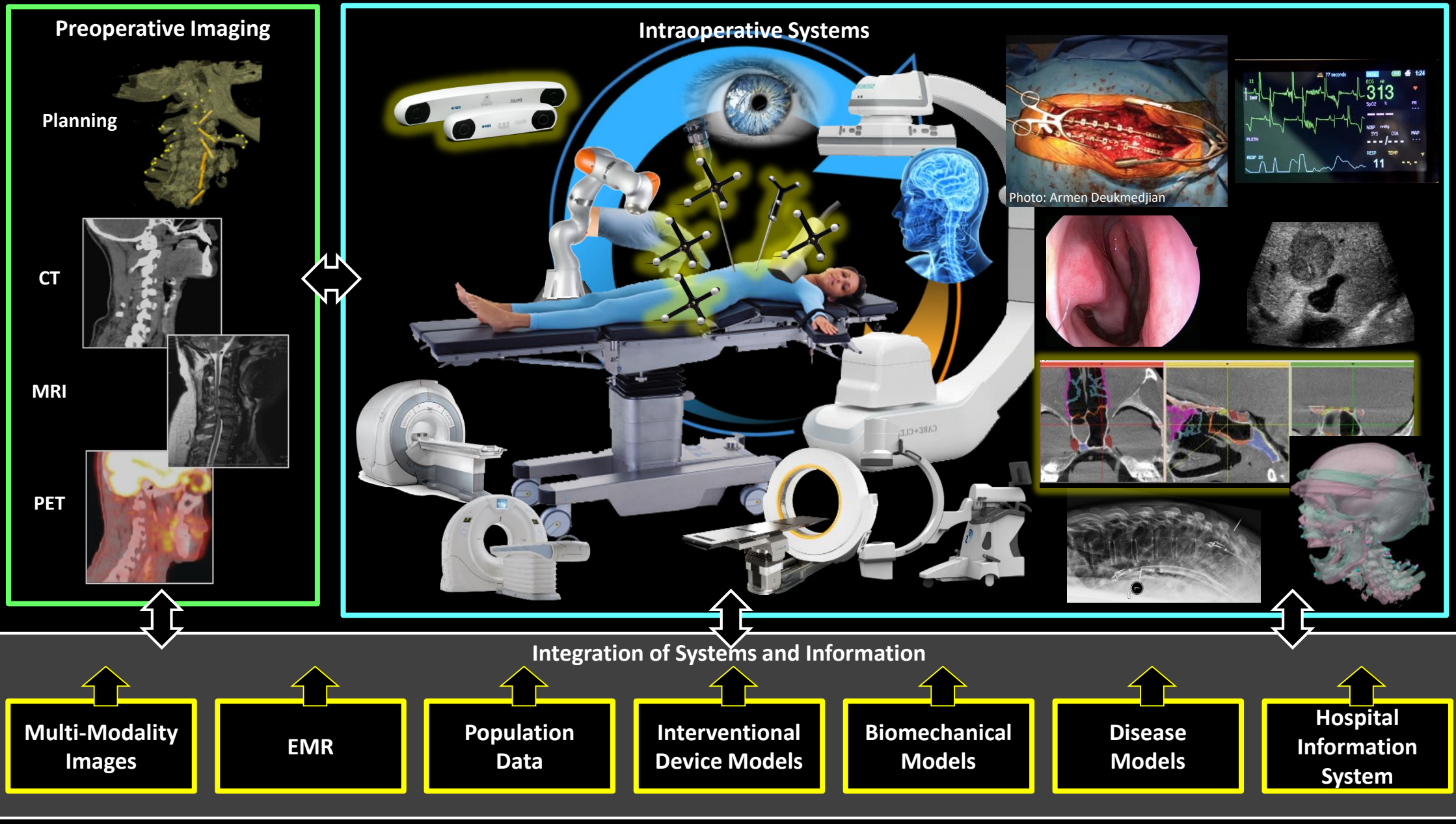
Preoperative Imaging
Planning
CT
MRI
PET
Intraoperative Systems
Photo: Armen Deukmedjian
313
Integration of Systems and Information
Multi-Modality Images
EMR
Population Data
Interventional Device Models
Biomechanical Models
Disease Models
Hospital Information System

## An Enormous (and Growing) Market

- 0.5M spinal fusion surgeries / yr
- $12B / year (70% increase 2001 – 2011)
- 7.5% compound annual growth by 2019

## High Range in Variability (Quality)

- Up to 53% of patients have comorbidity
- Approximately 8-25% of patients rehospitalized
- High variability in surgical outcomes

## A Major Source of Adverse Events

| | |
|---|---|
| Adverse event: | 16-28% |
| Device malplacement: | ~2-16% |
| Revision surgery: | ~1 in 150 |
| Wrong-level surgery: | ~1 in 3000 |

("Unintended-level" surgery)

THE WALL STREET JOURNAL.

**Rate of Spine Surgery Soars**

The Washington Post

**Spinal fusions serve as case study for debate over when certain surgeries are necessary**

The Washington Post

**Researchers: Medical errors now third leading cause of death in United States**

Wong et al, "Medical errors in orthopaedics. Results of an AAOS member survey," J Bone Joint Surg Am (2009)

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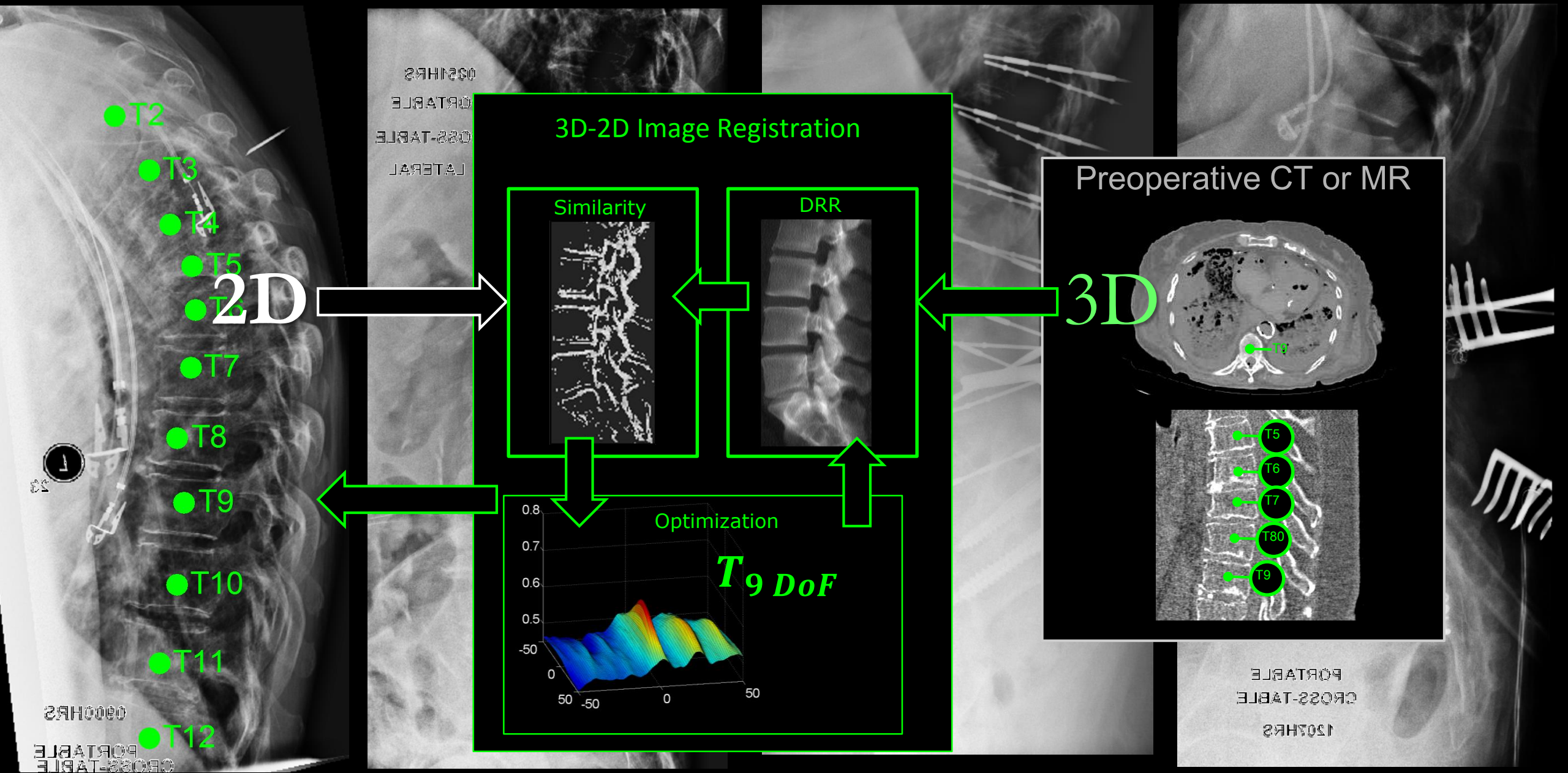
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2D
3D-2D Image Registration
Similarity
DRR
Optimization
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Preoperative CT or MR
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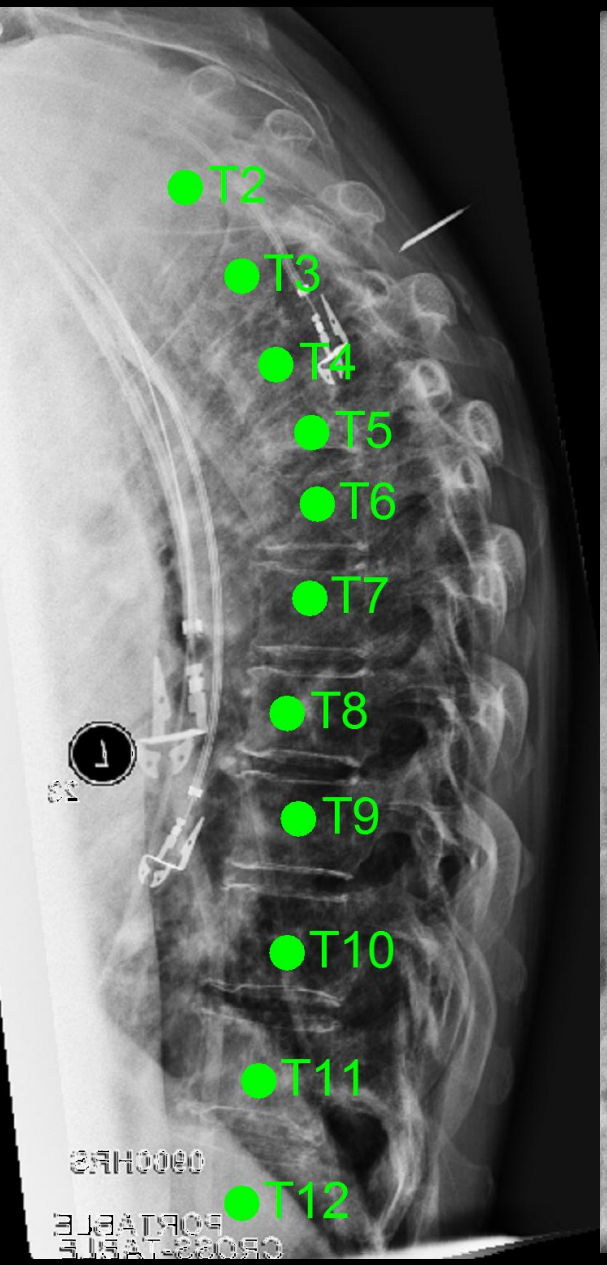
T80
T9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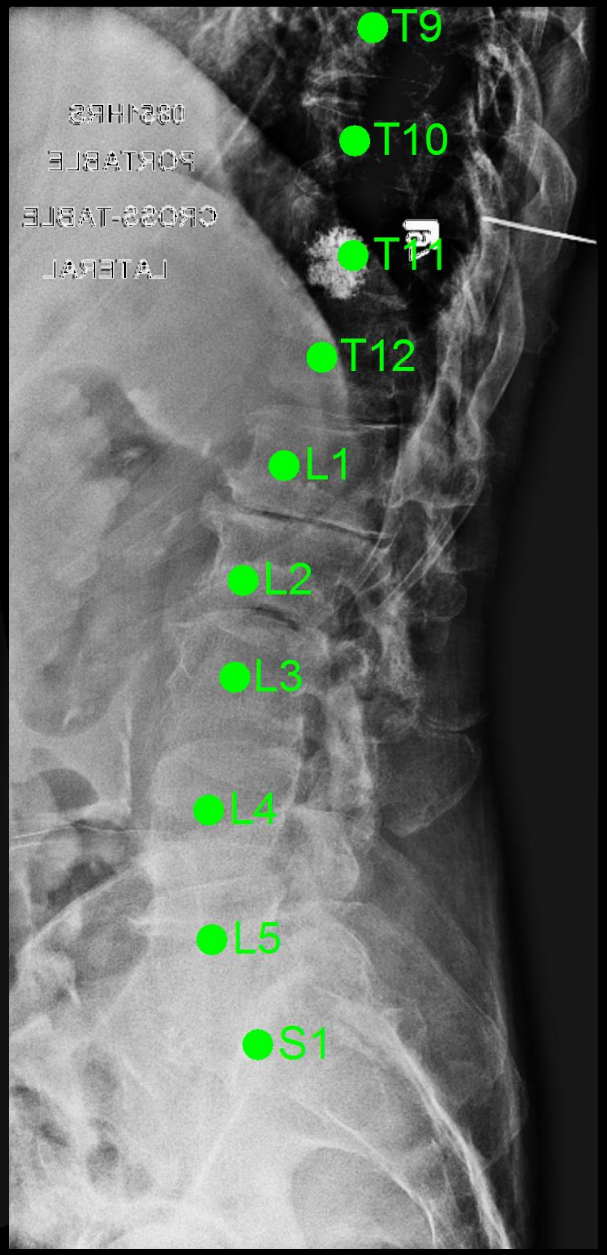
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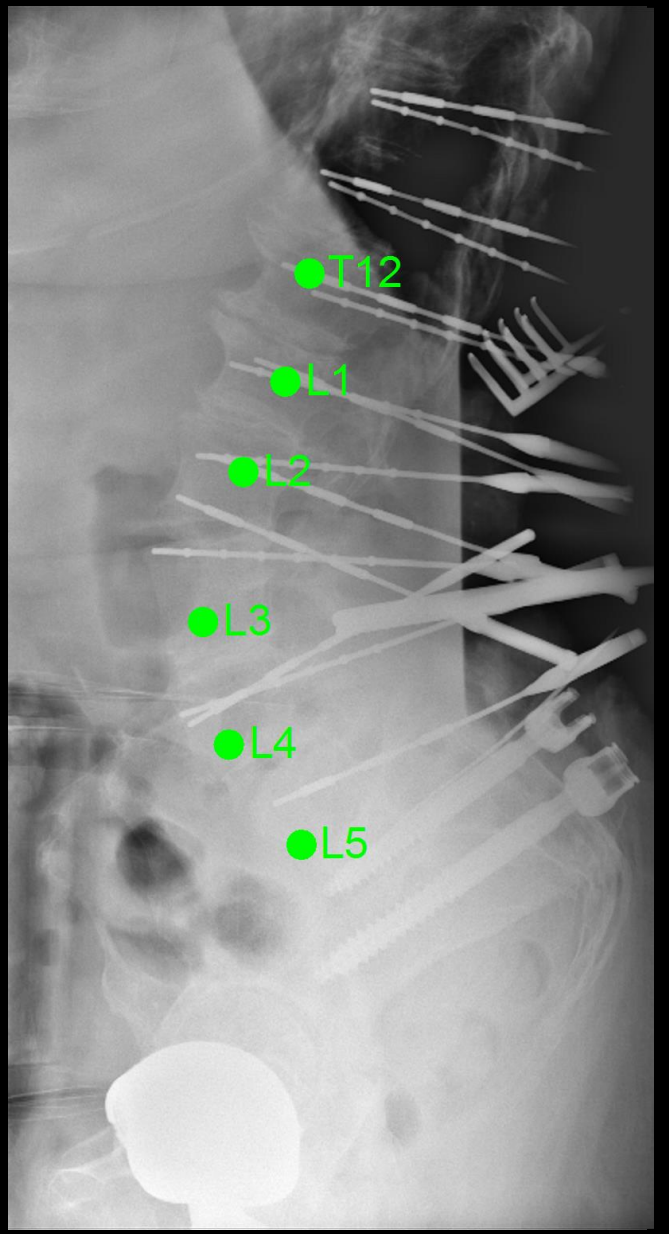
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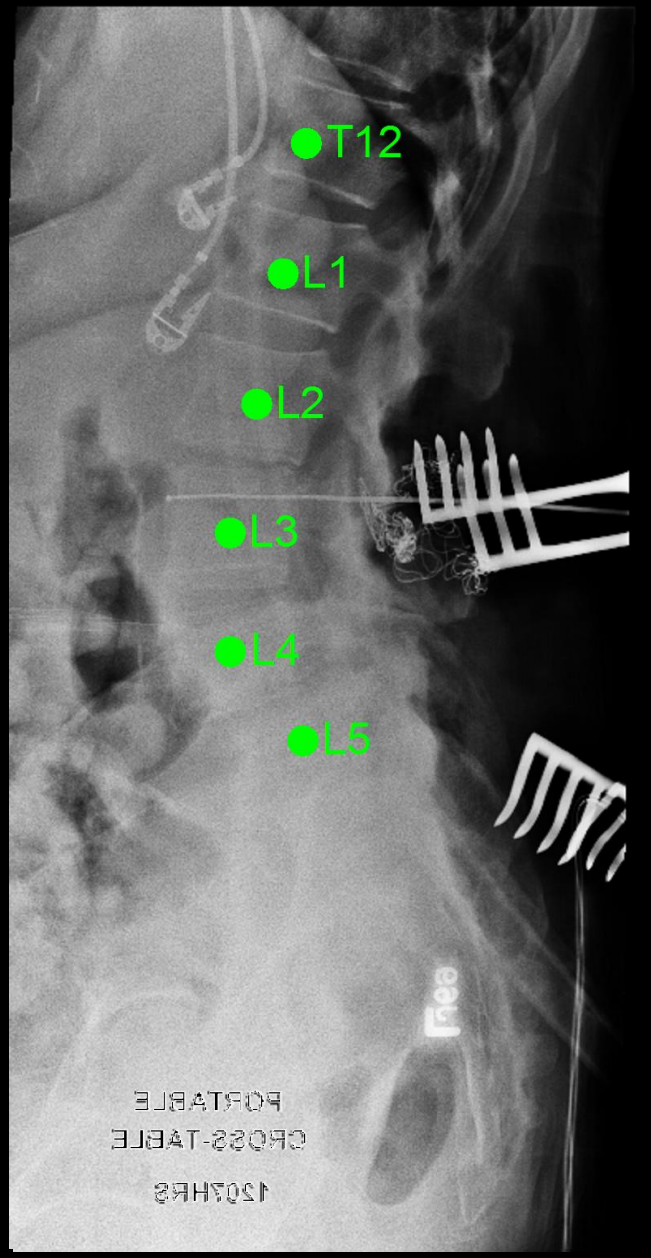
T12
L1
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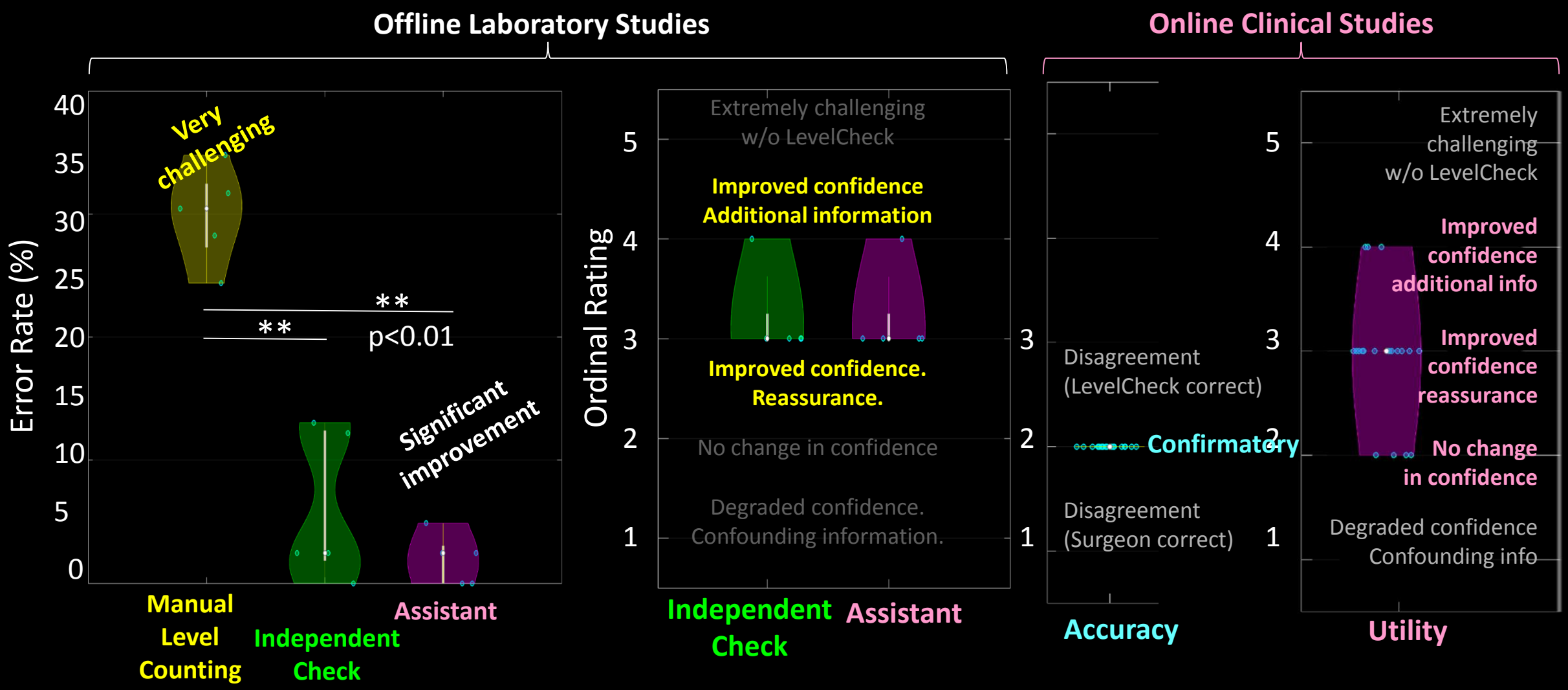
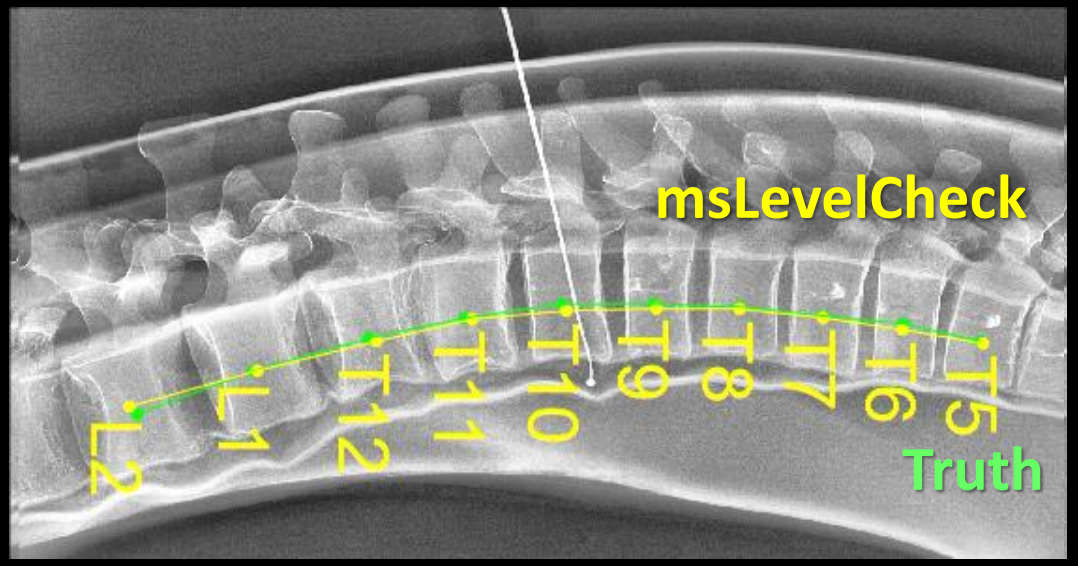
# Clinical Translation: *LevelCheck*

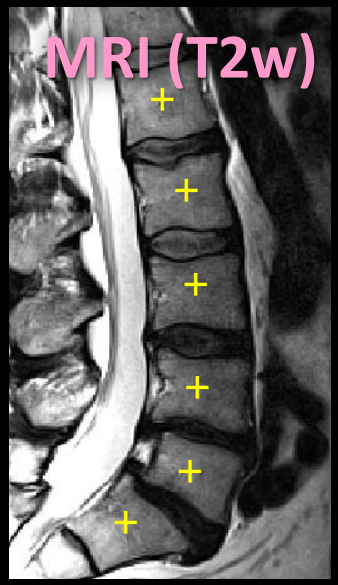


# LevelCheck: Extensions

**msLevelCheck (Deformable)**
Multi-stage pyramid
Phantom and clinical pilot studies
*Ketcha et al., Phys Med Biol 62(11)(2017)*

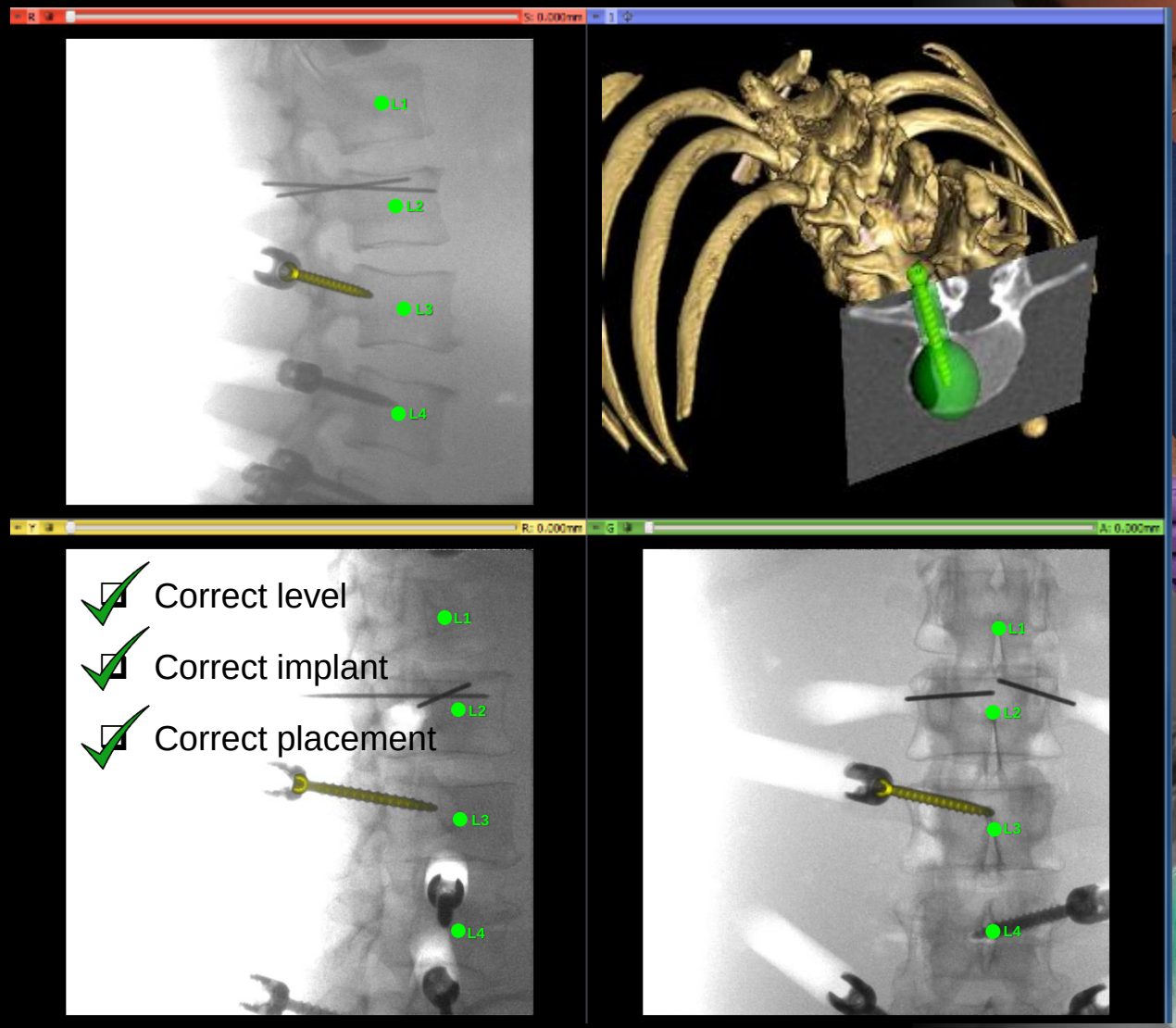



**MR-LevelCheck (MRI-to-radiograph)**
Simple segmentation + robust similarity
Clinical studies
*De Silva et al., Phys Med Biol 62(2)(2017)*



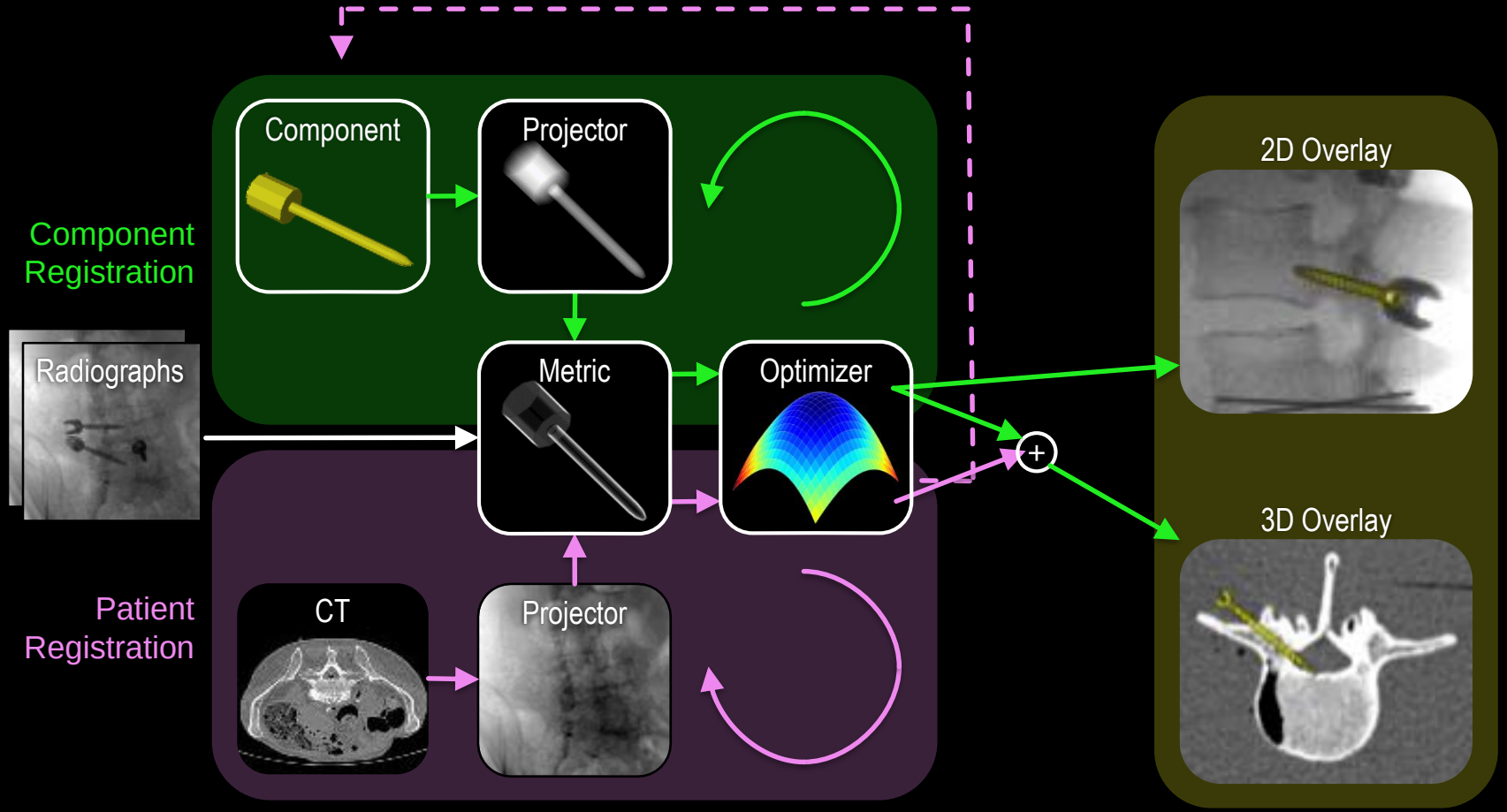


# OR Quality Assurance (ORQA)




- ☑ Correct level
- ☑ Correct implant
- ☑ Correct placement

# 3D-2D Registration for Intraoperative QA

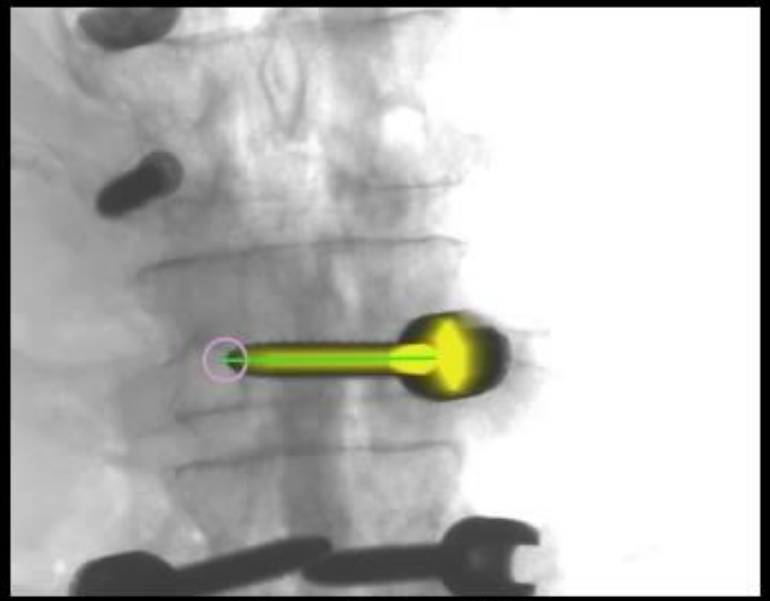



Uneri et al. Phys Med Biol (2014)
Uneri et al. Phys Med Biol (2015)

# 3D-2D Registration for Intraoperative QA

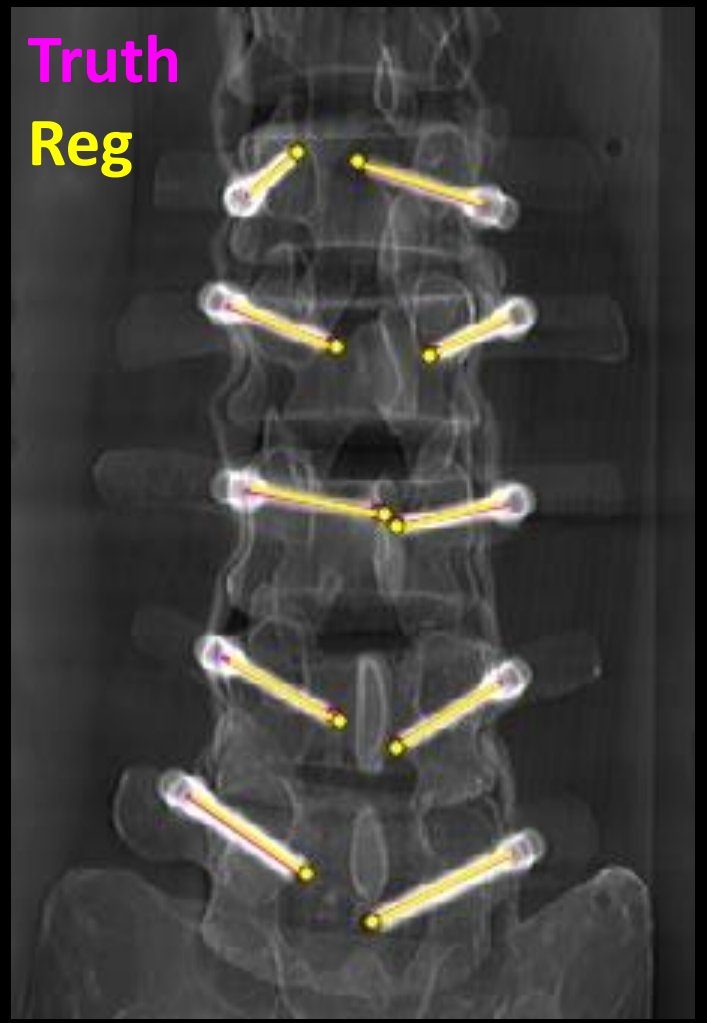
Polyaxial Pedicle Screw

Known-Component (KC) Model

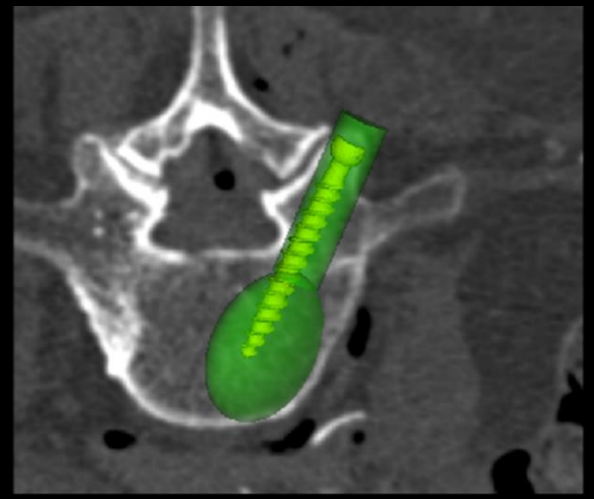


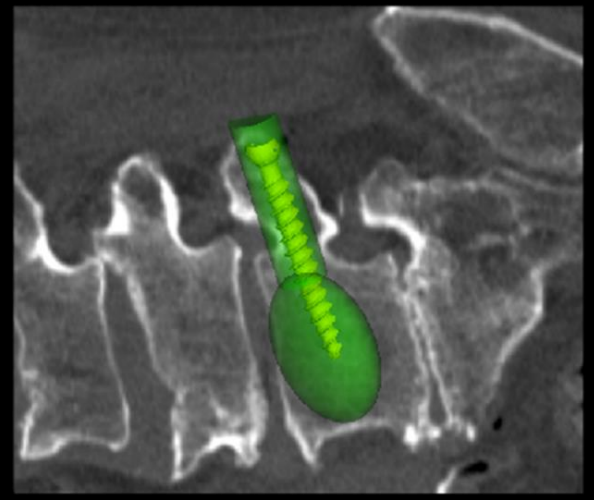
Iteration = 89

2D Overlay



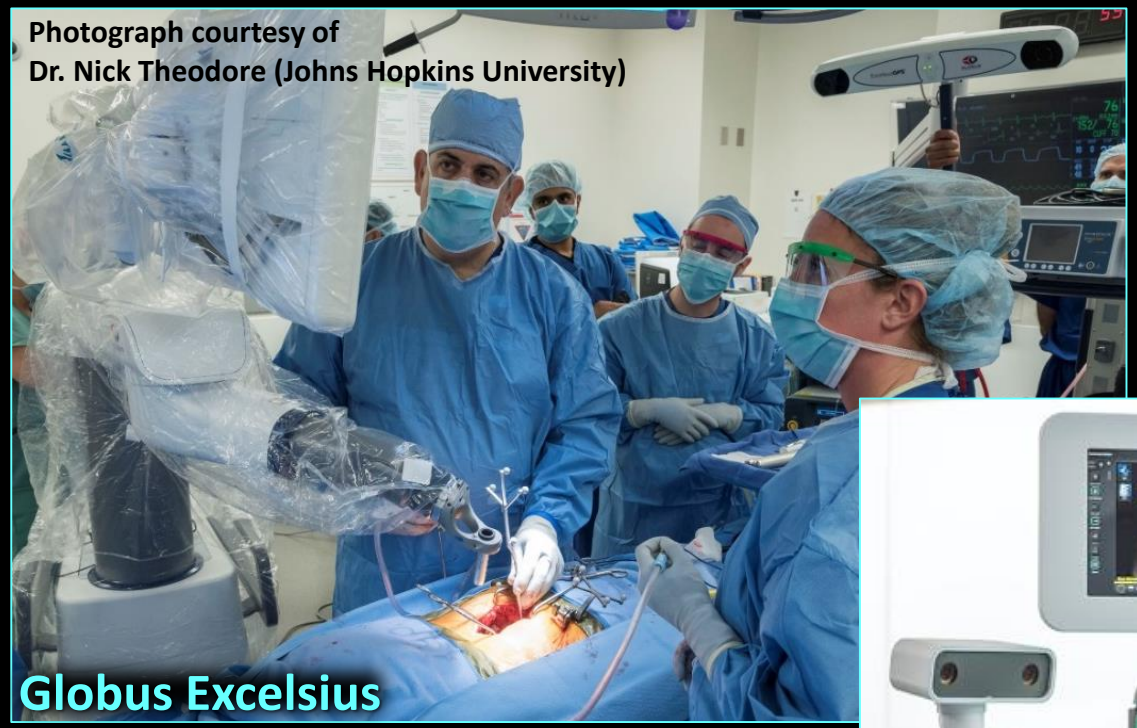

3D Overlay





Uneri et al. Phys Med Biol (2014) and (2015)

# Emerging Landscape of Surgical Robotics






**Current Approaches**

Integration with surgical navigation

Robot used for precise positioning of trans-pedicle instrumentation

**Potential Advantages**

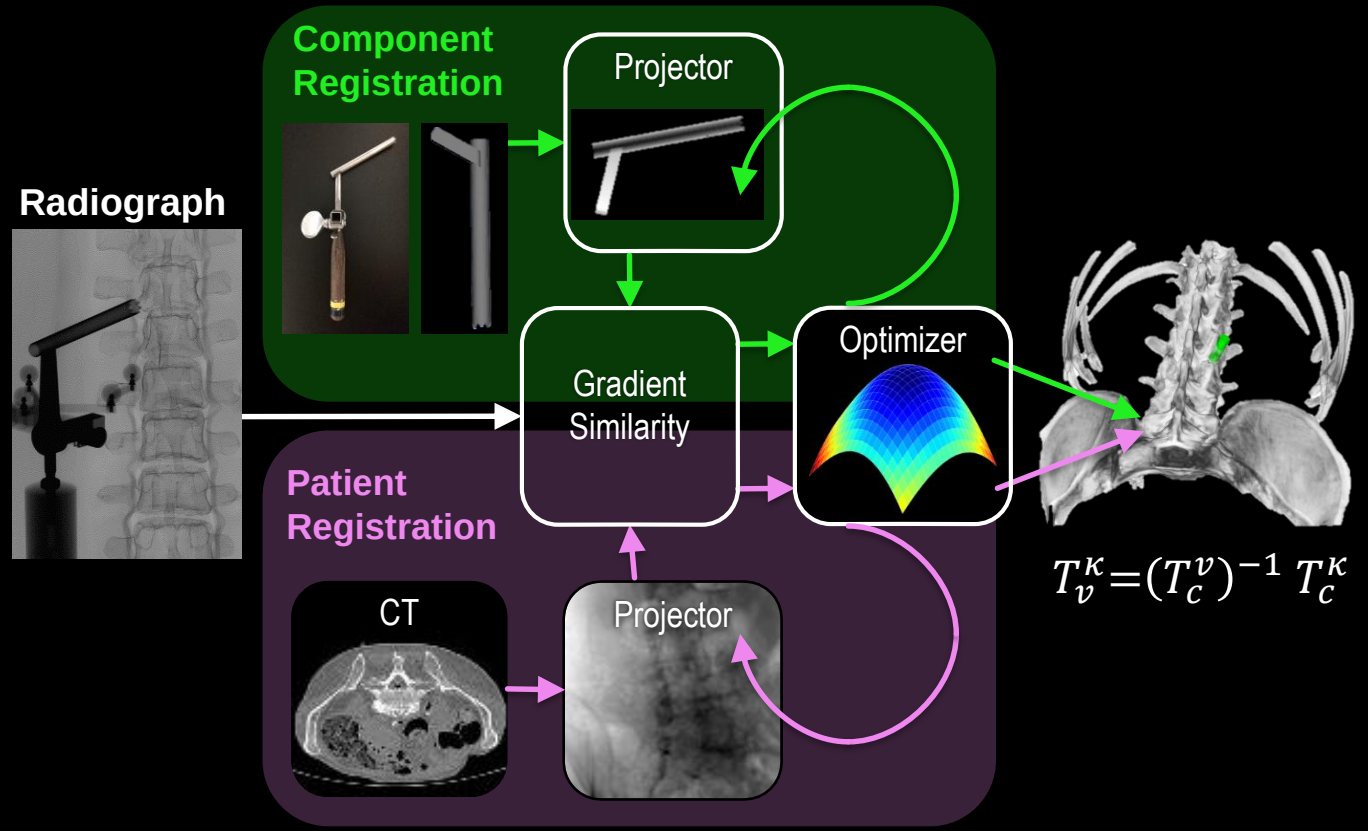
Precision, safety, and workflow

**Potential Limitations**

Precision and workflow are limited by (conventional) navigation using surgical trackers

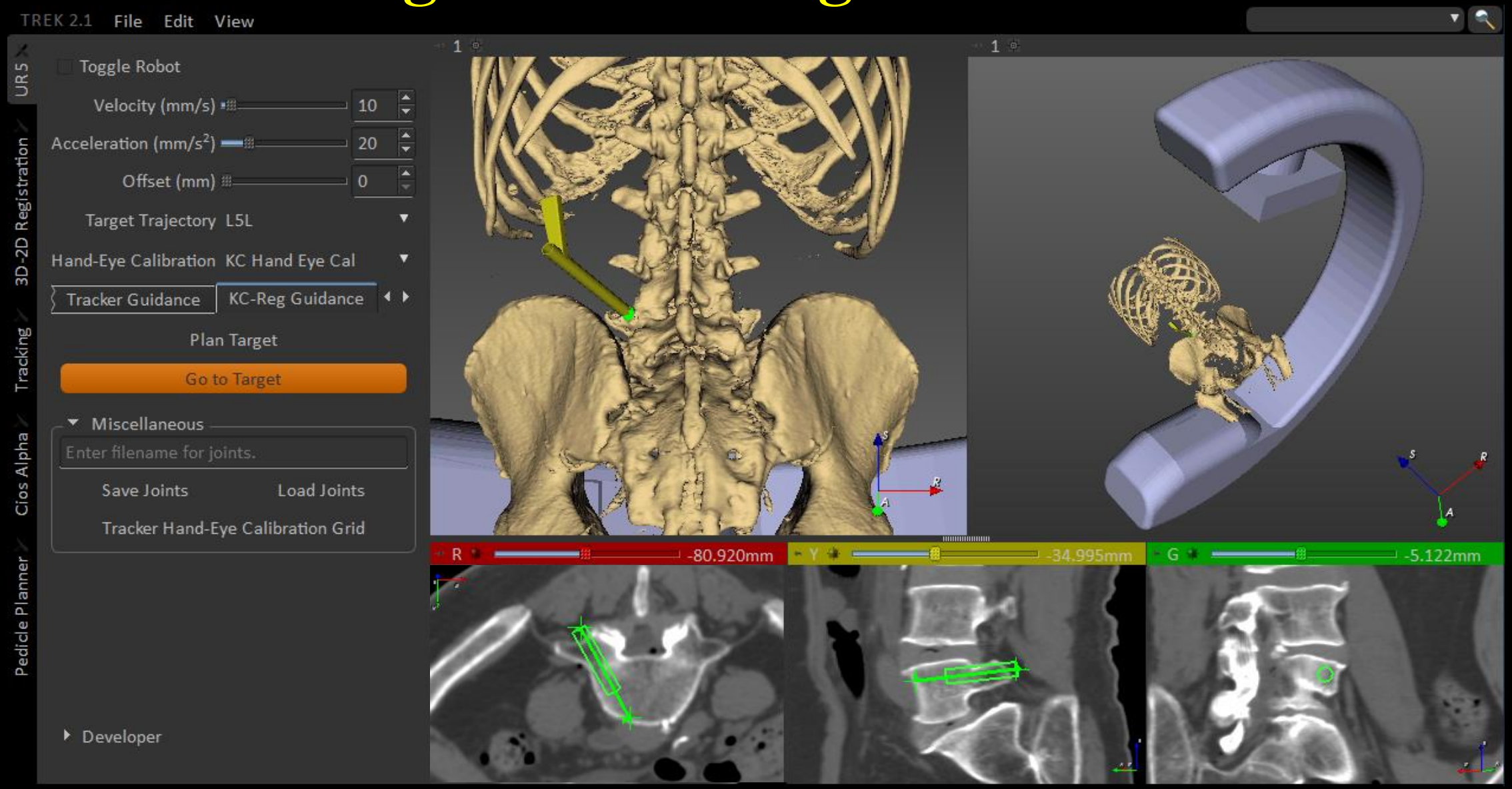
# Surgical Robotics: without Trackers

## X-Ray Guided Surgical Robot



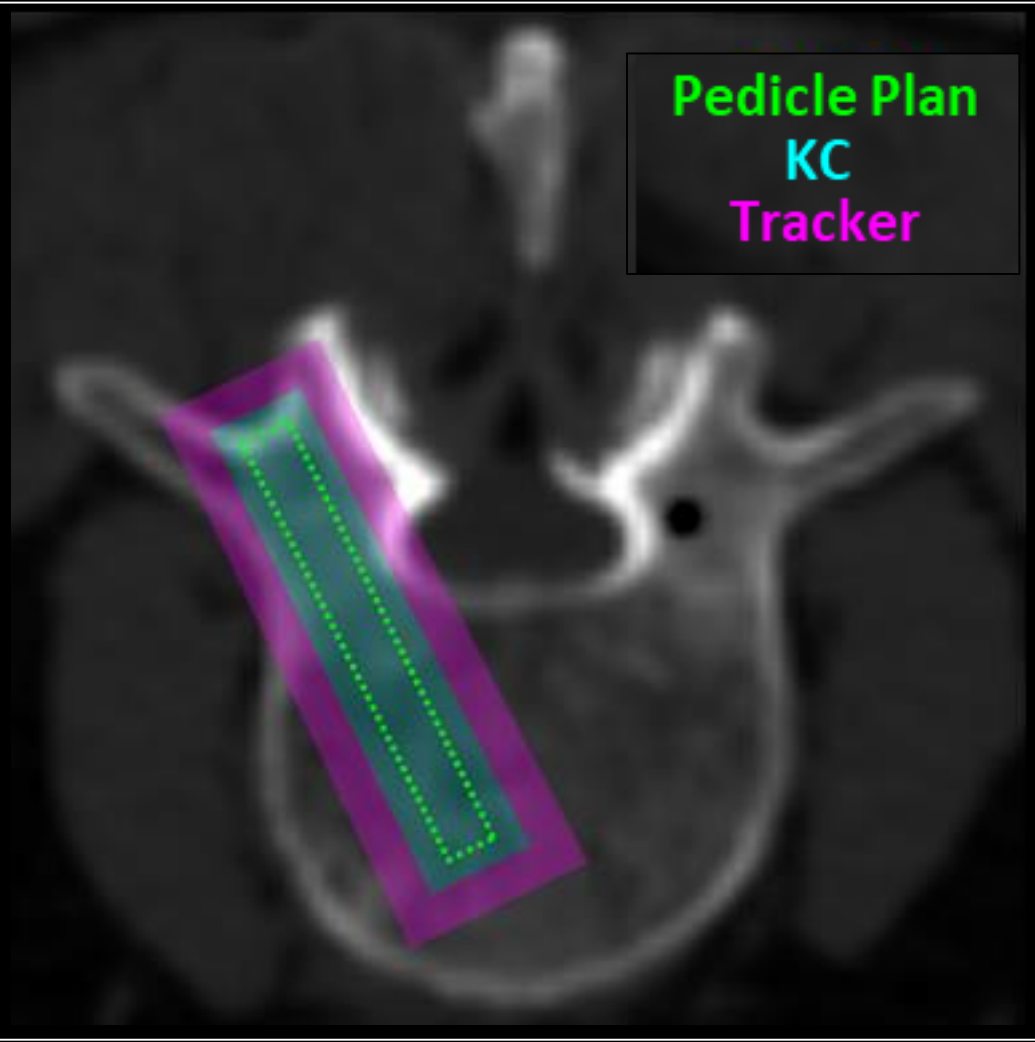

Thomas Yi et al. J. Med. Imag. (2018)

# Image-Guided Surgical Robotics



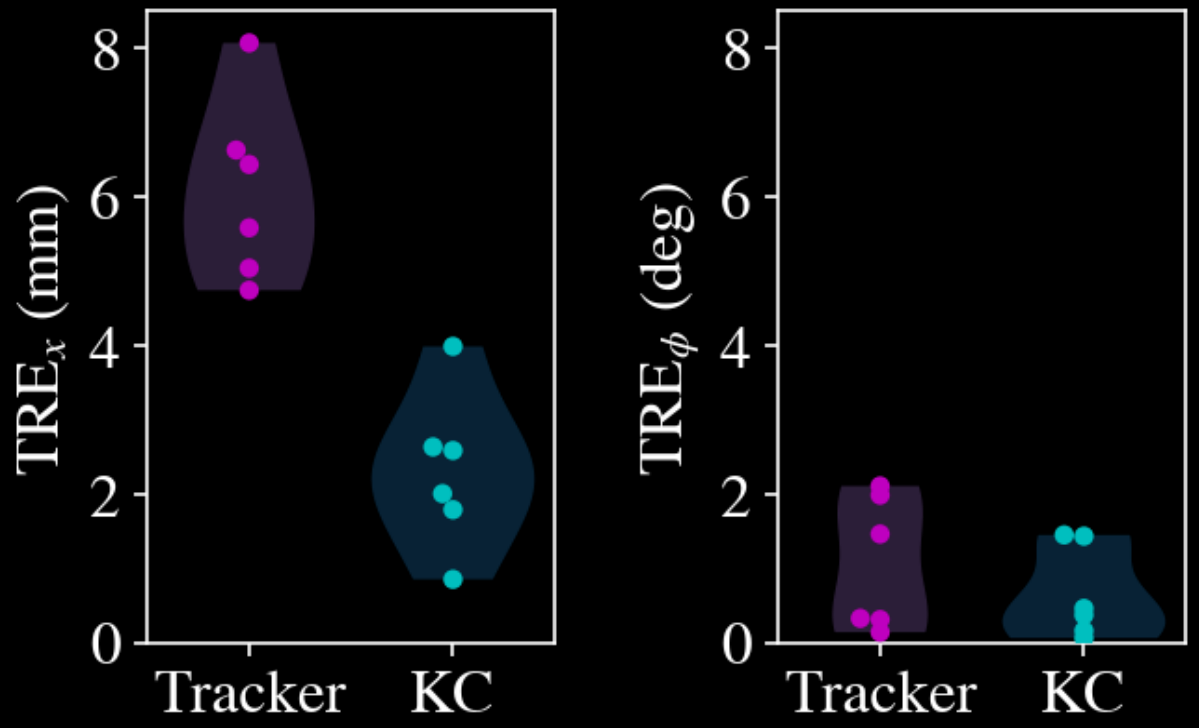

Uneri et al., "TREK: …" IJCARS (2011)

# Image-Guided Surgical Robotics




**Cadaver Studies**

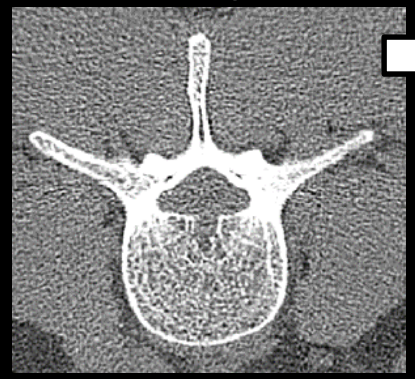
Strong Deformation between preop CT and intraop fluoroscopy
Robot-Assisted Pedicle Screw Placement

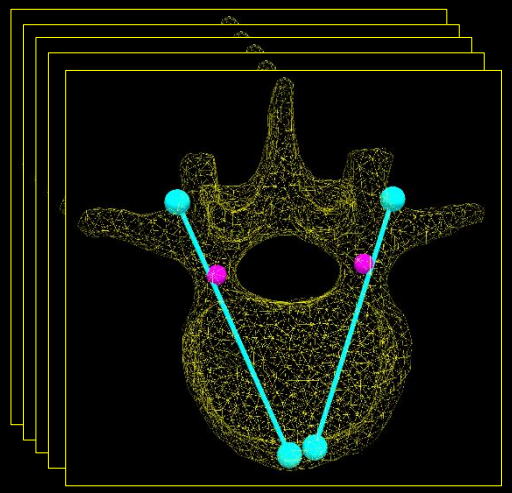



T. Yi et al., J Med Imag (2018)

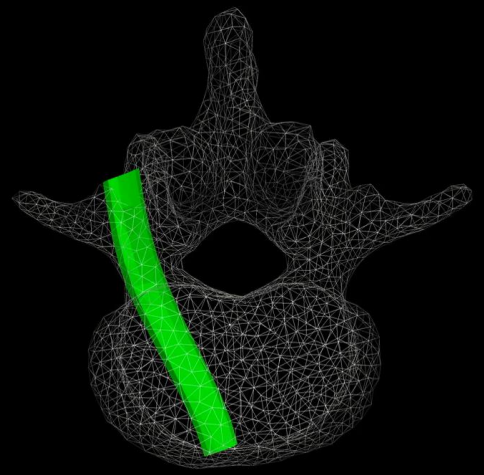
# A Need for Automatic Planning

Patient CT/MR

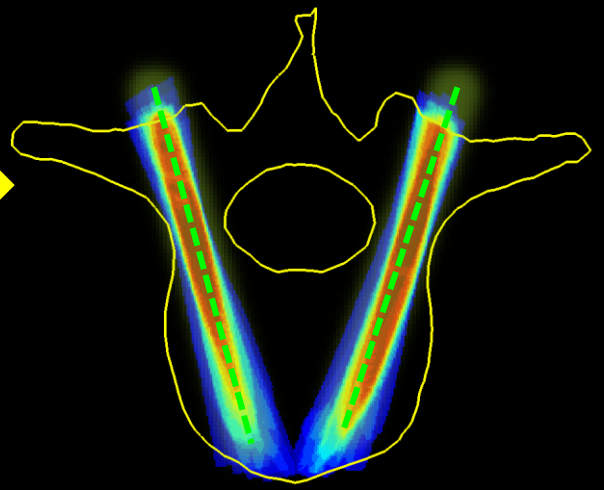




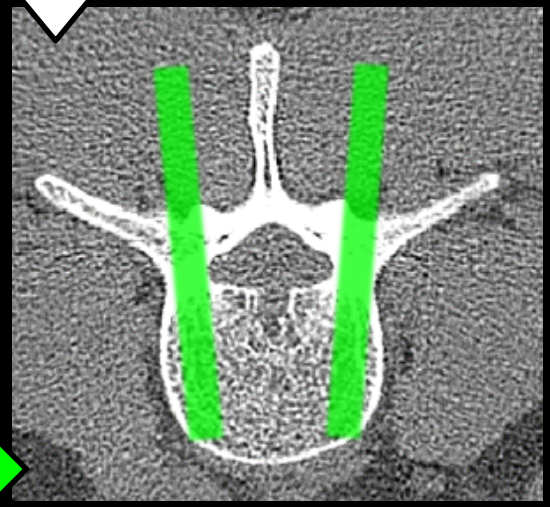
Atlas of Vertebrae and Trajectories



Registration



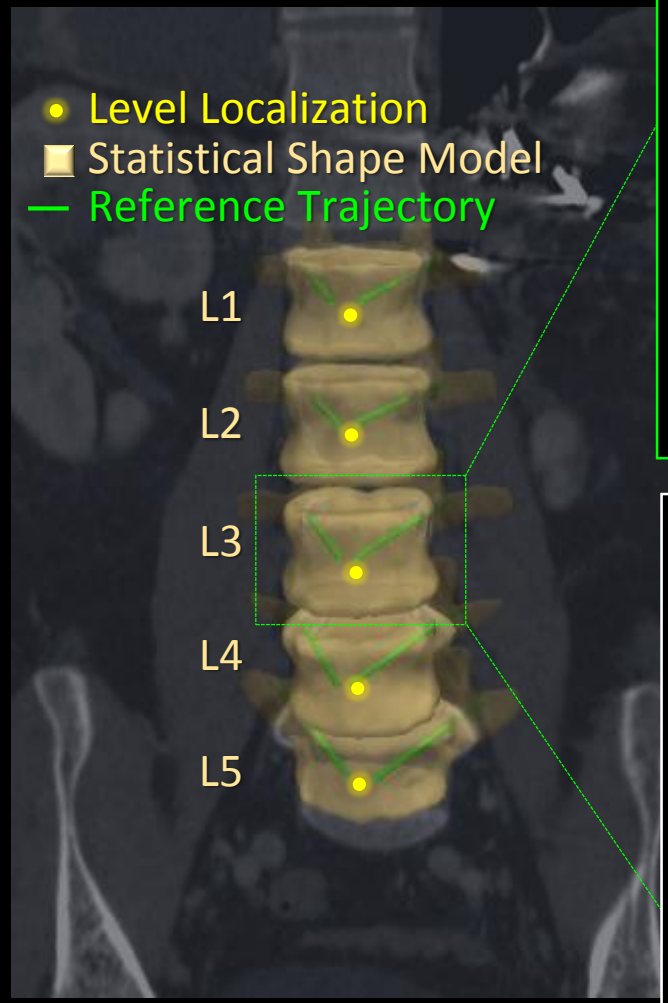
Maximization (Accumulation)



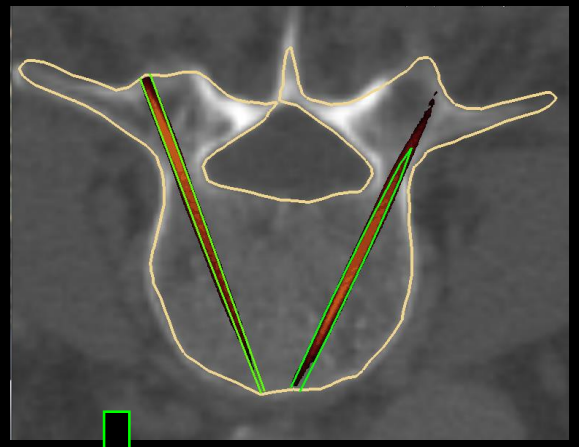
Patient-Specific Reference Trajectories

J. Goerres et al. Phys Med Biol (2017)

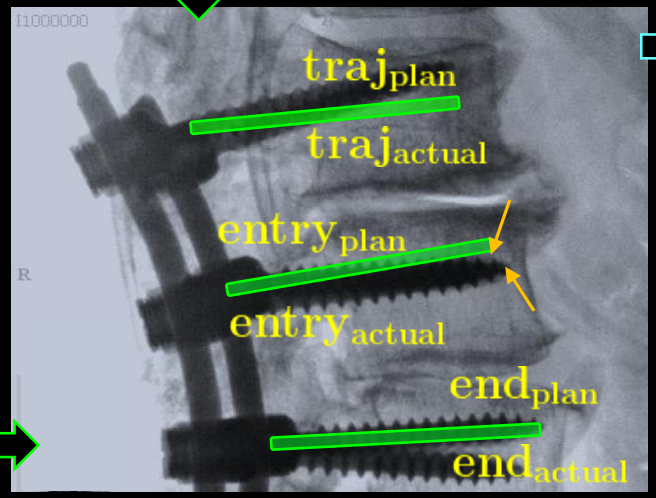
# And an Opportunity for Intraoperative QA




**Automatic Planning**



**3D-2D Registration**



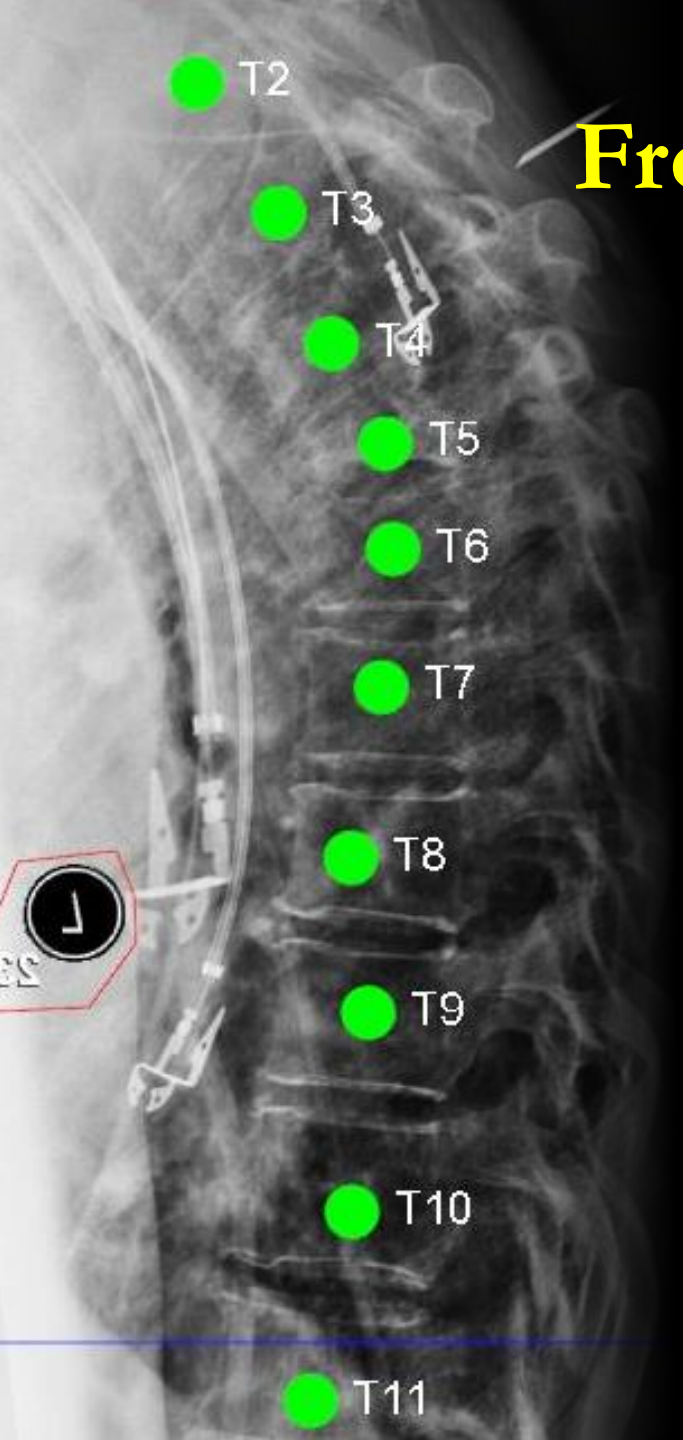

QA of the surgical product

$$\Delta_{entry} = entry_{plan} - entry_{actual}$$

$$\Delta_{end} = end_{plan} - end_{actual}$$

$$\Delta_{angle} = acos(\frac{traj_{plan} \cdot traj_{actual}}{\|traj_{plan}\|\|traj_{actual}\|})$$

Quantitative high-level features for large-scale, data-intensive analysis of outcome variations




# From Image Guidance → to Safety, Quality, and Data Science

***That which is measured improves.***

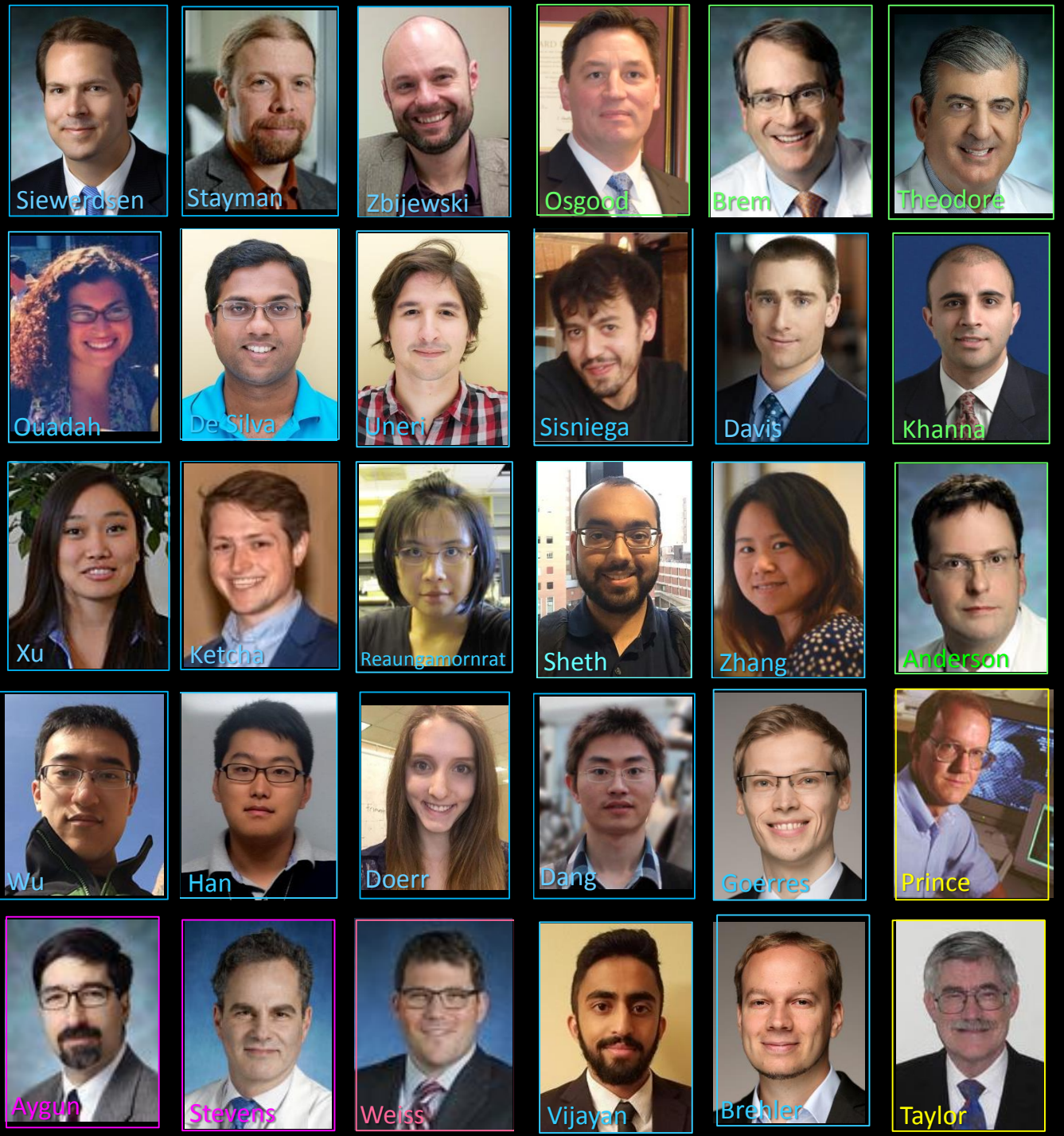
Expanding role of intraoperative imaging for safety and QA

- Broad utility – mobile imaging systems and existing workflow
- Safety – independent check and decision support
- Guidance – without trackers
- Overcome workflow bottlenecks and better enable robotic assistance
- Check vs complications, opportunity to revise in the OR
- OR quality assurance (ORQA)

**Image registration → Image analysis / analytics**

Expanding role of imaging in surgical data science

- Quantitative evaluation of the surgical product
- Correlation with outcomes measurement
- Data-driven understanding large variations in outcome
- Data-driven patient selection, planning, etc.

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