Intraoperative Imaging for Patient Safety and OR Quality Assurance

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Siemens Healthineers
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*This presentation includes research systems and off-label use.*
Preoperative Imaging

Integration of Systems and Information

Multi-Modality Images

EMR

Population Data

Interventional Device Models

Biomechanical Models

Disease Models

Hospital Information System

Photo: Armen Deukmedjian
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)

Preoperative CT or MR

3D-2D Image Registration

_similarity

Optimization

$T_9$ DoF
Clinical Translation: **LevelCheck**

**Offline Laboratory Studies**

- Error Rate (%)

- **Manual Level Counting**
  - Very challenging
  - Significant improvement
- **Independent Check**
- **Assistant**

- **Ordinal Rating**
  - Extremely challenging w/o LevelCheck
  - Improved confidence
  - Additional information
  - Improved confidence. Reassurance.
  - No change in confidence
  - Degraded confidence. Confounding information.

**Online Clinical Studies**

- **Accuracy**
  - Confirmatory
  - Disagreement (LevelCheck correct)
  - Disagreement (Surgeon correct)
  - No change in confidence
  - Degraded confidence. Confounding information.

- **Utility**
  - Extremely challenging w/o LevelCheck
  - Improved confidence
  - Additional info
  - Improved confidence
  - Reassurance.
LevelCheck: Extensions

msLevelCheck (Deformable)
Multi-stage pyramid
Phantom and clinical pilot studies

MR-LevelCheck (MRI-to-radiograph)
Simple segmentation + robust similarity
Clinical studies
OR Quality Assurance (ORQA)

Correct level
Correct implant
Correct placement
3D-2D Registration for Intraoperative QA

Component Registration

Radiographs

Patient Registration

CT

Optimization

Metric

Component

Projector

2D Overlay

3D Overlay

3D-2D Registration for Intraoperative QA

Polyaxial Pedicle Screw

Known-Component (KC) Model

Iteration = 89

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

Photograph courtesy of Dr. Nick Theodore (Johns Hopkins University)
Surgical Robotics: without Trackers

X-Ray Guided Surgical Robot

\[ T^\kappa_T = (T^\nu_c)^{-1} T^\kappa_c \]
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

Atlas of Vertebrae and Trajectories

Registration

Maximization (Accumulation)

Patient-Specific Reference Trajectories

And an Opportunity for Intraoperative QA

QA of the surgical product

\[
\Delta_{entry} = entry_{plan} - entry_{actual}
\]
\[
\Delta_{end} = end_{plan} - end_{actual}
\]
\[
\Delta_{angle} = \cos\left(\frac{\langle traj_{plan}, traj_{actual} \rangle}{||traj_{plan}|| \cdot ||traj_{actual}||}\right)
\]

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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