Opportunities in Image-Guided Surgery

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Origin of Stereotaxis

• 1908: Victor Horsley and Robert Clarke first published a 3D targeting technique for neurosurgery in Brain.
• They used a Cartesian coordinate system used to lesion targets in monkey brains from external cranial landmarks and cortical topography, coining the term “stereotaxis.”

Historical Perspectives

• Roentgen & X-ray (November 8, 1895)*
• Horsley & Clarke, Stereotaxis (1906)
• Dandy & Pneumoencephalography (1919)
• Moniz & Cerebral Angiography (1927)
• Spiegel & Wycis, Stereoecephalotome (1946)
• Leksell & Stereotactic Frame (1949)
• Hounsfield & Cormack, CT (1979)*
• Lauterbur & Mansfield, MRI (2003)*

• *Nobel Prize
Image Guided Brain Surgery

Evolution of Image Guided Spinal Surgery

• Plain radiography/C-arm fluoroscopy
• Preoperative CT-based
• Intraoperative CT-based
• Fluoroscopy-based
• Intraoperative mobile 3D imaging

Percutaneous Pedicle Screws for Trauma
Image Guided Brain Surgery
State of the Art

- Frameless stereotaxy
- Intraoperative cone beam imaging
- Intraoperative MRI
- Image-guided robotics

Navigation Adoption

“Fiddle-Factor” is Too High

Challenges
• Radiation Exposure
• Image Quality
• Image Merge
• Registration
• Automation

Why Image Guidance?

Bad Things Happen
Meta-Analysis Results
Navigation – Conventional vs. 2D vs. 3D

- Conventional Accuracy
  - Overall – 2532 or 3719 screws (68.1%)
    - Cervical 69.4%
    - Thoracic 50.8%
    - Lumbar 75.9%

- 2D Fluoro Navigation accuracy
  - Overall – 1031 or 1223 screws (84.3%)
    - Cervical 73.3%
    - Thoracic 78.4%
    - Lumbar 86.8%

- 3D Navigation
  - Overall – 4170 of 4368 screws (95.5%)
    - Cervical 90.3%
    - Thoracic 93.2%
    - Lumbar 96.7%

1985: The PUMA surgical robot was used to position a biopsy cannula as a stable platform for needle insertion of a brain biopsy.

Introduction of Surgical Robots

The first surgical robot

- 4 arms
- 7 degrees of freedom
- Master-slave

DaVinci Surgical System (1999)
1. Middle management
2. Salespeople
3. Report writers, journalists, authors
4. Accountants and bookkeepers
5. Doctors

*Spinal Surgery
Robotics in Spinal Surgery

- Capture Patients Seeking Less Invasive Surgery
- Reduce Radiation Exposure
- Surgeons, staff, and patients
- Procedural Consistency
- Automate trajectory alignment
- Pre-Operative and Intra-Operative Planning
- Optimize surgical placement

Patient Value = Efficacy * Less Invasiveness

Real-time visualization of instruments with trajectory guidance

Active feedback on movement of anatomic reference (DRB)

Deflection sensing technology

Robotics in Spinal Surgery


Future Directions

- Confocal Microscopy & imaging for virtual biopsy
- Fully automated surgery
- Artificial intelligence (& big data) for complex procedures
  - Tumor margins, bone density, surgical planning
- Multi-modality imaging (MRI, ultrasound, CT)
- Augmented reality for surgery

Future of Imaging