Opportunities in Image-Guided Surgery

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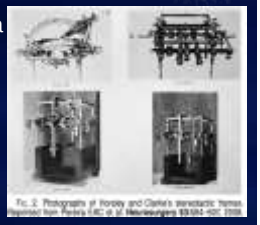
Origin of Stereotaxis

•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 land marks 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, Stereoencephalotome (1946)
- Leksell & Stereotactic Frame (1949)
- Hounsfield & Cormack, CT (1979)*
- Lauterbur & Mansfield, MRI (2003)*

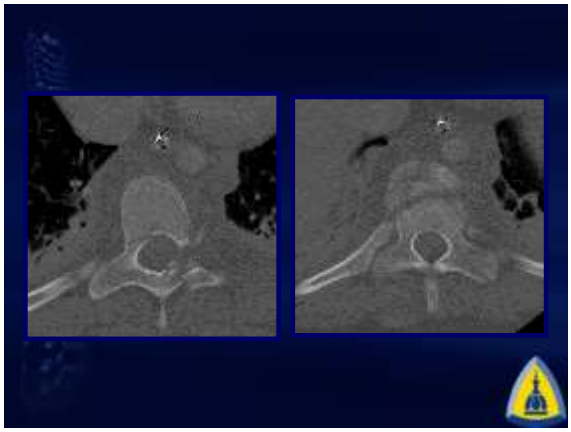
- *Nobel Prize

Image Guided Brain Surgery

Evolution of Image Guided Spinal Surgery

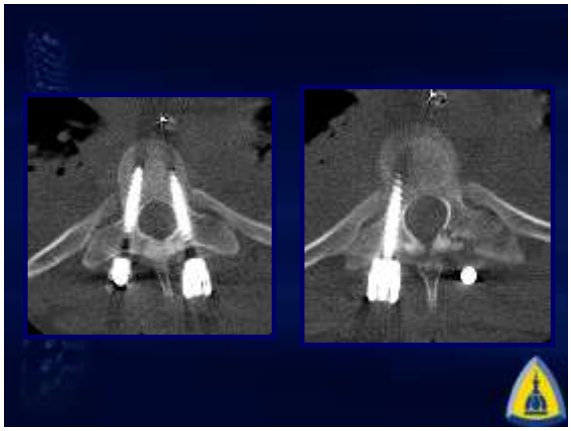
- Plain radiography/C-arm fluoroscopy
- Preoperative CT-based
- Intra-operative CT-based
- Fluoroscopy-based
- Intraoperative mobile 3D imaging

Percutaneous Pedicle Screws for Trauma



Registration

Intra-Operative Imaging



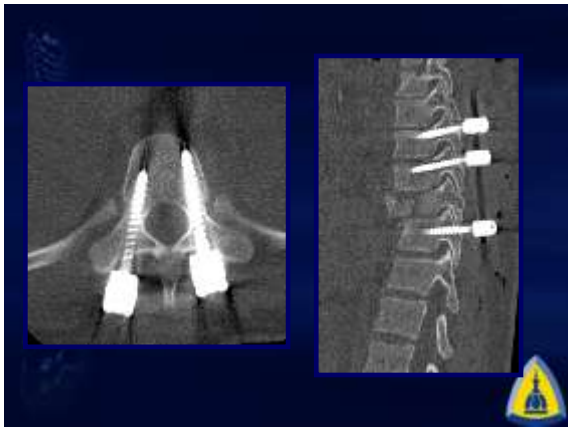
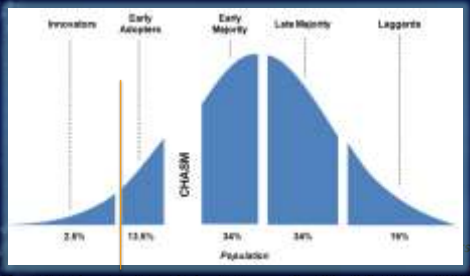


Image Guided Brain Surgery

State of the Art

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

Navigation Adoption



1996-2016

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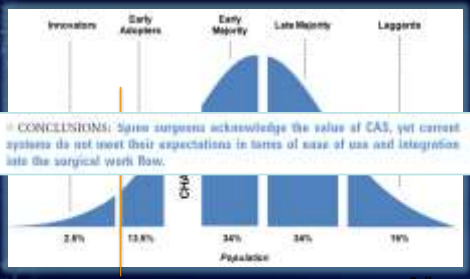
"Fiddle-Factor" is Too High



Leaders 1996-2016 *Followers*

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Challenges

- Radiation Exposure
- Image Quality
- Image Merge
- Registration
- Automation

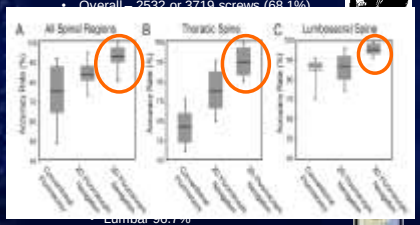
Why Image Guidance?

Bad Things Happen

Meta-Analysis Results

Navigation – Conventional vs. 2D vs. 3D

- Conventional Accuracy
  - Overall – 2532 or 3719 screws (68.1%)



- Lumbar 90.7%

Introduction of Surgical Robots

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

DaVinci Surgical System (1999)

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

CyberKnife® (Accuray) 1994

Mako Robot 2015

BNI, 2002 Theodore, Sonntag

- 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

Patient Value = Efficacy * Less Invasiveness

Reduce Radiation Exposure

Surgeons, staff, and patients

Procedural Consistency

Automate trajectory alignment

Pre-Operative and Intra-Operative Planning

Optimize surgical placement

Robotics in Spinal Surgery

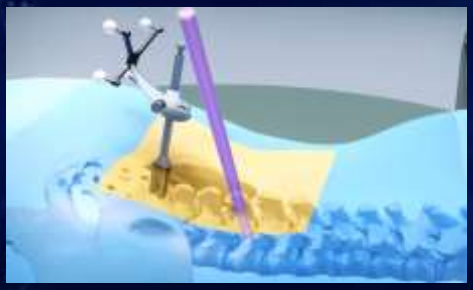
Real-time visualization of instruments with trajectory guidance

Active feedback on movement of anatomic reference (DRB)

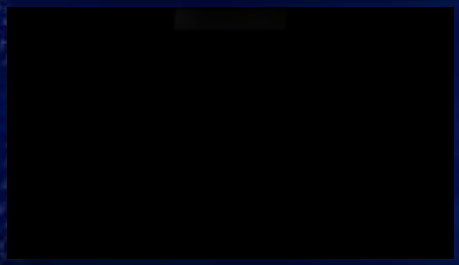
Deflection sensing technology

BNI, 2002 Theodore, Sonntag

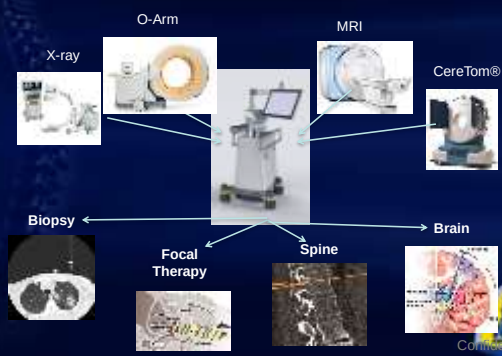
Image Guidance & Robotics



Excelsius GPS™ Workflow



Imaging, Robotics & Minimally Invasive Surgery



CT Guided Biopsy

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