

# Image-Guided Procedures

SPIE Workshop 2006

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TGT

## Disclosure

Bob Galloway is a founder, chief technical officer and president of Pathfinder Therapeutics Inc, of Nashville, TN



## Presentations

- 1:10 - 1:45 - Basics of Image-Guided Procedures  
Bob Galloway
- 1:45-2:20 - Medical Images  
Ken Wong
- 2:20-2:55 - Advances in Localization  
Kevin Cleary
- 2:55-3:10 - Break
- 3:10-3:45 - Interventional Radiology application  
Filip Banovac
- 3:45-4:20 - Dealing with intraprocedural deformation  
Mike Miga
- 4:20-5:00 - Panel discussion - What is the future of IGP

## Introduction to Image-Guided Procedures

- History
- Terminology
- Components
  - Images
  - Localization
  - Registration
  - Display
- Applications
- Validation

## History of Image-Guided Therapy

- 1896 J.H. Clayton. X-Ray use in surgery
- 1904 Horsley and Clarke. Stereotactic frame
- 1946 Spiegel and Wycis. Stereotactic frame using xrays.
- 1940's~1950s: Leksell, Riechert-Munding, Talairach, Cooper...

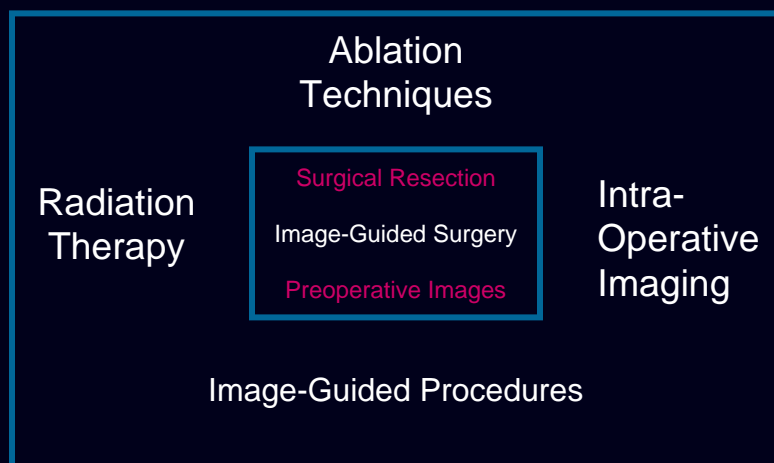
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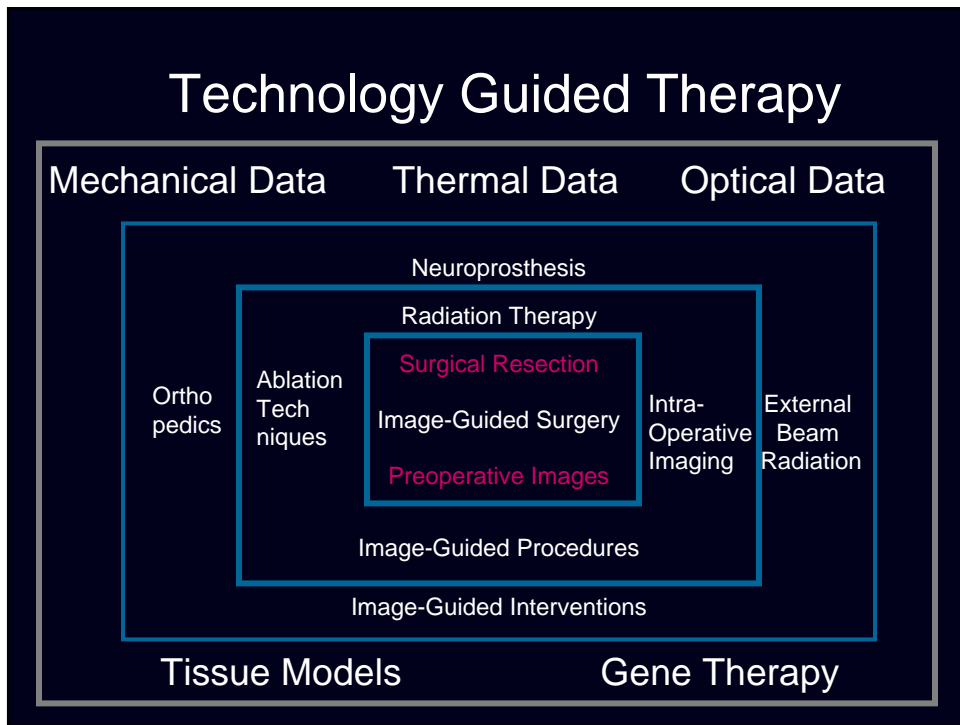
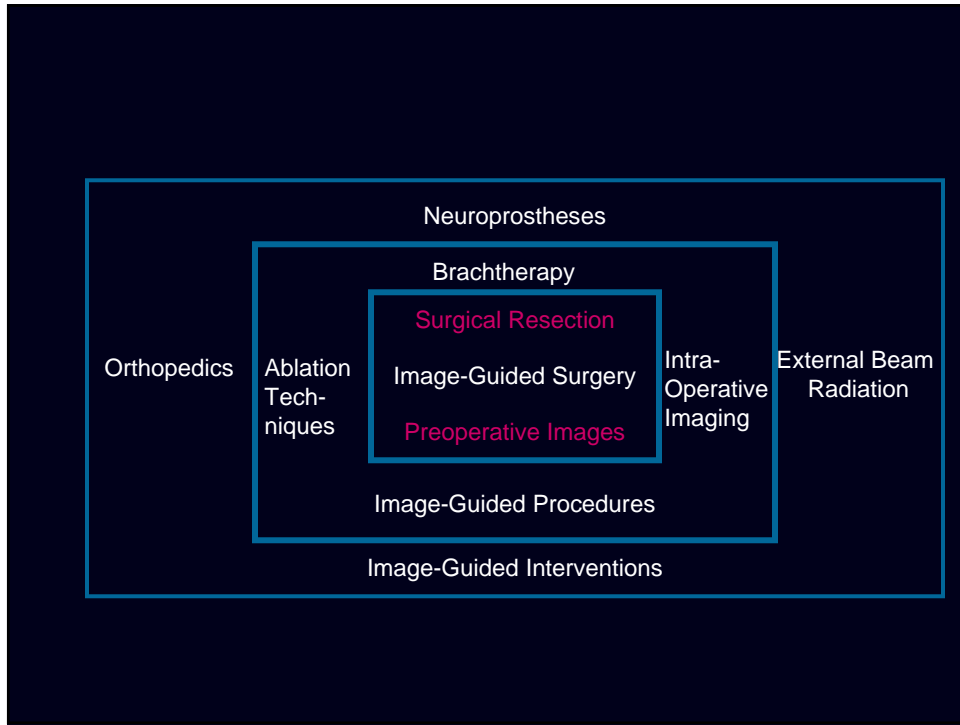
## Technology-Guided Therapy Timeline

- 1986
  - Roberts et al. A frameless stereotaxic integration of computerized tomographic imaging and the operating microscope, *J. Neurosurg*, 65, 545, 1986.

## Terminology

- “Frameless Stereotaxy”
- Image-Guided Surgery
- Image-Guided Procedures
- Image-Guided Interventions
- Technology-Guided Therapy





## TECHNOLOGY-GUIDED THERAPY

The central tenet of technology-guided therapy (TGT), is that a significant number of disease or disorder processes have a restricted spatial extent and that knowledge of the location and extent of that disease or disorder will allow more specific therapy. Specific therapy implies complete treatment of the disease or disorder with no therapy damage to the surrounding healthy tissue.

### IGS or TGT Requires

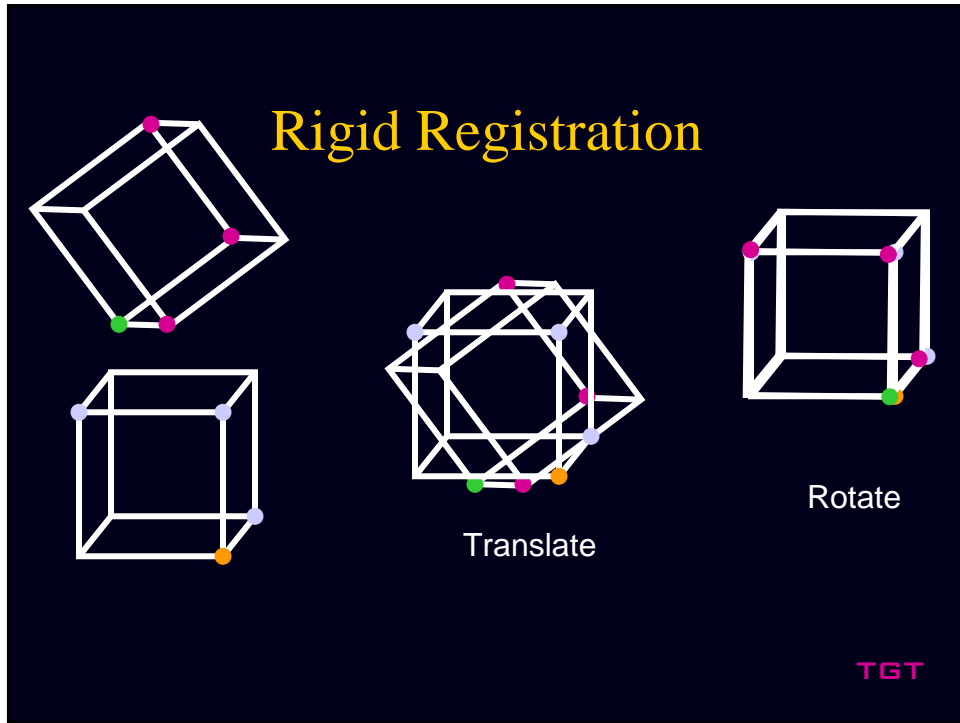
- Image Information
  - Image size and resolution
  - Understanding of Spatial Distortion
  - Image Contrast
  - Dealing with Multi-modal image information
- Physical Space Localizer
  - Range (Work volume)
  - Resolution
  - Update Speed
  - Sensitivities.

## IGS or TGT Requires

- Image-Space to Physical Space Registration
  - Intrinsic or Extrinsic Features
  - Speed to solution
  - Reliability and robustness of method
- Display of Information
  - N-dimensional information on a three dimensional (2 spatial 1 time) display
  - Role of rendering & transparency

## IGS or TGT Requires

- Dealing with changes
  - Changes between imaging and surgery
  - Intraoperative changes
    - Deformations due to pharmacological effects
    - Deformations due to tractions



## Registration

When the mathematical relationship between a point in one space and the homologous point in another space is known, the spaces are considered *registered*. If that relationship can be reduced to a single common translation and rotation, the registration is considered *rigid*.

TGT



## Transformation Matrix

$$\begin{bmatrix} X^P \\ Y^P \\ Z^P \end{bmatrix} = \begin{bmatrix} X^I \\ Y^I \\ Z^I \end{bmatrix} \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix} + \begin{bmatrix} T^X \\ T^Y \\ T^Z \end{bmatrix}$$

## Registration References

- Handbook of Medical Imaging, Vol 2, Chapter 8, Fitzpatrick, Hill and Maurer SPIE Press.
- Maintz and Viergever, "A survey of medical image registration", Medical Image Analysis, 1998 pp 1-36
- Maurer CR et al.. "Registration of head volume images using implantable fiducial markers". *IEEE Transactions on Medical Imaging*, 16:447-462, 1997.

## Articulated Arms

- All are revolute (only angular change)
- All use optical encoders for angle sensing
- Mark I and II – Vanderbilt
- Aachen
- Oolu
- Guthrie/Radionics
- Zamorano/Fischer

## Localizer References

- Edwards CA, Galloway RL. A Single Point Calibration Technique for a Six Degree of Freedom Articulated Arm. *International Journal of Robotics Research*. Vol. 13, No.3 June 1994, pp. 189-198.
- Wiles AD, Thompson, DG, Frantz DD. "Accuracy assessment and interpretation for optical tracking systems" Proceedings of SPIE -- Volume 5367 Medical Imaging 2004: Visualization, Image-Guided Procedures, and Display
- Birkfellner W, et al Systematic distortions in magnetic position digitizers. *Medical Physics*. 1998 Nov;25(11):2242-8.

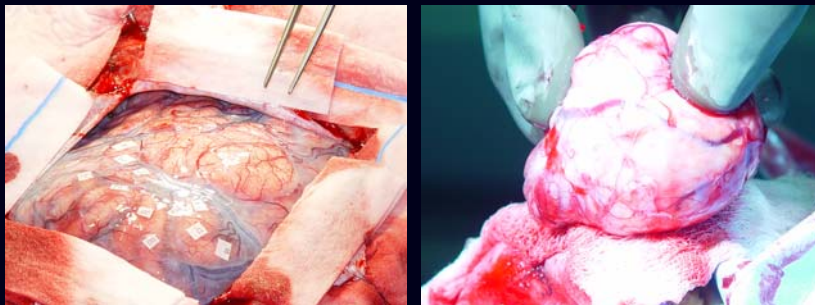
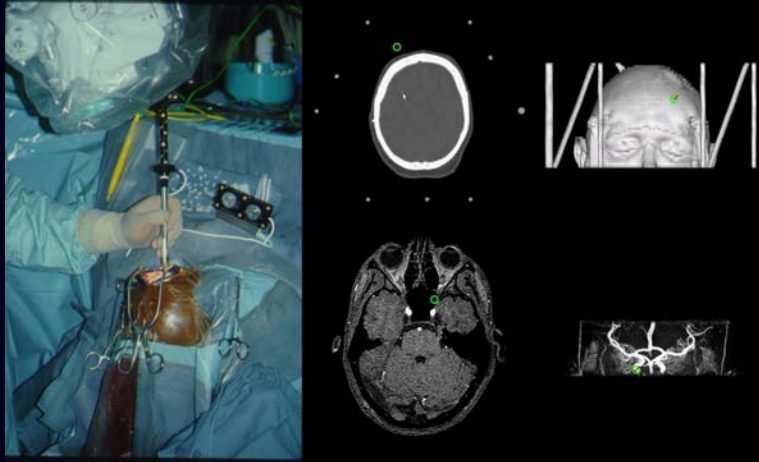
## Applications of TGT

- Intracranial Neurosurgery
  - Tumor resection
  - Implantation of Neuroprostheses
- Spinal Surgery
- Liver Surgery
- Orthopedic Surgery
- Colorectal Cancer Staging and Surgery
- Ophthalmologic Surgery
- Cochlear Implants

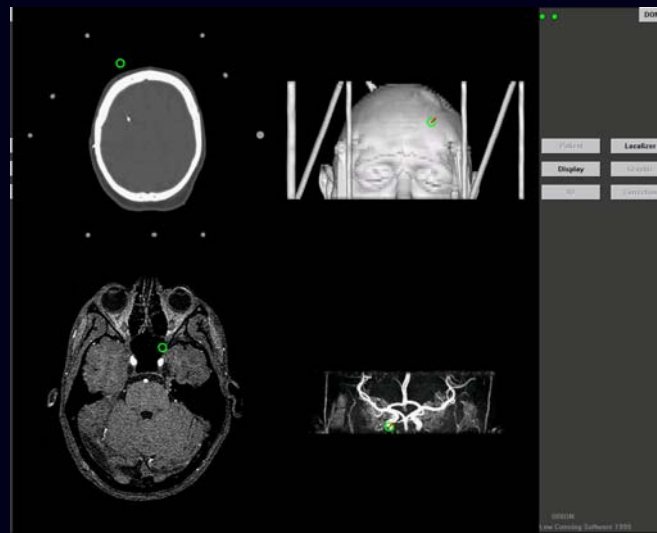
## Applications of TGT

- Lung Therapy
  - Tumor resection/ablation/brachytherapy
- Prostate Therapy
  - Open or robotic surgery
  - Brachytherapy
- Direct injection Chemotherapy/ Gene Therapy

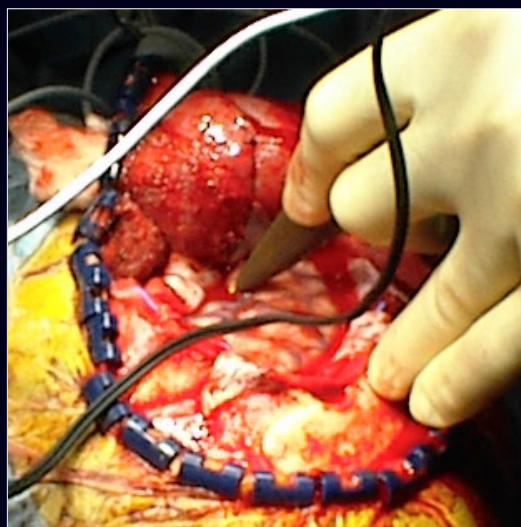
## Image-Guided Neurosurgery



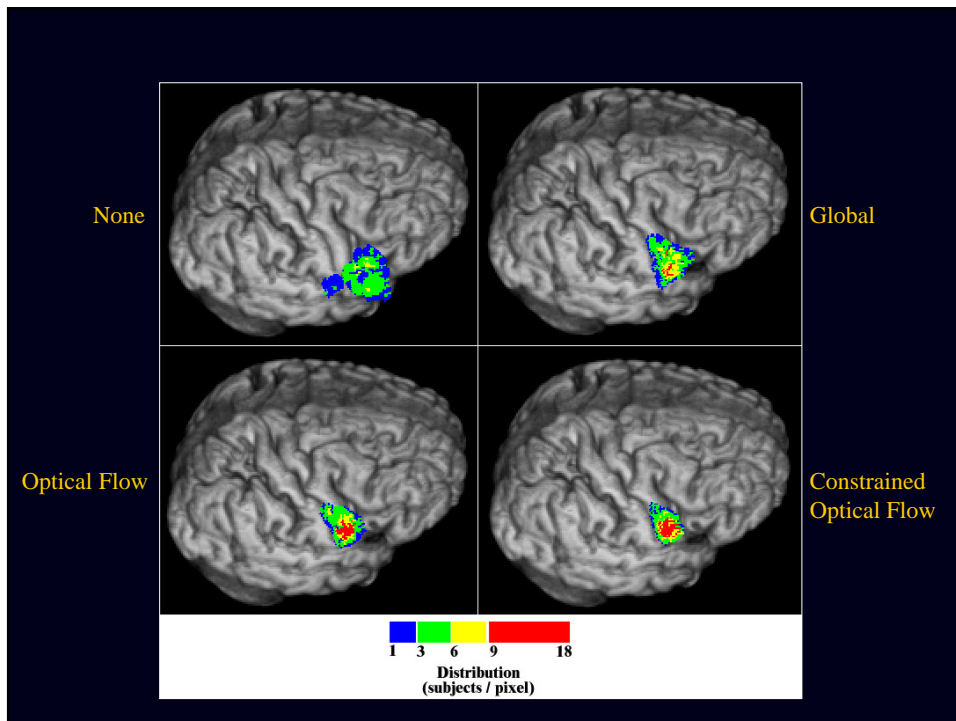
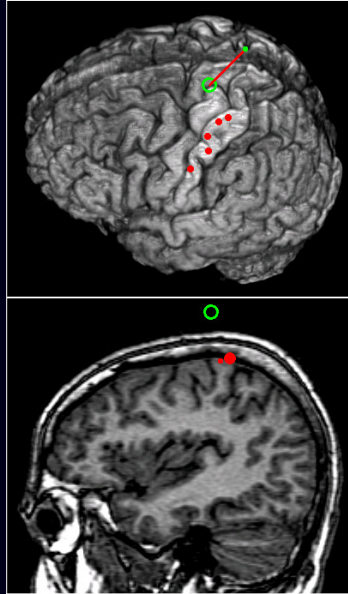
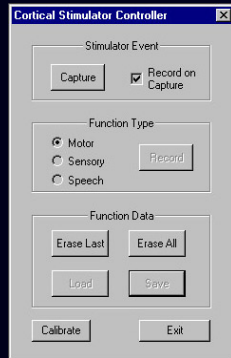
## Display Types



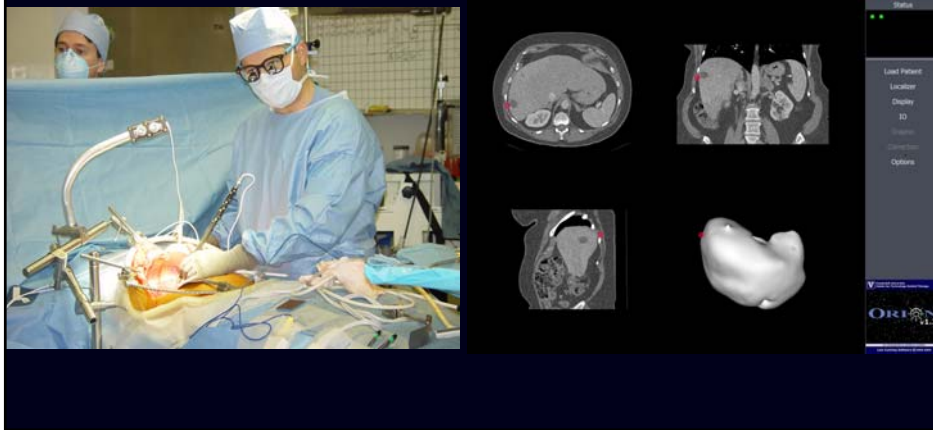
## Cortical Surface Mapping



## Display of function on brain images:



## Image-Guided Liver Surgery (IGLS)

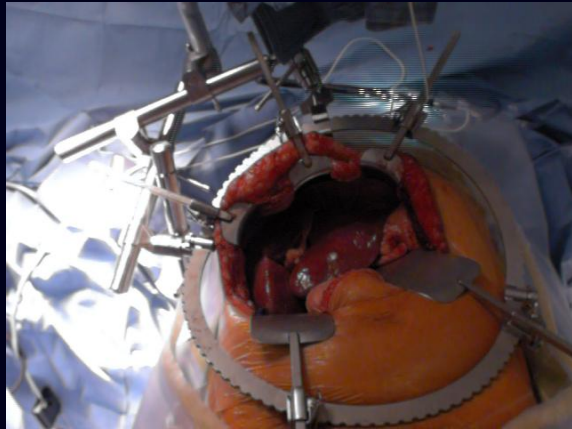


## Image-Guided Liver Surgery

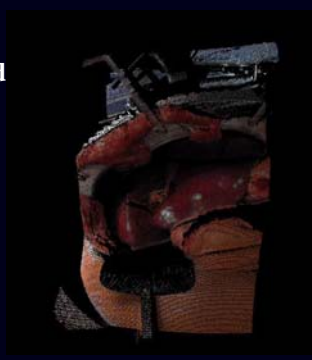
- Primary liver cancer is second most common cancer world-wide.
- Metastatic disease to the liver is common from colorectal & breast primaries
- Less than 50% of surgical candidates for liver metastatic tumors get surgery

# OR Results

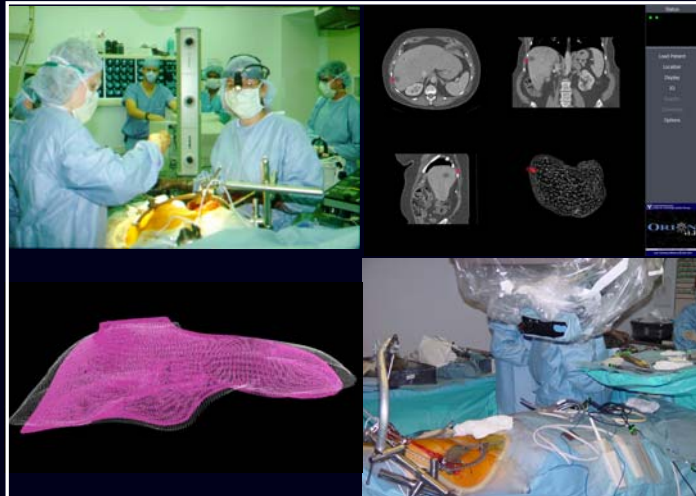
Point  
Cloud



Bitmap from Range Scanner



Tessellated  
Surface





## Spinal Surgery

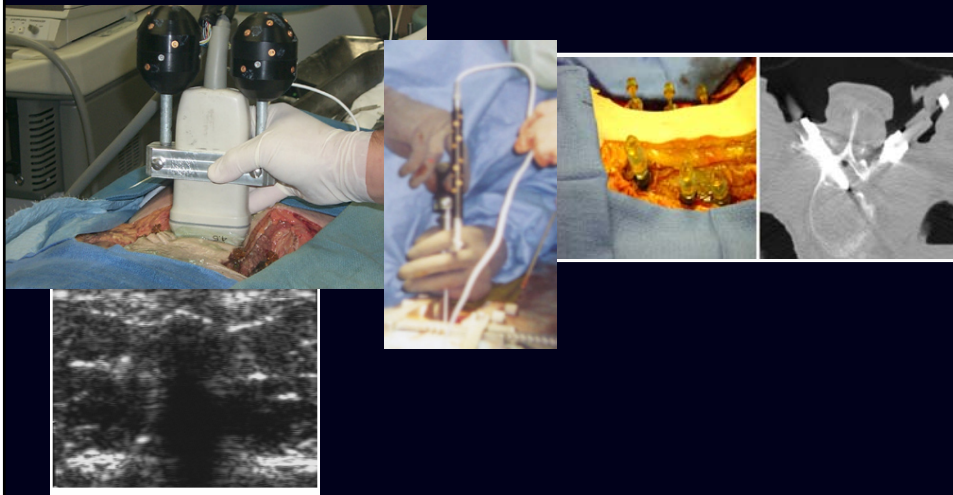
- >250,000 lumbar spine operations per year (US)
- Back-Pain Patient Outcomes Assessment Team (HS 06344): Cost of back pain: \$50 billion (US)
- Traditional posterior approaches are “suboptimal”

## Spinal Surgery

Image

Guide

Confirm



## Alternatives to IG – Colorectal staging and therapy

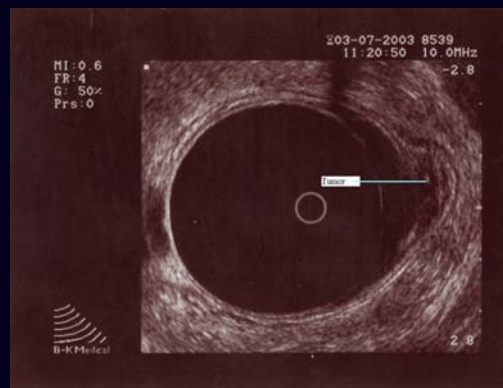
- Standard Endorectal US
  - 3-D anatomy not visualized
  - Very difficulty to take biopsy sample near US-identified structure.
- MR Imaging
  - Requires specialized coils
  - Postural changes between MR and procedure rooms make registration very difficult.

## Applications of TGT

### Colorectal Cancer Staging and Surgery

One of the most prevalent cancers in the US

Visualization of the layered structure of the rectum is important for staging and therapy



## New Therapeutic Applications

### Cochlear Implantation

- Only available therapy for the profoundly deaf
- Outcome tends to be binary
- 1% morbidity (Facial nerve)

## Applications of TGT

- Cochlear implants



## Other TGT

- Prostate
  - Aaron Fenster – Robarts
  - Intuitive Surgical – DaVinci
    - Radical versus targeted
- Lung
  - Bill Higgins at Penn State – 7<sup>th</sup> level branching
- Cardiac
  - Interventional applications of stents, balloons and RF ablation

## Validation

- System Performance in Phantoms
- System Performance in Animal Models
- Patient Outcome
- Device Accuracy
- Registration Accuracy
- System Information Transfer

## Thessalonians 5:21

Prove all things;  
hold fast that which is good.

## Contact Information

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