Advanced Multimodality Image Guided Operating (AMIGO) Suite

Precise Localization of Tumor Boundaries for Therapy
Clinical Testbed for P41 EB015898 (PI Tempany)
National Center for Image-Guided Therapy

Precise Localization of Tumor Boundaries for Therapy

5700 Square Feet
Launched in 2011

Courtesy Balasz Lengyel
1134 Procedures in AMIGO
08/31/2011-05/13/2016

Brain
- MRI Brain Biopsy
- MRI Spinal Cord Biopsy
- MRI Deep Brain Stimulation
- MRI Transcranial Pituitary Tumor
- MRI Skull Base Surgery

Head and Neck
- MRI Cryotherapy Head & Neck Tumor
- MRI Parathyroidectomy

Skeletal
- MRI Cryoablation Spine Tumor
- MRI Cryoablation Degenerative Spine

Heart, Lung, Breast
- PET/CT Microwave Ablation Lung Tumor

Abdominal
- MRI Cryoablation Liver/Kidney Tumor

Pelvic
- MRI Prostate Biopsy

AMIGO Procedures are
- Standard of Care +
- Under IRB (17 IRB protocols in place)
- Typically one surgery at a time, now 2 IR procedures in parallel
- Physician decides when AMIGO is beneficial
  - Gliomas for brain tumor surgery
  - Large cervical cancers for gynecologic brachytherapy
  - Repeat negative TRUS biopsy and rising PSA for MR-guided prostate biopsy
  - Location of tumor for osteoid osteomas for MR-guided cryoablation
  - Difficult to localize pheochromocytoma for FDG-PET/CT-guided resection
Some examples

• Brain tumor resection (121)
• Breast cancer surgery (23)
• Gynecologic Brachytherapy (92)

Optimal surgery for brain tumors

Goal
• Complete resection
• No neurologic injury

Alexandra Golby, MD Neurosurgeon

Goals of image-guided neurosurgery

For the individual patient

Surgeon wants to see:
Lesion and define margins
Critical structures
Relationship between lesion and eloquent areas
iMRI impact on survival, BWH 0.5T MRI series: 90 vs. 39 months, 164 patients


Brain tumor resection in AMIGO. Navigation on pre-operative MRI is used to perform a minimal craniotomy with optimized exposure of the lesion

When the dura is exposed, navigated ultrasound imaging is performed prior to making any incisions. Ultrasound provides a fast initial orientation, including the location of major blood vessels.
In a very small subset of cases (now), after the dura is opened and the cortex is exposed, intracranial electrical stimulation testing (ECS) is performed to map important functional areas. This is valuable in confirming and applying preoperative fMRI findings.

Increasingly BOLD fMRI maps are used (without ECS) to delineate the proximity of ‘eloquent cortex’ to lesion.

Navigation provides the surgeon with location and trajectory of her tools.
White matter tractography provides visualization of the tumor relative to the arcuate fasciculus white matter tract.

Image guidance makes effective tumor resection possible.

Intraoperative MR: Prior to intraoperative MRI, a temporary closure is performed.
A ceiling mounted high field (3T) MR scanner is brought into the OR for intra-operative imaging.

Tumor assessment from pre-op MRI image vs. residual tumor

Post-operative MR scan confirms no intraoperative complications and sets a new baseline. Once conscious, the patient is immediately asked to demonstrate motor control, such as foot movement.
Stereotactic Mass Spectrometry for Tumor Margin and Composition

Why Mass Spectrometry in Neurosurgery?

Many Intra-operative decisions are based on Frozen sections a technology that has been around for the last 150 years. This takes on average 30 minutes.

We want rapid and actionable intra-operative methods for molecular characterization of tissue samples in AMIGO.

Desorption electrospray ionization (DESI) MS can detect 2-hydroxyglutarate (2-HG), an onco-metabolite from tissue sections.

2-HG is present in very small amounts in normal cells.

It has been found in large quantities in cells with IDH-1/2 mutations. These include gliomas.


Intra-operative mass spectrometry mapping of an Onco-metabolite to guide brain tumor surgery


80% of grade II and grade III gliomas and majority of secondary glioblastomas contain IDH1 or IDH2 mutations

Monitoring 2-HG with intra-operative MS could become routinely used for surgeries of primary brain tumors, first to classify the tumor and then, if 2-HG is present, to guide optimal resection.
Breast Conservation Surgery

• Need for re-excision is 20-40% in US
• AMIGO
  ◦ intra-procedural supine breast MRI
  ◦ for assessment of tumor margins and localization of residual disease


Breast Conservation Surgery

Pre-procedural imaging

Surgery

Post-procedural imaging

Re-excision

Gynecologic Cancers

• 500,000 cases per year worldwide: Cervical, Uterine, Vaginal, Vulvar, Ovarian
• 4th leading cause of death in women in the US
• Treated with chemoradiation, brachytherapy
MRI-guided Gynecologic Cancer Brachytherapy

30% outcome improvement over chemo-radiation
MR is the preferred imaging modality for gyn cancer
Needle artifacts in MR are ambiguous vs. x-ray or CT

The Segmentation Algorithm

1. For each needle, use a manually defined tip to iteratively
   ▶ search for a short, dark, thin tube
   ▶ add this to segmentation if it conforms with the "physical model" for the needle; large deflections allowed near the tip and only very small near the base.
2. After all needs are individually segmented,
   ▶ identify needle pairs that are physically improbable
   ▶ remove the artifact that is causing the errors
   ▶ repeat the individual segmentation algorithm for the erroneous needle(s).

Search for a short, dark, thin tubes

Goal: Find points on the needle path to fit a Bézier curve accurately approximating the catheter shape

Pernelle et al. MICCAI 2013
Constrain by Angular Spring Model: large deflections near the tip and only very small near the base.

Andre Mastmeyer 2014

Remove Physical Improbably Pairs - Segment

Rubin Ma 2015

54 Patients
760 Catheters
93% accuracy
3sec/Catheter

- Mastmeyer et al. [In preparation] 2016
- Pernelle, G. et al. MICCAI. 2013.
Augment the eye with imaging
Augment the hand with robotics
Update images intraoperatively
Navigate to delivery site
Reduce invasiveness of surgery
Apply to multiple procedures

Workshops and Events

9th National IGT Workshop
March 14-15, 2017, Washington DC

24th NA-MIC Project Week Open Source Hackathon
January 9-13, 2017, MIT

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