

Open Source Software for Image Guided Therapy: 3D Slicer

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Brigham and Women's Hospital

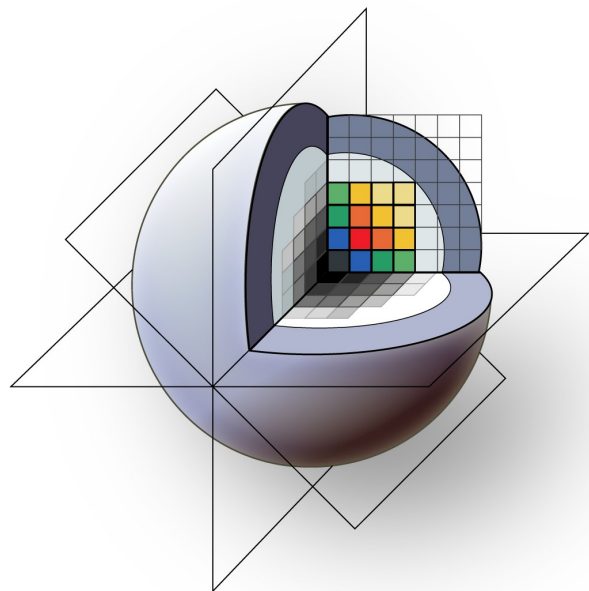
Harvard Medical School

Guest Lecture: MIT HST 582

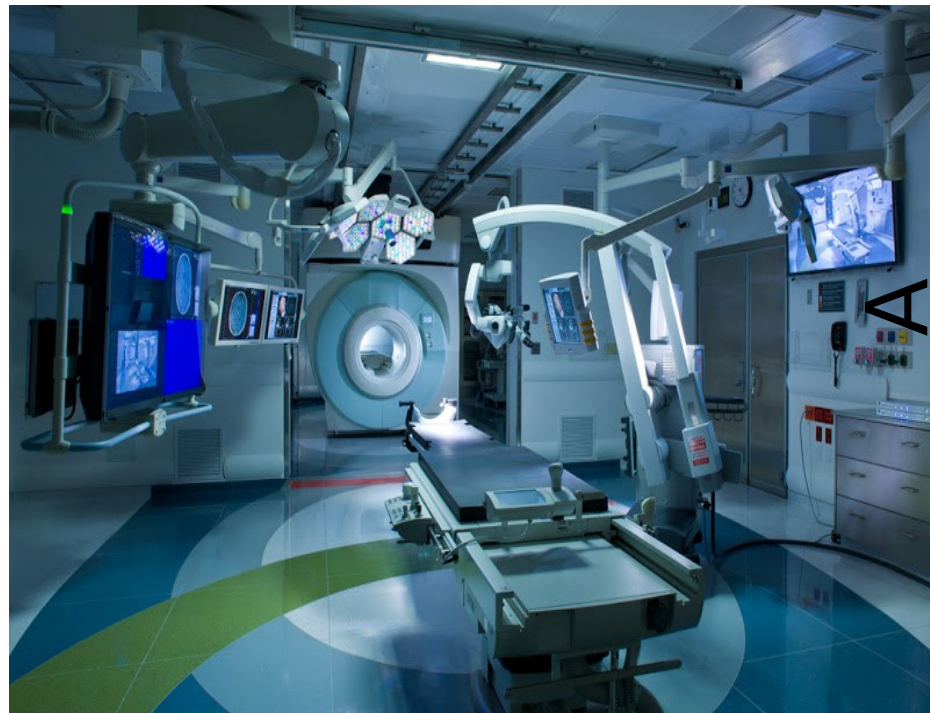
May 6, 2014



Two technologies
and
a community
developing open science
to accelerate important
discoveries
that improve health and save
lives.



3DSlicer



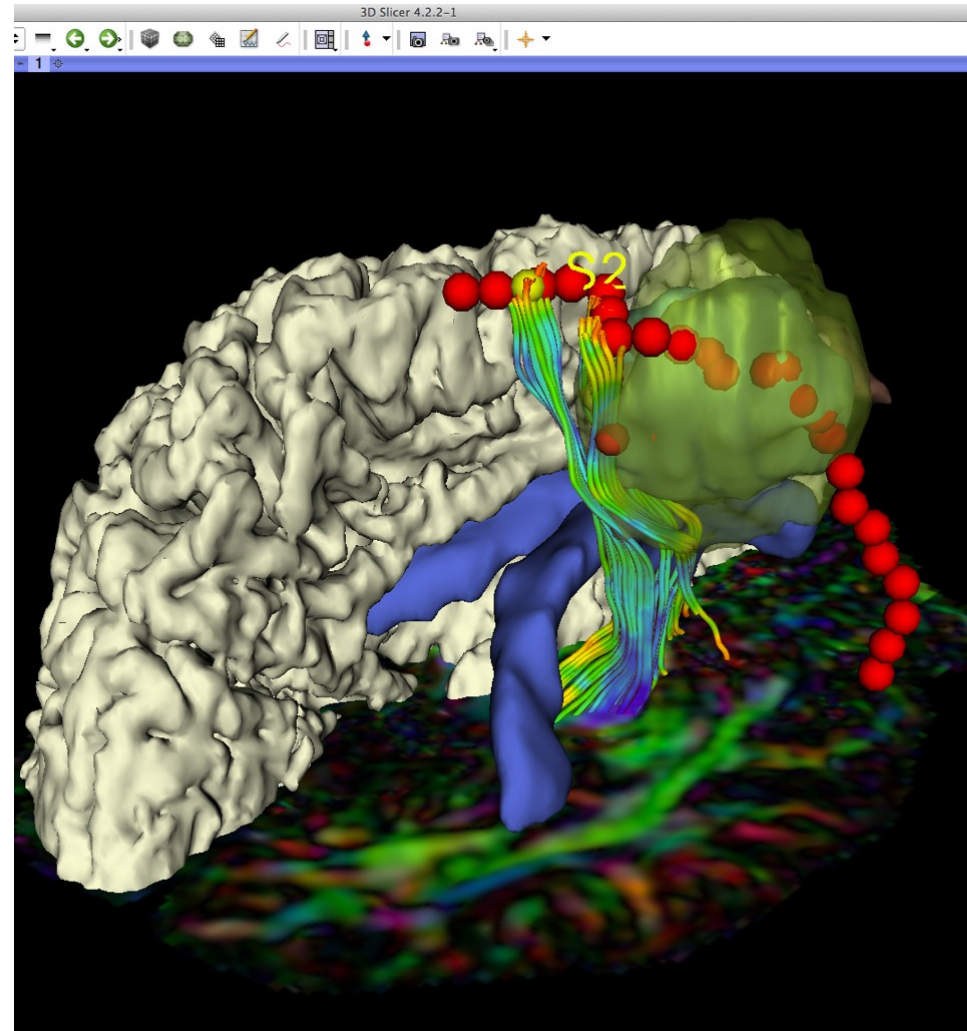
A
M



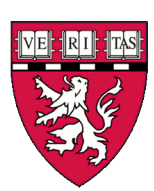


3D Slicer: <http://slicer.org>

- Medical Image Visualization and Analysis
 - Multi-Modal: CT, MR, fMRI, dMRI+
 - Integrated View: Images, Surfaces, Annotations, Devices...
- Multi-OS End-User Application (Windows, Linux, Mac)
- Extensible Architecture
 - Dozens of Custom Modules
 - Application Specific Functionality
- Fully Open and Non-Restrictive License
 - All Source Code Available
 - Can Be Used in Commercial or Proprietary Projects
- 100+ person-years of effort
- PI Ron Kikinis, MD



Courtesy Pieper, Kikinis, S. Pujol, A. Golby



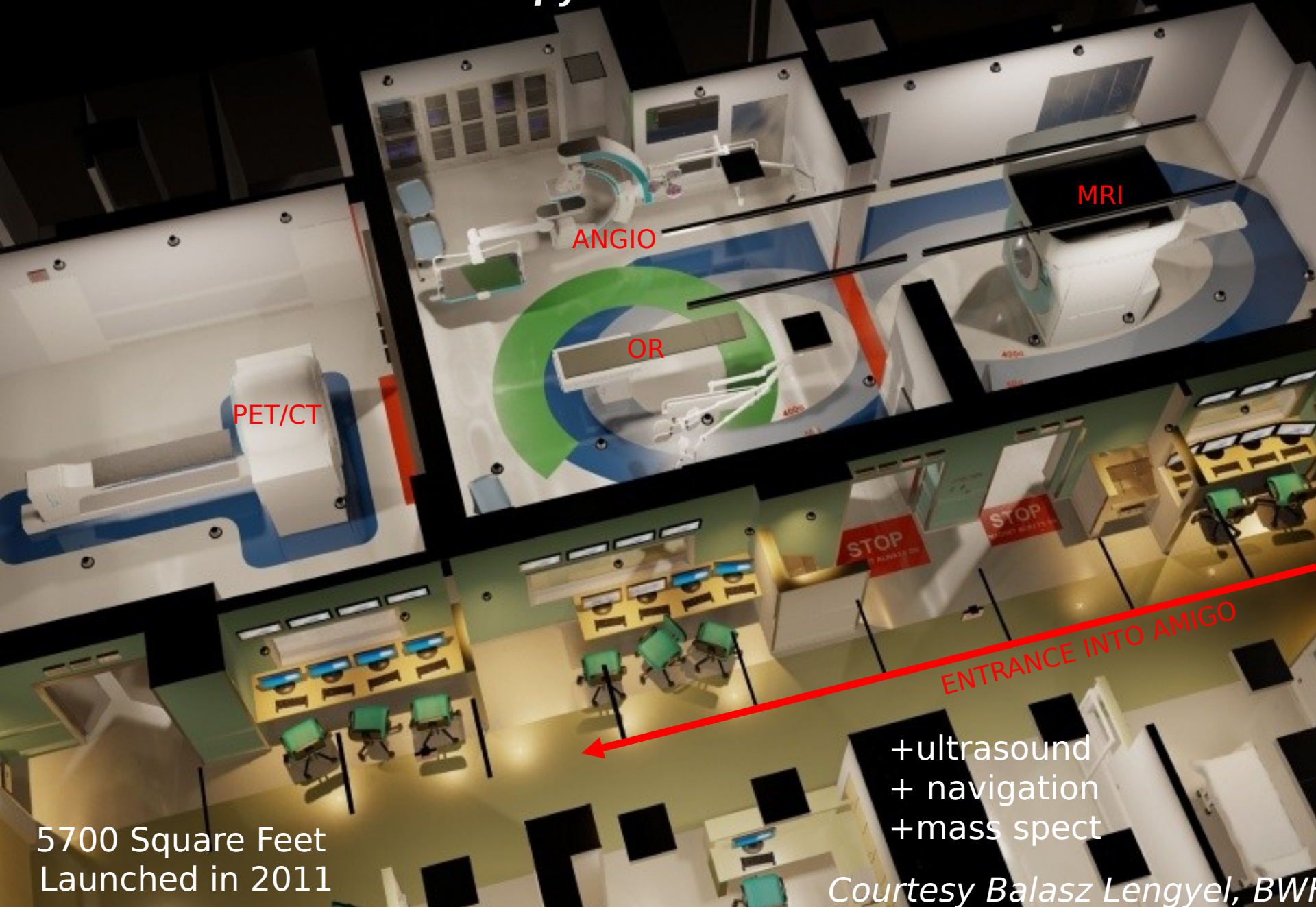
Advanced Multimodality Image Guided Operating Suite (AMIGO)



Precise Localization of Tumor Boundaries for Therapy

P41EB015898 (PI Ferenc Jolesz, Clare Tempany)

Precise Localization of Tumor Boundaries for Therapy



PET/CT

ANGIO

OR

MRI

ENTRANCE INTO AMIGO

+ultrasound
+ navigation
+mass spect

5700 Square Feet
Launched in 2011

Courtesy Balasz Lengyel, BWH

520 Procedures in AMIGO (08/31/2011-04/18/2014)

Neuro 108

- 70 Craniotomies/Biopsies
- 22 Transsphenoidals
- 7 Laser Ablations
- 7 Deep Brain Stimulation electrodes placement
- 1 Epilepsy Electrode Placement
- 1 Skull Base

Head and Neck 5

- 5 Parathyroidectomies/Hemithyroidectomies

Spine 1

- 1 MR Cryoablation/Biopsy (Spinal Tumor Mass)

Thorax 51

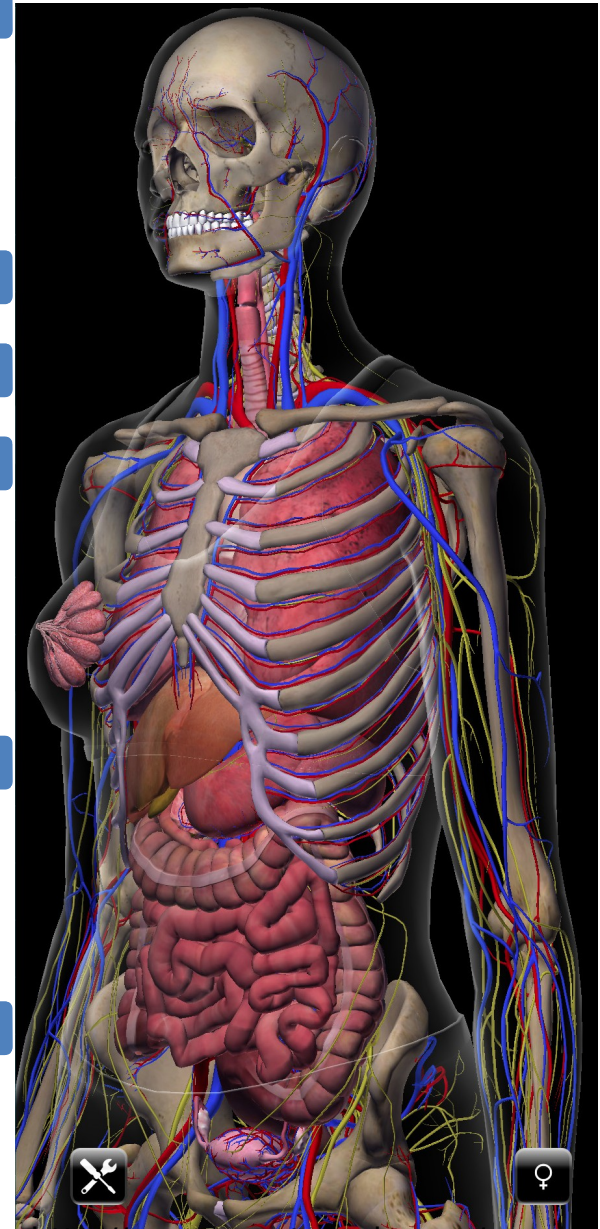
- 19 Video Assisted Thoracoscopic surgeries (iVats)
- 8 Breast Lumpectomies
- 7 EP Cardiac Ablations
- 7 Microwave ablations PET/CT guided (lung)
- 6 Biopsy PET/CT guided (lung)
- 3 Cryoablations PET/CT guided (lung, rib)

Abdomen 159

- 98 Cryoablations MRI guided (liver, kidney)
- 24 Biopsies MR guided (liver, kidney)
- 14 Cryoablations PET/CT guided (liver, kidney)
- 13 Microwave Ablations PET/CT guided (liver, kidney)
- 9 Cryoablations & Biopsies MR guided (liver, kidney)
- 1 Cryoablation & Biopsy PET/CT guided (liver)

Pelvis 196

- 115 Prostate Biopsies
- 67 Gynecologic Cancer Brachytherapy
- 7 Prostate Brachytherapy
- 5 Cryoablations MR guided (iliac, prostate)
- 1 Biopsy MR guided (penile)
- 1 Biopsy/Cryoablation combo MR guided

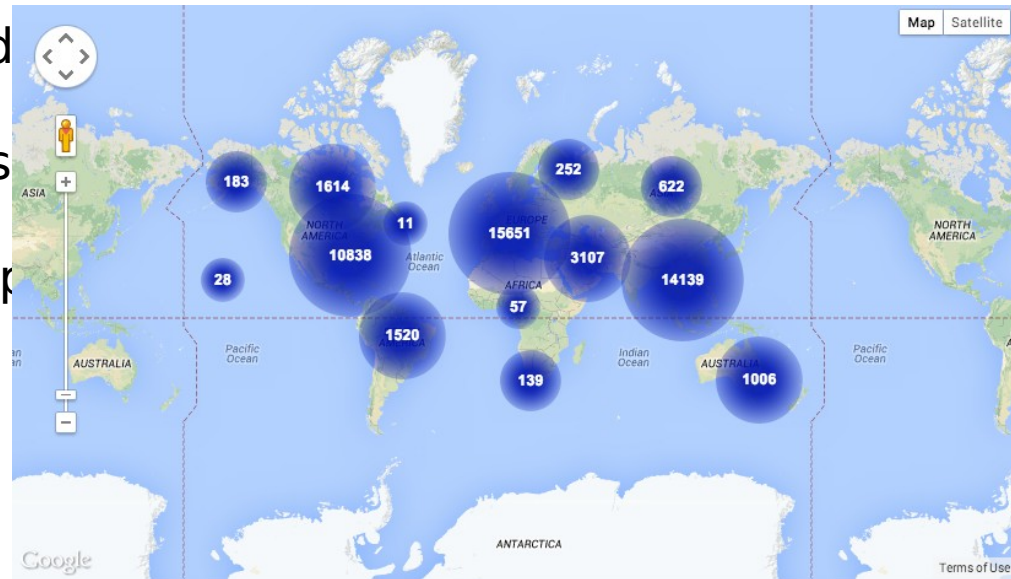


3D Slicer Community

,000 Downloads in 12 months/168 a d

00 messages per year on mailing lists

mi-annual Project Weeks with 100+ op
ource developers and scientists



3D Slicer Enabled Research In...

Huntington's Disease (HD)

Chronic Obstructive Pulmonary
Disease (COPD)

Gynecologic Cancer Brachytherapy

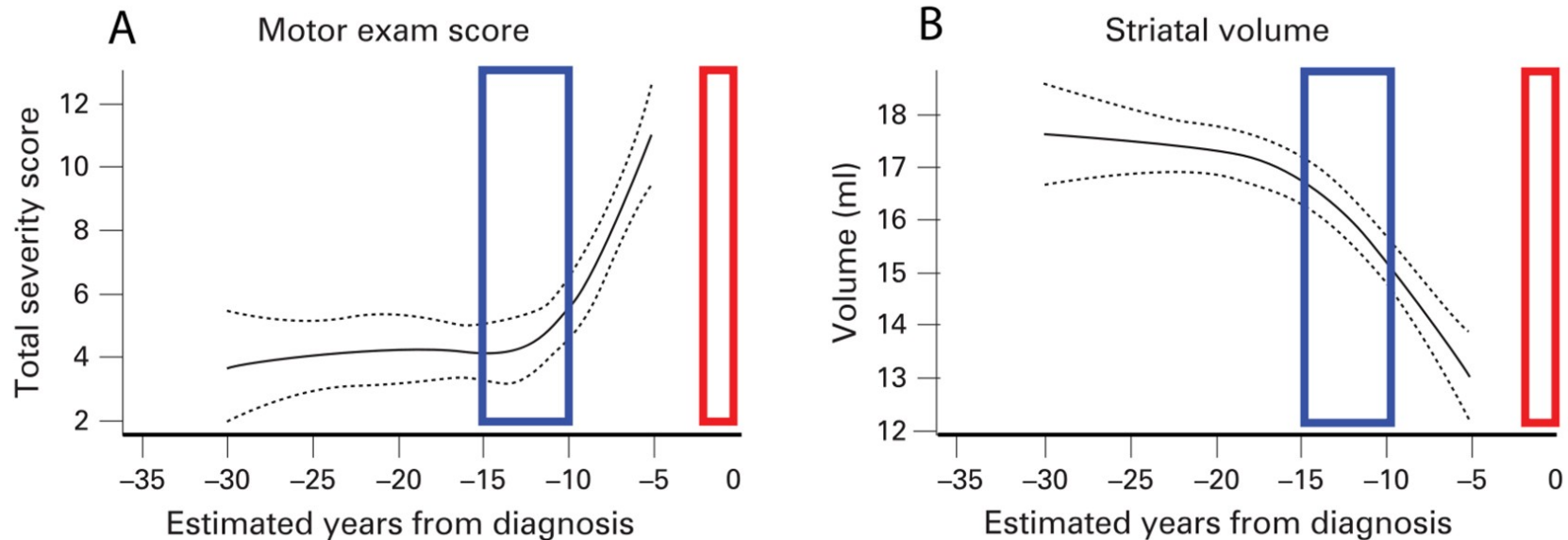
Image Guided Parathyroid Tumor
Resection

Huntington's Disease (HD)

- HD is a Neurodegenerative Disease
 - Affects Muscle Coordination, Behavior, and Cognitive Function
 - Causes Severe Debilitating Symptoms by Middle Age
- Caused by mutation of Huntingtin gene, HTT, on chromosome 4
- If CAG repeats on HTT > 40 , individual will be affected
- The more CAG repeats on HTT, the lower the HD onset age is likely to be.

Clinical Symptoms vs. MR

Clinical symptoms are used to estimate most likely **time of neurological diagnosis** and to propose **window for starting disease-modifying intervention**.



Regional brain volume and white matter integrity changes may even precede clinical symptoms, and improve timing for intervention.

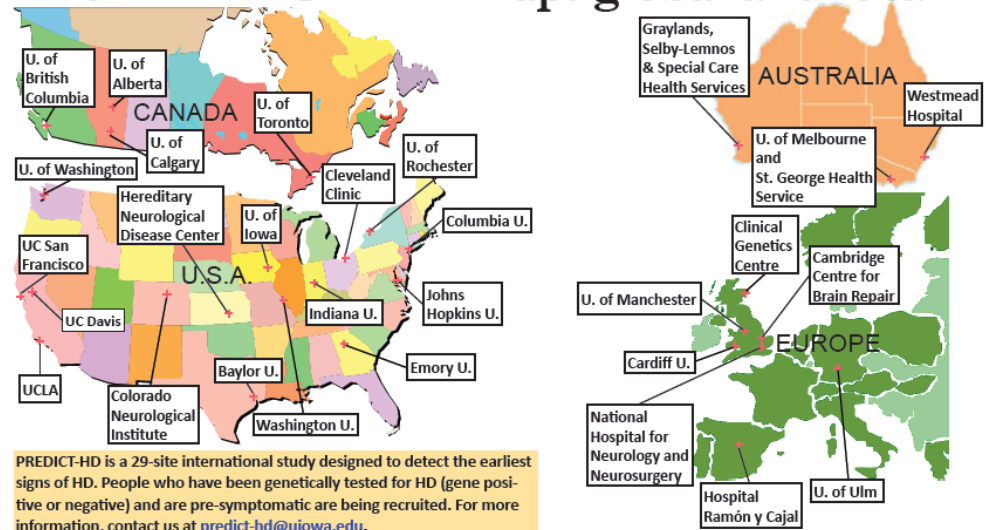
Paulsen JS et al. J Neurol Neurosurg Psychiatry.
2008;79:874-80.

PredictHD

- Genetic and Imaging Study at 29 sites
 - Detect Earliest Signs of Huntington's Disease
- PI: Jane Paulsen, PhD, University of Iowa
- **3D Slicer Scientists: Hans Johnson** and Colleagues, University of Iowa



The PREDICT-HD map: global and local



Accurate Detection of Brain Volume and White Matter Integrity Changes Requires:

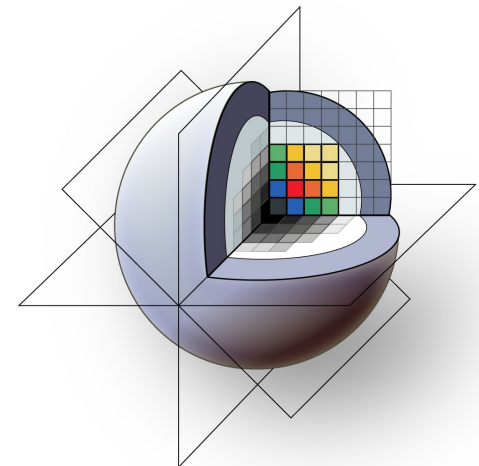
Well Calibrated Acquisitions

Robust Analysis Pipelines

Registration

Segmentation

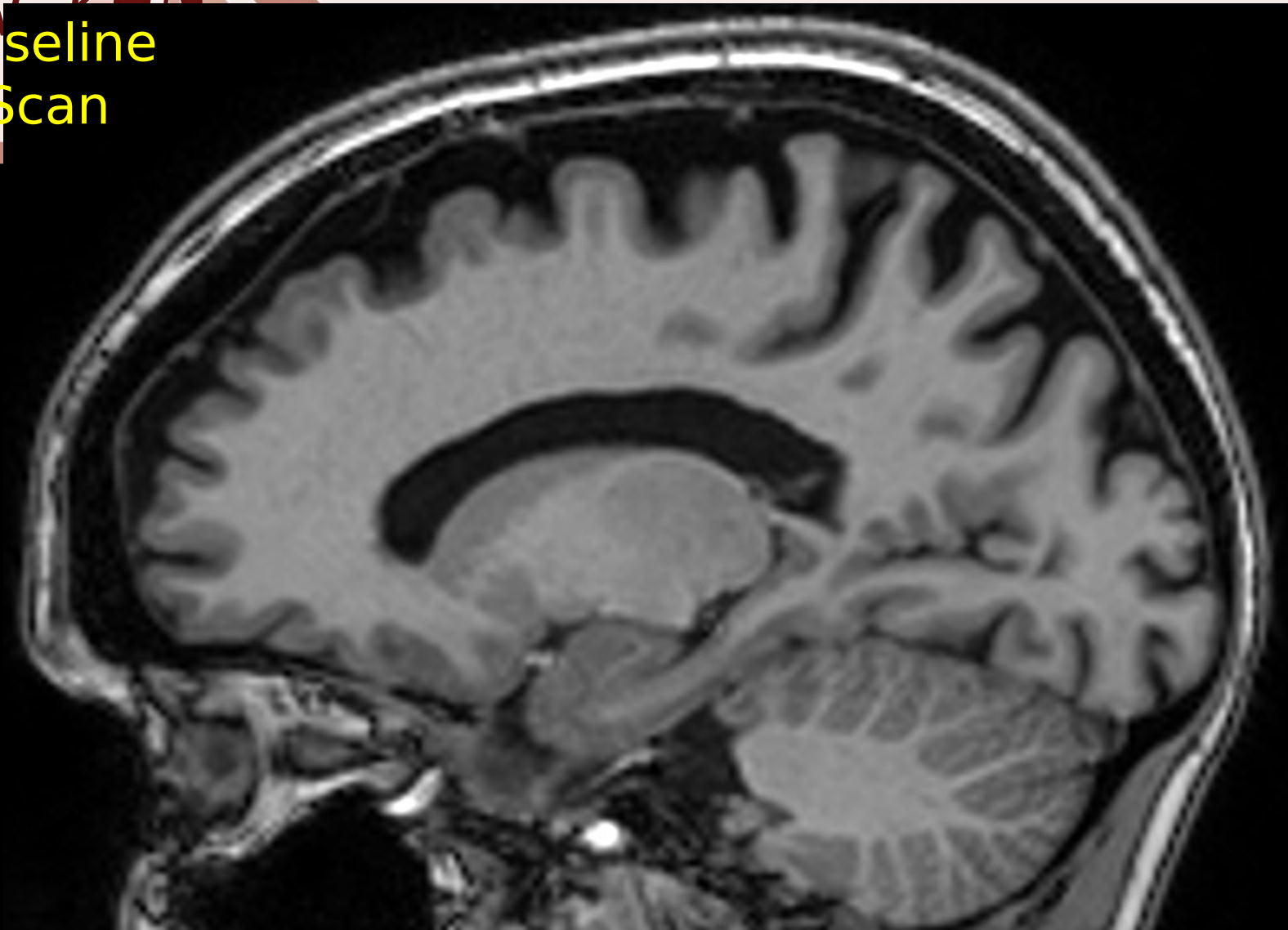
Diffusion Analysis



3DSlicer

TRACK-HD Stage 1 HD Subject

Baseline
Scan



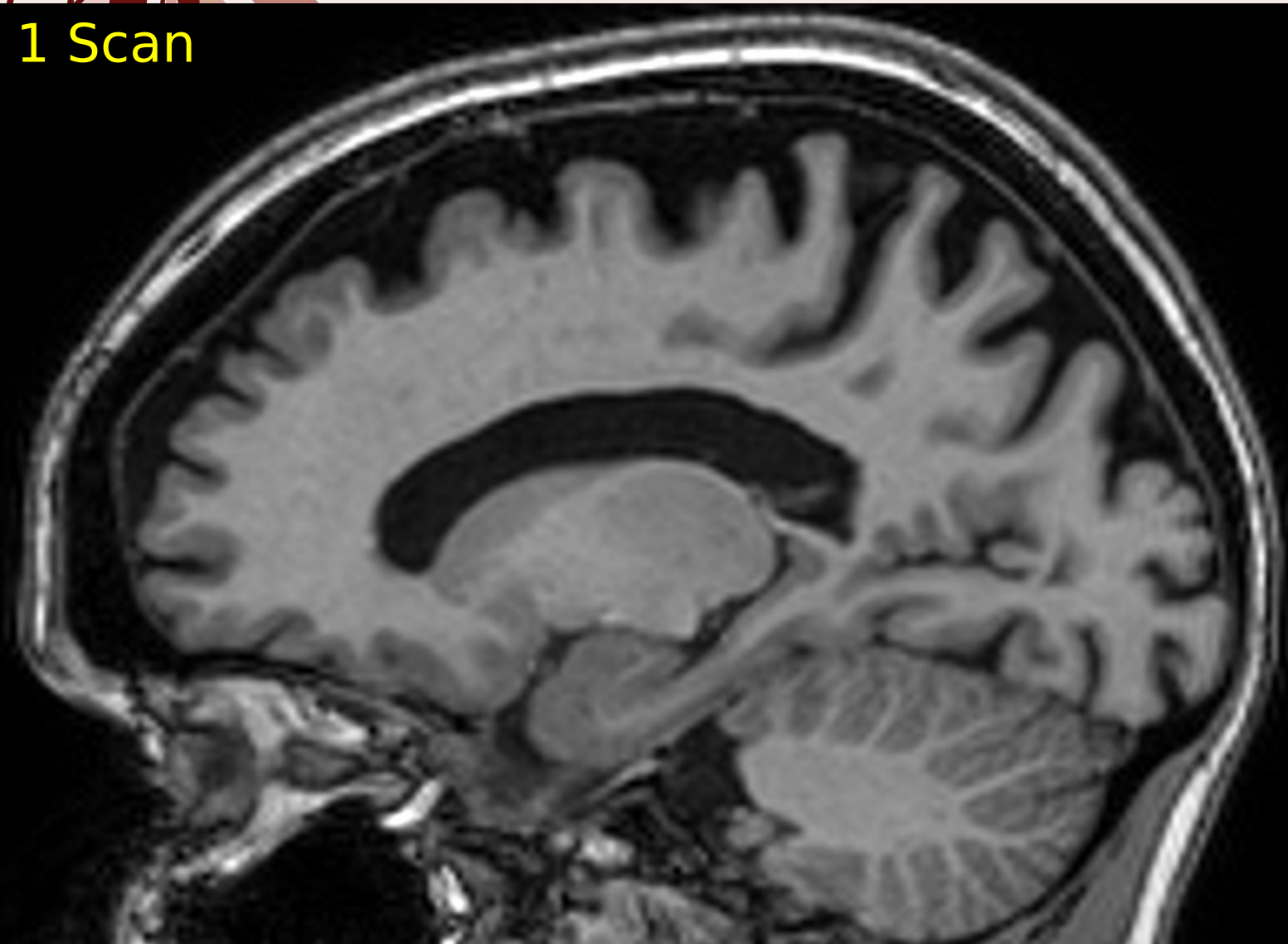
Sarah J Tabrizi et al. Lancet Neurol. 2009 September; 8(9): 791–801.

Slide courtesy Hans Johnson, Ulowa

<http://www.track-hd.net>

TRACK-HD Stage 1 HD Subject

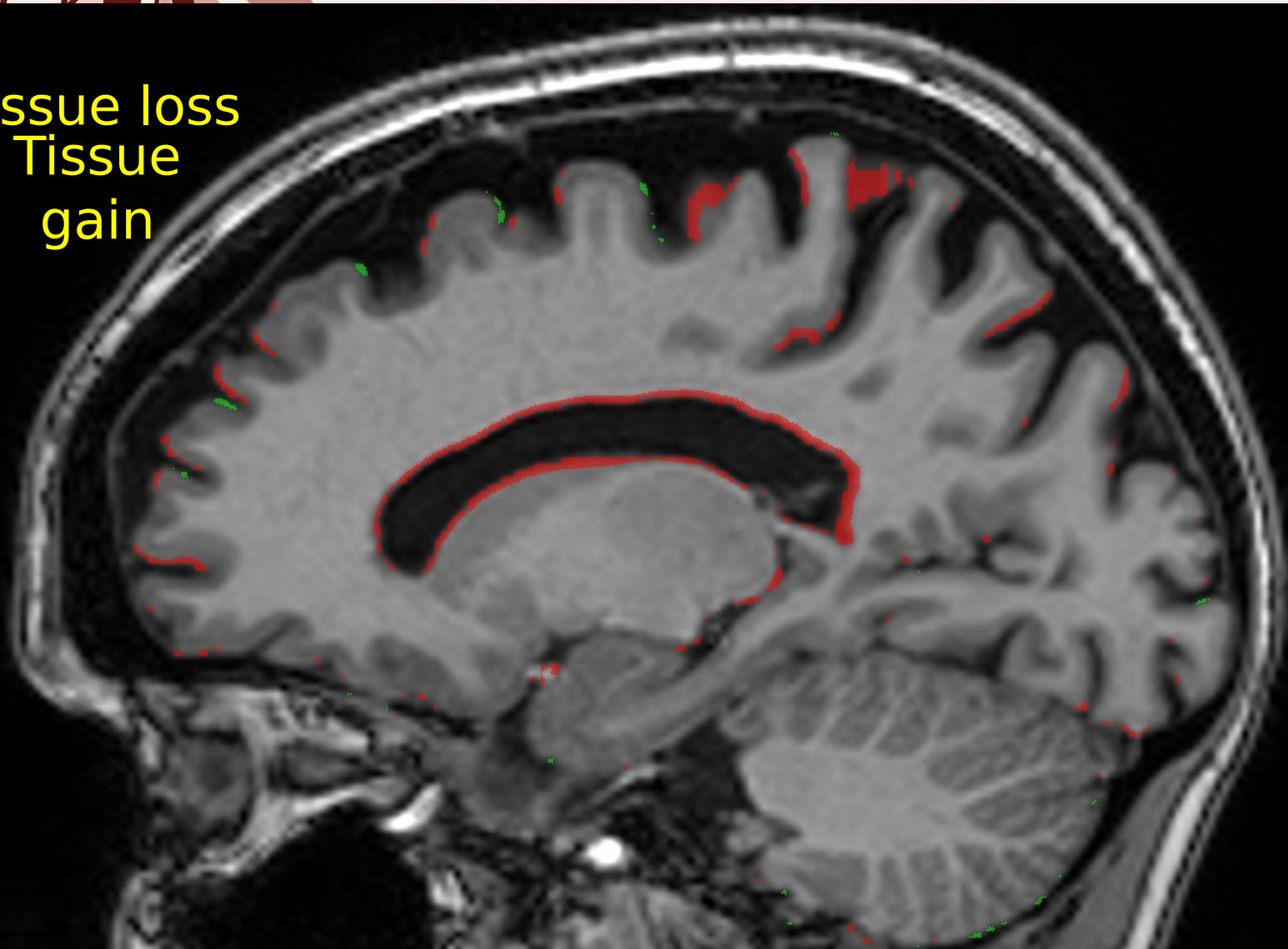
TRACK-HD
Year 1 Scan



TRACK-HD Stage 1 HD Subject

TRACK-HD

- Tissue loss
- Tissue gain



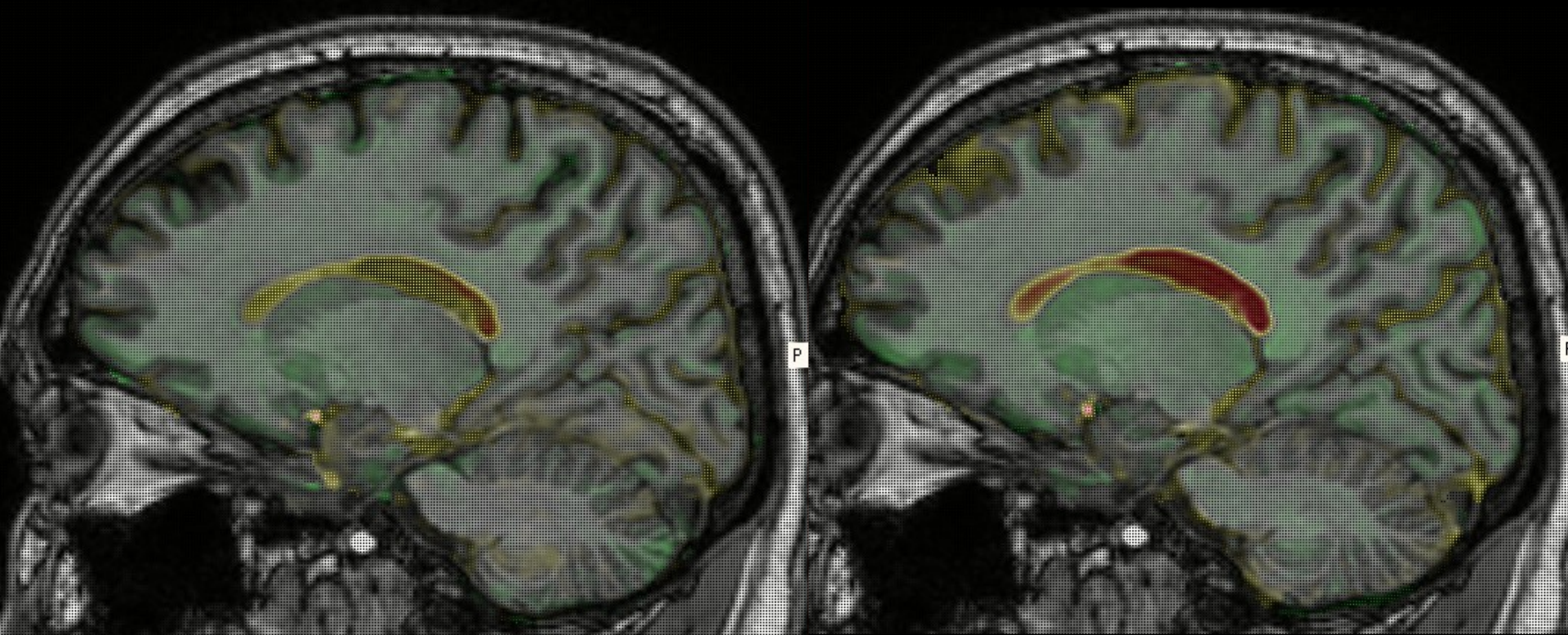
Atrophy Rate: 1.9%

Premanifest Rate: 0.7%

Control

<http://www.track-hd.net>

TRACK-HD Premanifest A Subject: voxel-compression mapping



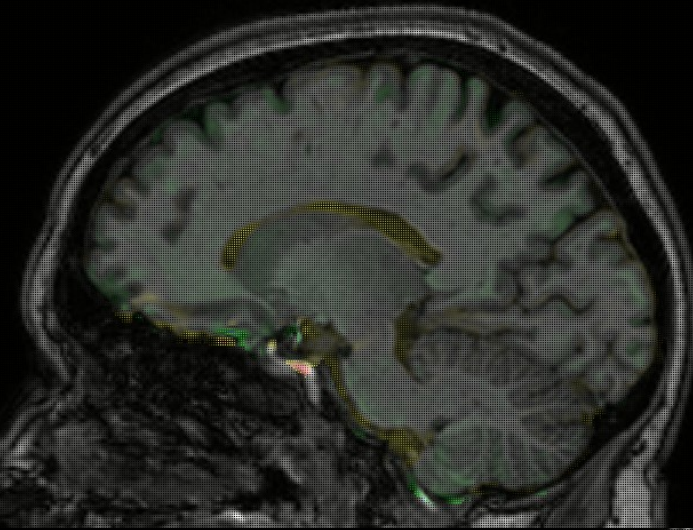
12-month
atrophy

24-month
atrophy

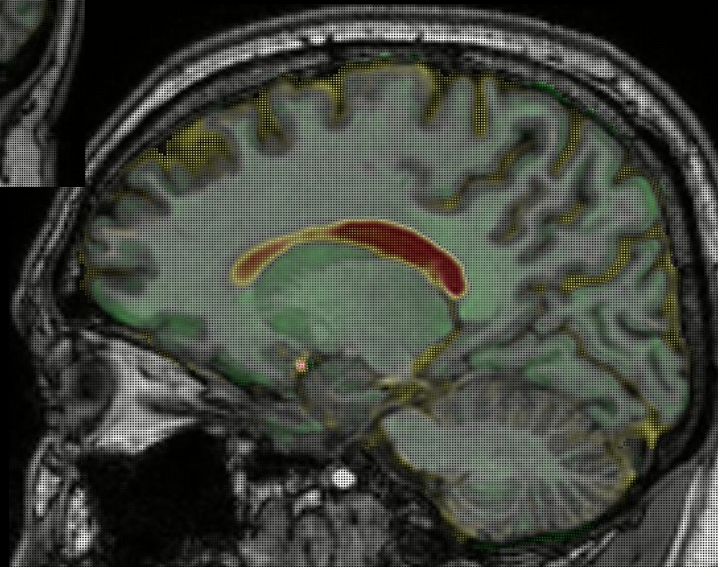
Contraction $\leq 20\%$  Expansion $\geq 20\%$

24-month voxel-compression mapping

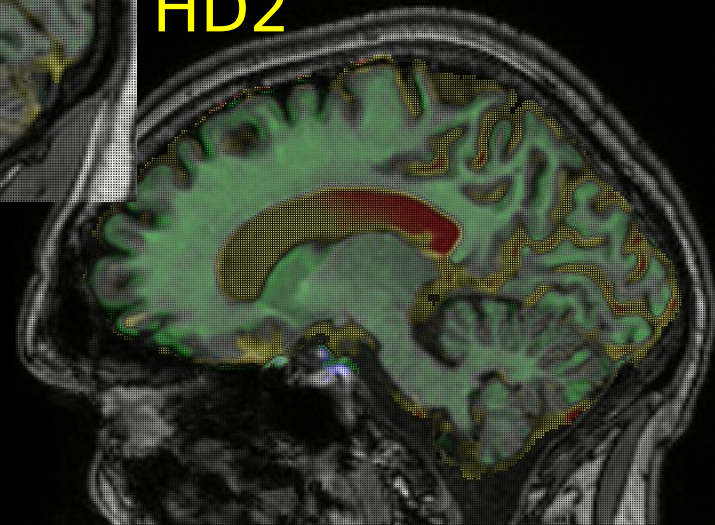
Control



PreA



HD2



Additional Information

- **Hans Johnson** and Colleagues at University of Iowa
- <http://www.predict-hd.net/>

3D Slicer Enabled Research In...

Huntington's Disease (HD)

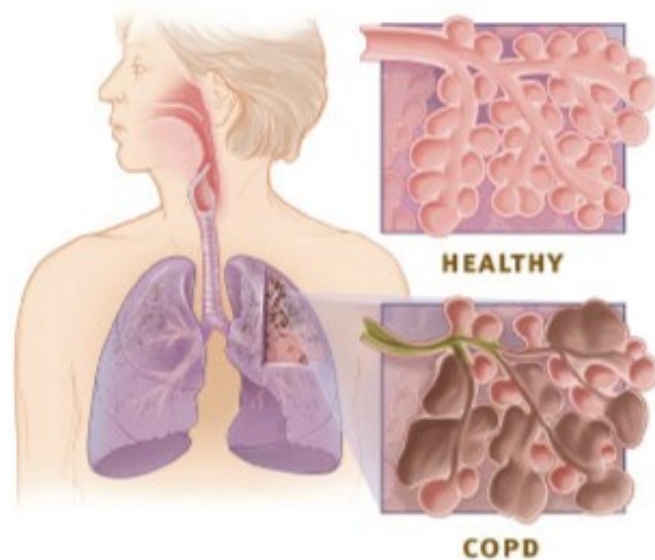
Chronic Obstructive Pulmonary
Disease (COPD)

Gynecologic Cancer Brachytherapy

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Chronic Obstructive Pulmonary Disease

- Lung Disease that makes it difficult to breathe
- 5-10% of adults may have COPD
- 3rd leading cause of death behind heart disease and cancer; increased in frequency over the last 30 years.



Chronic Obstructive Pulmonary Disease

- Almost all COPD occurs in smokers
- But only 20% of smokers develop COPD
- Strong belief that there is a genetic predisposition

- Characterized by presence of two disease processes:
 - Airway disease - airway wall thickening (visible in CT)
 - Emphysema - destruction of air spaces in the lungs (visible in CT)

COPDGene

Seeks genetic predisposition by means of a thorough phenotypic characterization

Multi-center study funded by the National Heart, Lung and Blood Institute (NHLBI).



Co-PIs: Drs. James Crapo, Edwin Silverman.

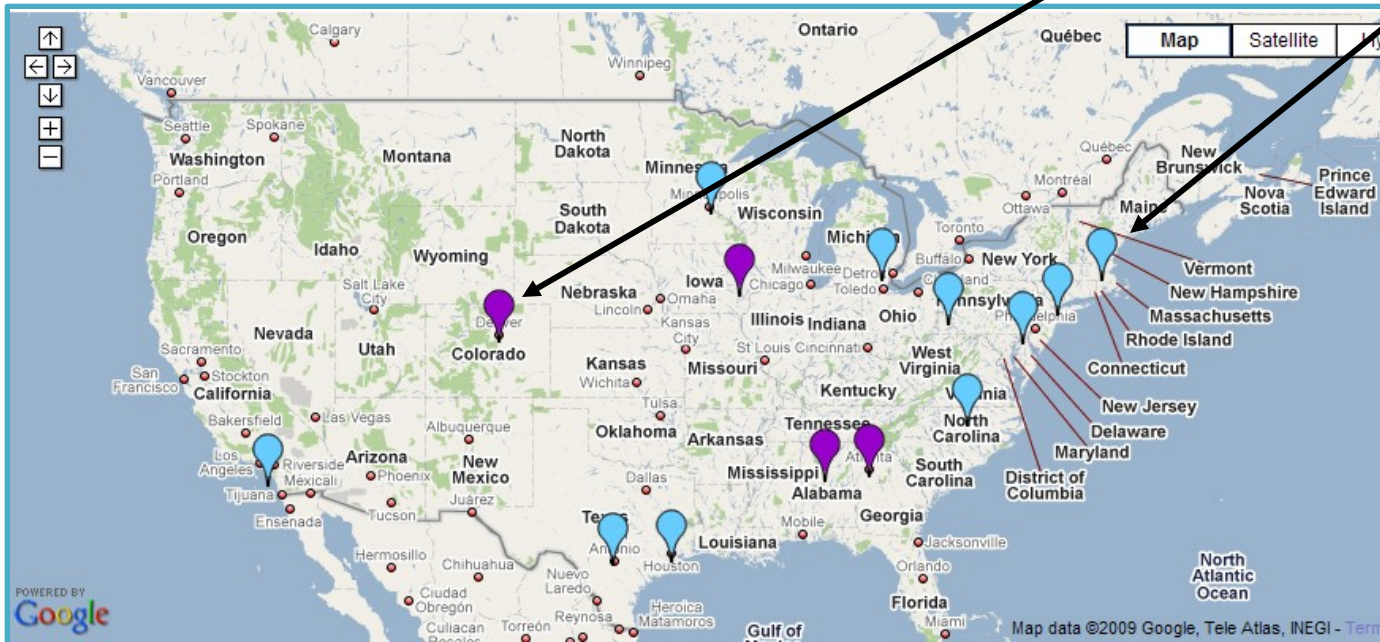
21 clinical sites

3 image analysis centers:

- Denver
- Boston

2 imaging platforms:

- VIDA
- Slicer



Emphysema Classification for Gene Discovery



- Identification of emphysema patterns based on local histogram classification



Normal



Severe CLE



Mild CLE



PLE



Moderate CLE



Paraseptal

- Centrilobular (CLE) and panacinar (PLE) emphysema
- GWAS in 9000 smokers

Castaldi PJ, San Jose Estepar R, Sanchez Mendoza C, Crapo JD, Lynch D, Beaty TH, Washko GR, Silverman EK, Proc. ATS, 2012, p.A3808.

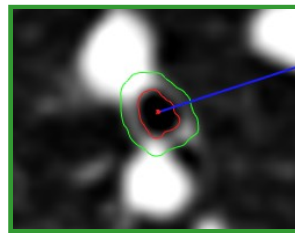
Phenotype Extraction In The Lung

Airways

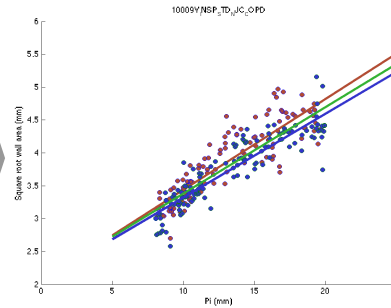
Extraction



Sizing

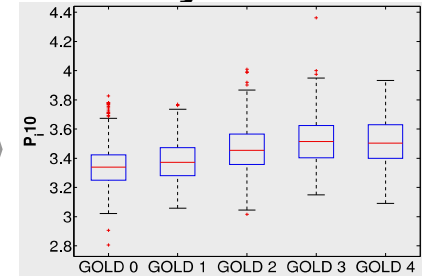


Phenotype



Airway Wall corresponding to a 10 mm internal Perimeter

Population Study

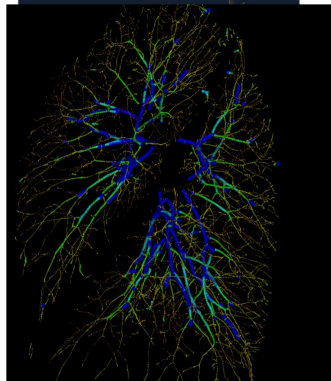


Smoker Controls

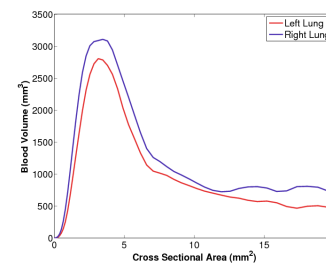
Severe Disease

San Jose Estepar R et al, **Automatic Airway Analysis for Genome-Wide Association Studies in COPD**, ISBI 2012

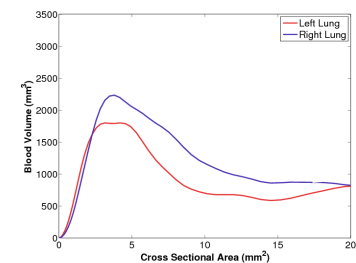
Vessels



Smoker control



Severe disease



Shift in blood volume per cross sectional area indicating distal pruning and proximal remodeling with disease progression

3D Slicer Enabled Research In...

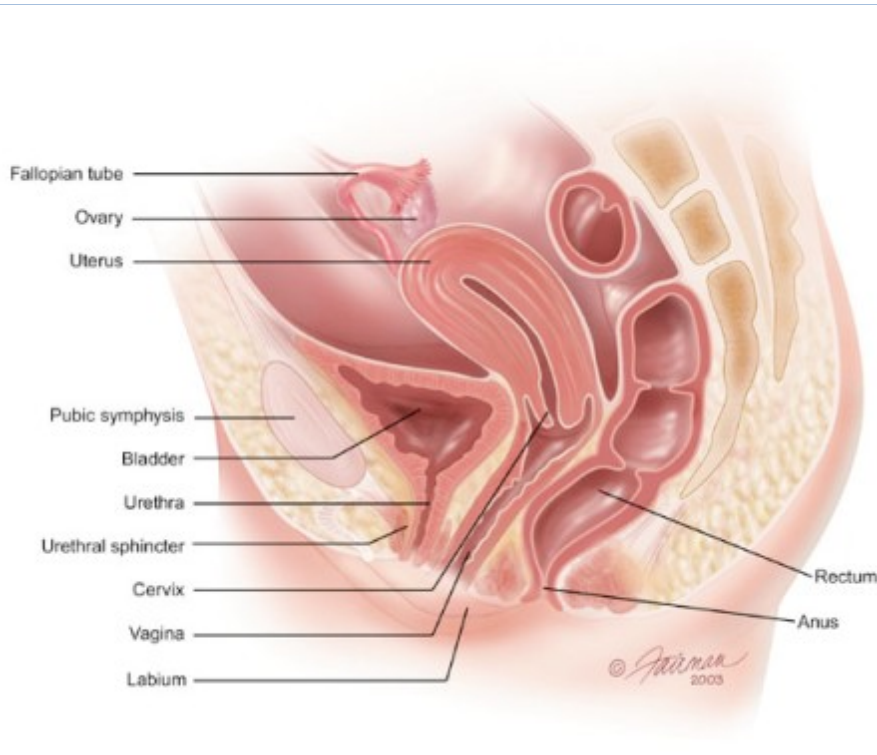
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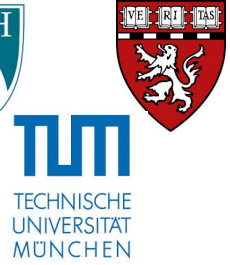
Gynecologic Cancers



- 500,000 cases per year worldwide: Cervical, Uterine, Vaginal, Vulvar, Ovarian
- 4th leading cause of death in women in the US



MR-guided Gynecologic Cancer Brachytherapy In AMIGO

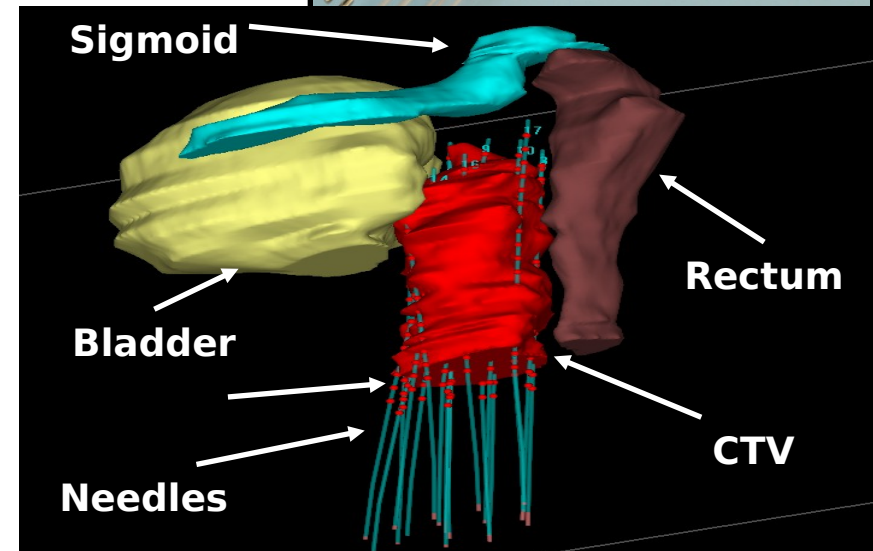
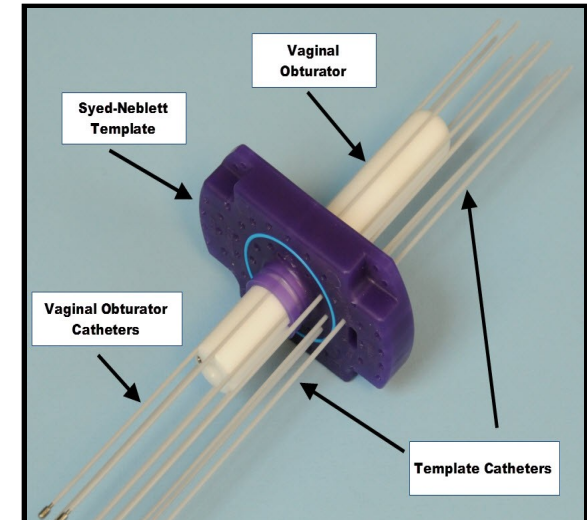


MR is the preferred imaging modality for visualization of gynecologic cancers

Needle artifacts in MR are ambiguous compared to x-ray or CT

10-50 needles are inserted in a case

Need for applicator identification/verification





Iterative Catheter Detection

Idea: find n control points on the needle path to fit a Bézier curve **accurately approximating the catheter shape**

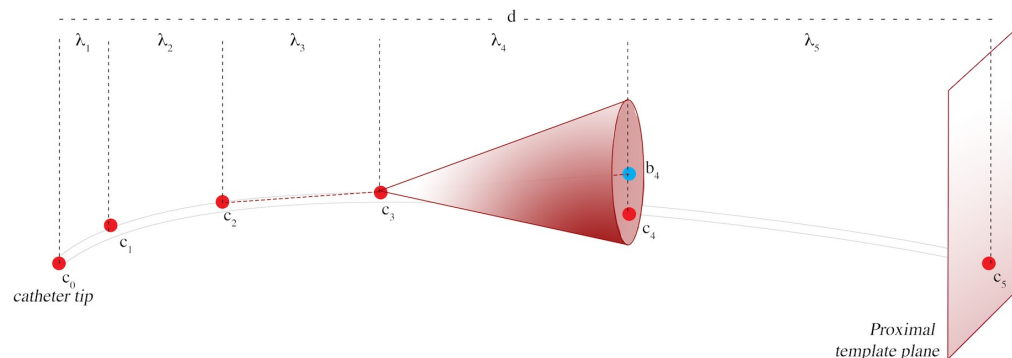
Algorithm structure

(0) **Interactively** provided needle-tip

(1) Algorithm searches the MR image for a segment that **maximizes the "needle likelihood"** in a conic volume. (needle tip = cone tip)

(2) **Reiterate** from the second extremity of the found segment.

(3) Extremities of the segments provide control points used to fit a Bézier curve.

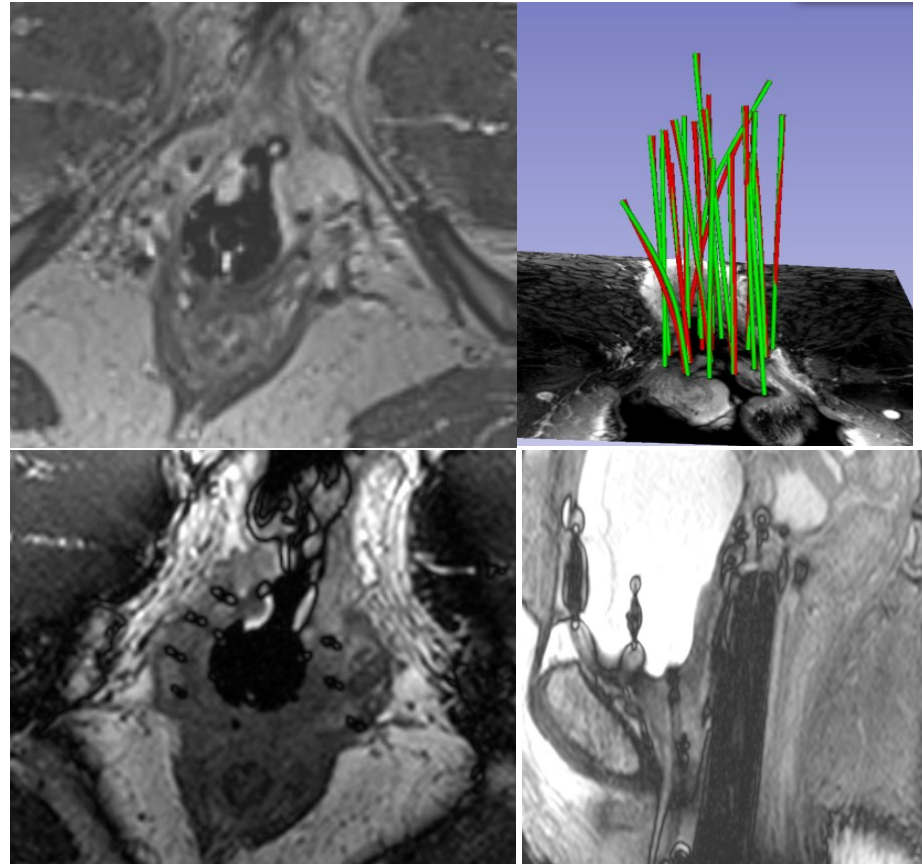




10 brachytherapy patients, 101 catheters.

Hausdorff distance* manual and interactive segmentations.

93/101 HD error < 2mm.
computation time < 1s/catheter.



interactive segmentation (red)
expert manual segmentation
(green)

**HD is the distance of closest points of two surfaces that disagree the most*

3D Slicer Enabled Research In...

Huntington's Disease (HD)

Chronic Obstructive Pulmonary
Disease (COPD)

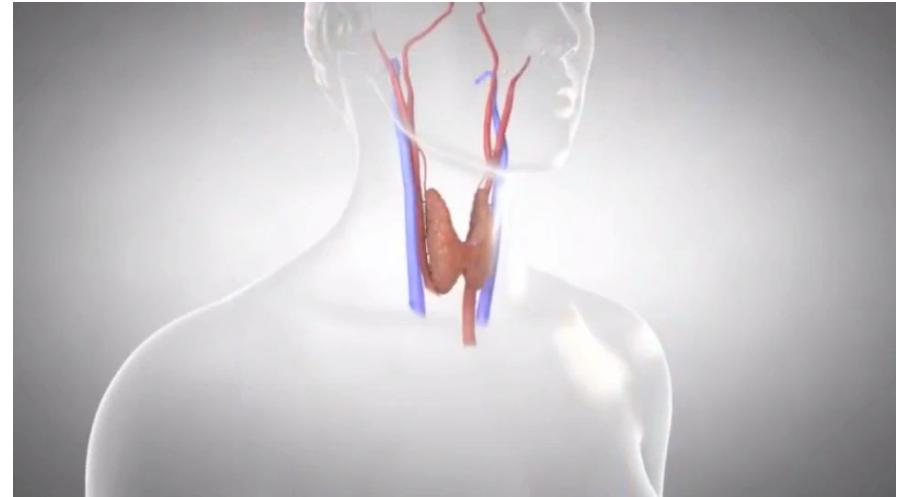
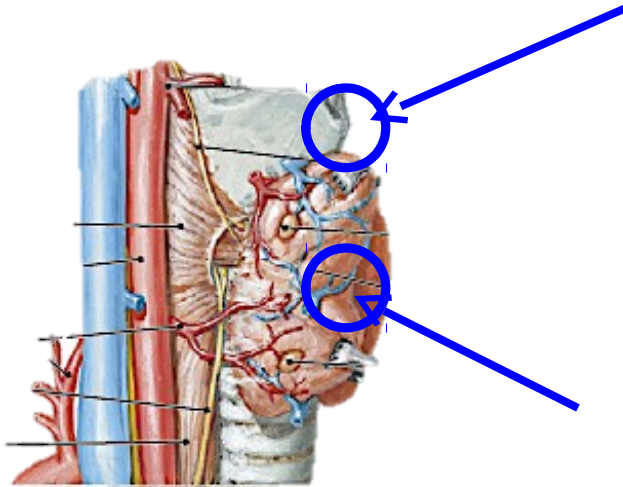
Gynecologic Cancer Brachytherapy

Image-Guided Parathyroid Tumor
Resection

Image-guided Parathyroidectomy in AMIGO

Jayender Jagadeesan, Daniel Rual, Thomas Lee

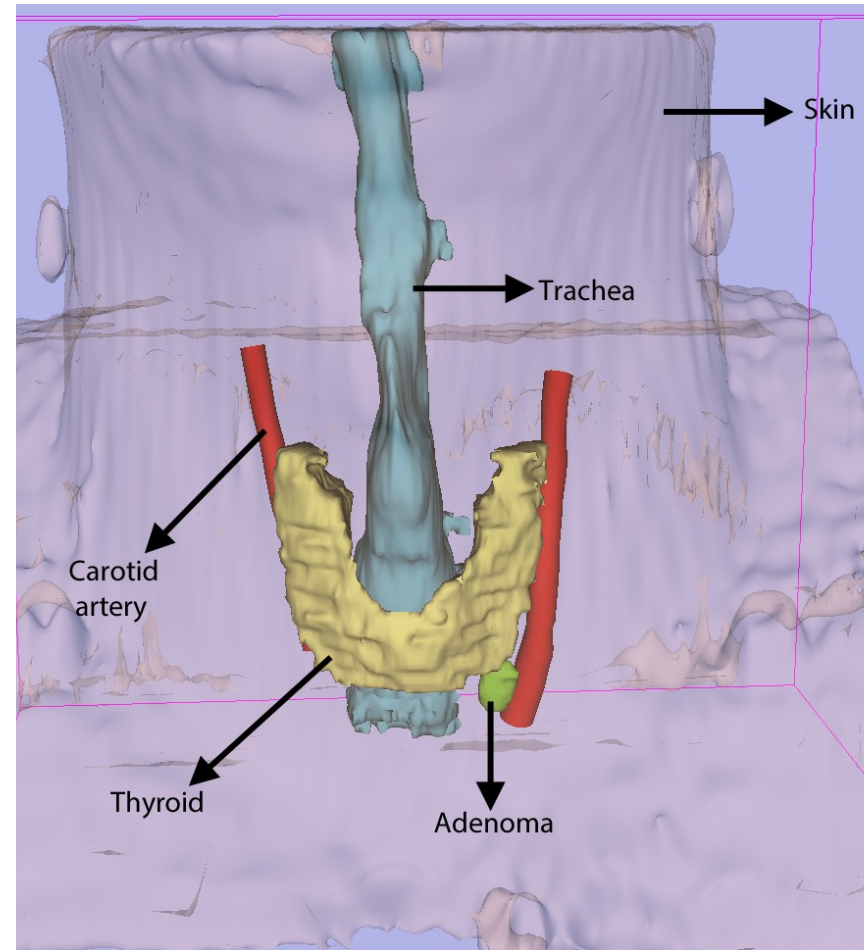
Problems with Diagnosis and Surgical Resection



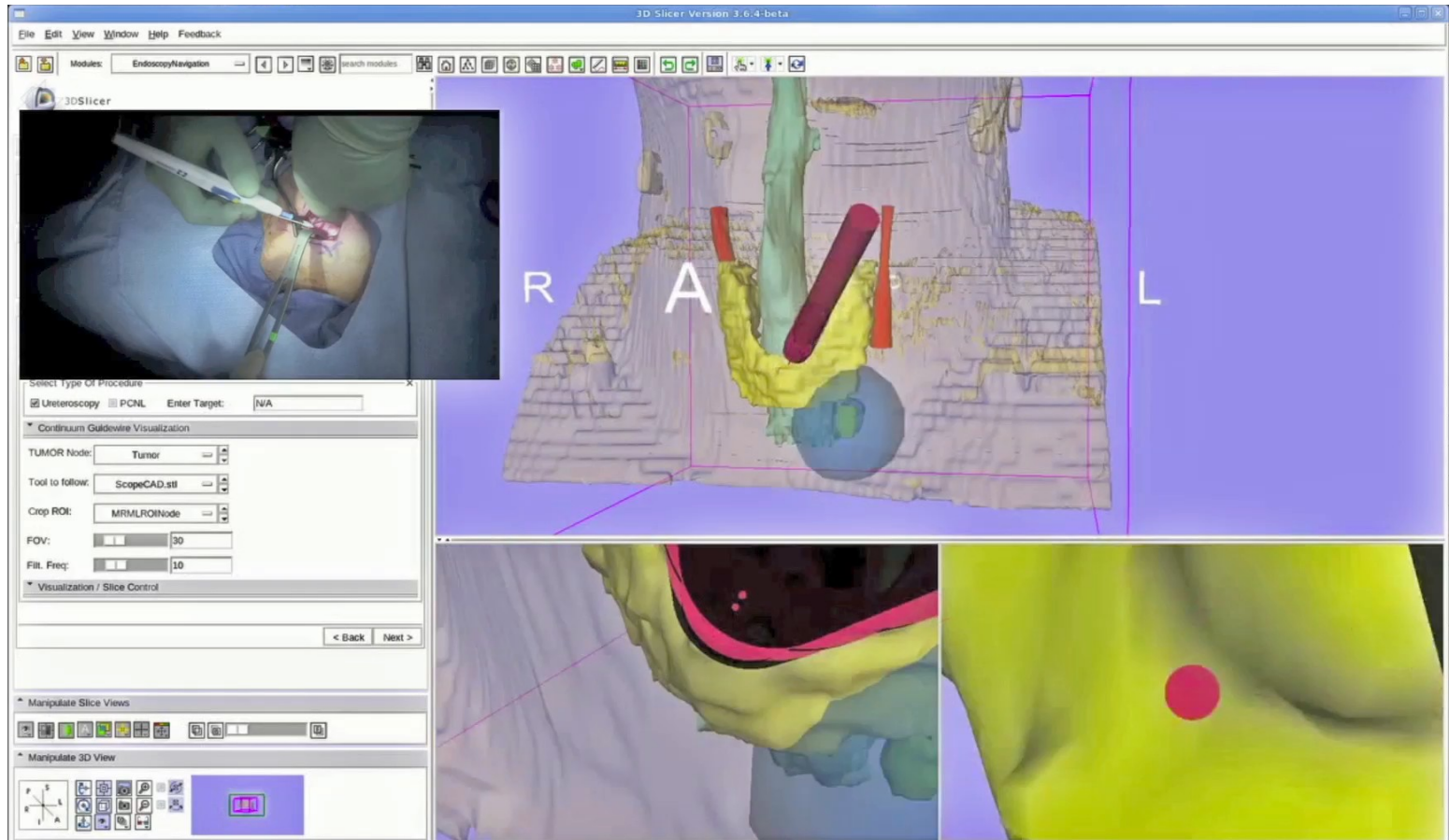
- Small glands hidden behind the thyroid gland
 - As small as a rice grain
- Numerous sensitive structures around the parathyroid making surgical resection difficult
- Damage to laryngeal nerve could lead to hoarseness, inability to speak and difficulty in breathing

Creation of 3D models

- Relevant anatomical structures are rapidly segmented in 3D Slicer1
- Segmentation done in parallel with imaging
- Fast vessel segmentation based on an interpolated cubic Hermitian polynomial
- Semi-automatic techniques to segment the tumor, skin, trachea, thyroid and parathyroid adenoma



Video



x 2 speed

Slide courtesy of Jayender Jagadeesan

Result of Navigation System

- Five patients completed to date
- Registration error = 3.1 mm
(Rigid = 1.97mm)
- Minimum distance of the instrument to
 - Tumor = 0.31 mm
 - Trachea = 0.64 mm
 - Thyroid gland = 1.26 mm
- NASA TLX
 - Physical, Mental demand very low

AMIGO Parathyroid Team

- Surgeon: Daniel Ruan, MD
- Radiologist: Thomas Lee, MD
- Navigation Scientist: Jayender Jagadeesan, PhD

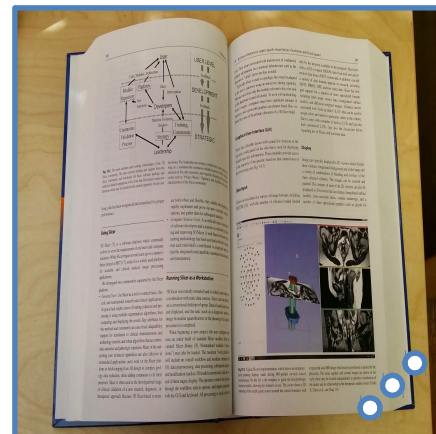
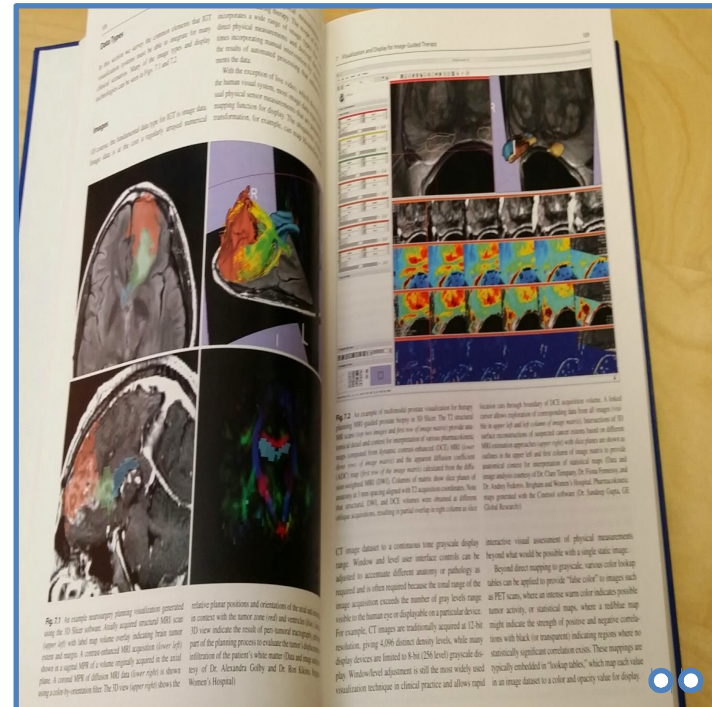
AMIGO Support Team

- Techs/Nurses: Dan Kacher, Janice Fairhurst, Angela Kanan, Shivon Cesar, Sue Sheehan, Sandra Lawson, Julia Bousquet, Sean Jackson, Nikita Aristarkhov

Ferenc A. Jolesz
Editor

Intraoperative Imaging and Image- Guided Therapy

Springer



**64 Chapters, 893 Pages,
6 pounds!**

Join 3D Slicer Community

- June 23-27, 2014: Summer Project Week at MIT
- Thursdays 3pm ET, Weekly teleconferences



Acknowledgments



National Alliance for Medical Image Computing

www.na-mic.org



Neuroimage Analysis Center

Nac.spl.harvard.edu



National Center For Image Guided Therapy

www.ncigt.org

National Institute for Biomedical Imaging and Bioengineering



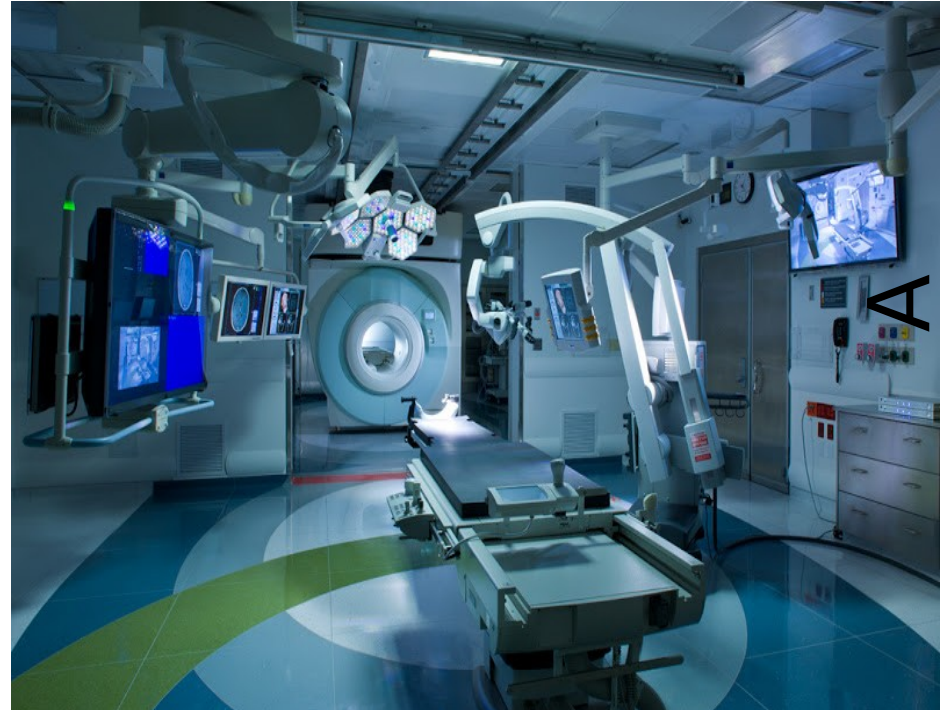
National Center for Research Resources



Brigham and Women's Hospital



The End



A
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