Open Source Software for Image Guided Therapy: 3D Slicer

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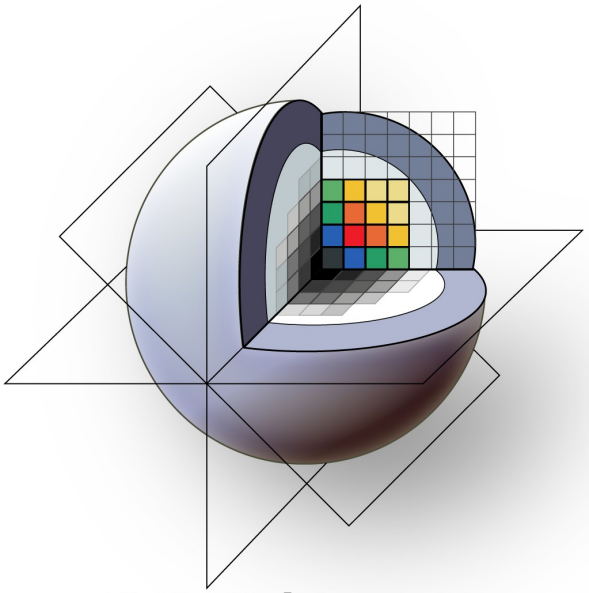
UNDERSTANDING BIOMARKER SCIENCE: FROM MOLECULES TO IMAGES

March 20, 2014

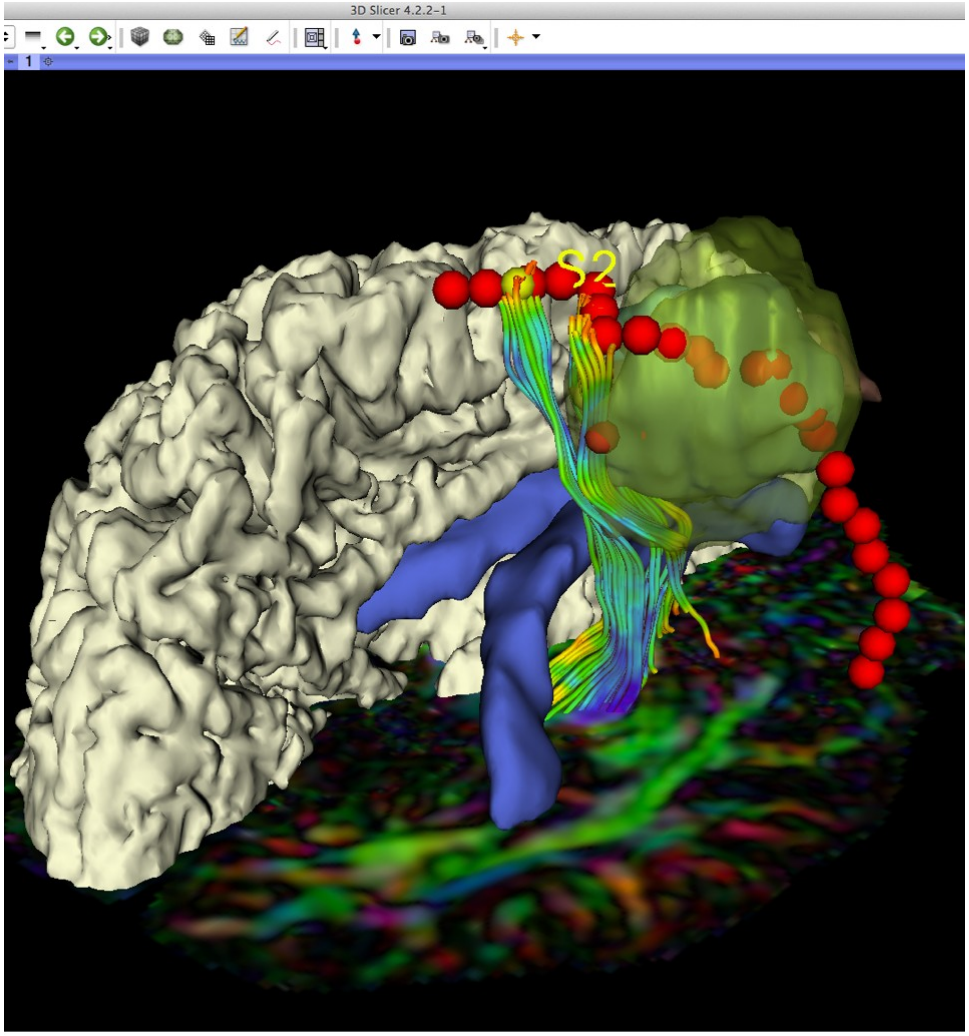
Two technologies
and
a community
developing open science
to accelerate important
discoveries
that improve health and save
lives.



AM

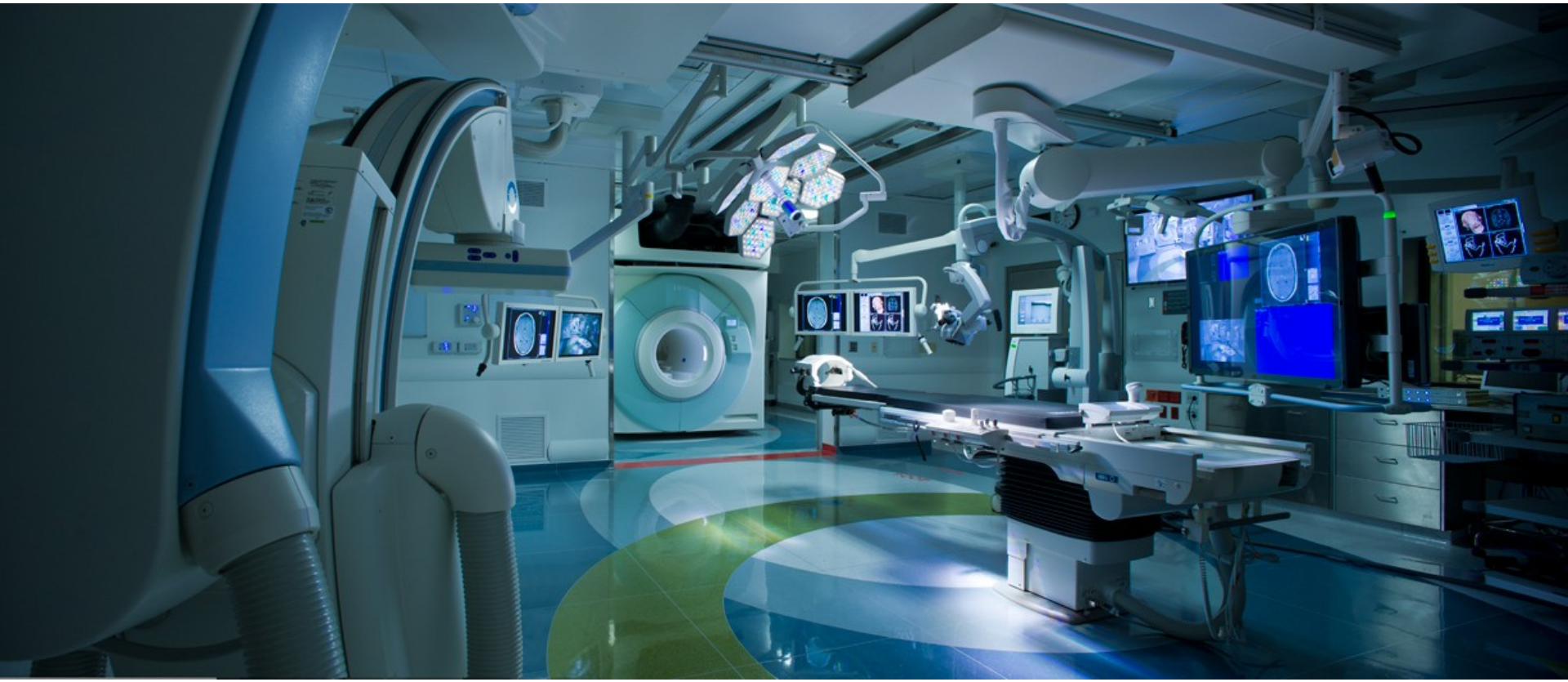
3D Slicer: http://slicer.org

- 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

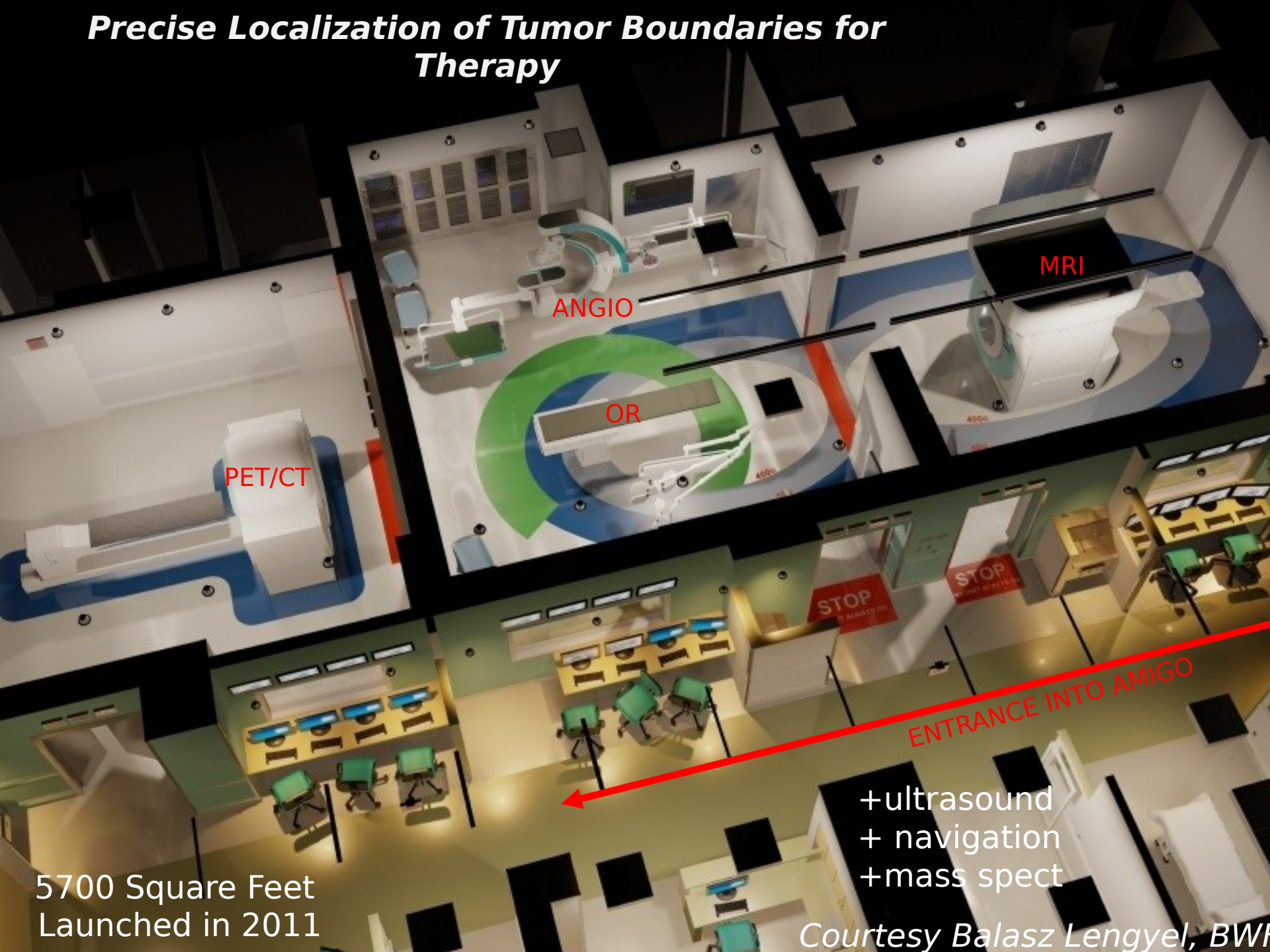
Advanced Multimodality Image Guided Operating Suite (AMIGO)



Precise Localization of Tumor Boundaries for Therapy

P41EB015898 (PI Ferenc Jolesz, Clare Tempany)

Precise Localization of Tumor Boundaries for Therapy



Courtesy Balasz Lengyel, BWH

493 Procedures in AMIGO
8/31/’11 - 3/21/’14

Neuro 103

- 67 Craniotomies/Biopsies
- 22 Transsphenoidals
- 7 Laser Ablations
- 6 Deep Brain Stimulation electrodes placement
- 1 Epilepsy Electrode Placement

Head and Neck 5

- 5 Parathyroidectomies/Hemithyroidecotmies

Spine 1

- 1 MR Cryoablation/Biopsy (Spinal Tumor Mass)

Thorax 44

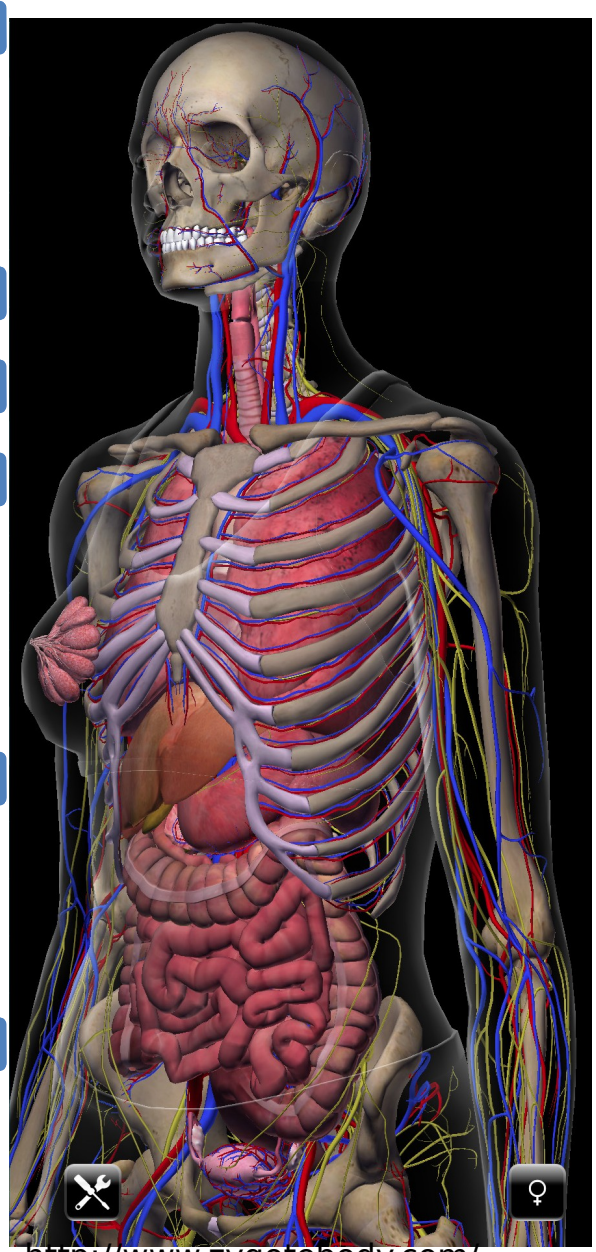
- 15 Video Assisted Thoracoscopic surgeries (iVats)
- 8 Breast Lumpectomies
- 7 EP Cardiac Ablations
- 7 Microwave ablations PET/CT guided (lung)
- 3 Cryoablations PET/CT guided (lung, rib)
- 3 Biopsy PET/CT guided (lung)

Abdomen 153

- 96 Cryoablations MRI guided (liver, kidney)
- 23 Biopsies MR guided (liver, kidney)
- 13 Microwave Ablations PET/CT guided (liver, kidney)
- 11 Cryoablations PET/CT guided (liver, kidney)
- 9 Cryoablations & Biopsies MR guided (liver, kidney)

Pelvis 187

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



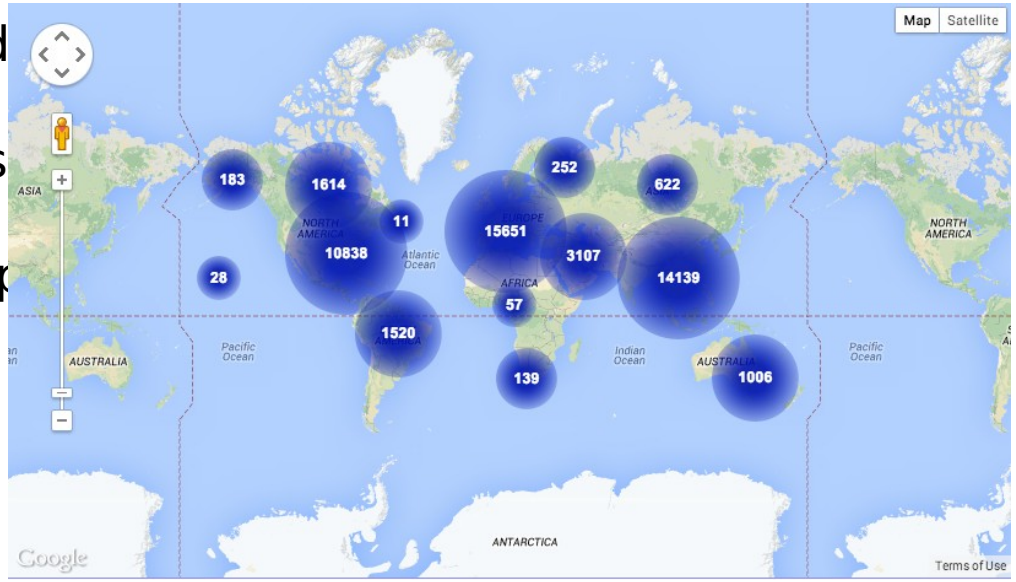
http://www.zygotebody.com/

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
urce 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)

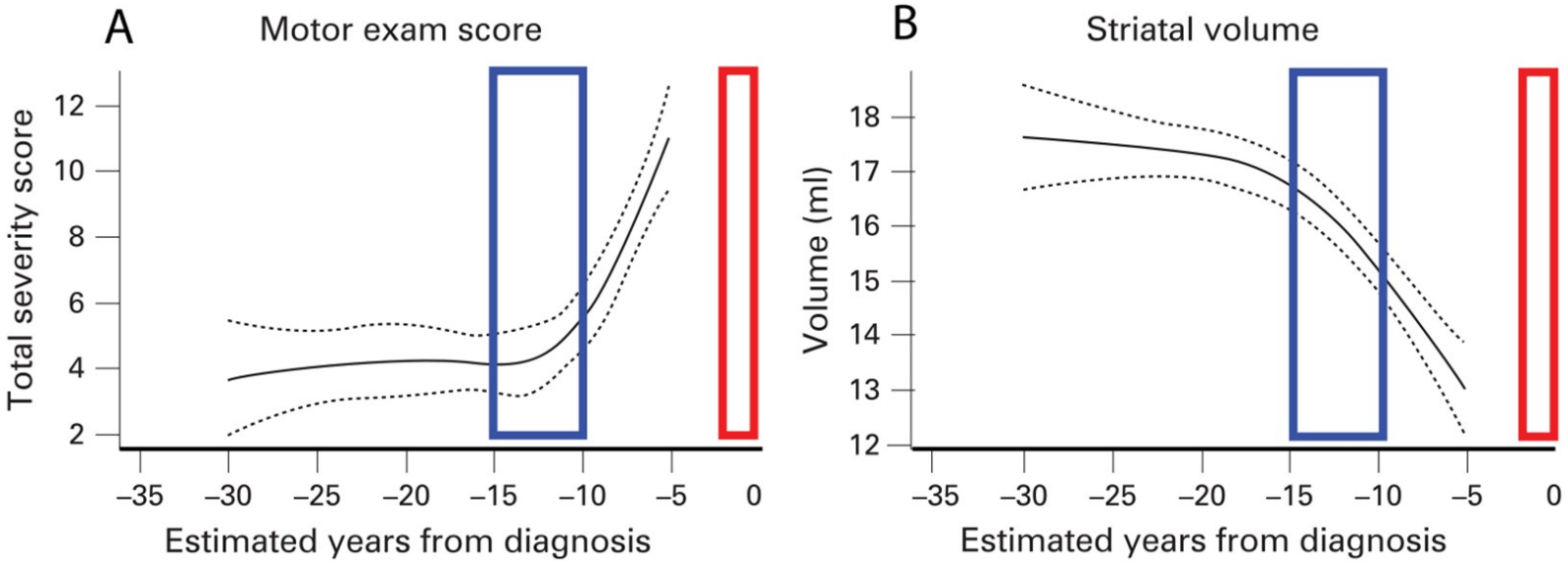
- HD is a Neurodegenerative Disease
  - Affects Muscle Coordination, Behavior, and Cognitive Function
  - Causes Severe Debilitating Symptoms by Middle Age
- Caused by mutation of Huntingtin gene, HTT, on chromosome 4
- If CAG repeats on HTT > 40, individual will be affected
- The more CAG repeats on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

Langbehn DR et al. Clin Genet. 2004;65(4):267-77

Detection: 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.



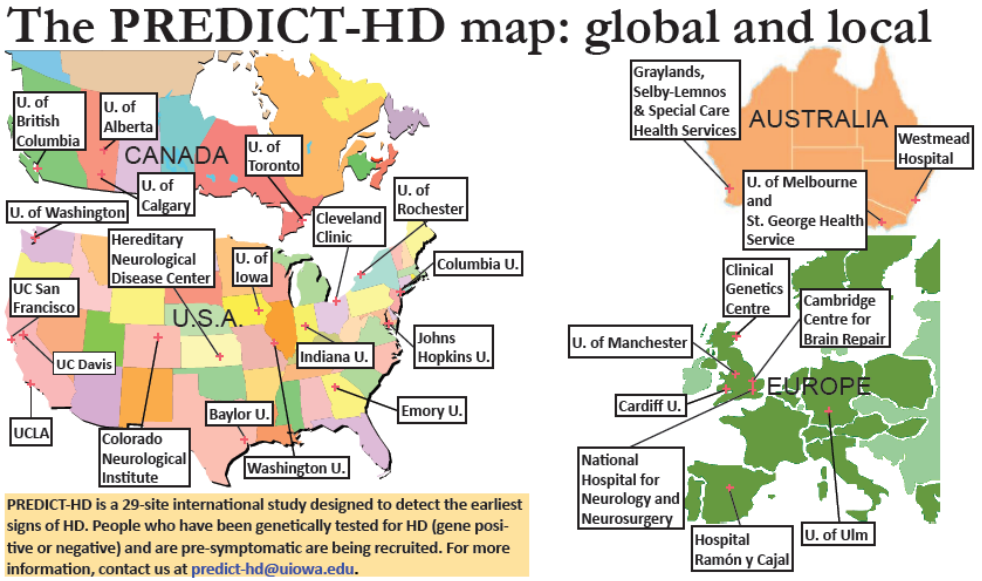
Regional brain volume and white matter integrity changes may even precede clinical symptoms, and improve timing for intervention.

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
- NA-MIC Collaboration with
  - **Hans Johnson** and Colleagues at University of Iowa

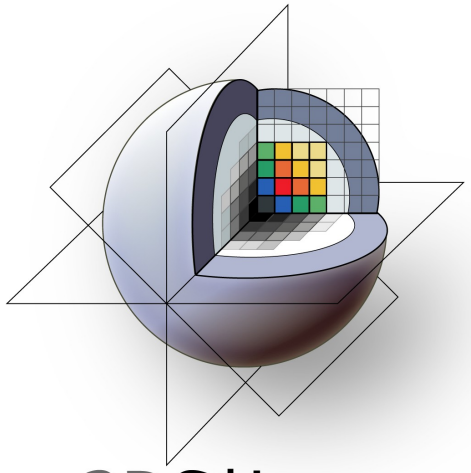
THE UNIVERSITY OF IOWA



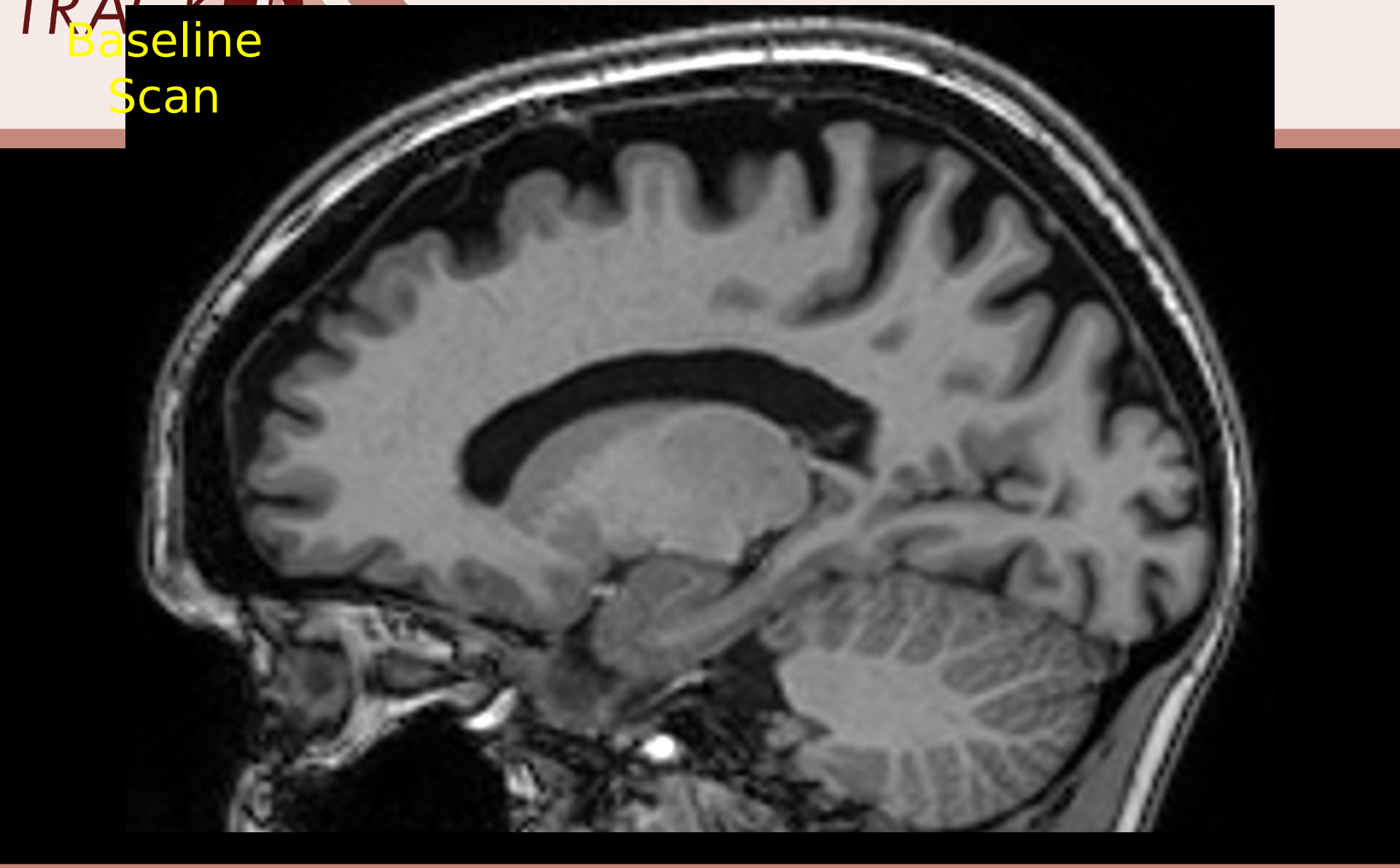
http://www.predict-hd.net/

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

- Well Calibrated Acquisitions
- Robust Analysis Pipelines
  - Registration
  - Segmentation
  - Diffusion Analysis



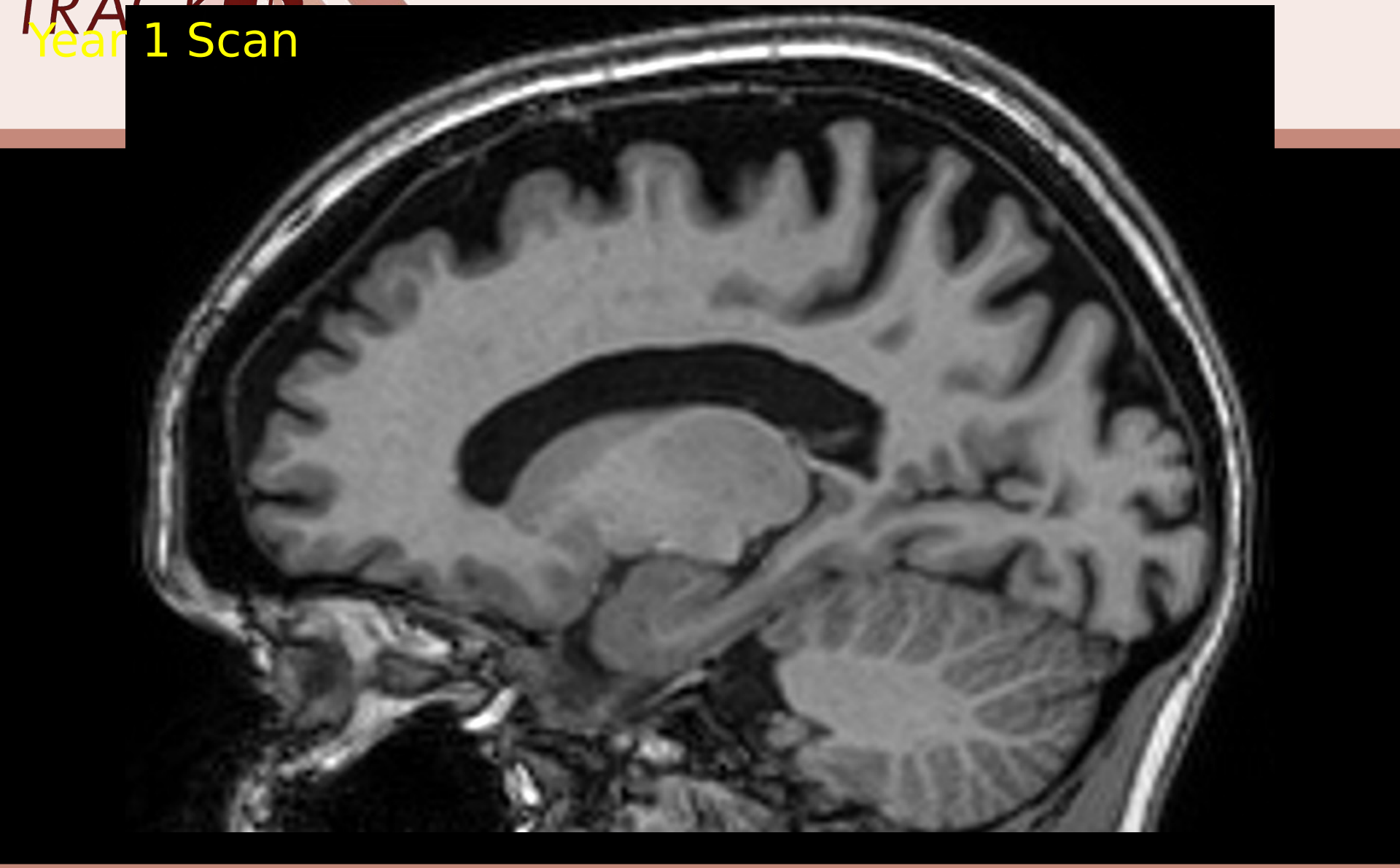
TRACK-HD Stage 1 HD Subject



Sarah J Tabrizi et al. Lancet Neurol. 2009 September; 8(9): 791–801.
Slide courtesy Hans Johnson, UIowa

http://www.track-hd.net

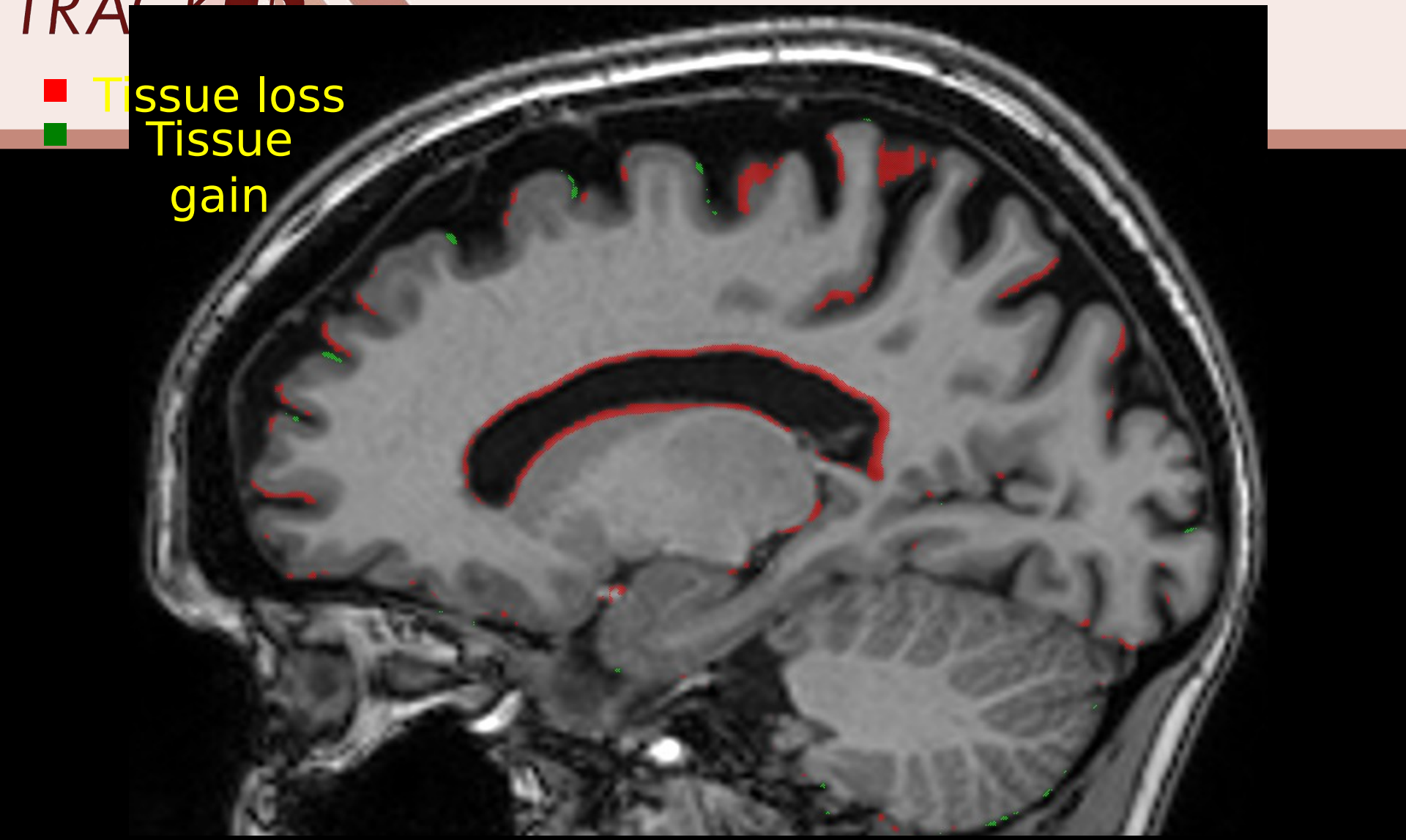
TRACK-HD Stage 1 HD Subject



Slide courtesy Hans Johnson, UIowa

http://www.track-hd.net

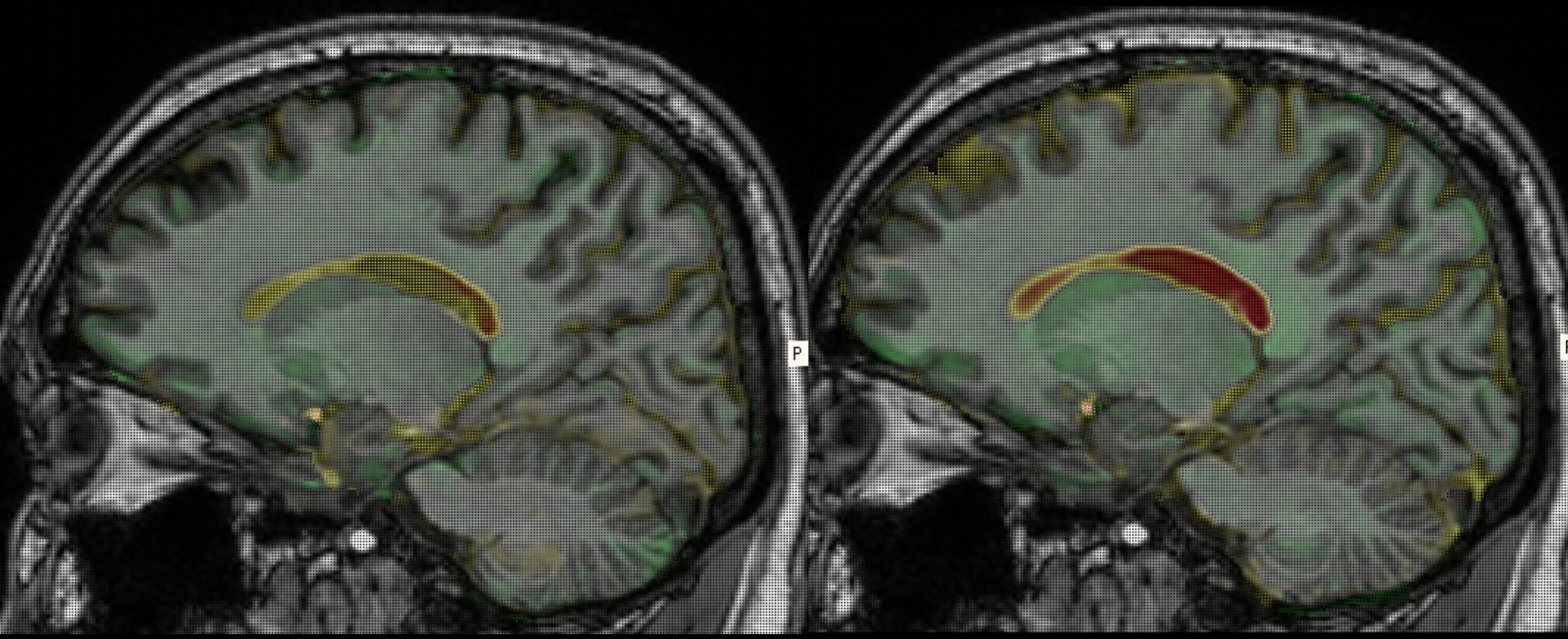
TRACK-HD Stage 1 HD Subject



Atrophy Rate: 1.9% Premanifest Rate: 0.7% Control

http://www.track-hd.net

TRACK-HD Premanifest A Subject: voxel-compression mapping

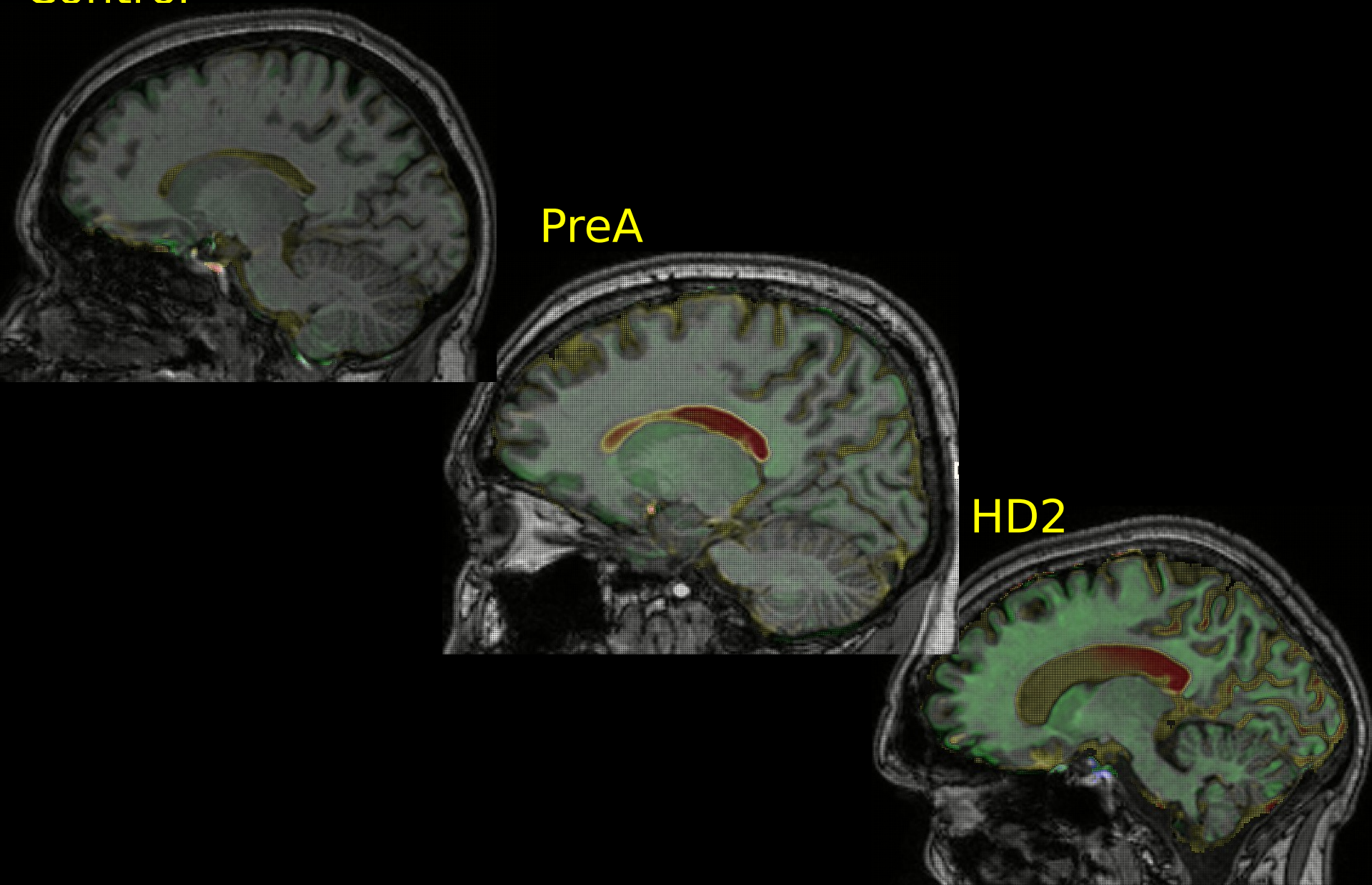


12-month atrophy

24-month atrophy

Contraction ≤ 20% — Expansion ≥ 20%

24-month voxel-compression mapping



Additional Information

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

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- Chronic Obstructive Pulmonary Disease (COPD)
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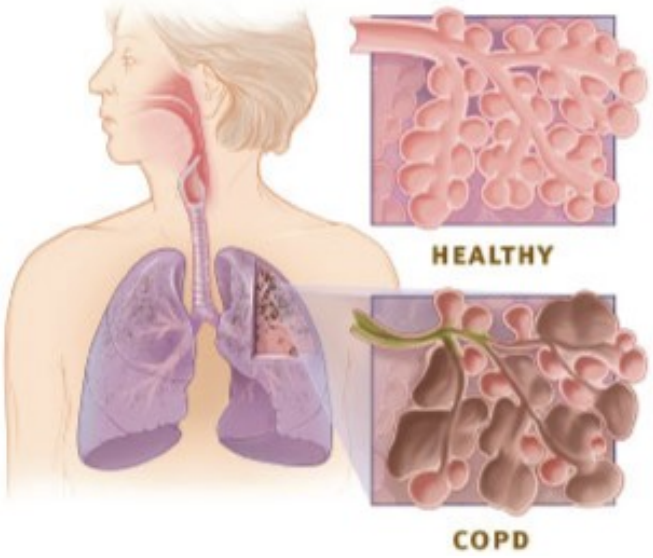
Chronic Obstructive Pulmonary Disease

- 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.



http://copdgene.org/information-copd

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)

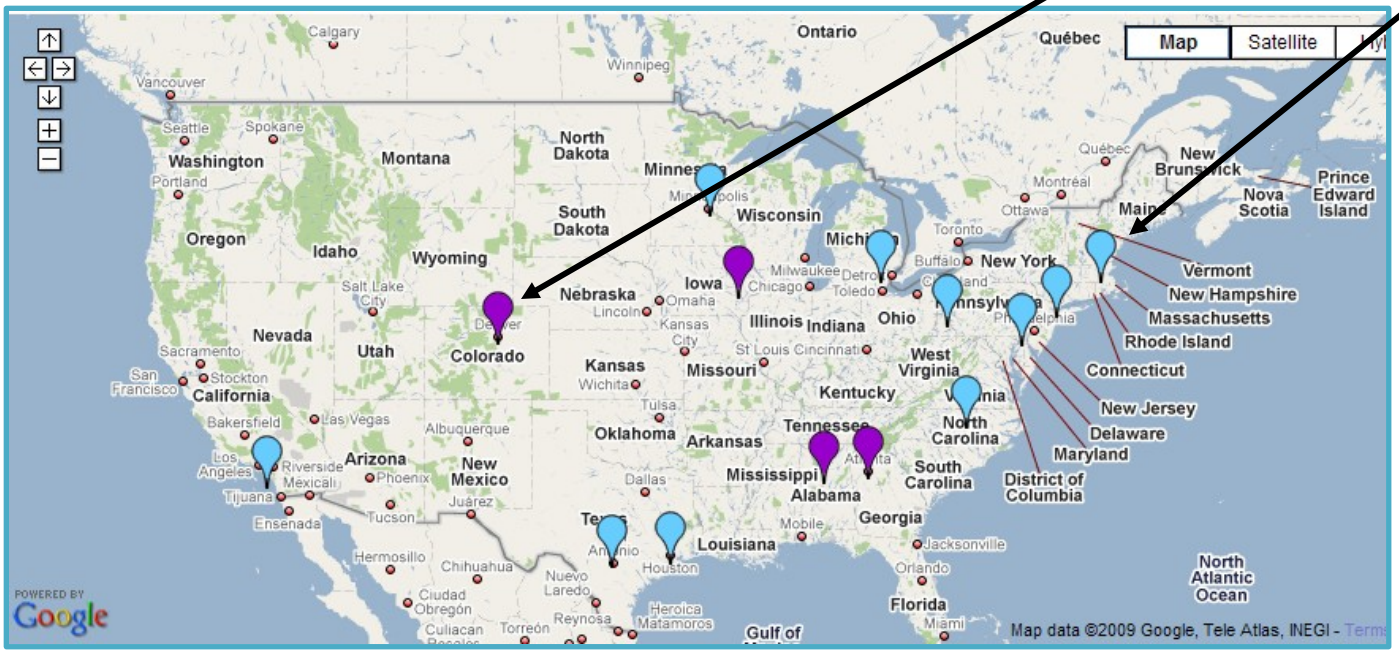
COPDGene

Seeks genetic predisposition by means of a thorough phenotypic characterization

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

COPDGene®
COPD Genetic Epidemiology

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



21 clinical sites

3 image analysis centers:

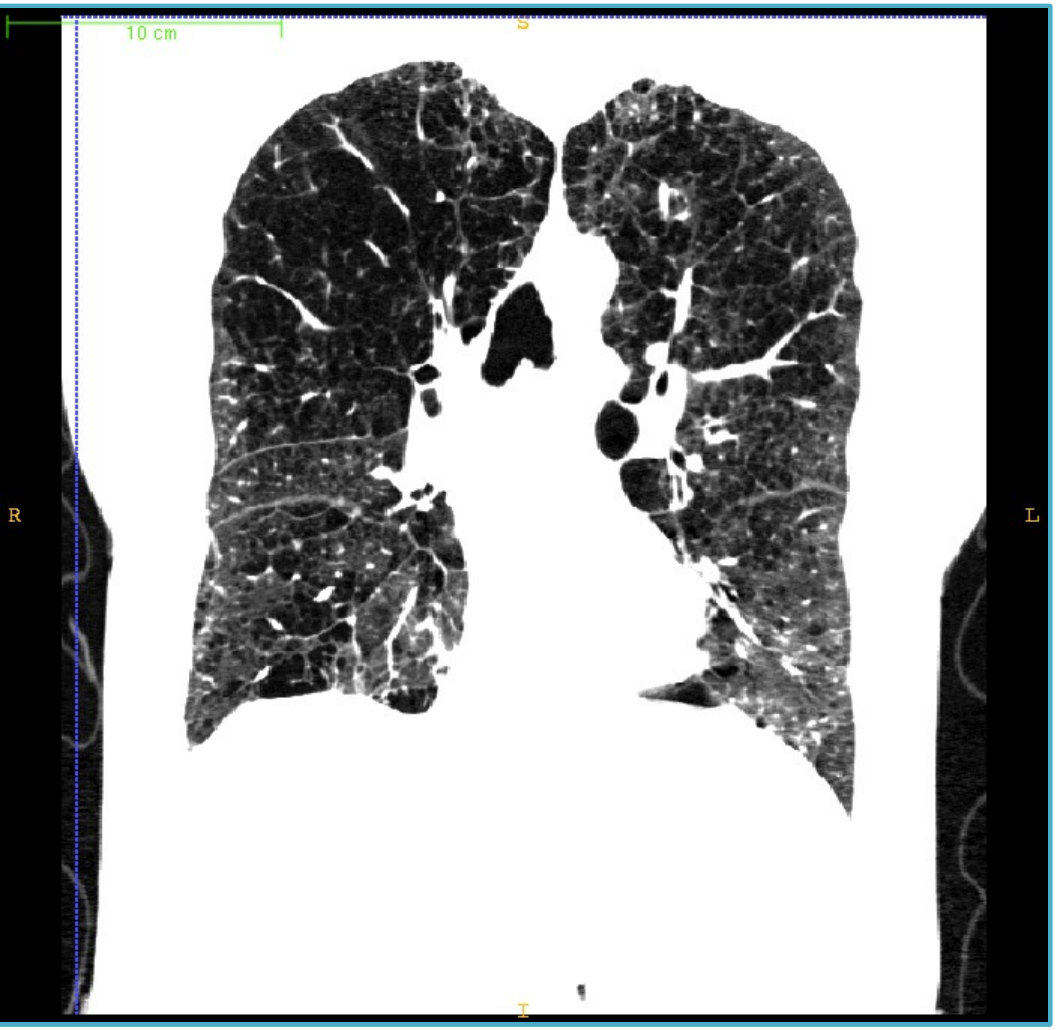
- Denver
- Boston
- Iowa

2 imaging platforms:

- VIDA
- Slicer

Slides courtesy R. San Jose Estepar

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.

Slide courtesy R. San Jose

Phenotype Extraction In The Lung

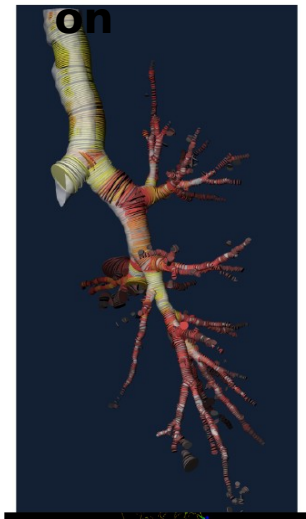
Extraction

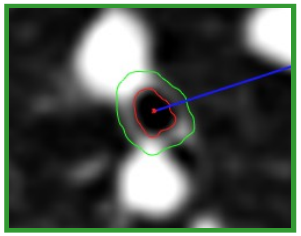
Sizing

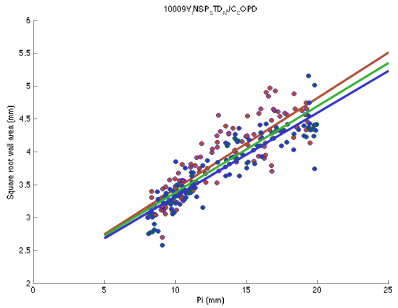
Phenotype

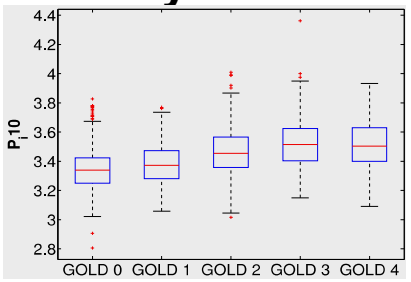
Population Study

Airways







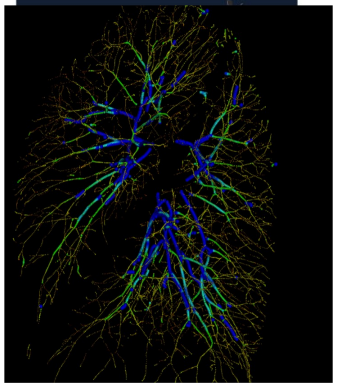


Airway Wall corresponding to a 10 mm internal Perimeter

Smoker Controls → Severe Disease

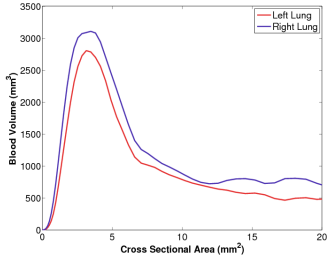
San Jose Estepar R et al, **Automatic Airway Analysis for Genome-Wide Association Studies in COPD,** ISBI 2012

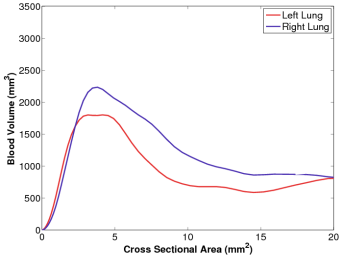
Vessels



Smoker control

Severe disease





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

Kindlmann G, San José Estépar R, Smith SM, Westin CF**. Sampling and visualizing creases with scale-space particles**. IEEE Transactions on Visualization and Computer Graphics 2009;15(6):1415-1424. PMID: 19834216.

San Jose Estepar R et al, **Computational Vascular Morphometry for the Assessment of Pulmonary Vascular Disease based on Scale-Space Particles,** ISBI 2012

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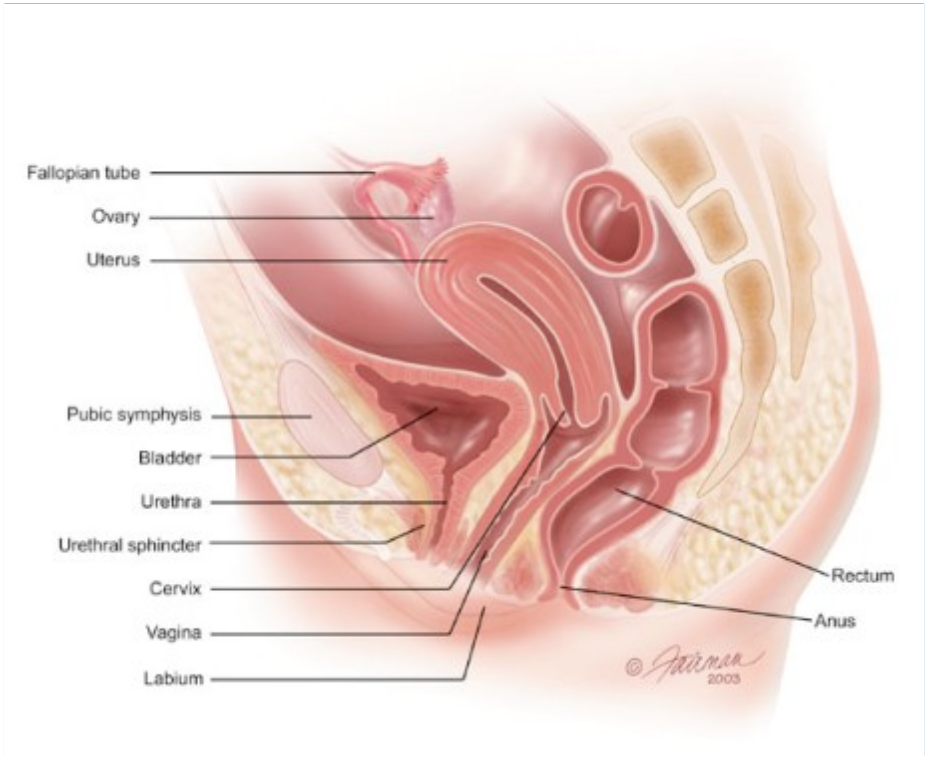
Gynecologic Cancers



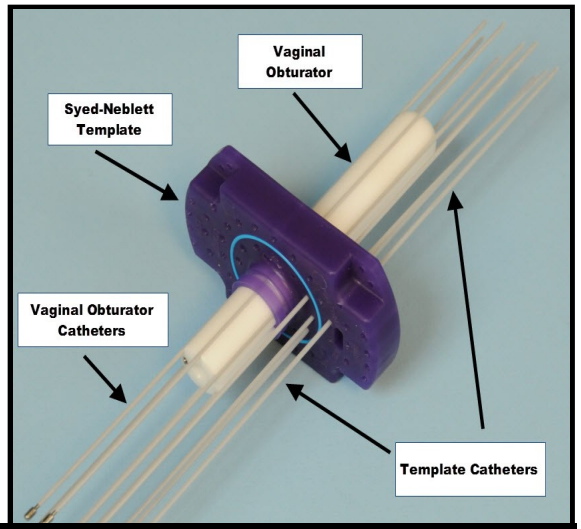
- 500,000 cases per year worldwide: Cervical, Uterine, Vaginal, Vulvar, Ovarian
- 4th leading cause of death in women in the US

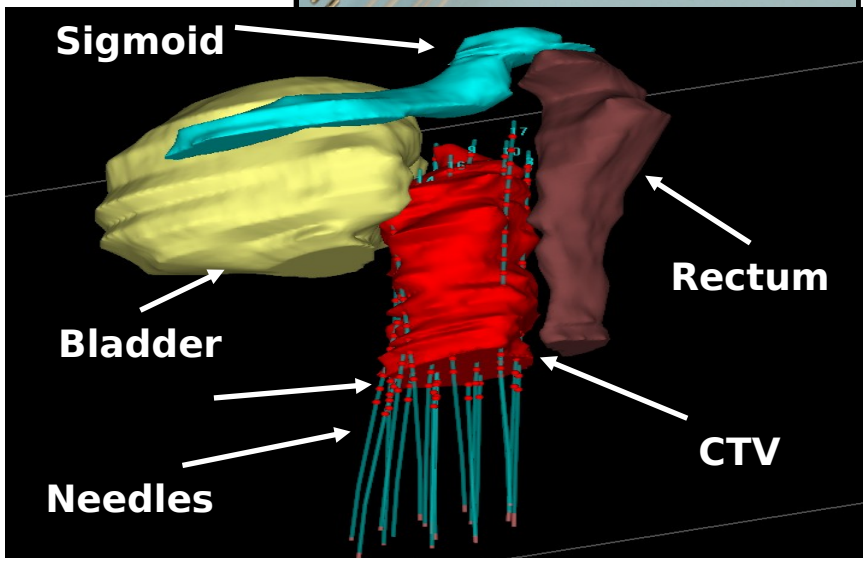
MR-guided Gynecologic Cancer Brachytherapy

MR is the preferred imaging modality for visualization of gynecologic cancers

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

Need for applicator identification/verification





3DSlicer

Iterative Catheter Detection

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

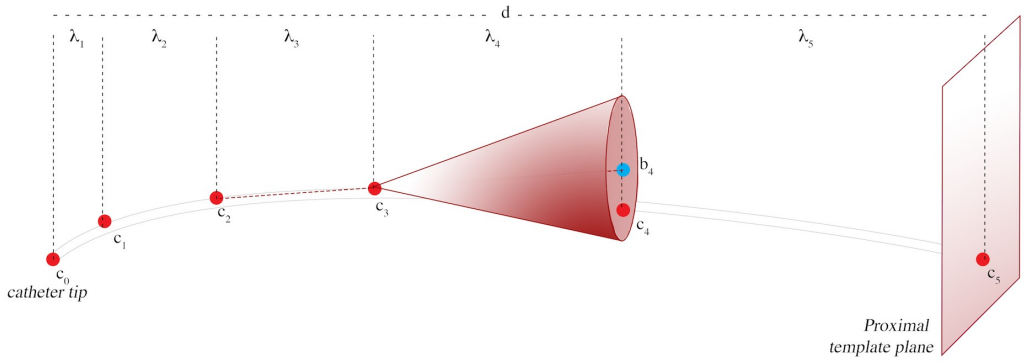
Algorithm structure

(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.



Guillaume Pernelle et al.
[MICCAI 2013]

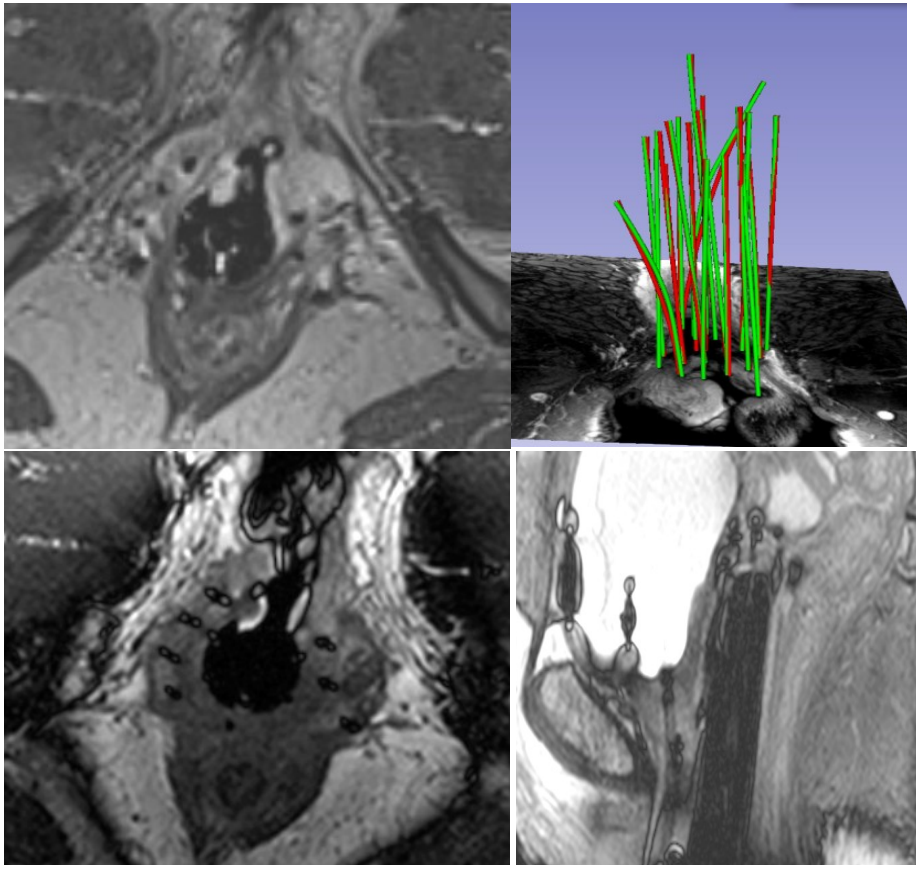
3DSlicer

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*

Guillaume Pernelle et al.
[MICCAI 2013]

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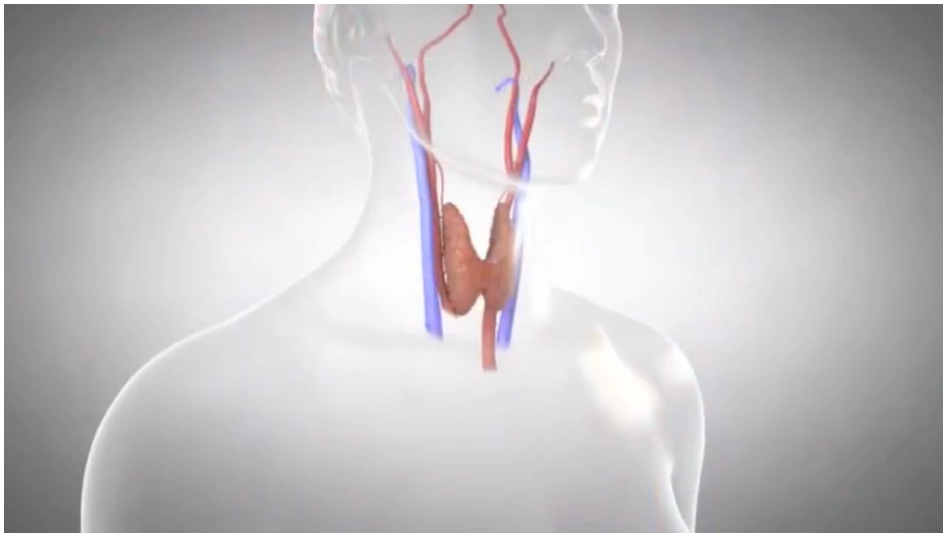
Parathyroidectomy in AMIGO

Image-guided navigation to localize and excise parathyroid adenoma

Slide courtesy of Jayender Jagadeesan

Hyperthyroidism

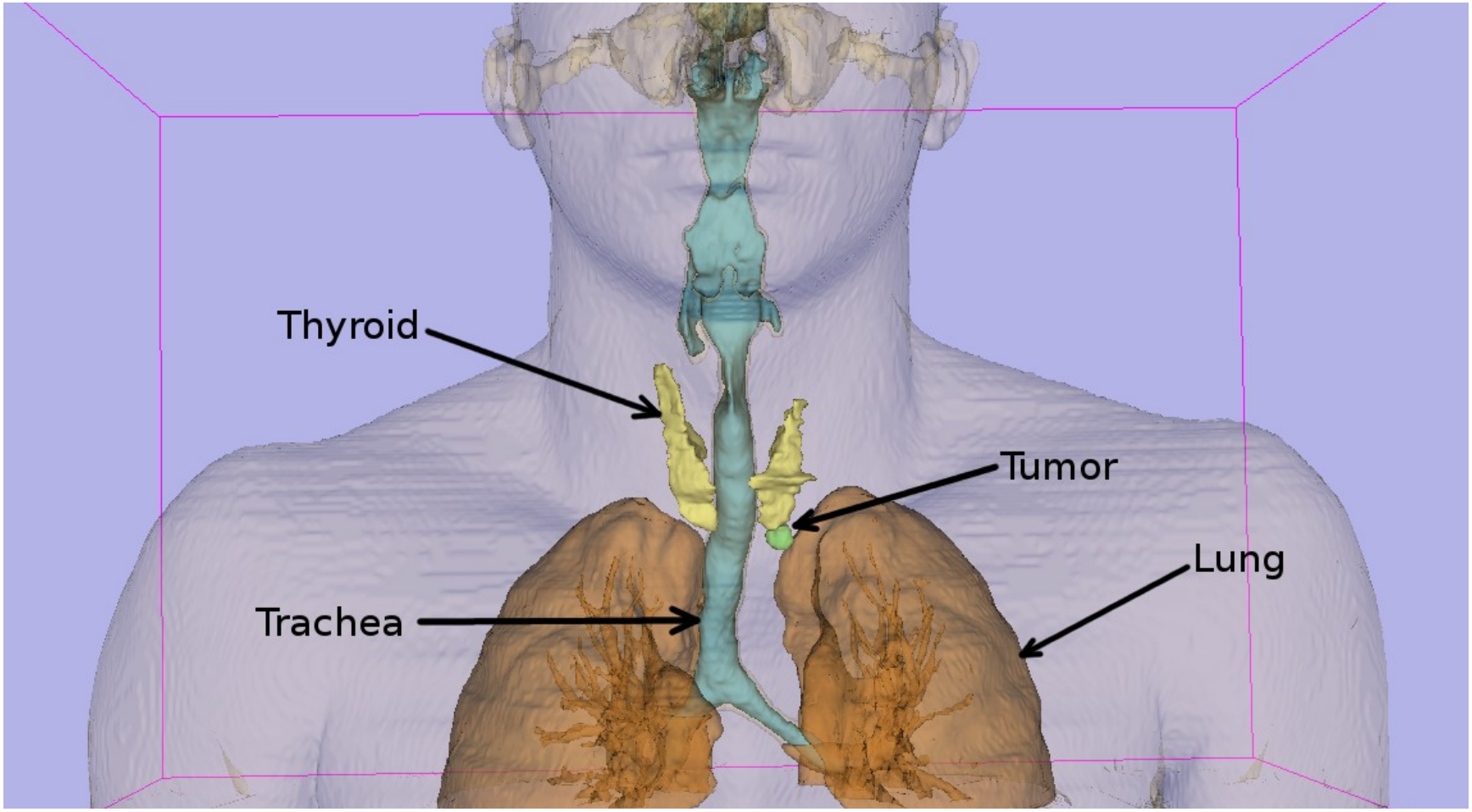
- Primary hyperthyroidism (HPT) affects 0.2 to 0.5% of the population
- 100,000 new cases in the US per year
- Surgery is the only treatment option
- 5-10% of cases are recurrent or persistent HPT after surgery



Video: ParathyroidTV.com

Slide courtesy of Jayender Jagadeesan

rgical Planning for Procedure



de courtesy of Jayender Jagadeesan

x 2 speed

de courtesy of Jayender Jagadeesan

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

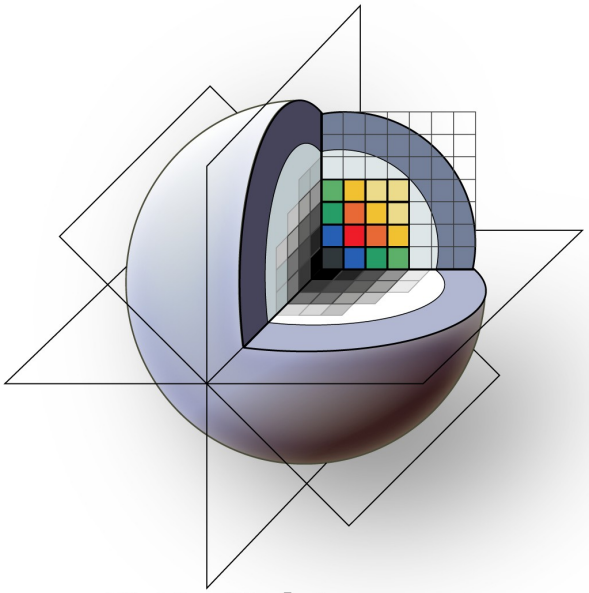
Nac.spl.harvard.edu

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