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3D Slicer And The NA-MIC Kit

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Acknowledgments

- F. Jolesz, C. Tempany, P. Black, A. Golby, S. Wells, N. Hata, CF. Westin, M. Halle, S. Pieper, F. Talos, W. Schroeder, and many more….

3D Slicer

- Software platform for analysis and visualization.
- An extensible platform with plug-ins.
- Free, multiplatform, open source software.

- http://www.slicer.org

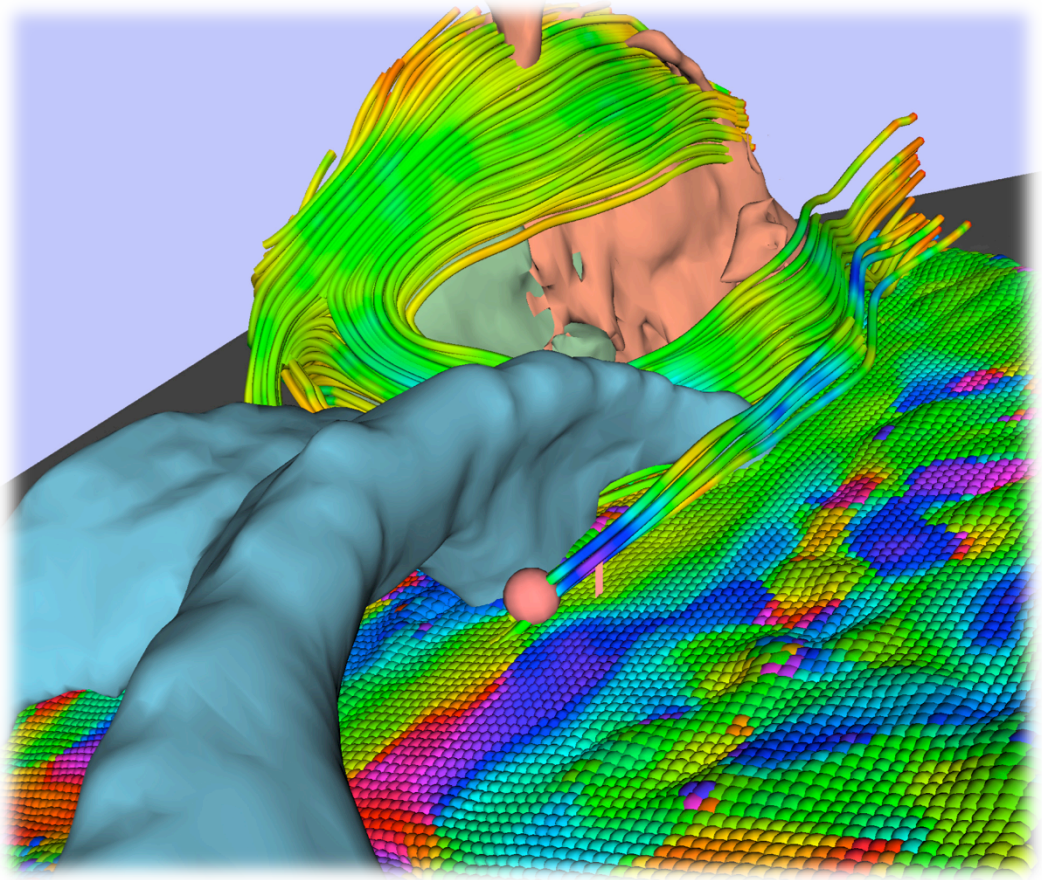
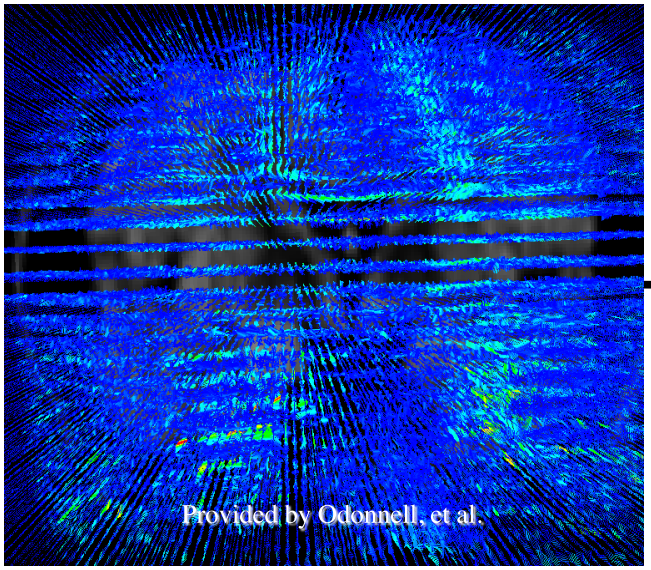


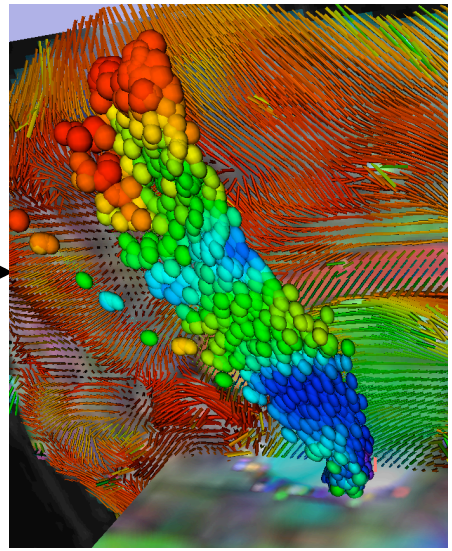
Image taken by R. Kikinis

Our Science

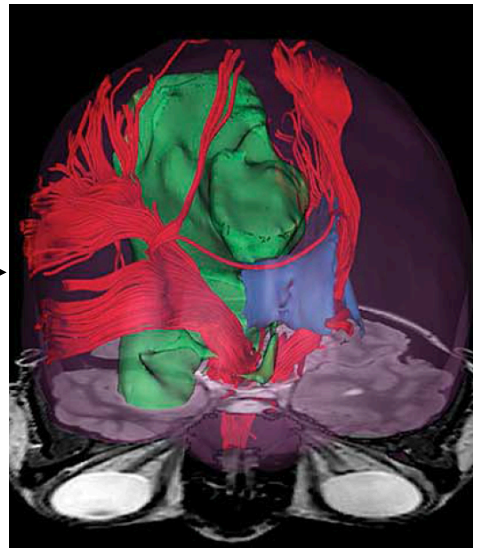
- Algorithm research
- Tool development
- Biomedical Research

Golby, et al.





Provided by Kikinis

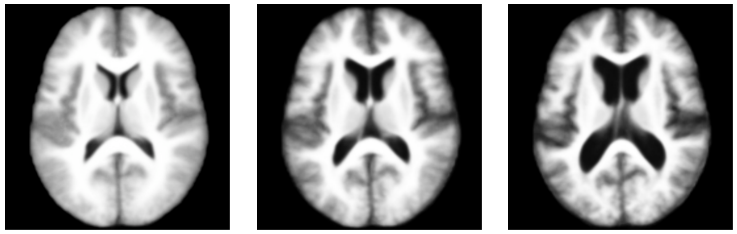


Basic Science Use of Image Analysis

- Focus is on group analysis in the brain
  - Where is a function typically located
  - What is the variability?

3 Templates

M.R. Sabuncu, S.K. Balci, M.E. Shenton, and P. Golland. Image-Driven Population Analysis Through Mixture Modeling. IEEE Transactions on Medical Imaging, 28(9):1473 - 1487, 2009

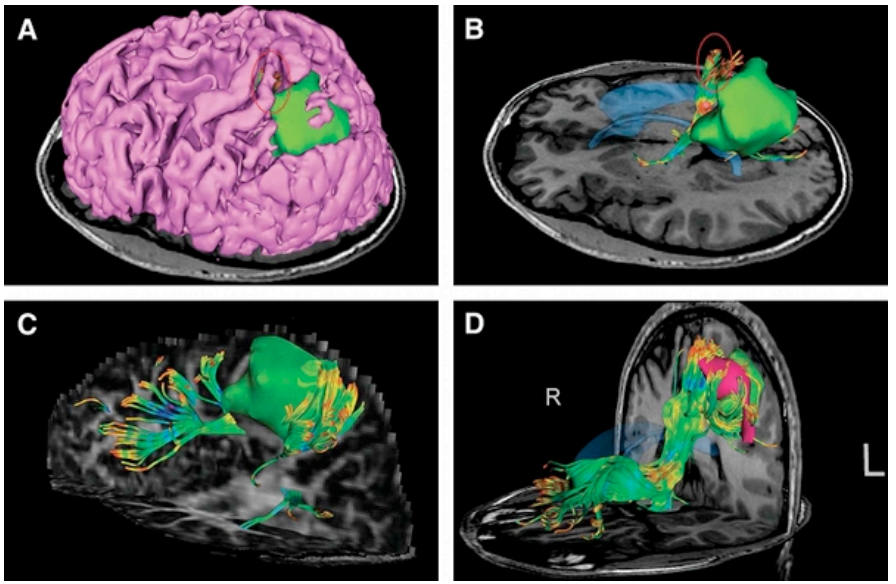


Young Middle Old

Translational Clinical Work

Subject specific analysis

- Where is the pathology?
- Where are surrounding structures



Golby A.J., Kindlmann G., Norton I., Yarmarkovich A., Pieper S., Kikinis R. *Interactive Diffusion Tensor Tractography Visualization for Neurosurgical Planning*. Neurosurgery. 2011 Feb; 68(2):496-505. PMID: 21135713

Basic Versus Translational Science

- Basic science
  - Months for calibration
  - Automation is more important, than speed
  - Large computational resources
- Translational
  - Minutes to hours per case
  - Automation is less important than speed
  - Limited computational resources

A New Style of Research

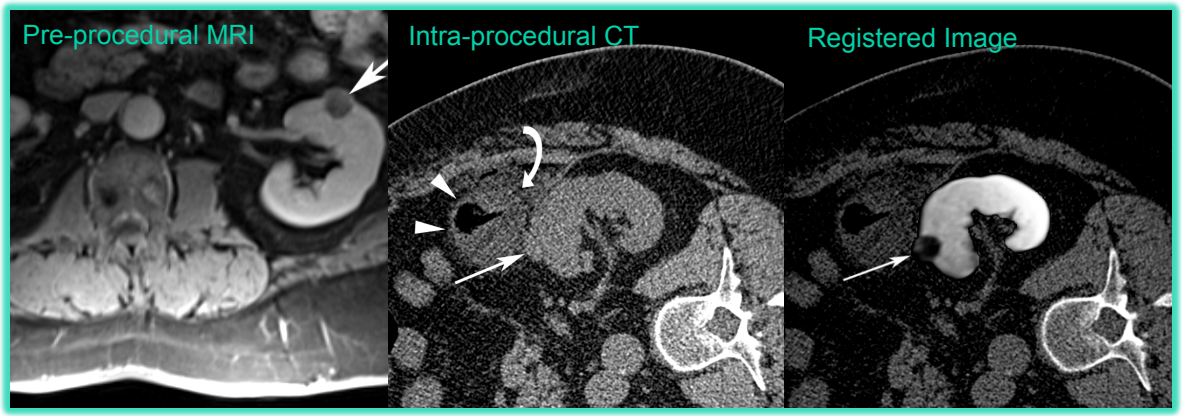
- Open Science
  =
  Open Source
  +
  Open Data
  +
  Open Community

Tokyo 2010, hosted by H. Iseki

Boston 2010

A New Style Of Software

- Medical Image Computing for personalized medicine
  - Software runs on your computer (Patient privacy)
  - Fast processing (clinical research)
  - Subject-specific analysis (pathology)



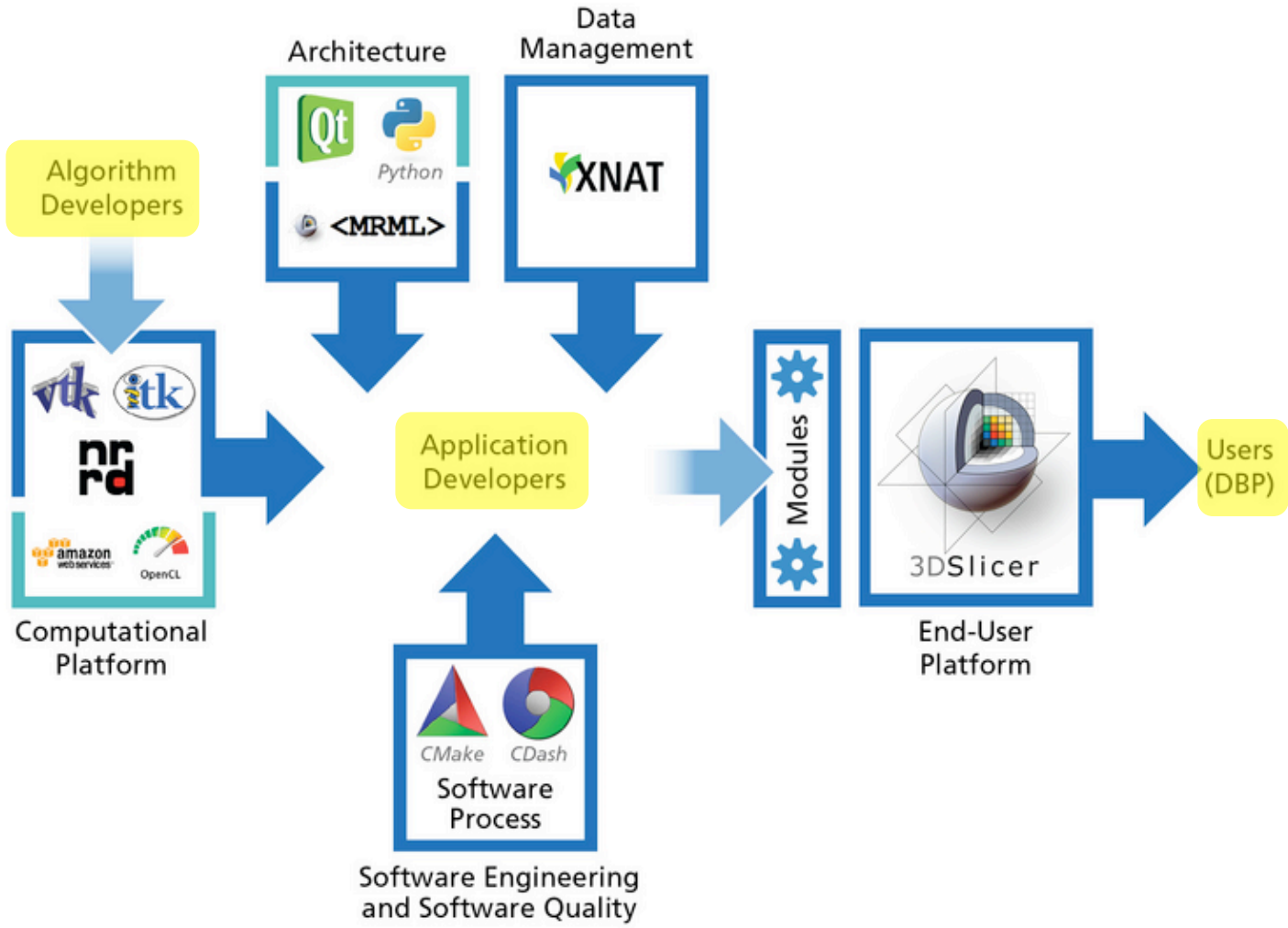
Oguro et al, Int J Comput Assist Radiol Surg, 2011
Elhawary et al, Acad Rad, 2010

3D Slicer (slicer.org)

- 3D Slicer is a platform for delivering image computing technology for personalized medicine research
  - Basic and clinical visualization
  - Registration
  - Segmentation
  - Plug-In Architecture
  - Based on the NA-MIC Kit

Picture courtesy Wendy Plesniak

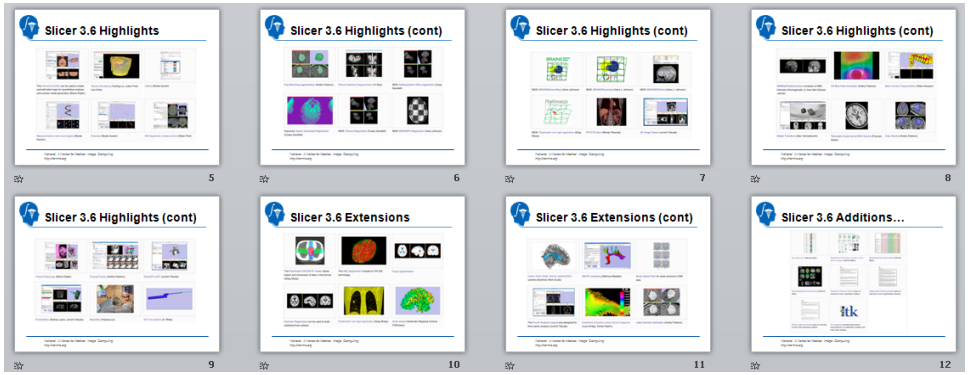
Slicer Is Based On The NA-MIC Kit



Picture courtesy W. Schroeder

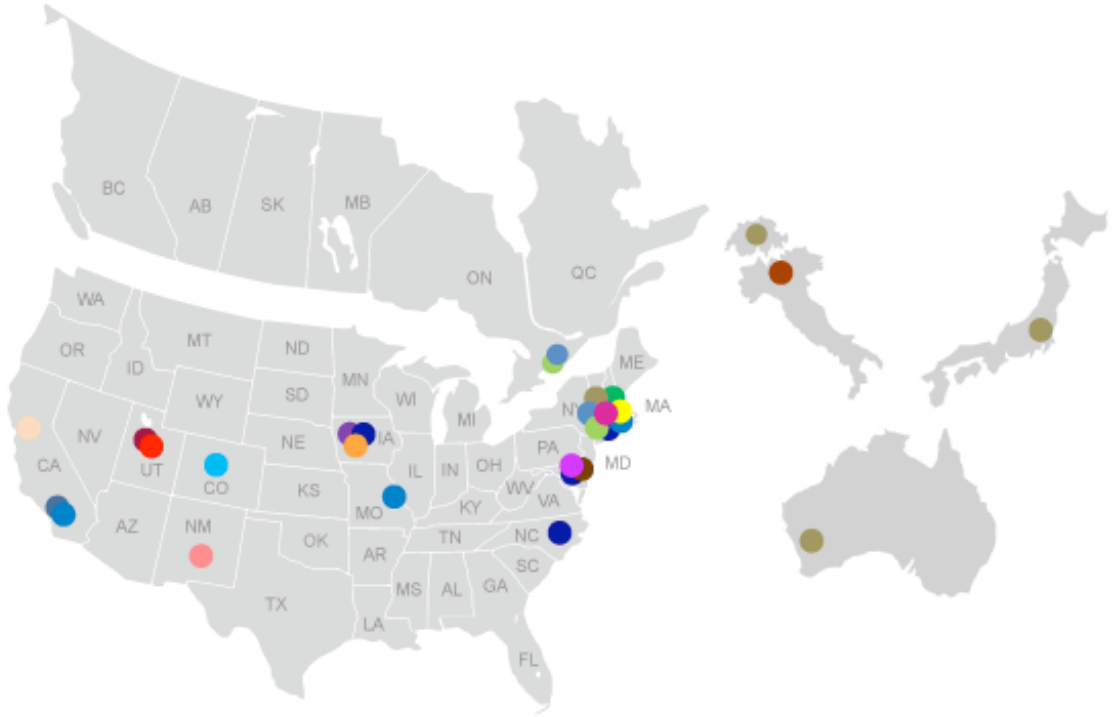
Slicer Is Accessible And Extensible

- Distributed Team
- Training and Outreach Events
  - Over 30 in 2010 Alone!
- Twice-Yearly Project Weeks with 100+ Developers
- Slicer Extension Modules
  - Standard Framework for Disseminating our Science
  - End-to-End Solutions Contributed by Dozens of Institutions
    - Publications, Code, Data, Tutorials
    - *Reproducible Science*
- Yearly Stable Releases Integrate Latest Advances
  - Slicer 3.6.3 Released March, 2011



Funded Collaborations

- Autism
- Brain Cancer
- Depression
- Head and Neck Cancer
- Huntington's Disease
- Lupus
- Schizophrenia
- Traumatic Brain Injury
- VCFS
- Neuroimage Analysis
- Lung Disease
- Atrial Fibrillation
- Cardiovascular Disease
- Liver Cancer
- Colon Cancer
- Prostate Cancer
- Orthopedic Injury
- Neuromuscular Dynamics
- Image Informatics



Active

R01MH084795, U41RR019703, NSF CCF-0916526, R01EB008171, U01HL089897, R01CA124377, R01CA131718, R01CA11128
R01EB005973, U54EB005149-05S2, U54GM072970, P41RR013218, R01EB006733, R01NS050568, R21EB009900, U54EB005149-05S3
UL1RR025758, U54LM008748, U24RR025736, U24RR021992, U24RR021382, U24RR026057, AIST, Japan, UWA, Australia
Mario Negri Institute, Italy, CO-ME, Switzerland, OCAIRO, Canada

Completed

U54EB005149-04S1

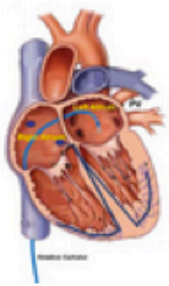
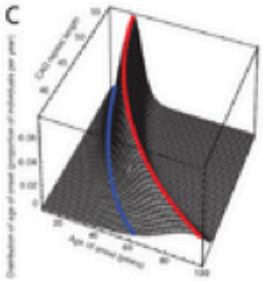
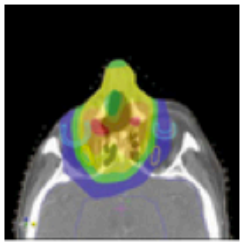
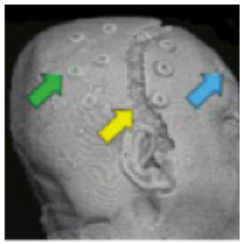
Picture courtesy Kapur, Jakab, Kikinis

Driving Biological Projects

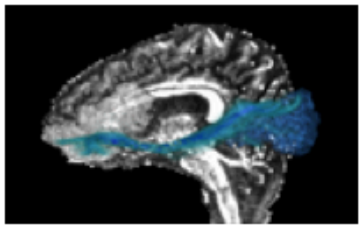
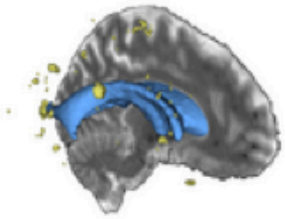
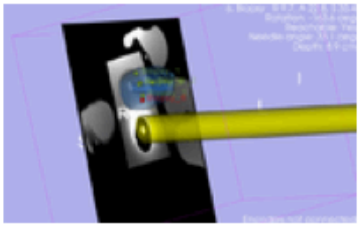
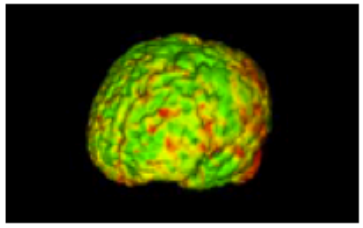
To ensure that, at the end of the day, demonstrable healthcare improvements are achieved, Driving Biological Projects (DBPs) are selected to guide research development. The role of a NA-MIC DBP is to:

- define a clinical problem
- provide a clinical dataset (individual or population)
- collaborate with algorithms scientists to develop a solution
- work with software engineers to create end-to-end applications for clinical users

Overview

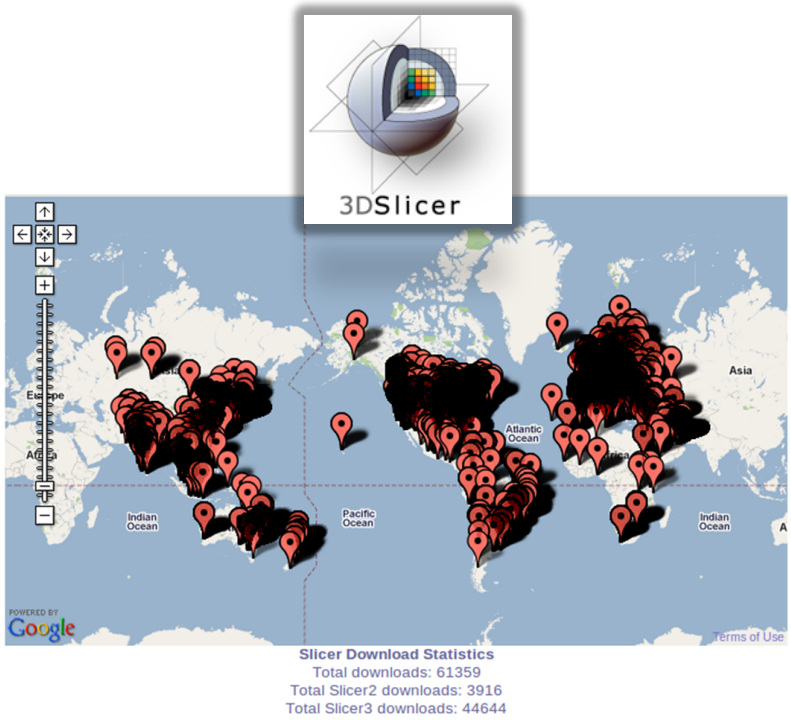
			
Atrial Fibrillation	Huntington's Disease	Head and Neck Cancer	Traumatic Brain Injury

At the inception of NA-MIC, the focus of biological project development was centered on schizophrenia. Schizophrenia provided a rich resource of neuroimaging data and a pressing need for new imaging technologies to unlock the white matter regions of the brain. The DBPs contributing to this effort were based at Harvard Medical School, University of California at Irvine, Dartmouth College, Indiana University, and University of Toronto. In the ensuing years, the scope of project development expanded to include a broader range of diseases. Links are provided to disease-specific datasets, tutorials, software, representative peer review publications, and notes maintained by the individual DBPs on NA-MIC's interactive Wiki.

			
Schizophrenia	Lupus	Prostate Cancer	Autism

Slicer Impact www.slicer.org

- 20,000 Downloads Per Year
- 200 Peer Reviewed Publications
- Dozens of Funded Collaborations
- Active Academic and Industrial Participation



Software is **Increasingly Essential** for Medical Research

Slicer has a Proven Formula for Software Innovation and Dissemination

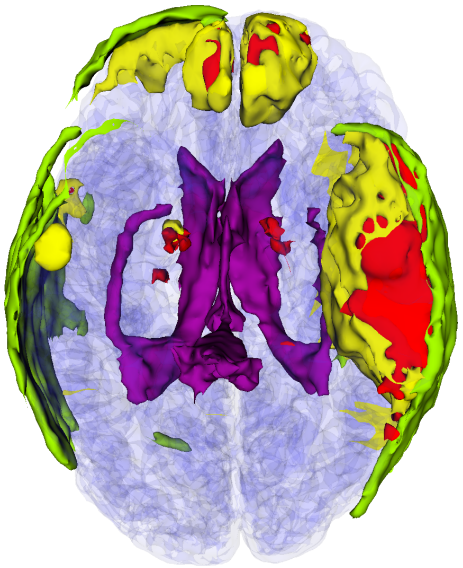
Lets get down to business

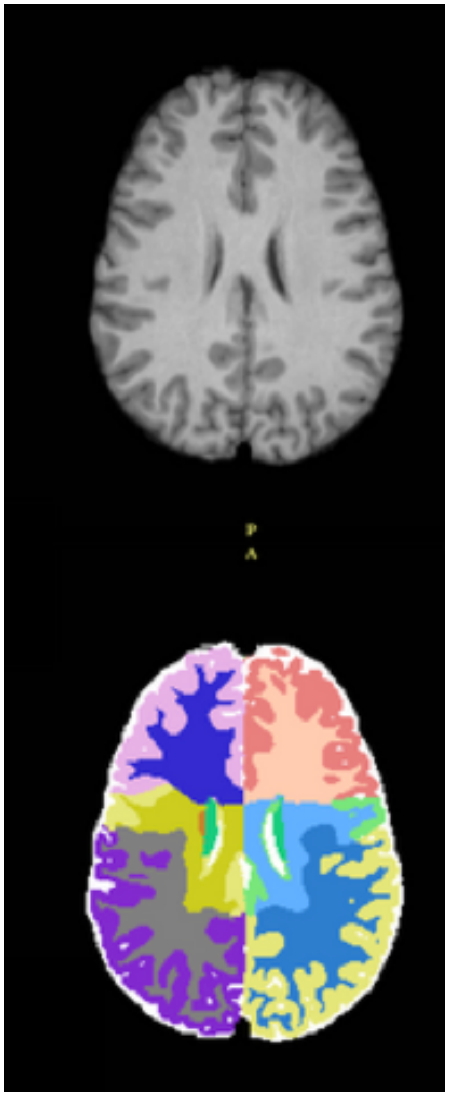
- Segmentation, Registration, Visualization
- Change Detection
- IGT

Segmentation: Anatomical Labeling

- Image Driven Tissue Differentiation
  - Atlas-Based
- Basis for Region-Specific Change Quantification
  - With Respect to Subject Baseline
  - With Respect to Population
- Software
  - EMSegmenter, Kilian Pohl, University of Pennsylvania
  - ABC, Marcel Prastawa, U of Utah

http://slicer.spl.harvard.edu/slicerWiki/index.php/Modules:EMSegmenter-3.6

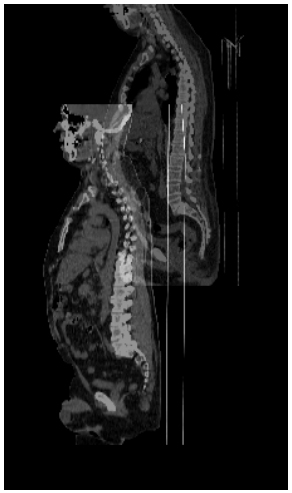


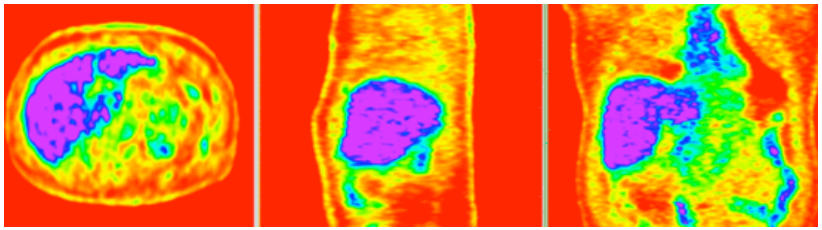


Picture courtesy Prastawa, Pohl, Srinivasan

Registration: Data Fusion

- Identify Corresponding Anatomical Regions
  - Linear and Non-Linear Mappings
- Control for Normal Changes
  - Pose in Scanner
  - Metabolic Differences (Digestive/ Respiratory/Cardiac Cycles, Weight Gain/Loss…)
  - Scan Artifacts
- Detect & Quantify Important Differences
  - Pathology Growth/Shrinkage
  - Functional Differences
  - Overall Atrophy, Edema, Other Responses…
- NA-MIC Use Case Library
  - Dominik Meier, BWH



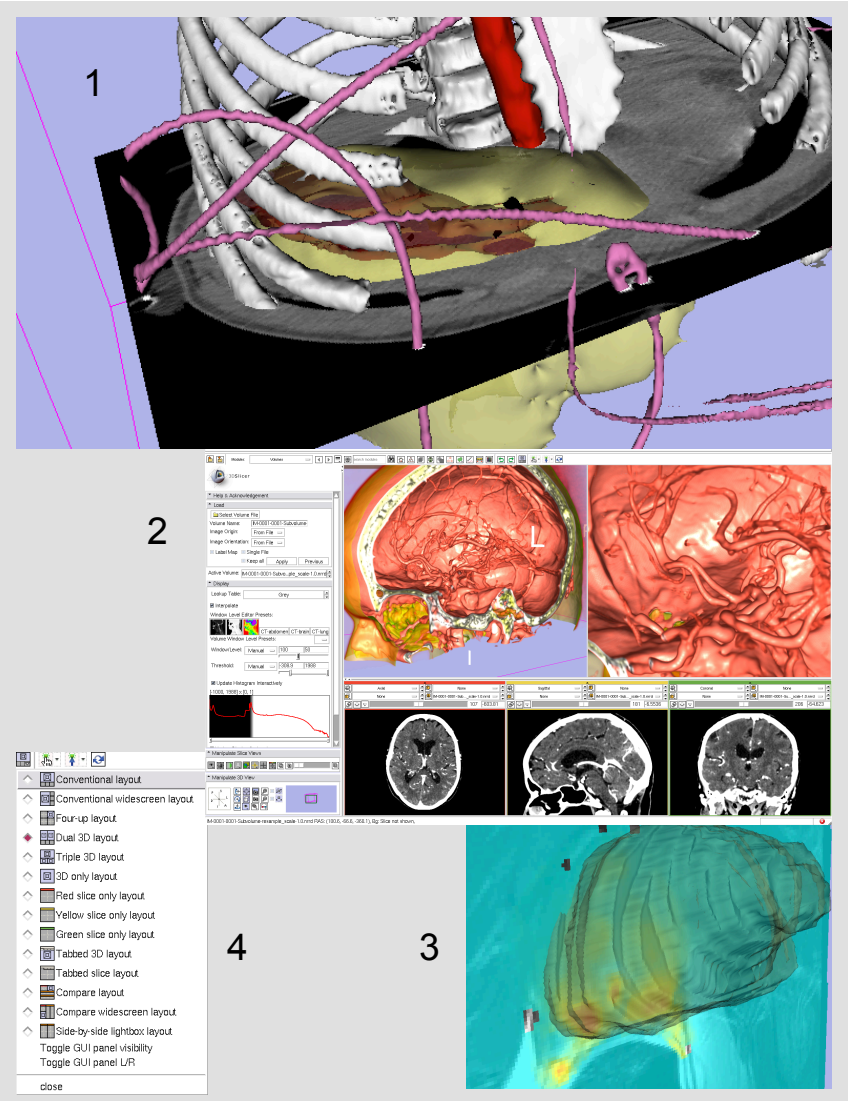


http://na-mic.org/Wiki/index.php/Projects:RegistrationDocumentation:UseCaseInventory

Visualization: Data → Information

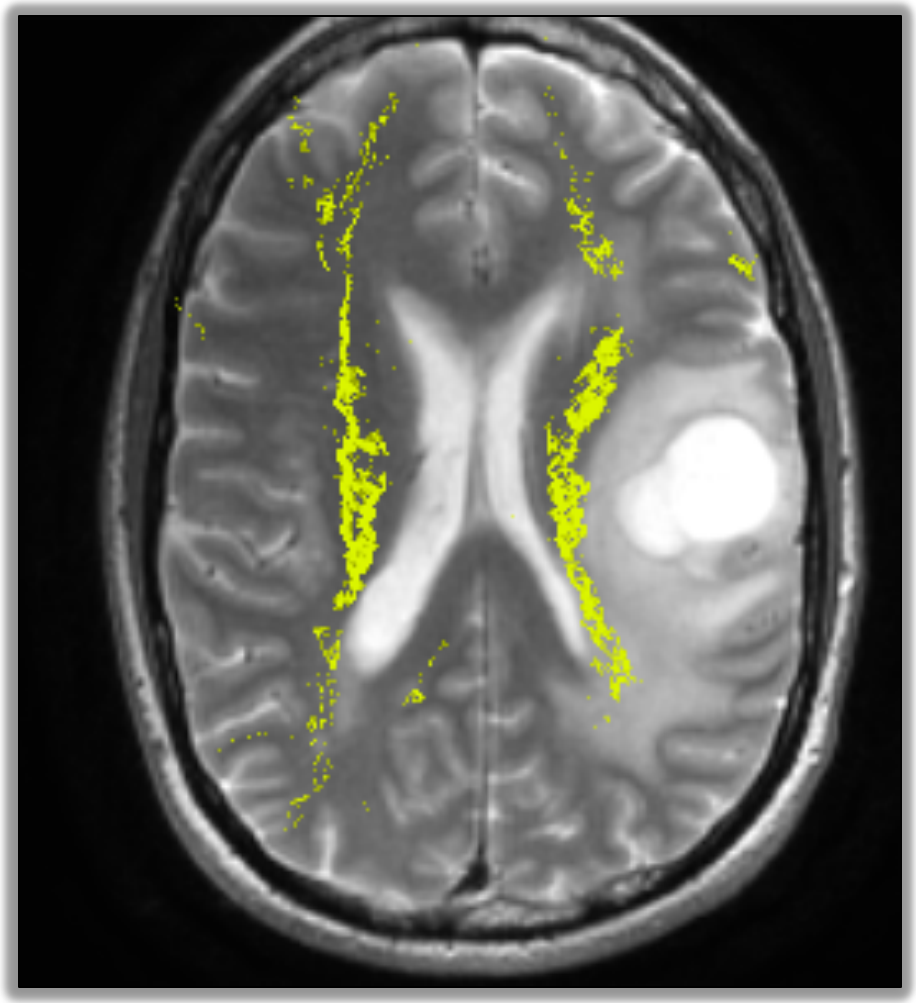
- Interactivity for Rapid Assessment of Large Collections of Images

1. Surface models
2. Volume rendering and cross sections
3. 2D/3D Combination
4. Library of layouts



Picture courtesy Shaffer, Pujol, Kikinis, Fenessy, Fedorov

DTI Tractography for Neurosurgery



- DTI Tractography has the potential to provide clinically relevant information on the integrity and location of eloquent white matter pathways
- However, neurosurgeons face the challenge of selecting the appropriate tractography method from a wide variety of algorithms, in the absence of ground truth.

Slide courtesy S. Pujol

MICCAI 2011 Workshop

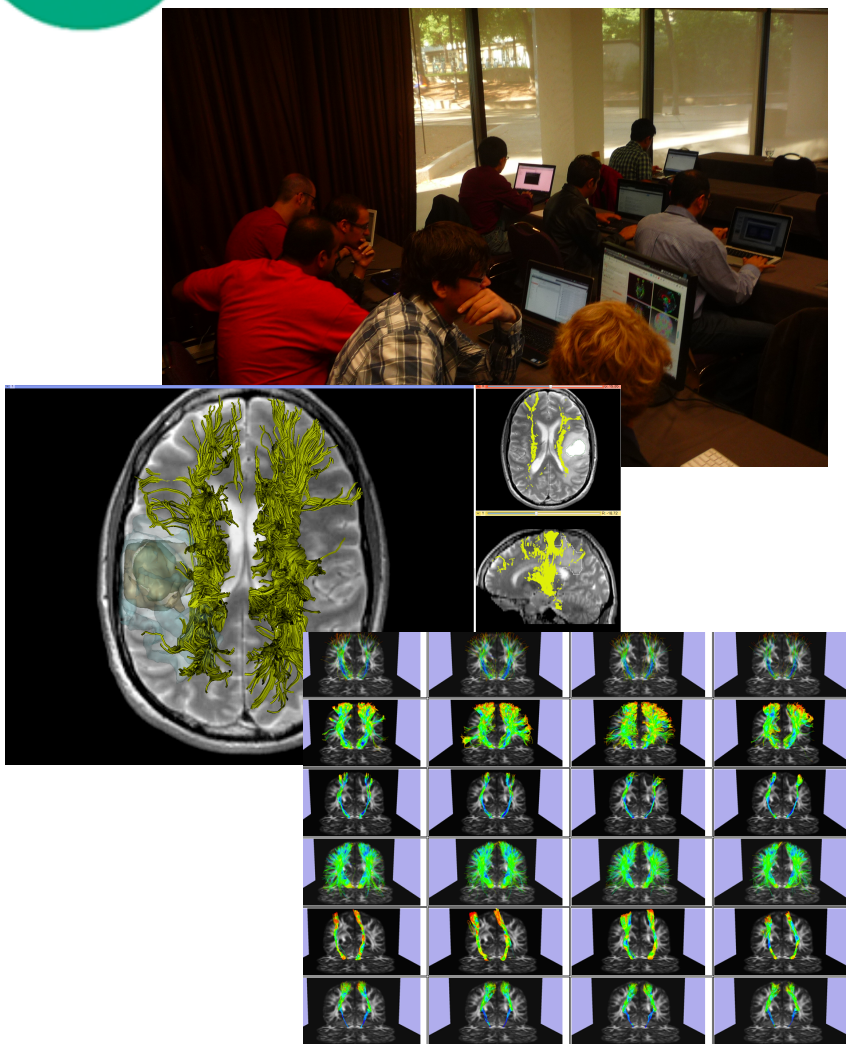
Goal: Evaluation of the performances of tractography algorithms on a common set of data, using clinical criteria and quantitative metrics

- 4 patient cases & 2 healthy subjects
- Segmented tumor and edema regions
- Pre-workshop processing + 5-hour on-site analysis

Slide courtesy S. Pujol

http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

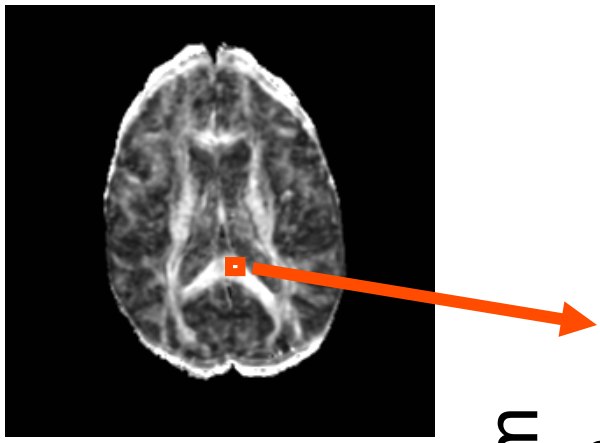
Workshop



- 8 international teams processing data
- 352 corticospinal tracts generated
- 3D visualization and standardized comparison of different tractography results using Slicer4

Slide courtesy S. Pujol

Evaluation of tractography



Algorithm Decision

Truth ?

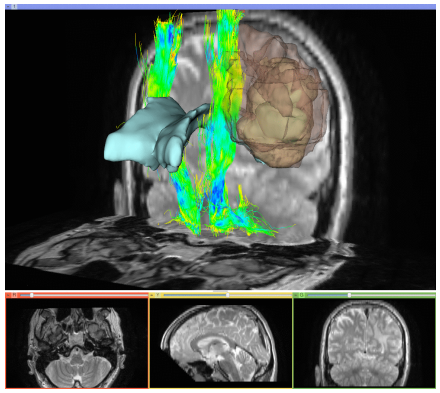
	Tract	No tract
Tract detected	True Positive	False Positive
No tract detected	False Negative	True Negative

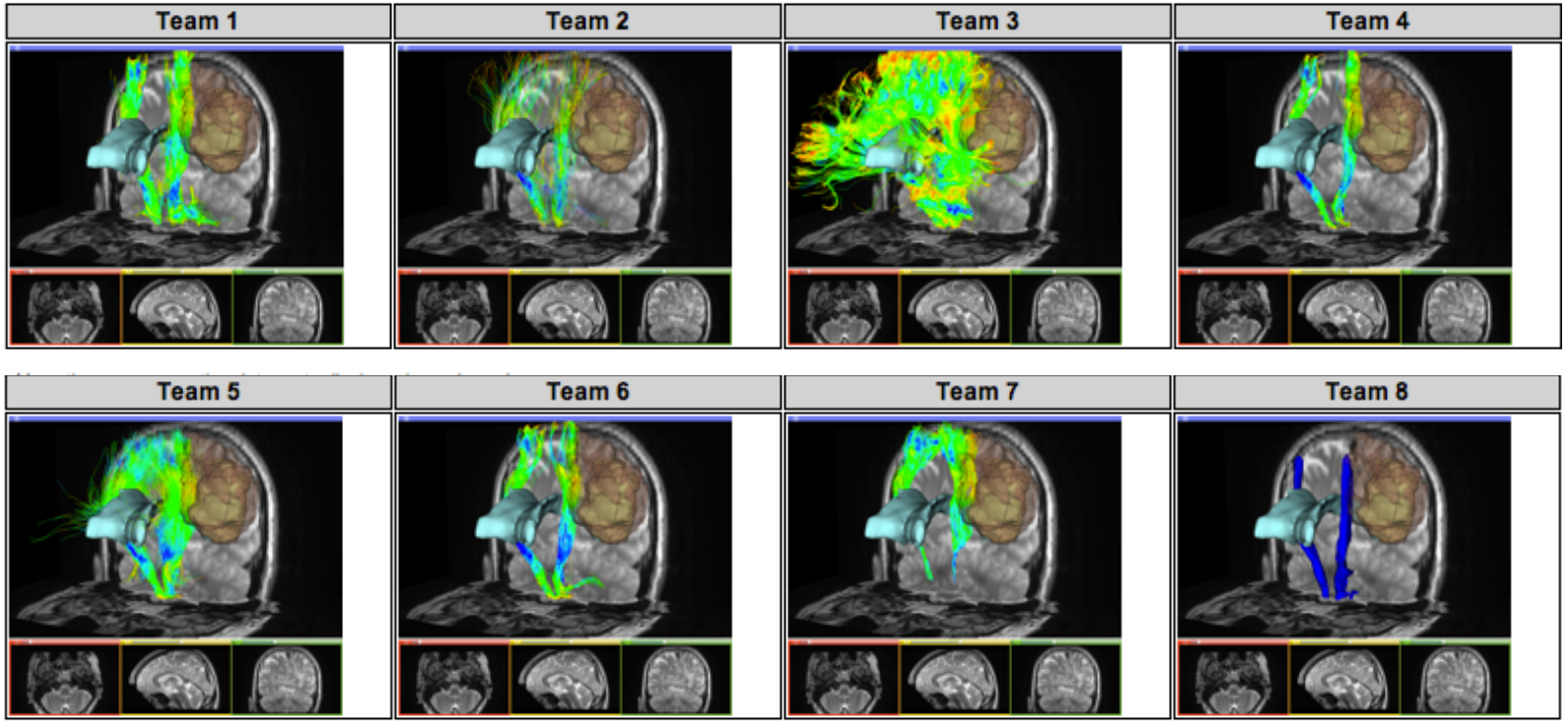
Challenge: absence of ground truth

Slide courtesy S. Pujol

Workshop Outcomes

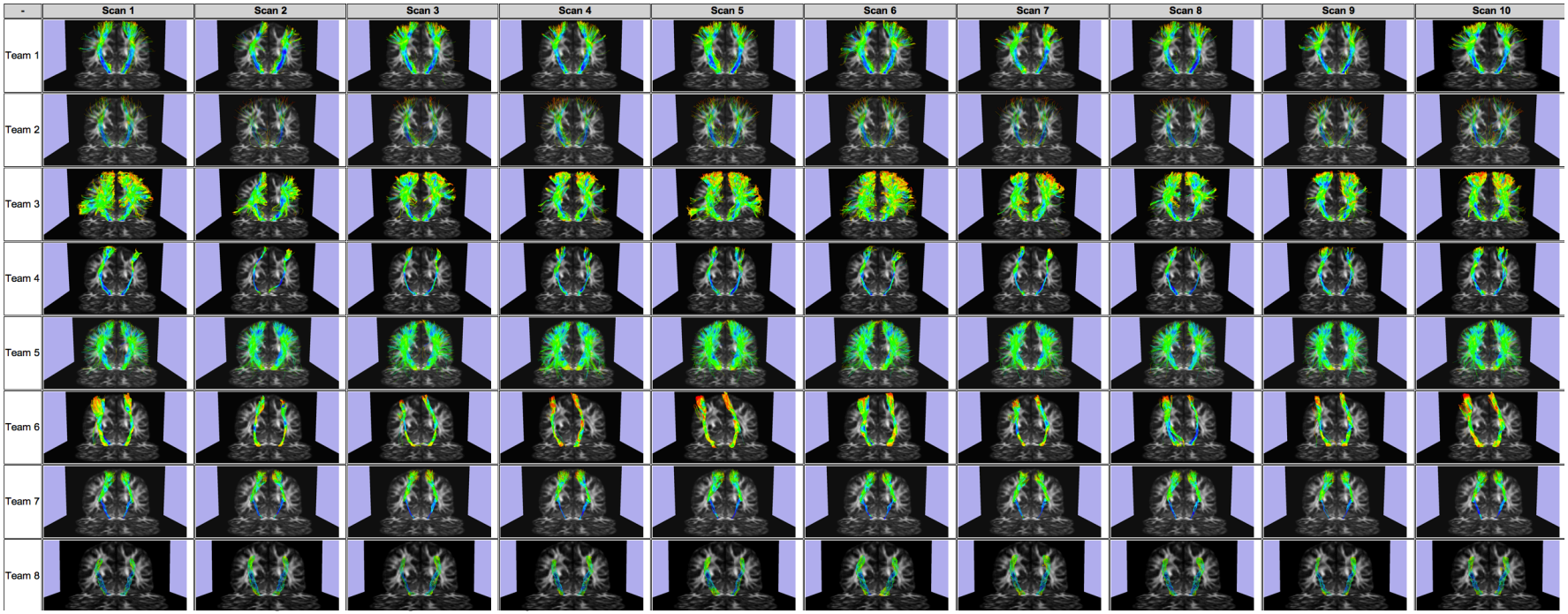
Neurosurgical cases results →
large **inter-algorithm** variability



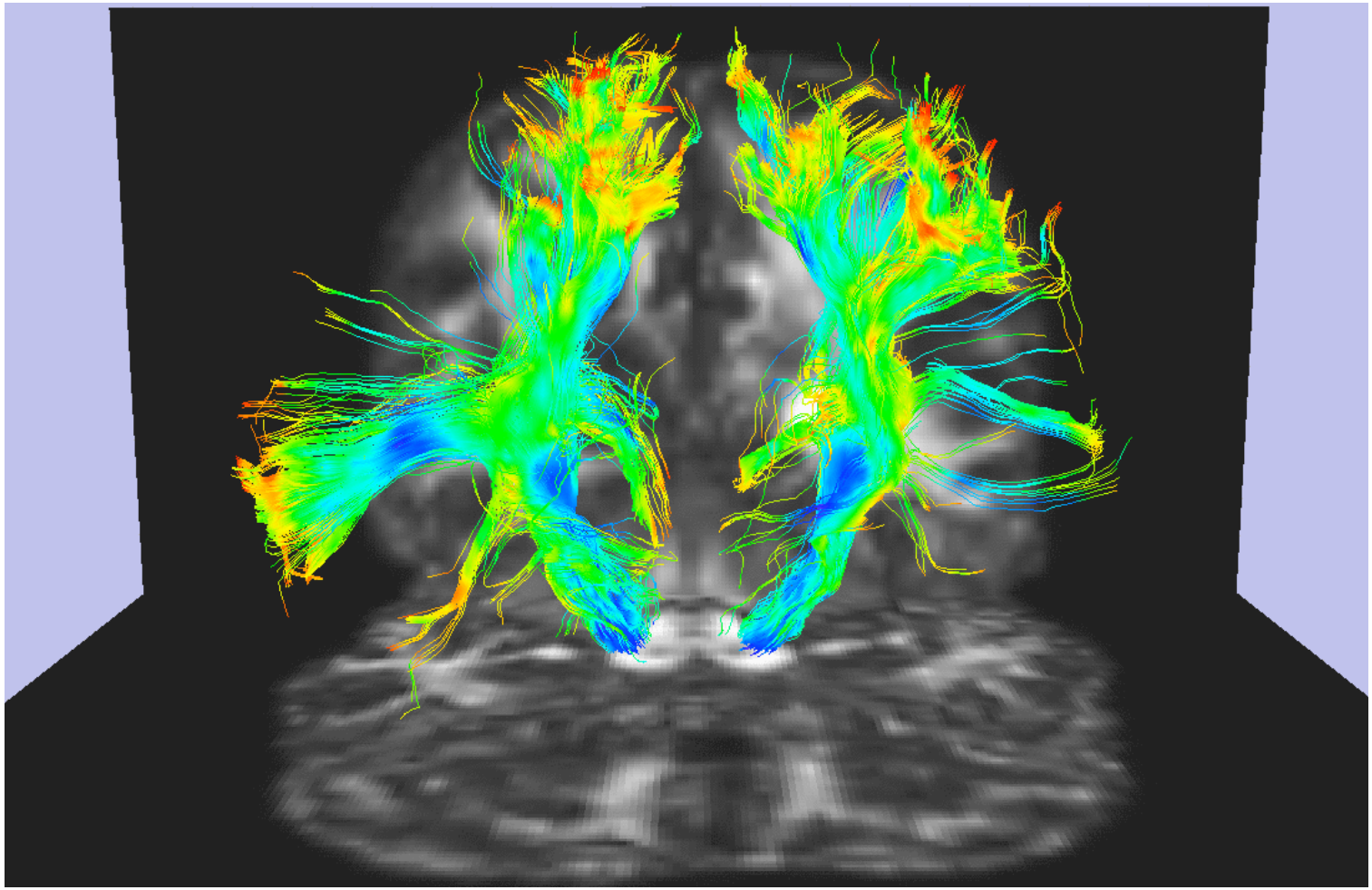


Workshop Outcomes

Healthy subject study→
large **intra-algorithm** variability



Intra-Algorithm Variability



Quantitative Imaging

- Extracting quantitative measures from images
  - Biomarker for treatment tracking

- ChangeTracker
- PET SUV

Evaluating Tumor Size and Shape

- Clinical standard
  - RECIST: Uni-dimenional or Bi-dimensional measurements

    RECIST = Response Evaluation Criteria in Solid Tumors
- Issues
  - Not designed to detect small changes
  - Does not track volume, shape
- Higher sensitivity and specificity desired for subject specific analysis

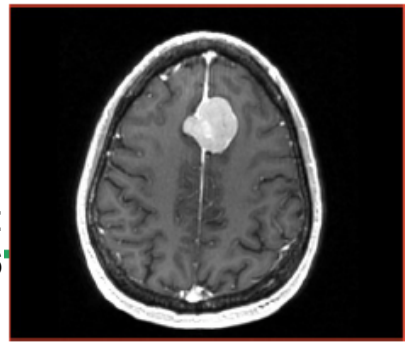
http://www.eortc.be/recist/documents/RECISTGuidelines.pdf

Tracking Changes in Meningioma

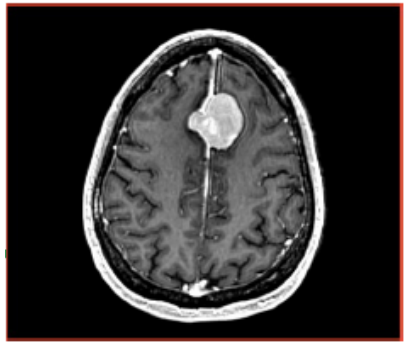
- Acquisition:
  - Axial 3D SPGR T1 Post-Gadolinium Scans
- Radiologist 1: Baseline reading
  - Large Falcine Lesion is Identified
  - Measures 3.1 cm Anteroposteriorly, 3.05 cm from Side-to-Side, 3.5 cm in Height
- Radiologist 2: Follow-up reading
  - Left Frontal Lobe Mass **Appears Unchanged** on all Series
  - Measures 3.3 x 3.2 cm in Maximum Dimension

- This is a very typical situation
  - Measurements performed by different radiologists

SCAN1
Baseline:
June 2006

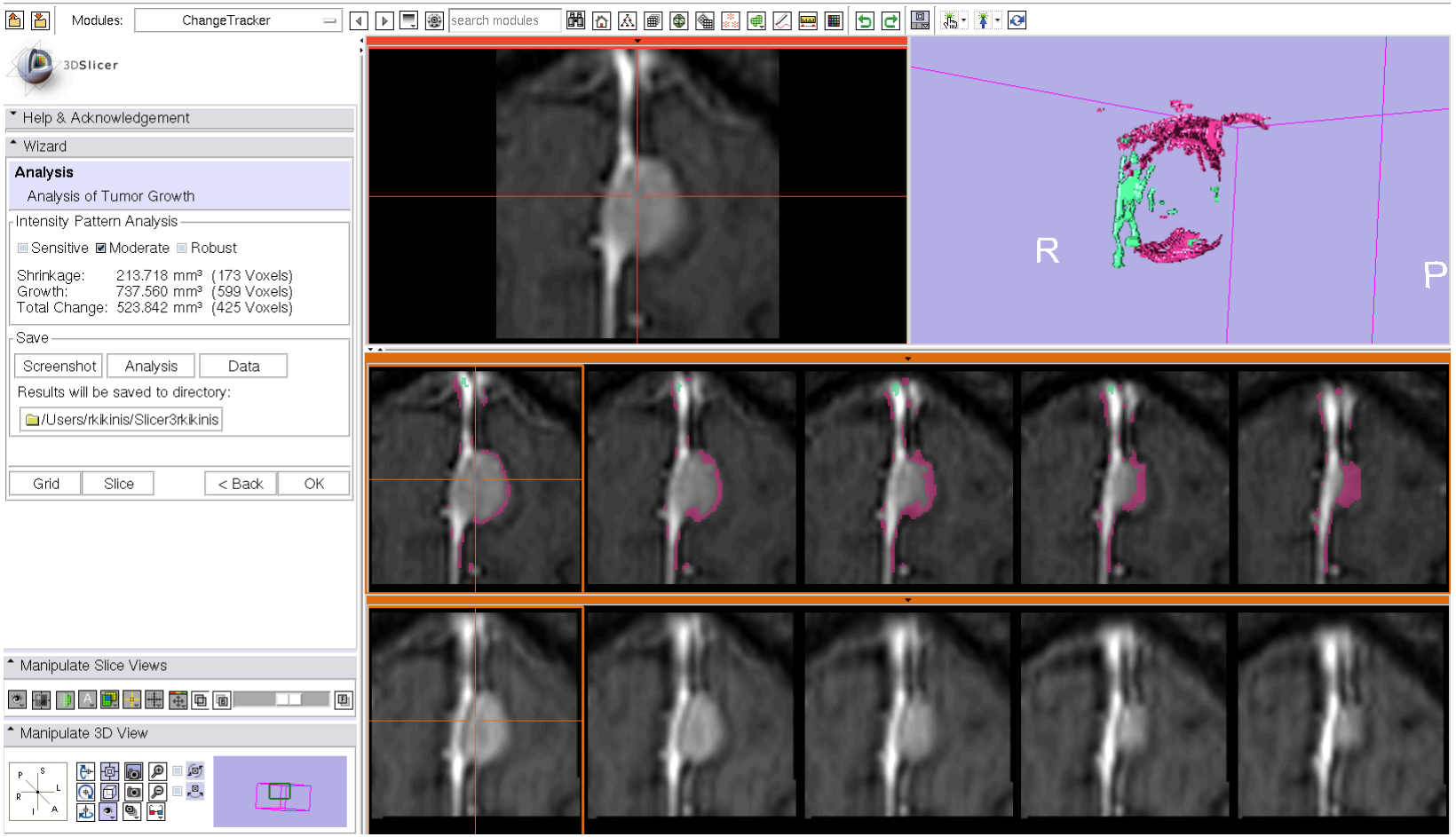


SCAN2
Follow-up:
June 2007



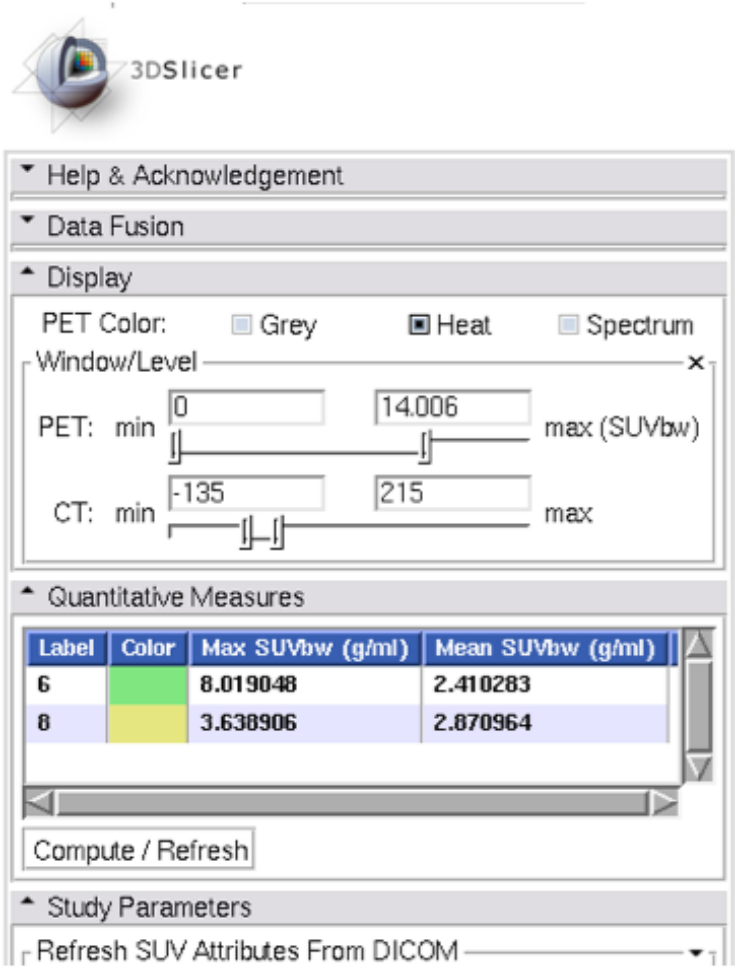
ChangeTracker: Results

Analysis of small volumetric changes by comparing two time points



http://www.slicer.org/slicerWiki/index.php/Modules:ChangeTracker-Documentation-3.6

Comparing SUV at 2 Time Points



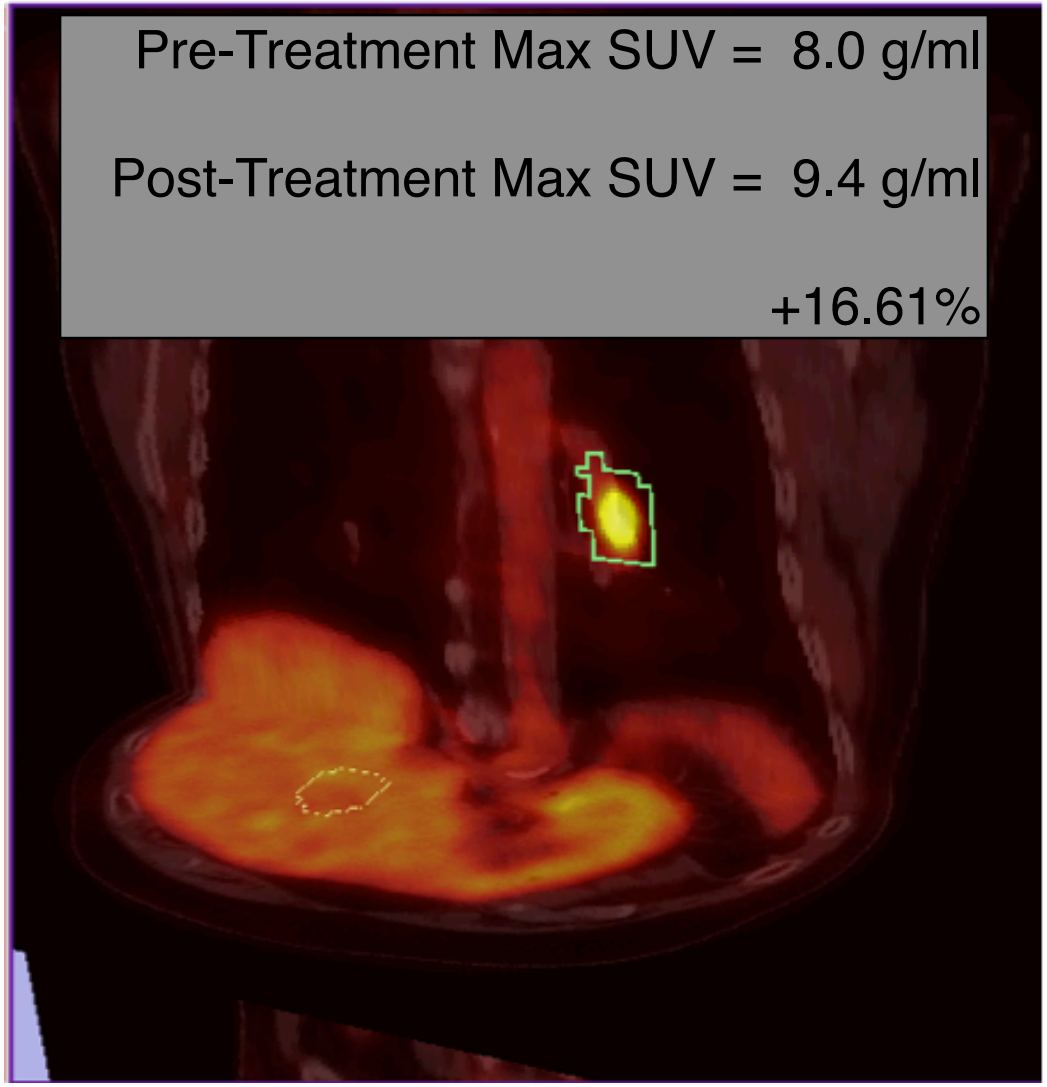


Image taken by W. Plesniak, R. Kikinis

“Non-Quantitative Imaging”

- High precision is not always needed
- What is good enough?

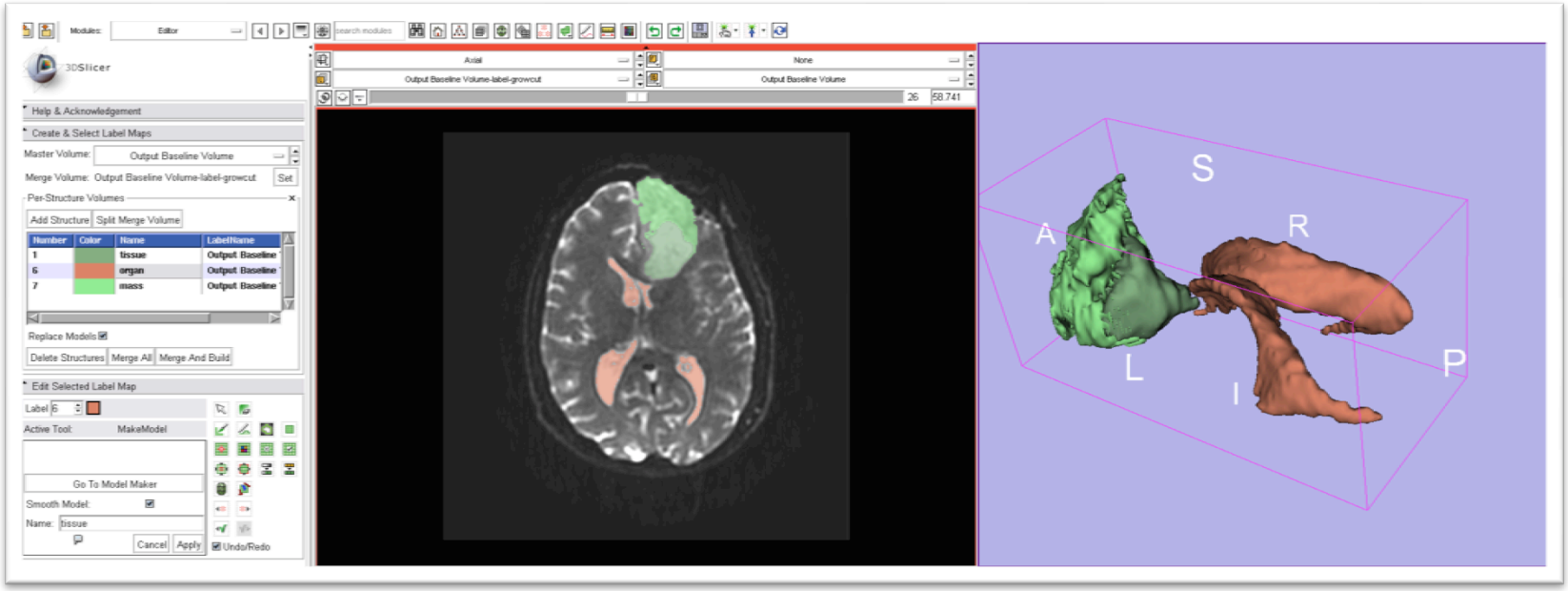
Subject Specific Analysis For IGT

- Quick and good enough is better than slow and perfect!
- Image processing problems cannot be compensated by adding subjects (you have only one)
- Interactive work is the norm
- Location: ± 2 voxels is often good enough

"Ron's rules for tools" is an informal set of rules that developers should keep in mind when working on **interactive tools** for translational clinical research. If you follow them, you will create tools that many people will use.
•You make it, I break it.
•Your tool does not exist, until it works on my laptop with my data.
•I am lazy. I do not like to move the mouse or to type.
•No more than one simple parameter.
•I have ADD. Make your algorithm fast.

The Slicer Interactive Editor

- Painting, Drawing
- Semiautomatic algorithms
  - Connectivity, GrowCut, morphologic operations



Interactive segmentation of brain tumor and ventricles

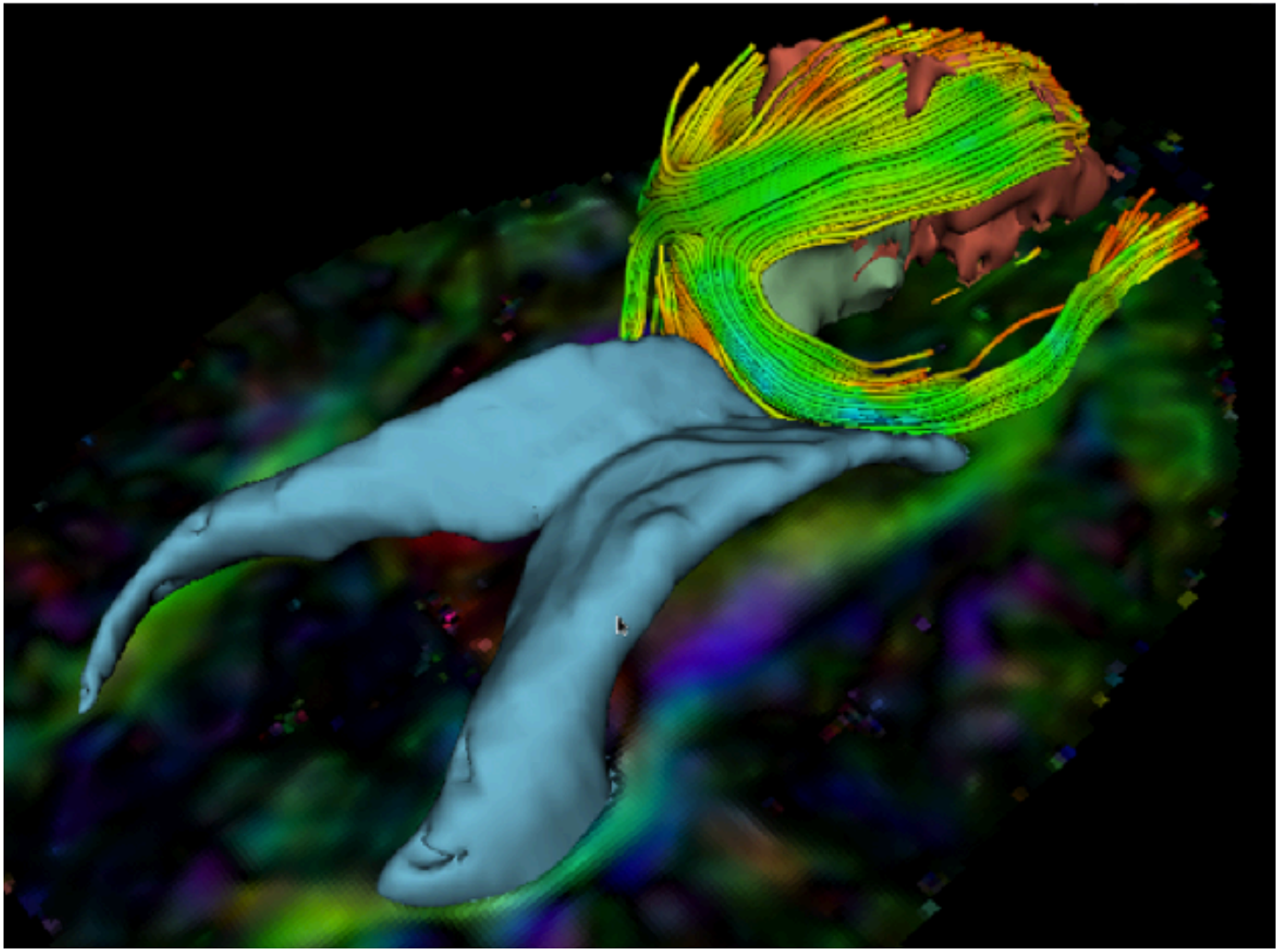
Image taken by R. Kikinis

Slicer Tractography

Seeding with:

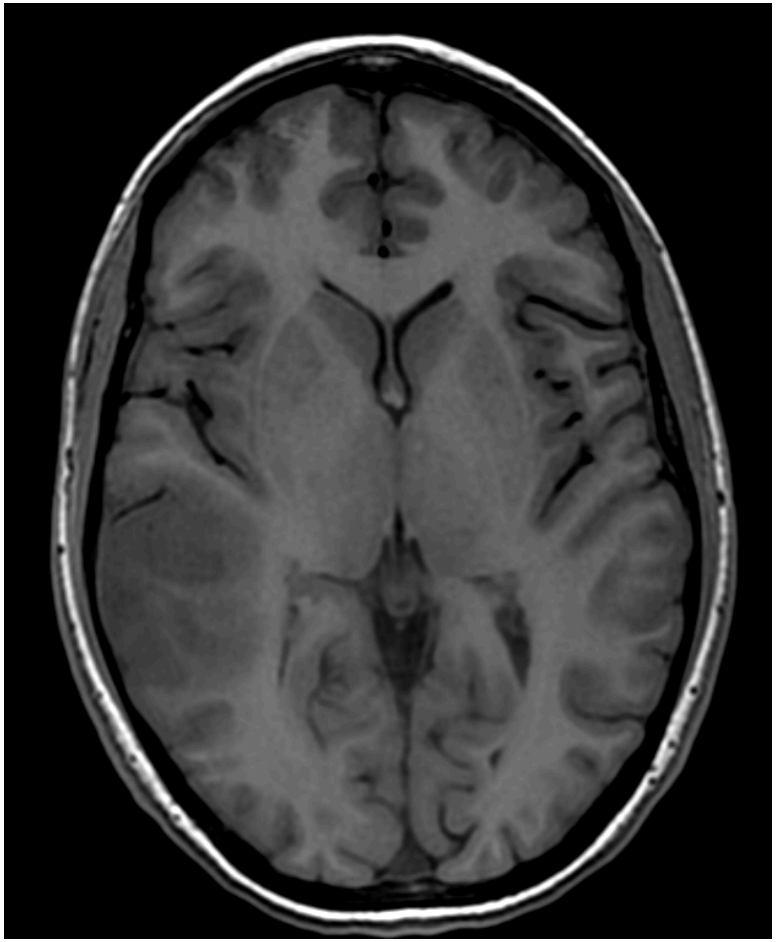
-3d models

-fiducials

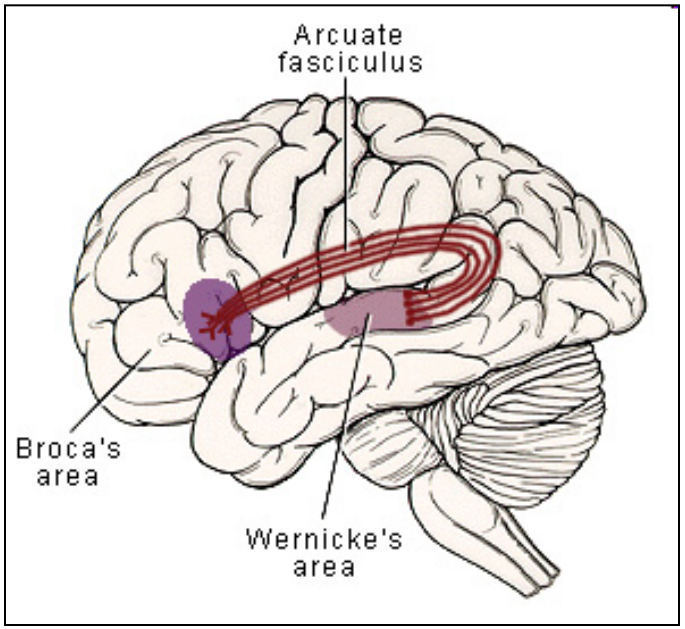


Case 2: Tumor and Language

Where is Wernicke's area?

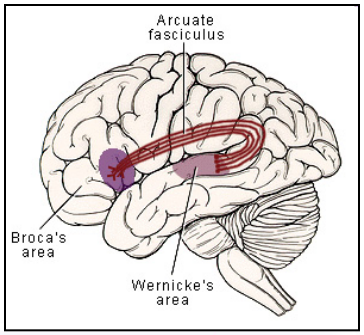


- Lesions affecting the arcuate fasciculus, a white matter tract connecting Wernicke's and Broca's speech regions, result in conduction aphasia.
  - (from http://www.lib.mcg.edu/edu/eshuphysio/program/section8/8ch15/s8c15_14.htm)

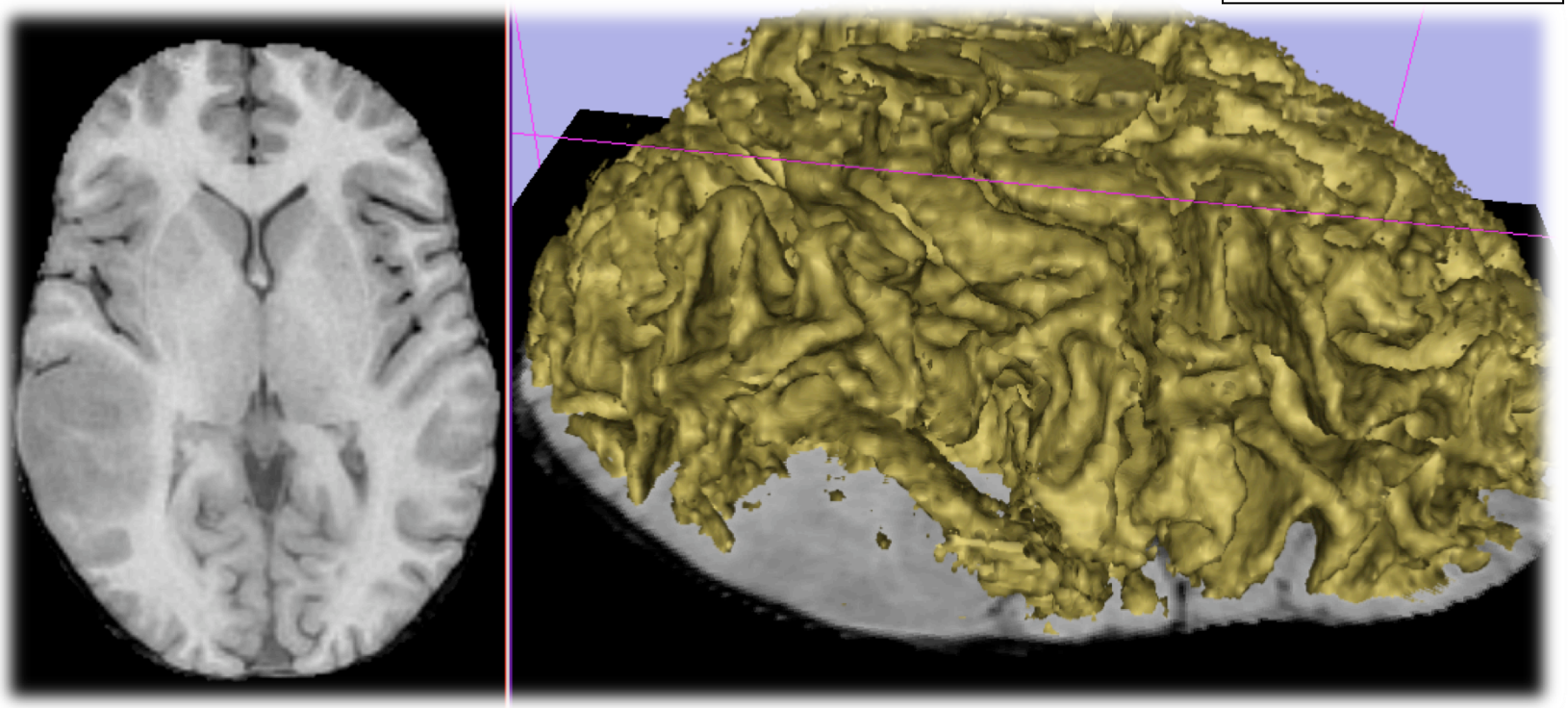


White Matter Surface On The Quick

- Where are Broca, Wernicke?
- Skullstrip → Volume render



from http://www.lib.mcg.edu/edu/eshuphysio/program/section8/8ch15/s8c15_14.htm



Slicer image taken by R. Kikinis

Open Image Guided Therapy

- IGT:
  - Use imaging to replace and augment direct inspection
  - Use devices to replace direct manipulation
- But: Devices are not just bits in the cloud
  - Software concepts need adjustment
  - Devices are proprietary by their very nature
  - API's are a key: they are the interface between proprietary systems and open source research systems

MR Interventions at BWH

Beginning 1994

MRT

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A Teaching Affiliate of Harvard Medical School

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Neurosurgery Milestone

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BWH completes 1,000th Intraoperative MR-guided Craniotomy

In August 1996, neurosurgeons at Brigham and Women's Hospital (BWH) performed the world's first intraoperative MR-guided brain tumor craniotomy, successfully removing a tumor using the most advanced imaging techniques available.

As BWH marks the 10th anniversary of this landmark procedure, Neurosurgery, Neuroradiology and Magnetic Resonance Therapy (MRT) teams last month combined to perform the hospital's 1,000th intraoperative MR-guided craniotomy.

"This milestone is testament to how effective this

Teams from Neurosurgery, Neuroradiology, and Magnetic Resonance Therapy (MRT) worked together to perform the hospital's 1,000th intraoperative MR-guided craniotomy.

http://www.brighamandwomens.org/ofcurrentinterest/craniotomy.aspx

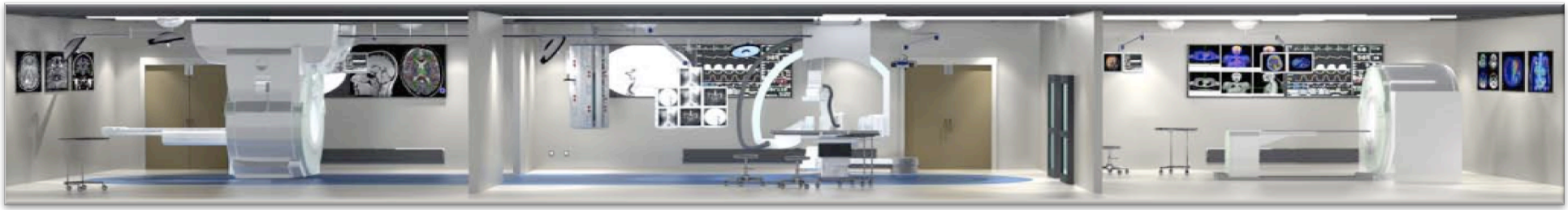
AMIGO, Our IGT Lab

- Advanced Multimodality Image Guidance Operating Suite
- Wide bore, ceiling mounted 3T MRI
- Cone beam CT, US, Microscope
- Navigation system
- PET CT

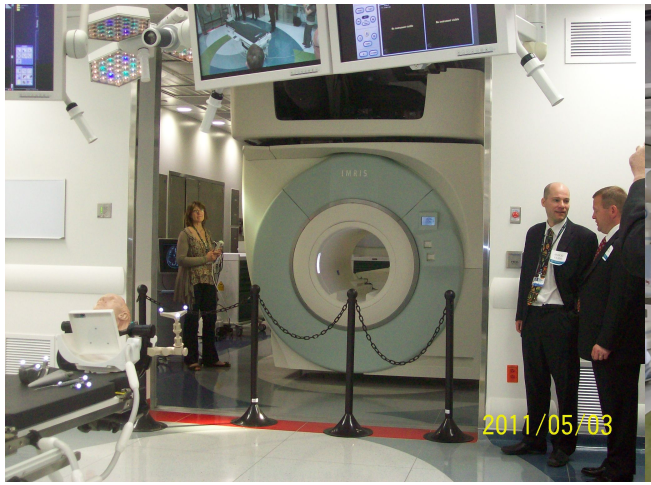
Principal Investigator: FA Jolesz

AMIGO Today

Advanced **M**ultimodality **I**mage **G**uided **O**perating Suite



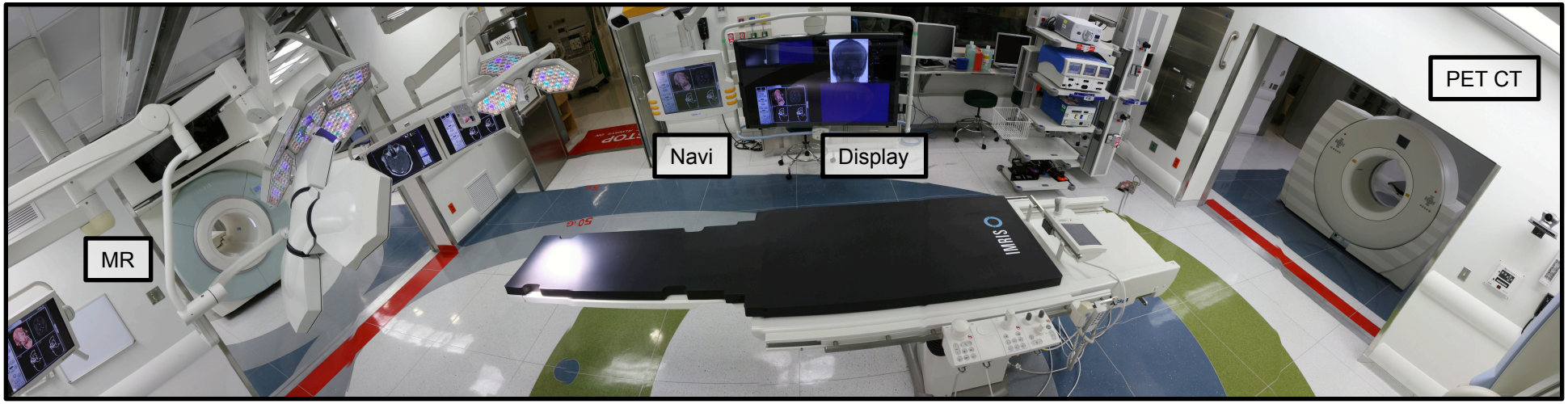
MRI Room **Operating Room** **PET/CT Room**

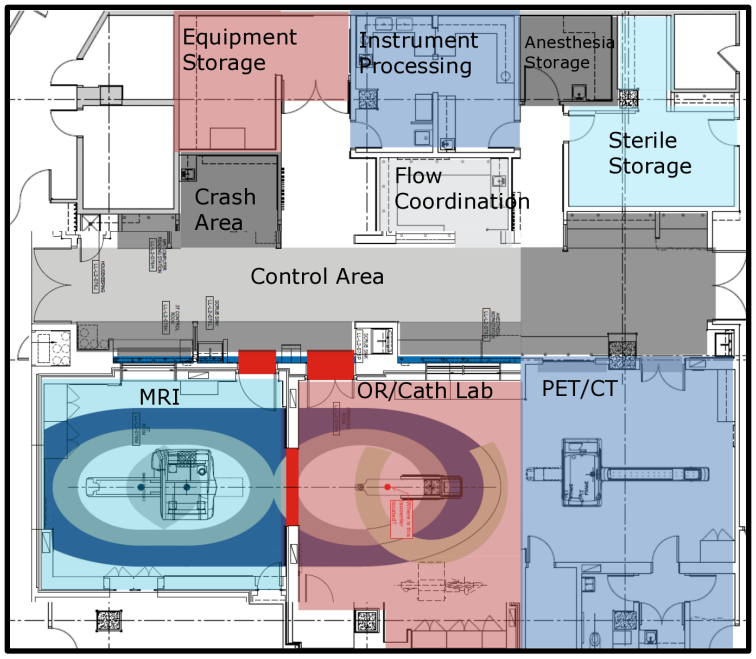


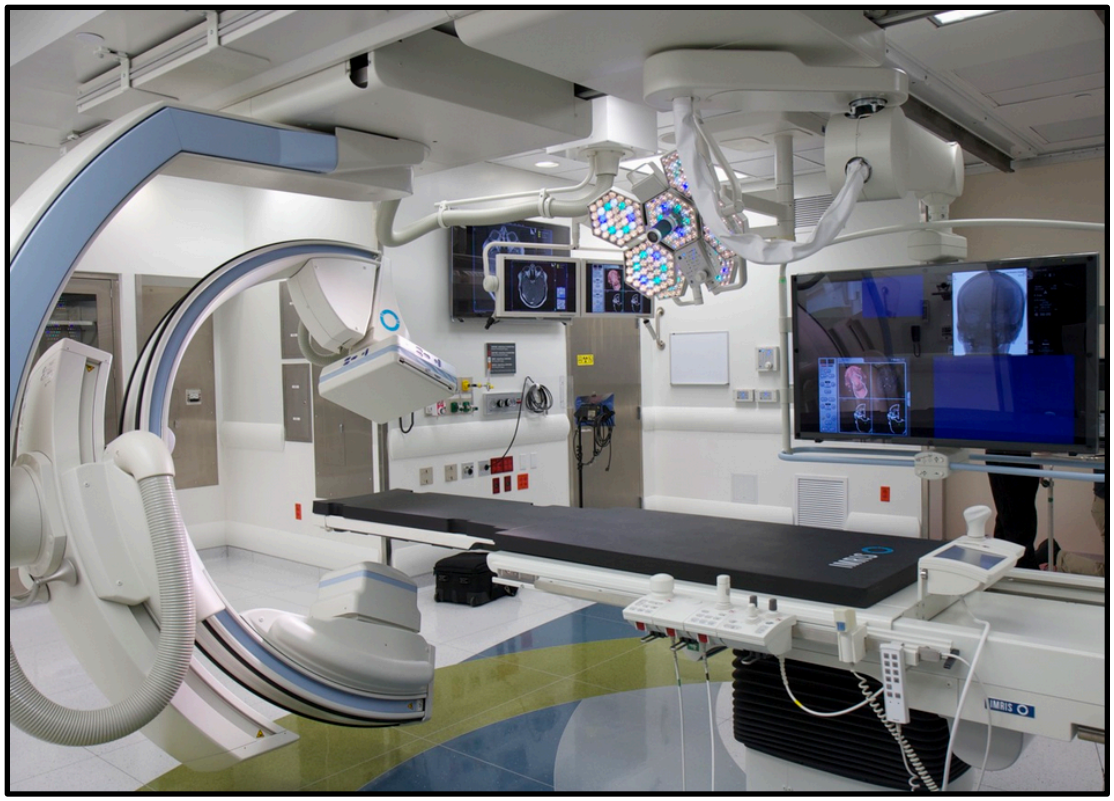
Advanced Multimodality Image Guided Operating (AMIGO) Suite

P41 RR019703 – National Center for Image Guided Therapy (NCIGT) 2005-2015

Ferenc Jolesz, MD Clare Tempany, MD







Principal Investigator: FA Jolesz

Images courtesy D. Kacher, J Tokuda

AMIGO Phase 1 Planned Procedures

- 16 procedures across 7 services have been proposed to begin during Phase I

Procedure Name
Brain Tumor Laser Ablation
Brain Tumor Resection
Pituitary Procedures
Brain Biopsy
Prostate Biopsy
Prostate Brachytherapy
Cervical Cancer Brachytherapy
Percutaneous Tumor Ablation
Soft Tissue Biopsy
Breast Cancer Lumpectomy
Cardiac Ablation (XMR Guided)
Image Registered Endoscopy - Pancreas
Image Registered Endoscopy - Abdomen
Peripheral Sarcoma
Parathyroid Adenoma
Image Registered Endoscopy - Thorax

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Imaging Equipment in AMIGO

- Room 1: MRI Room
  - Siemens 3T Verio MR scanner that moves along a ceiling track between the MRI room and the OR
- Room 2: PET-CT Room
  - Siemens PET-CT
- Room 3: Operating Room
  - BK Medical Pro Focus UltraView Surgical Ultrasound with Prostate Transducer
  - Siemens S2000 Ultrasound
  - Siemens Artis Zee ceiling mounted X-ray Fluoroscopy system with Navigation Package and DynaCT
  - Zeiss Pentero surgical microscope
- Navigation
  - BrainLAB navigation system
  - Sentinelle Medical (Hologic) Aegis Navigation Workstation
  - St Jude Medical mapping and navigation system
  - IntraMedical Imaging Node Seeker and Beta Probe
  - Robin Medical Endoscout

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