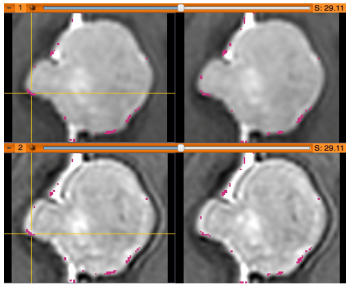
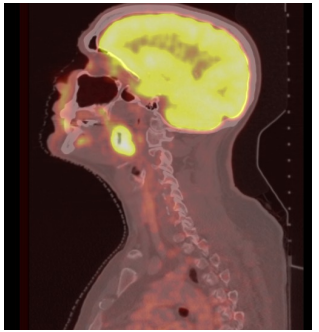
Surgical Planning Laboratory
Brigham and Women's Hospital
Boston, Massachusetts USA

a teaching affiliate of
Harvard Medical School



Quantitative Medical Imaging for Clinical Research and Practice



Sonia Pujol, PhD, Katarzyna Macura MD, PhD, Kitt Shaffer, MD, PhD, Hatsuho Mamata, MD, PhD, Andriy Fedorov, PhD, Wendy Plesniak, PhD, Ron Kikinis, MD

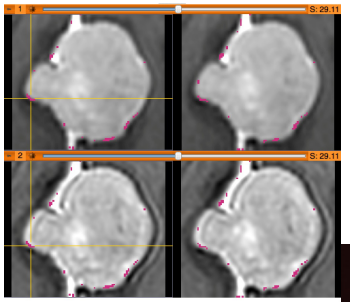
Quantitative Imaging Tutorial

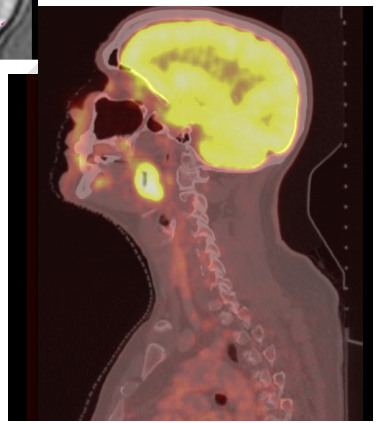
Quantitative imaging is the extraction of quantitative measurements from medical imaging.

This tutorial is built upon two examples of quantitative imaging:

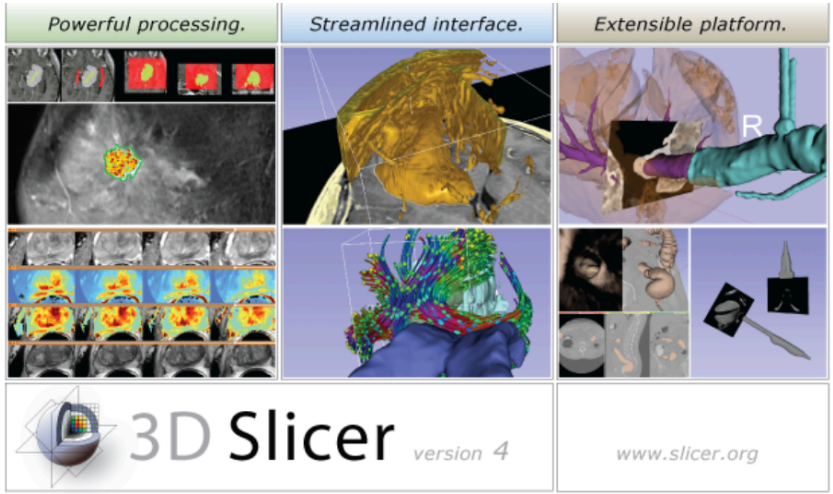
- **Morphology**: small volumetric changes in slow growing tumors

- **Function**: metabolic activity in squamous cell carcinoma





Quantitative Imaging: Software



www.slicer.org

This hands-on tutorial will guide you step-by-step through the use of quantitative imaging modules of the 3D Slicer software.

3D Slicer is a freely available open-source platform for medical imaging research supported by the National Institutes of Health.

Course Overview

Part 1: Measurement of small Volumetric Changes in meningioma using the Change Tracker module

Part 2: Measurement Metabolic Activity in squamous cell carcinoma using the PET

Standard Uptake Value Computation module

Course Datasets

The course data is located in the directory:

/QuantitativeImaging

- dataset1_MR_Head
- dataset2_ChangeTracker
- dataset3_PETCT

Each dataset is in Slicer **.mrb file format.**

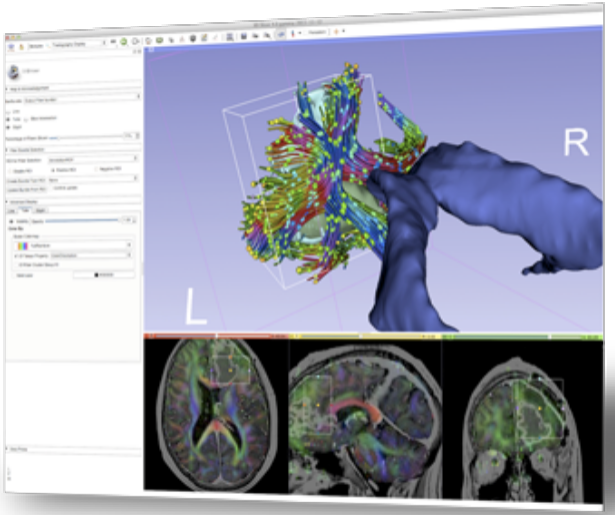
Slicer mrb file format

A Slicer mrb file is an archive file that contains all data for loading into Slicer4.

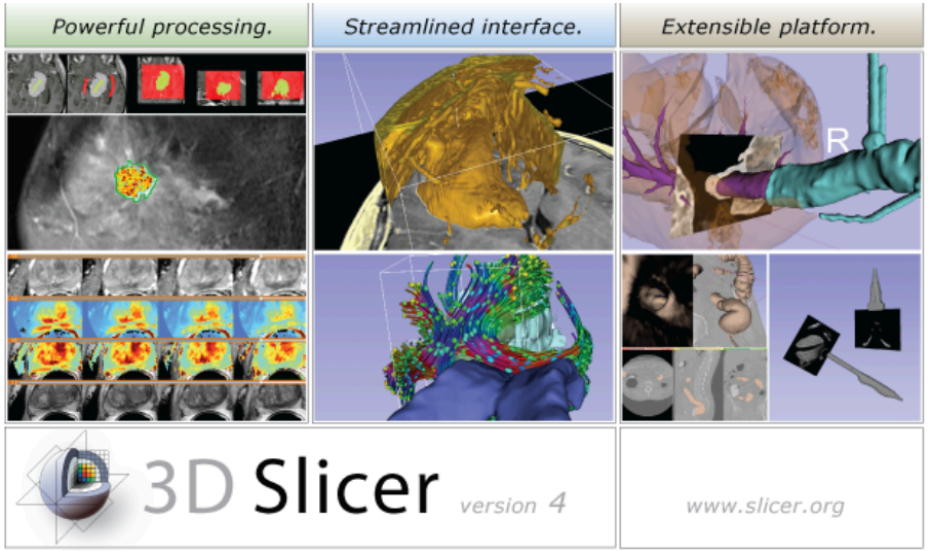
The .mrb file is a .zip file but with a different file extension.

Introduction to the 3D Slicer software

Sonia Pujol, PhD
Director of Training,
Neuroimage Analysis Center
Brigham and Women's Hospital, Boston, MA



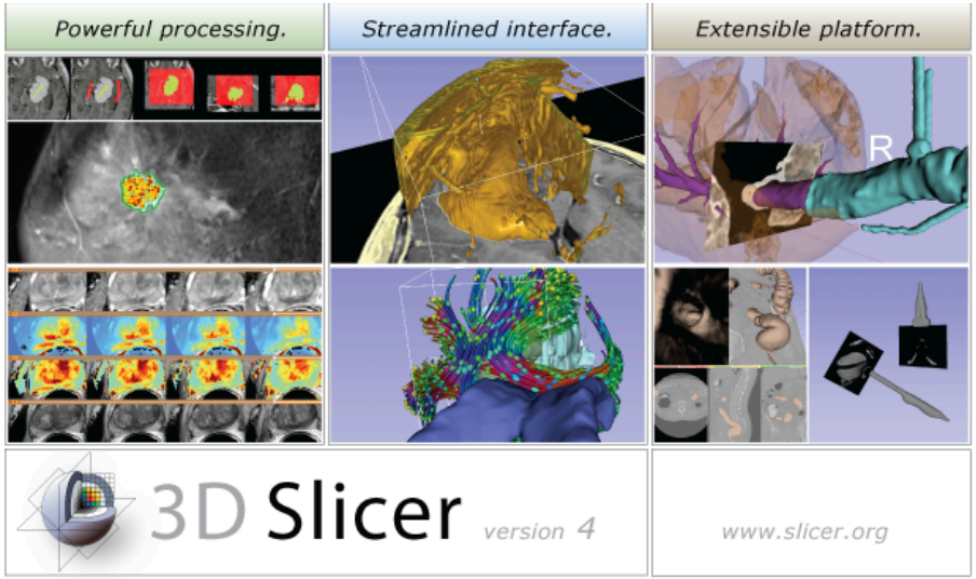
3D Slicer



3D Slicer is a freely available open-source platform for segmentation, registration and 3D visualization of medical imaging data.

3D Slicer is a multi-institutional effort supported by the National Institutes of Health.

3D Slicer

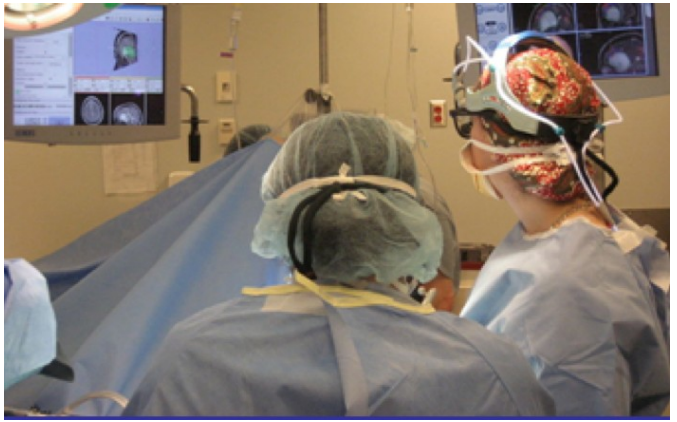


- 3D Slicer version 4.5 is a multi-platform software running on Windows, Linux, and Mac OSX
- Slicer is distributed under a BSD license with no restriction on use
- Slicer is a tool for research, and is not FDA approved

Disclaimer
It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules.

An interdisciplinary platform

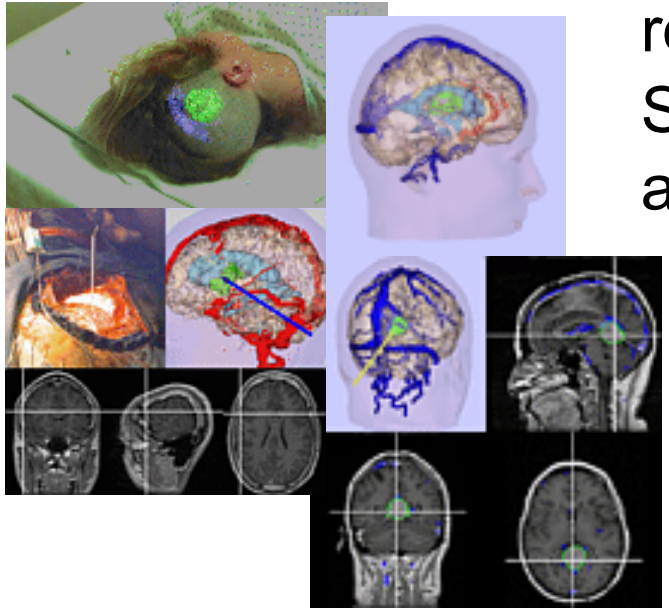
An open-source environment for software developers



An end-user application for clinical investigators and scientists

A software platform that is both easy to use for clinical researchers and easy to extend for programmers

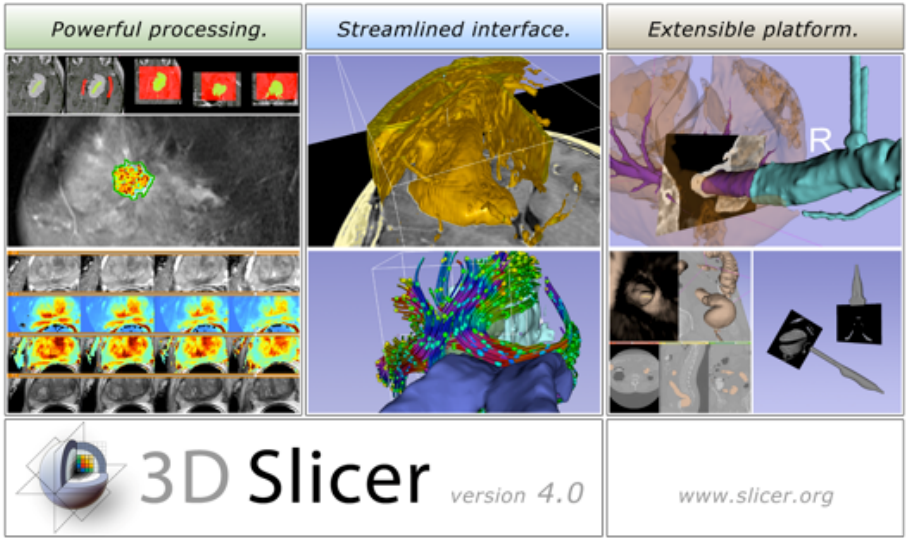
3D Slicer History



- 1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)

Image Courtesy of the CSAIL, MIT

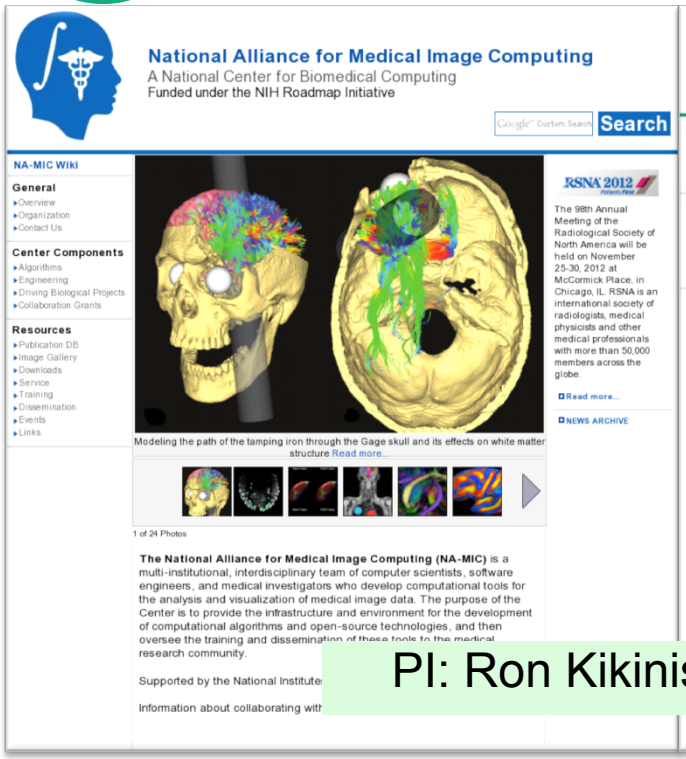
3D Slicer History

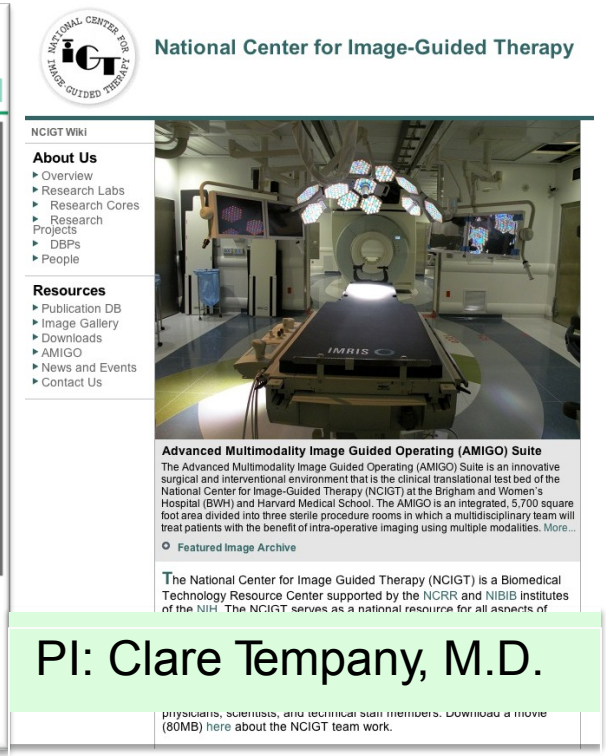


1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)

2015: Multi-institution effort to share the latest advances in image analysis with clinicians and scientists

A multi-institution: NA-MIC, NAC, NCIGT

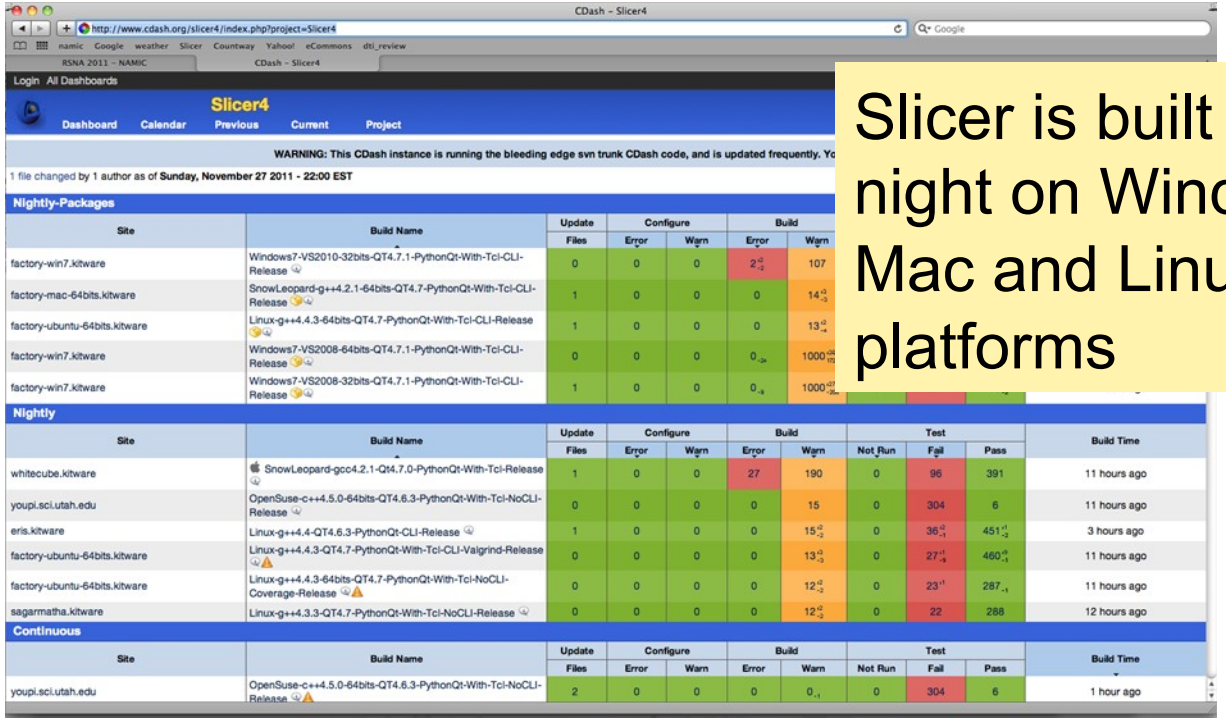




PI: Ron Kikinis, M.D.

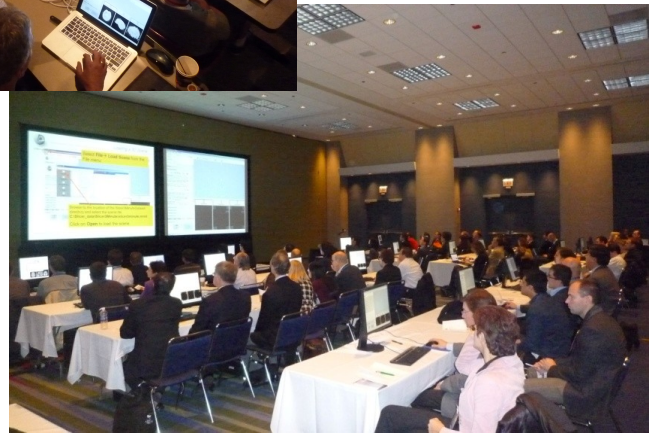
PI: Clare Tempany, M.D.

Slicer: Behind the scenes



Slicer is built every night on Windows, Mac and Linux platforms

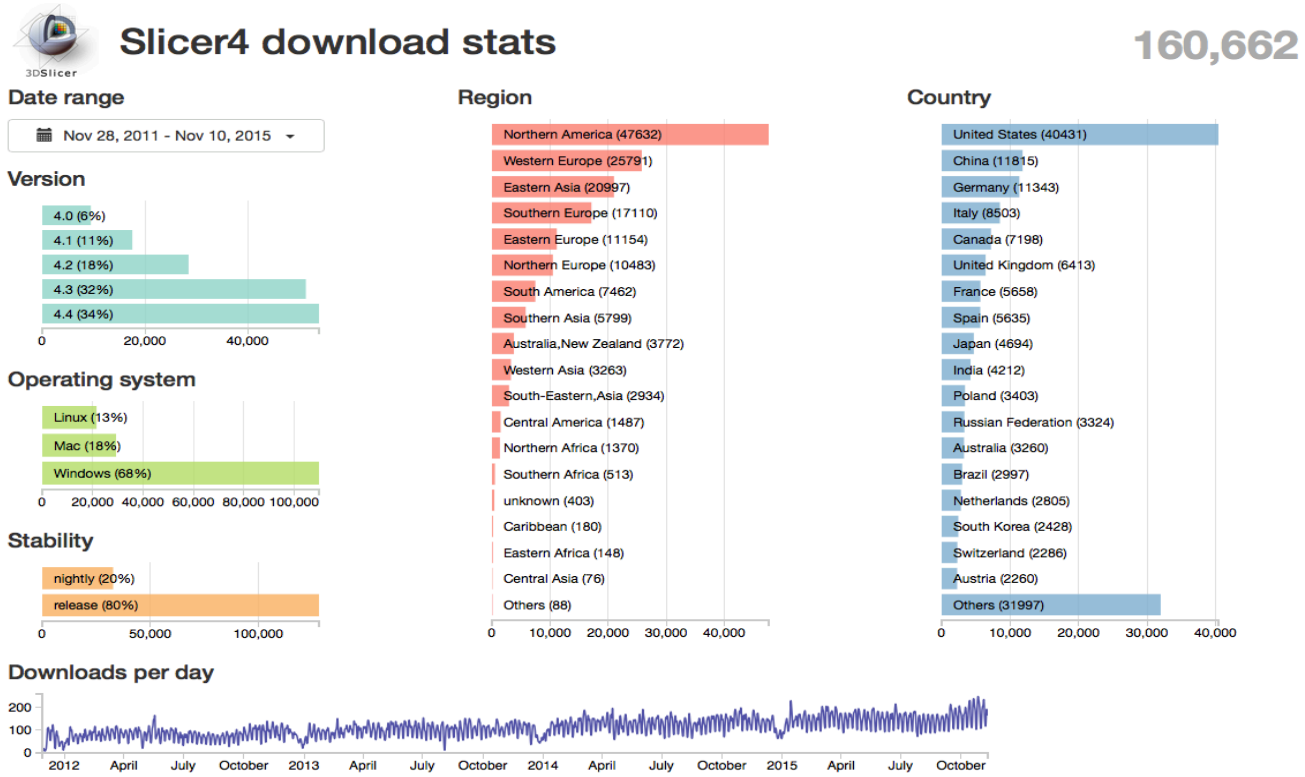
Slicer Training

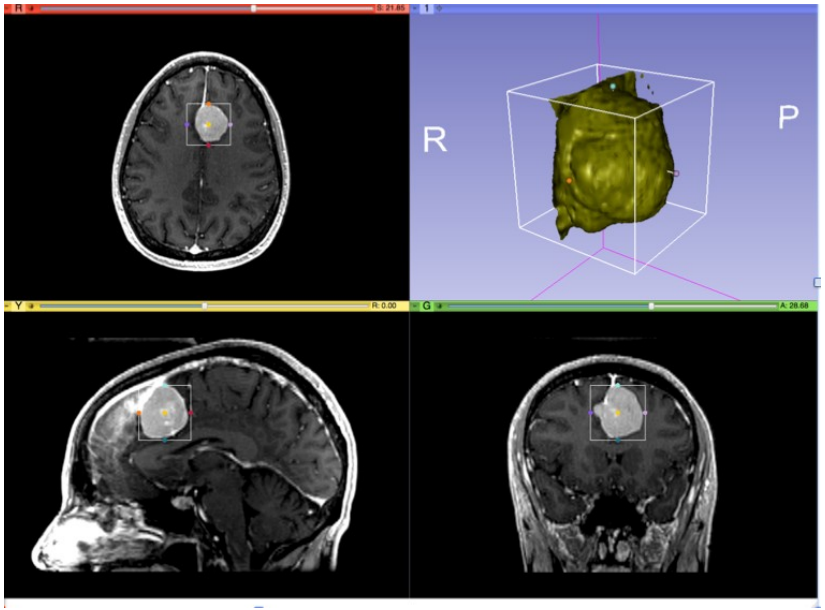


RSNA 2015

- Hands-on training workshops at national and international venues
- More than 3,000 clinicians, clinical researchers and scientists trained since 2005

Slicer Downloads

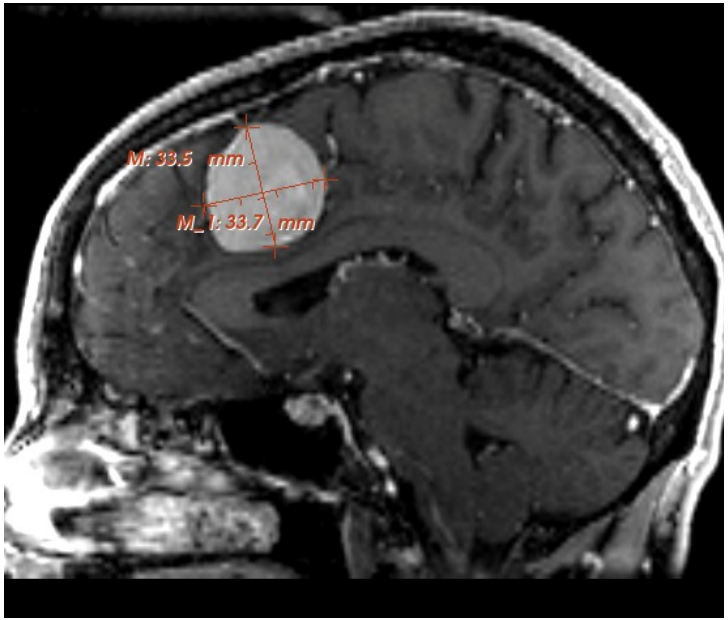




Part I: Analyzing Small Volumetric Changes

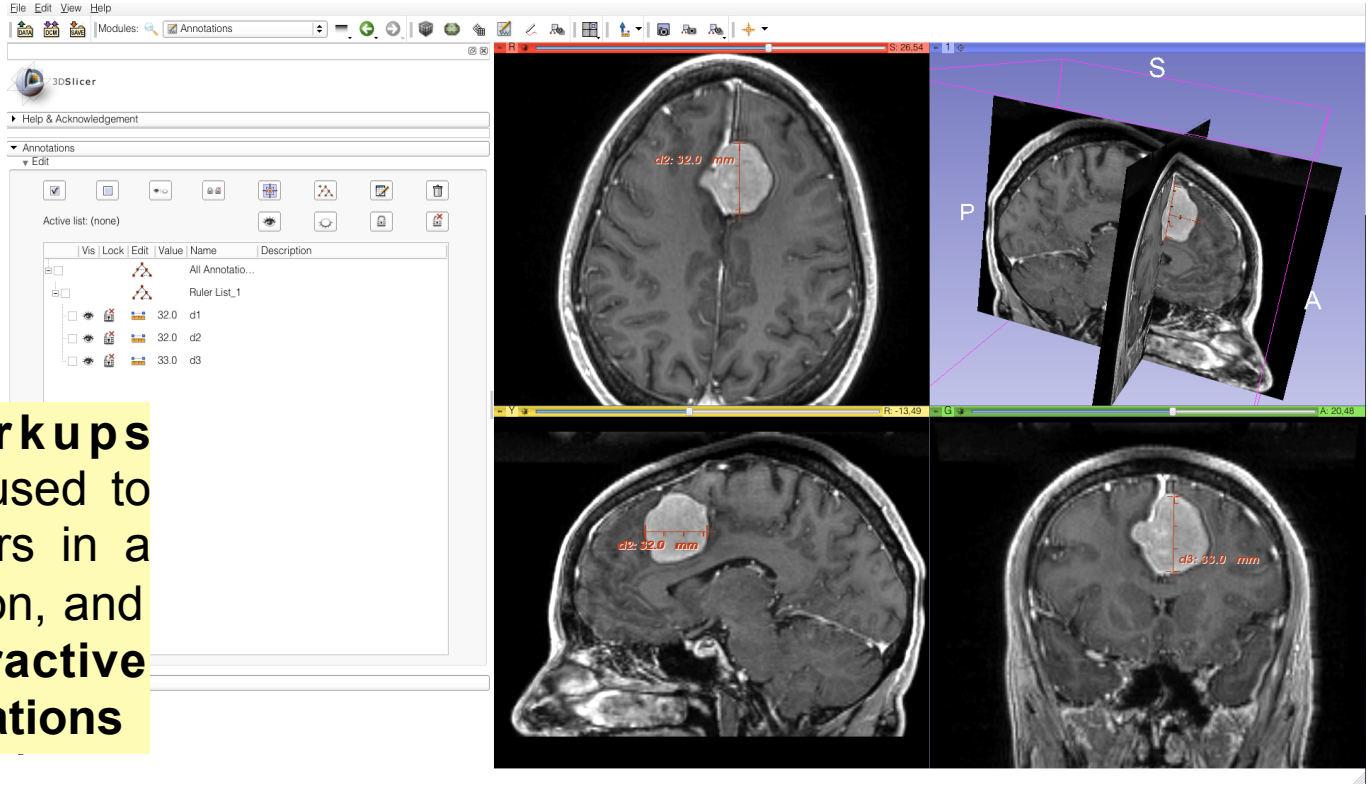
Sonia Pujol, PhD
Kilian M Pohl, PhD
Andriy Fedorov, PhD
Ender Konukoglu, PhD
Ron Kikinis, MD

Conventional measures of tumor response



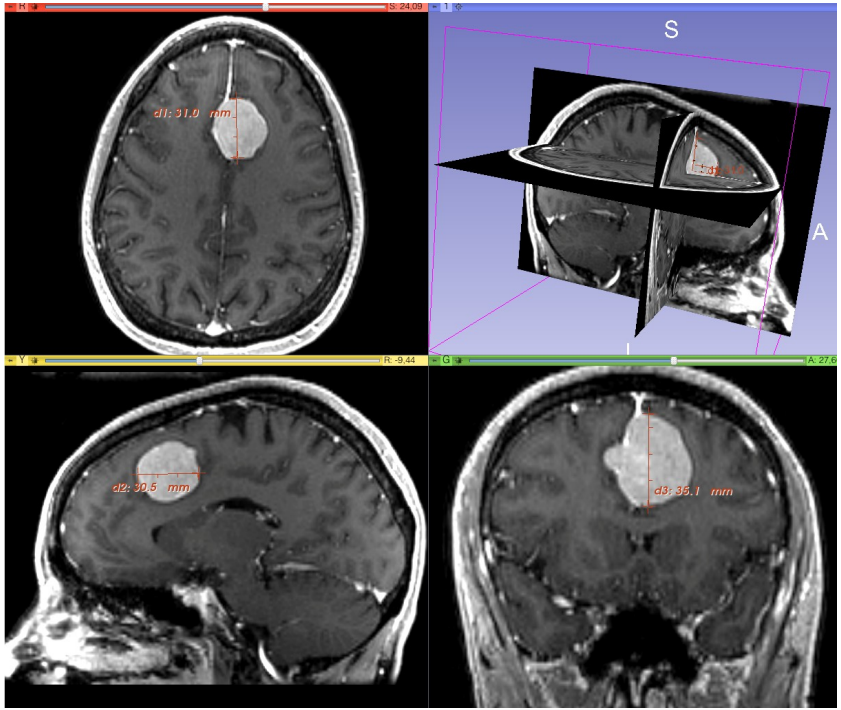
- Conventional anatomic imaging using CT or MRI are often used to evaluate tumor size and shape
- Most clinical trials that evaluate new chemotherapeutic drugs use changes in uni-dimensional or bi-dimensional measurements to assess response (*e.g.* RECIST)
- Slicer has several tools for applying RECIST methodologies

Conventional measures of tumor response



3D Slicer **Markups module** can be used to measure diameters in a tumor cross section, and to provide **interactive numerical annotations**

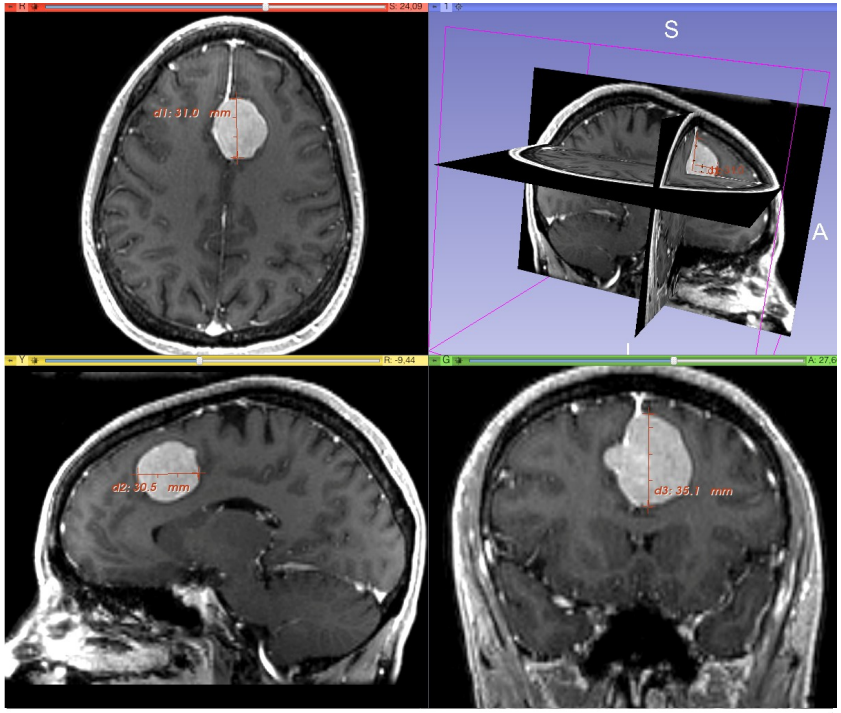
Clinical Case: baseline scan



Baseline radiologist's clinical impression:

- large falcine lesion is identified.
- measures 3.10 cm anteroposteriorly and 3.51 cm in height.
- enhances moderately on post gadolinium imaging.

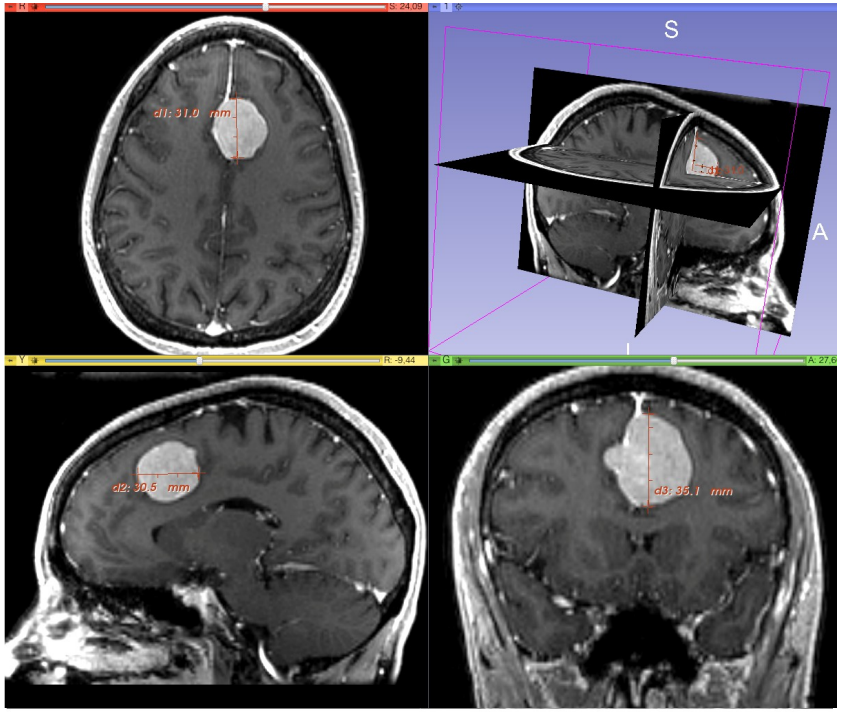
Clinical Case: follow-up scan



Follow-up radiologist's clinical impression:

- left frontal lobe mass appears unchanged on all series.
- measures 3.3 x 3.2 cm in maximum dimension.
- enhances moderately on post gadolinium imaging.

Clinical Case: follow-up scan



Follow-up radiologist's clinical impression:

- left frontal lobe mass appears unchanged on all series.
- measures 3.3 x 3.2 cm in maximum dimension.
- enhances moderately on post gadolinium imaging.

→ **How has the tumor changed?**

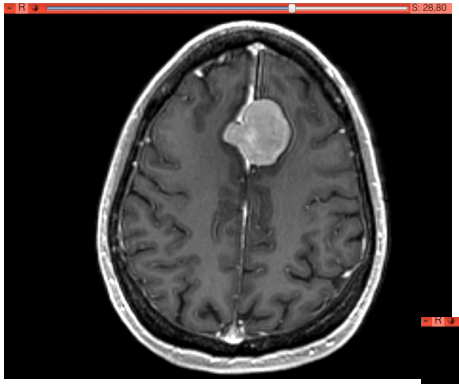
ChangeTracker: rationale for new approaches

More accurate and precise methods for understanding volume changes may be useful when:

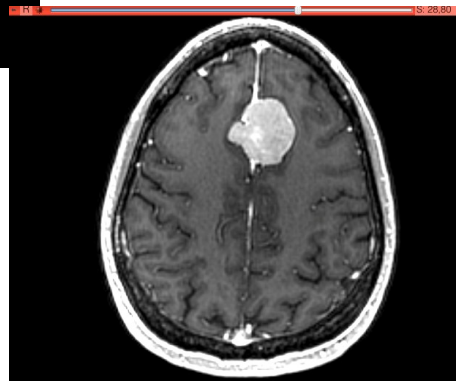
- **benign tumor change** is being monitored, or
- where **small changes may be clinically significant** but difficult to assess with RECIST

Goal of the tutorial

MR Scan1 June 2006



MR Scan2 June 2007

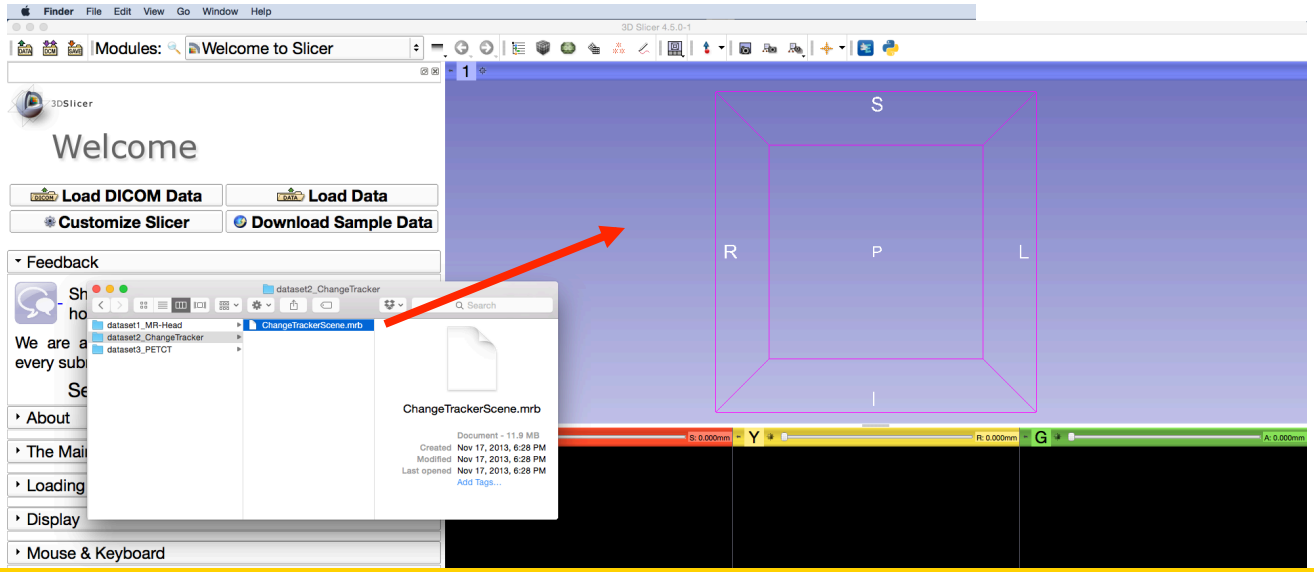


(Voxel dimension: 0.94mm x 0.94mm x 1.20mm, FOV: 240mm, Matrix: 256 x 256)"

The following section will guide you step-by-step through the computation of small volumetric changes in a slow growing tumor.

This tutorial is built upon two scans (Axial 3D SPGR T1 post Gadolinium) of a patient with meningioma, and uses the Change Tracker module of Slicer.

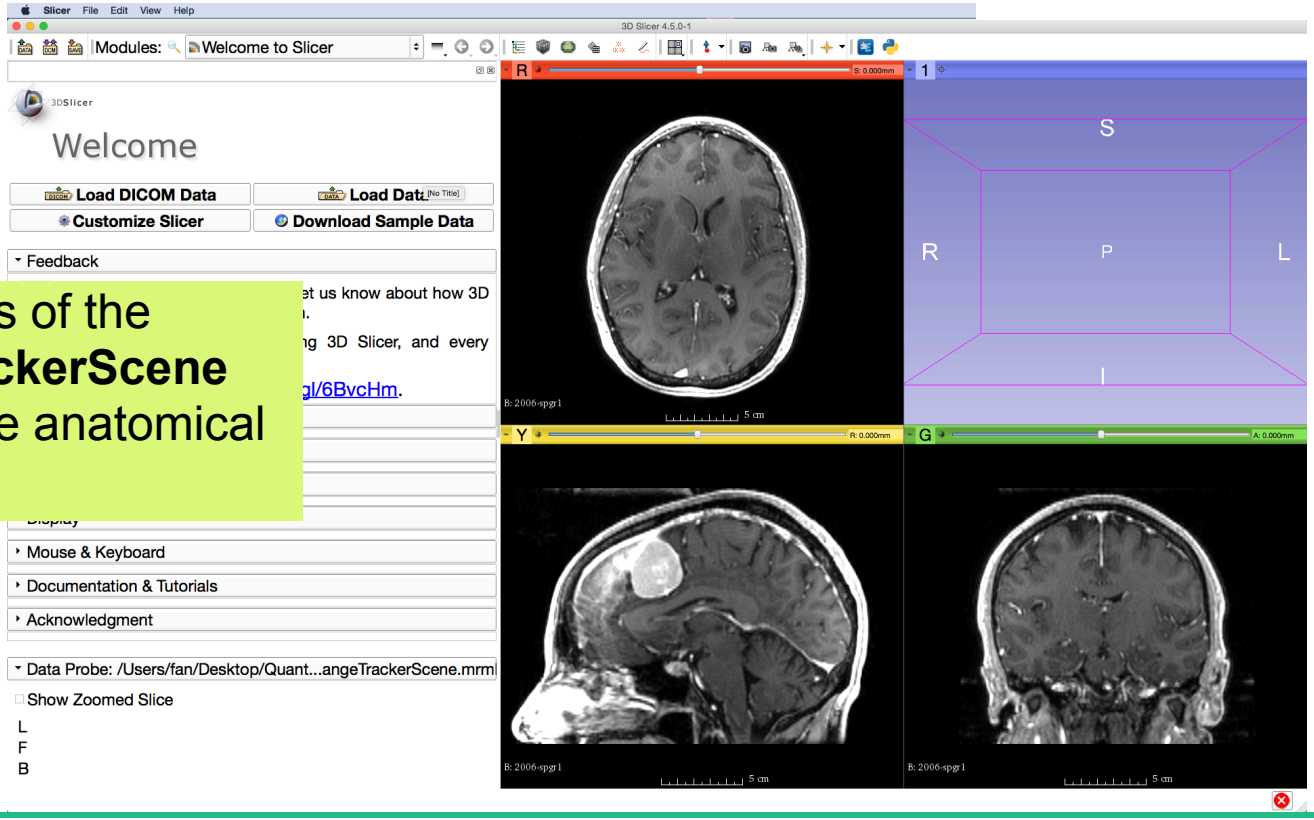
ChangeTracker: Load the dataset



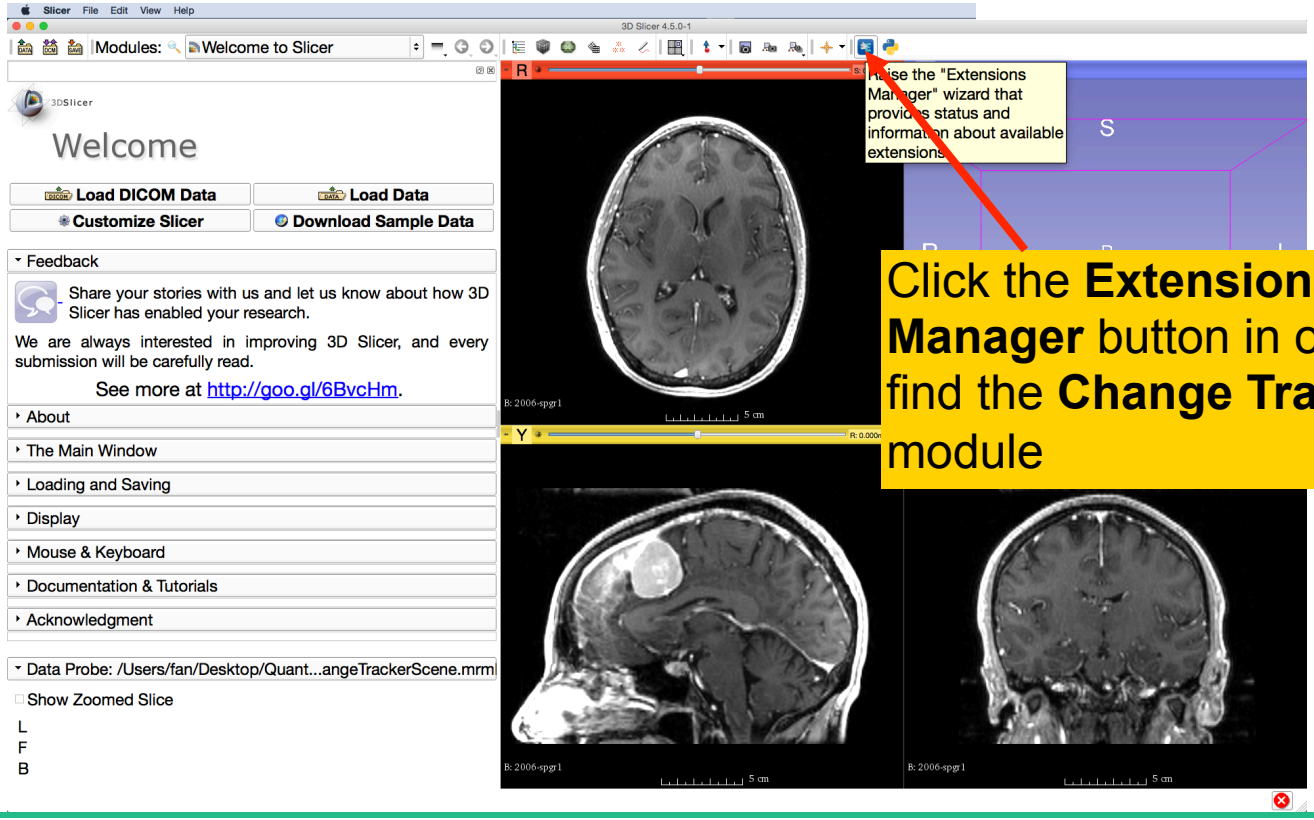
Drag and drop the file **ChangeTrackerScene.mrb** located in **/Users/Desktop/QuantitativeImaging/dataset2_ChangeTracker,** into the 3D Viewer. Then press **OK**

Loading the data

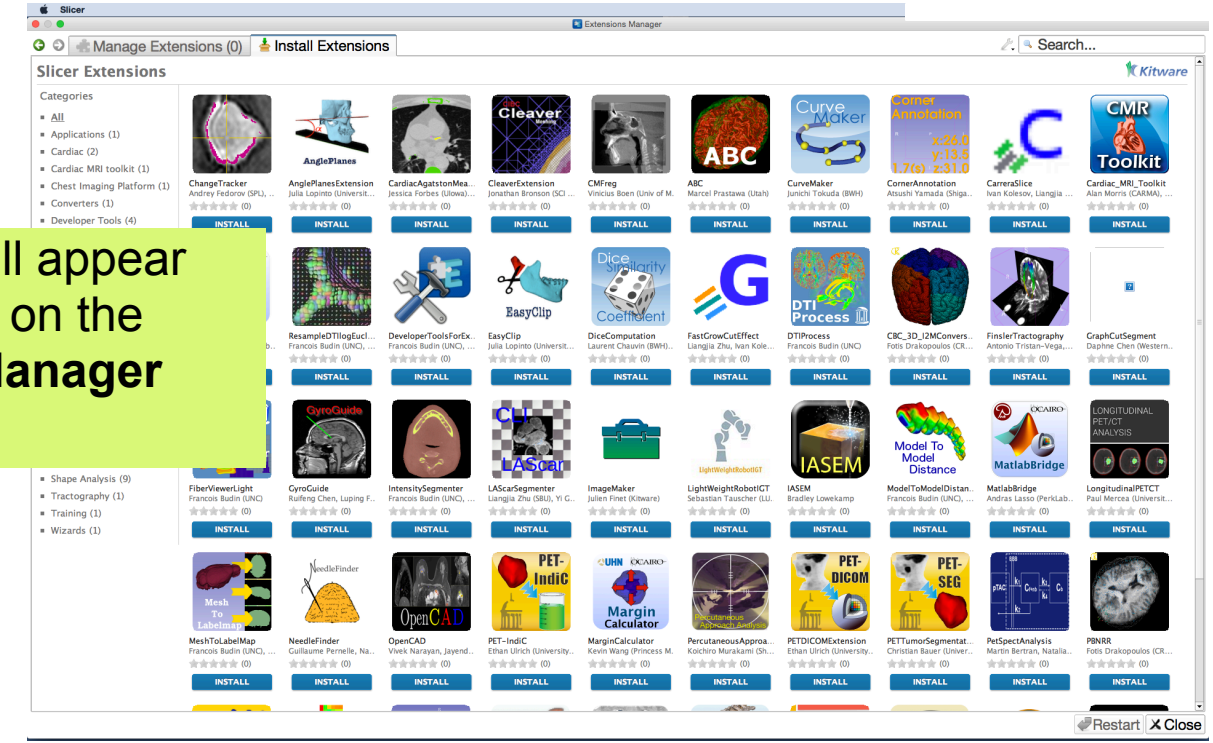
The datasets of the **ChangeTrackerScene** appear in the anatomical viewers.



ChangeTracker: exploring small volumetric changes

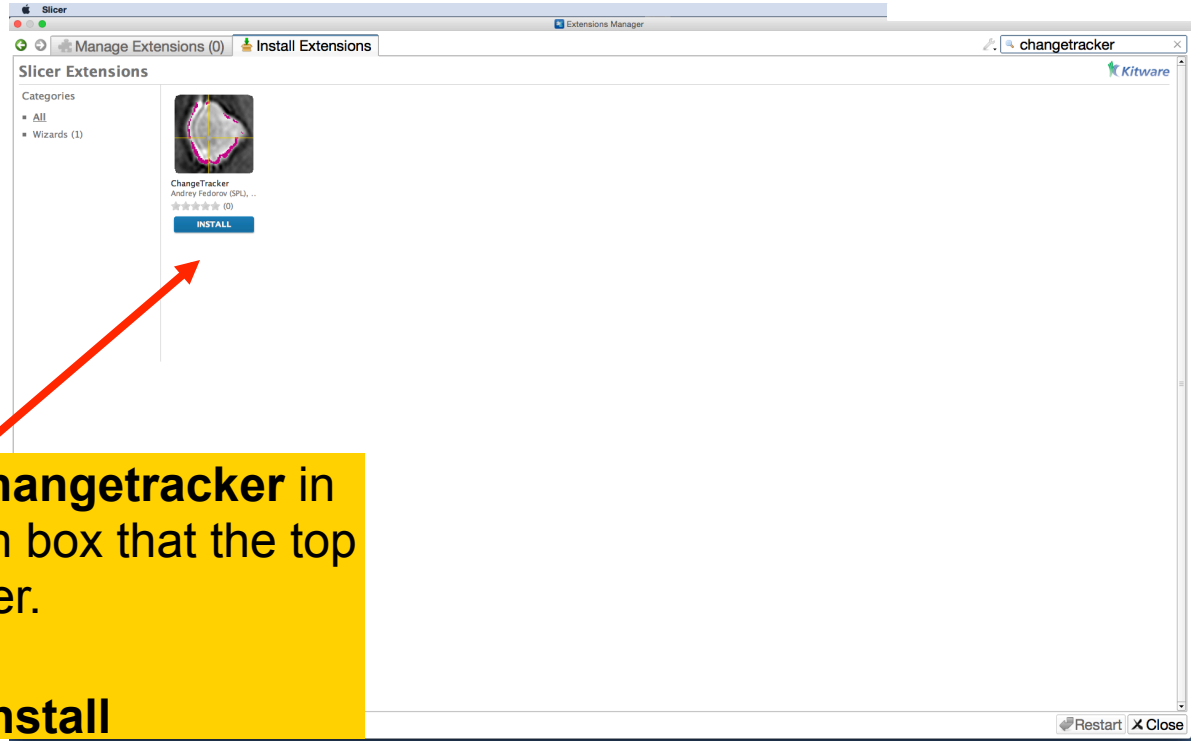


ChangeTracker: exploring small volumetric changes



This screen will appear once you click on the **Extensions Manager** button

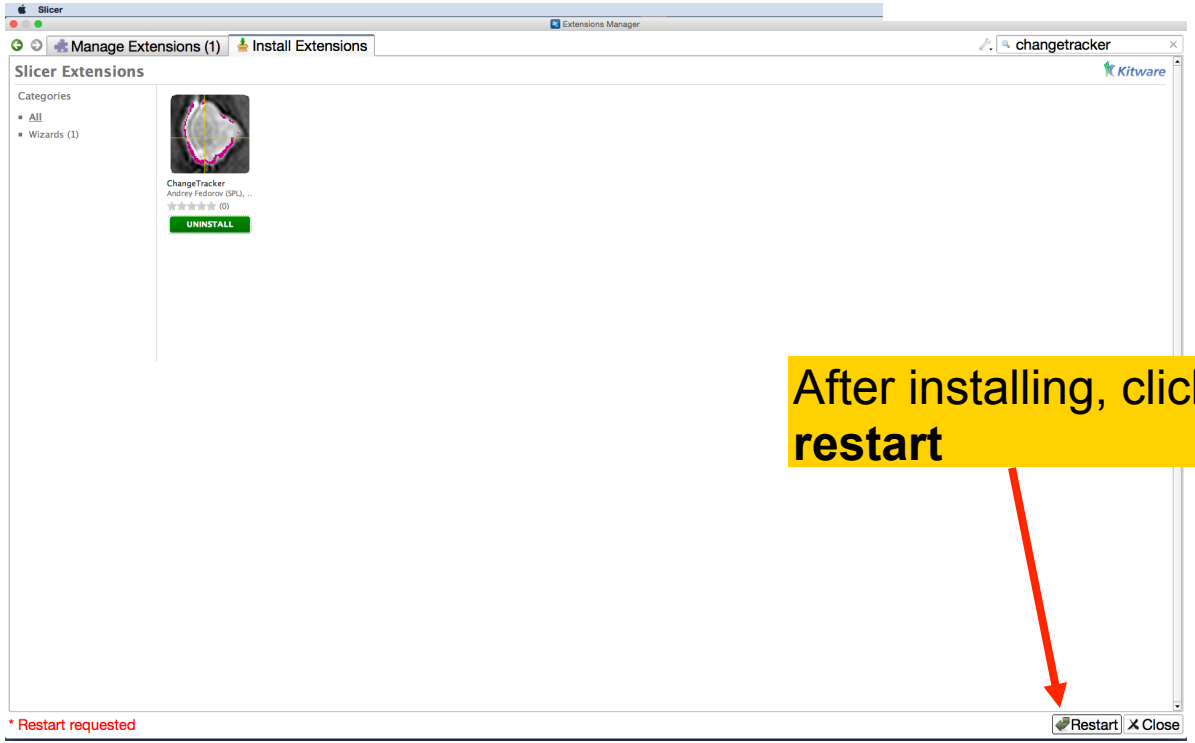
ChangeTracker: exploring small volumetric changes



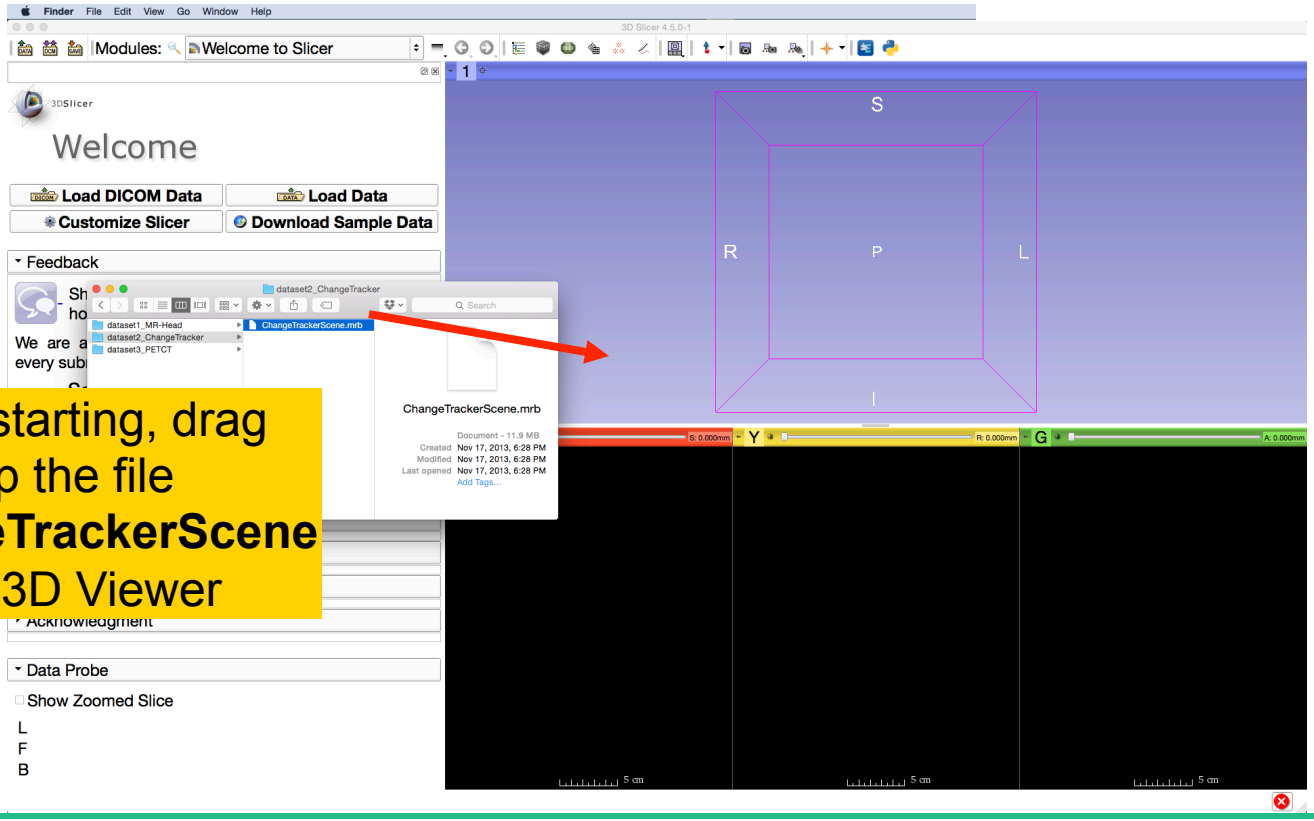
Type in **changetracker** in the search box that the top right corner.

Click on **Install**

ChangeTracker: exploring small volumetric changes



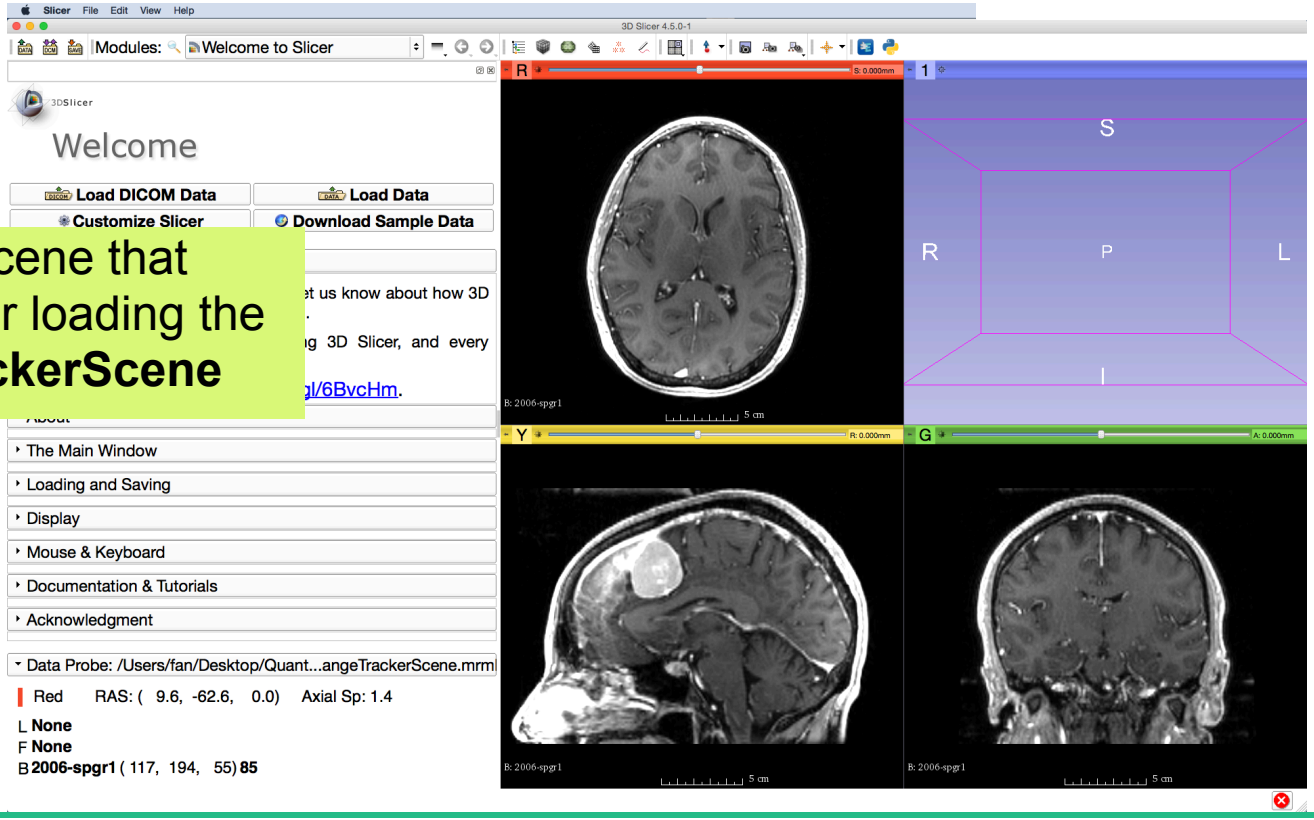
ChangeTracker: exploring small volumetric changes



After restarting, drag and drop the file **ChangeTrackerScene** into the 3D Viewer

ChangeTracker: exploring small volumetric changes

This is the scene that appears after loading the **ChangeTrackerScene**



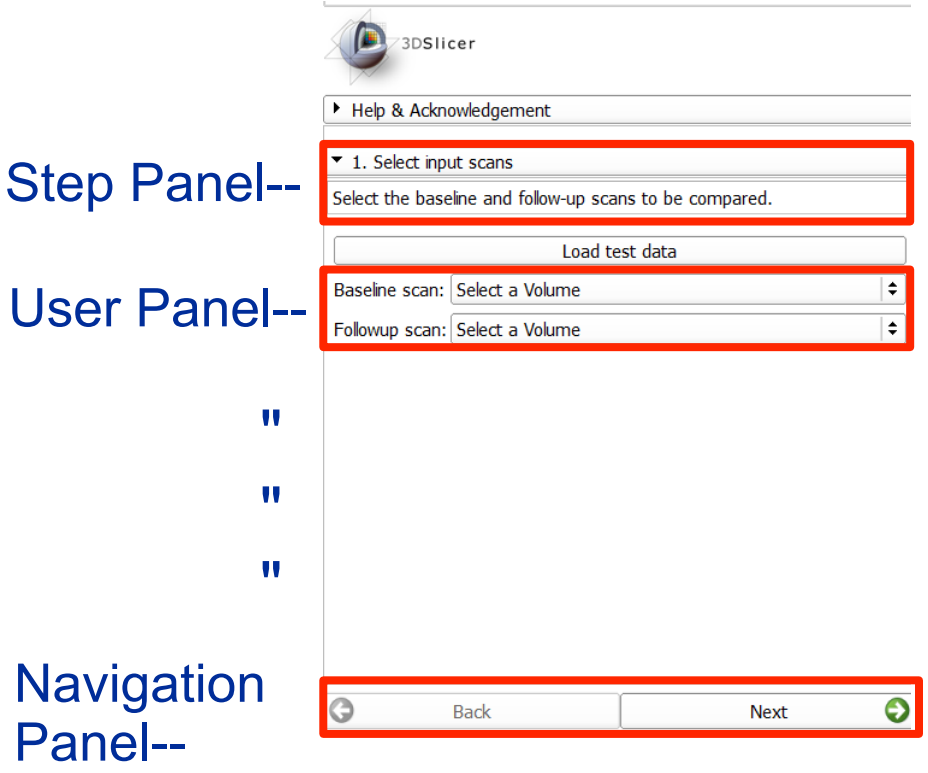
ChangeTracker: exploring small volumetric changes

Go to the modules menu and select the **ChangeTracker** module

ChangeTracker: a note about the Workflow wizard

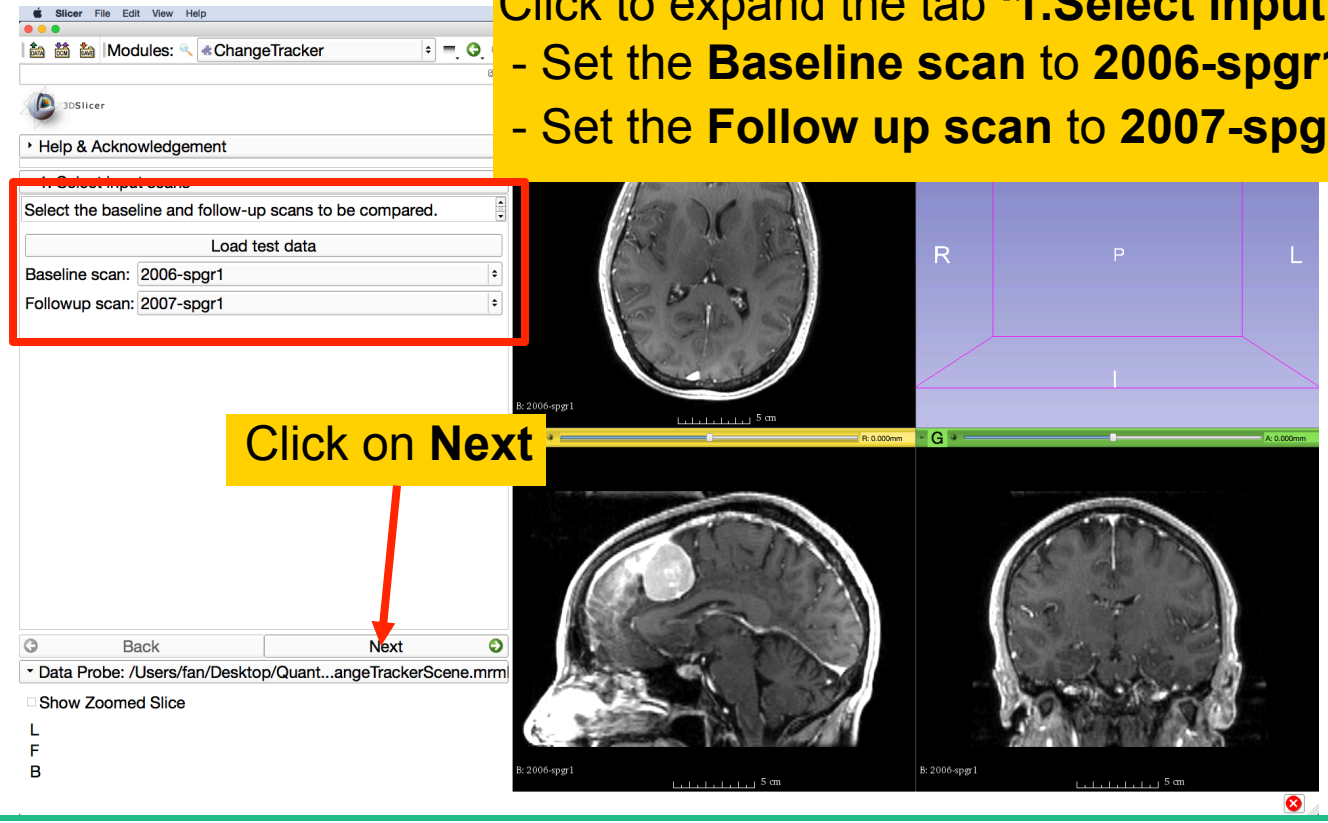
The **Workflow Wizard** guides the user through a sequence of steps and has the following components:

- the Step Panel
- the User Panel
- the Navigation Panel



Step1: Select input scans

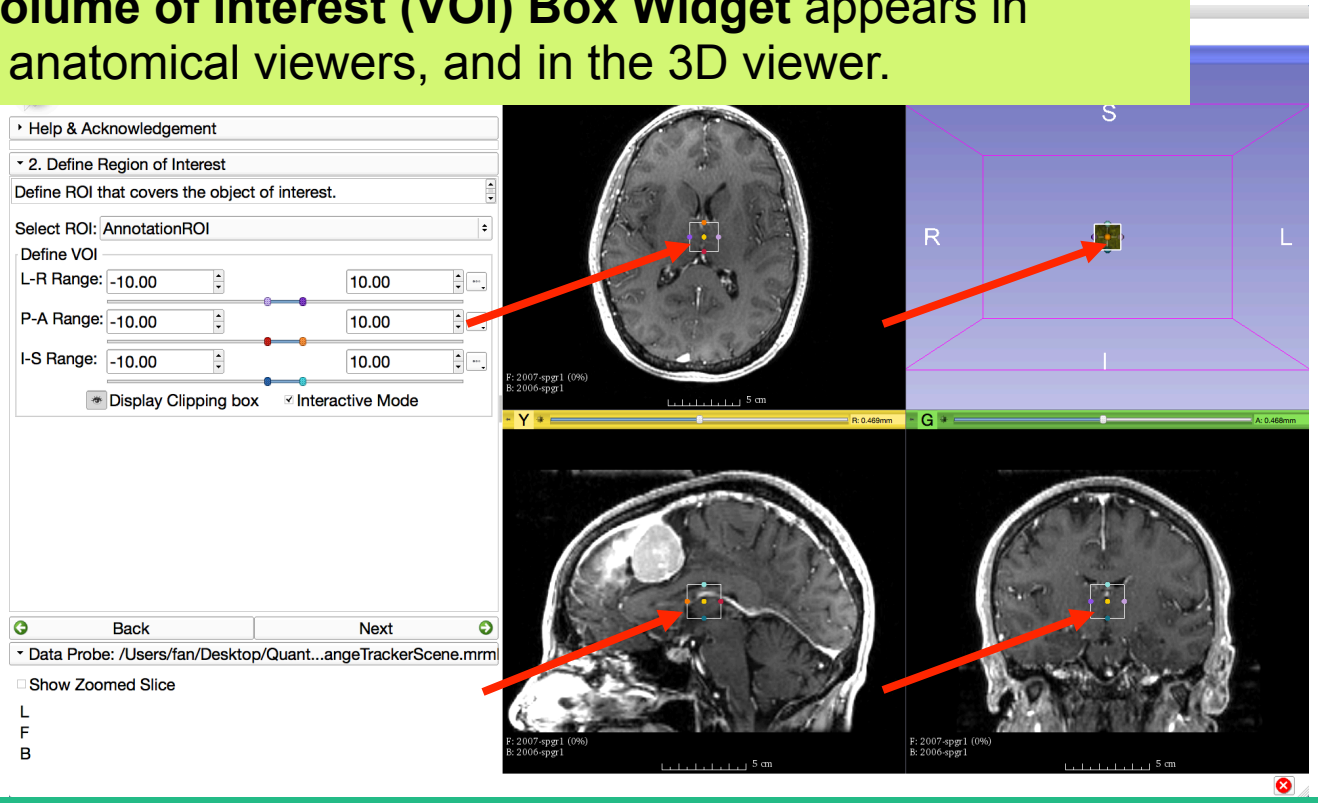
Click to expand the tab **'1.Select input scans'**
- Set the **Baseline scan** to **2006-spgr1**
- Set the **Follow up scan** to **2007-spgr1**



Click on **Next**

Step2: Define Region of interest

A **Volume of Interest (VOI) Box Widget** appears in the anatomical viewers, and in the 3D viewer.

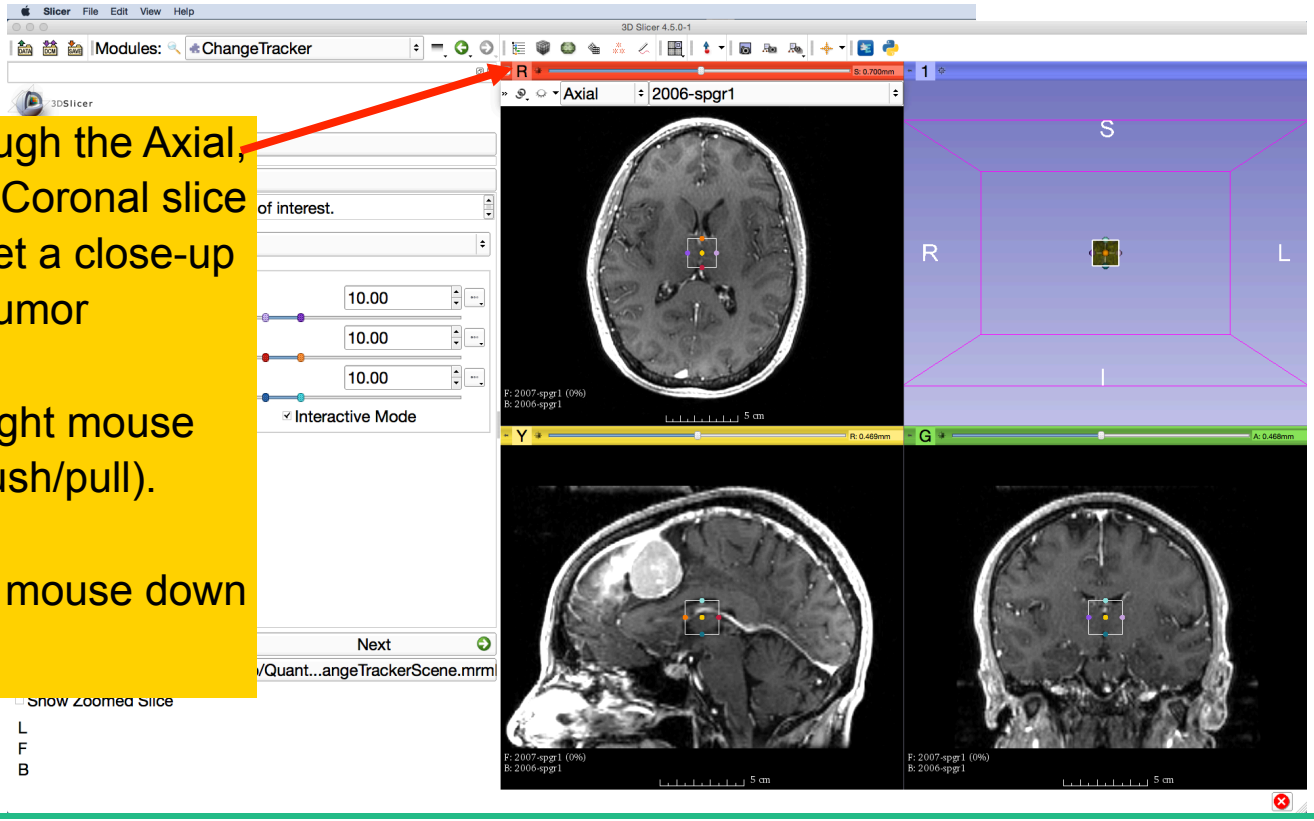


Step2: Define Region of interest

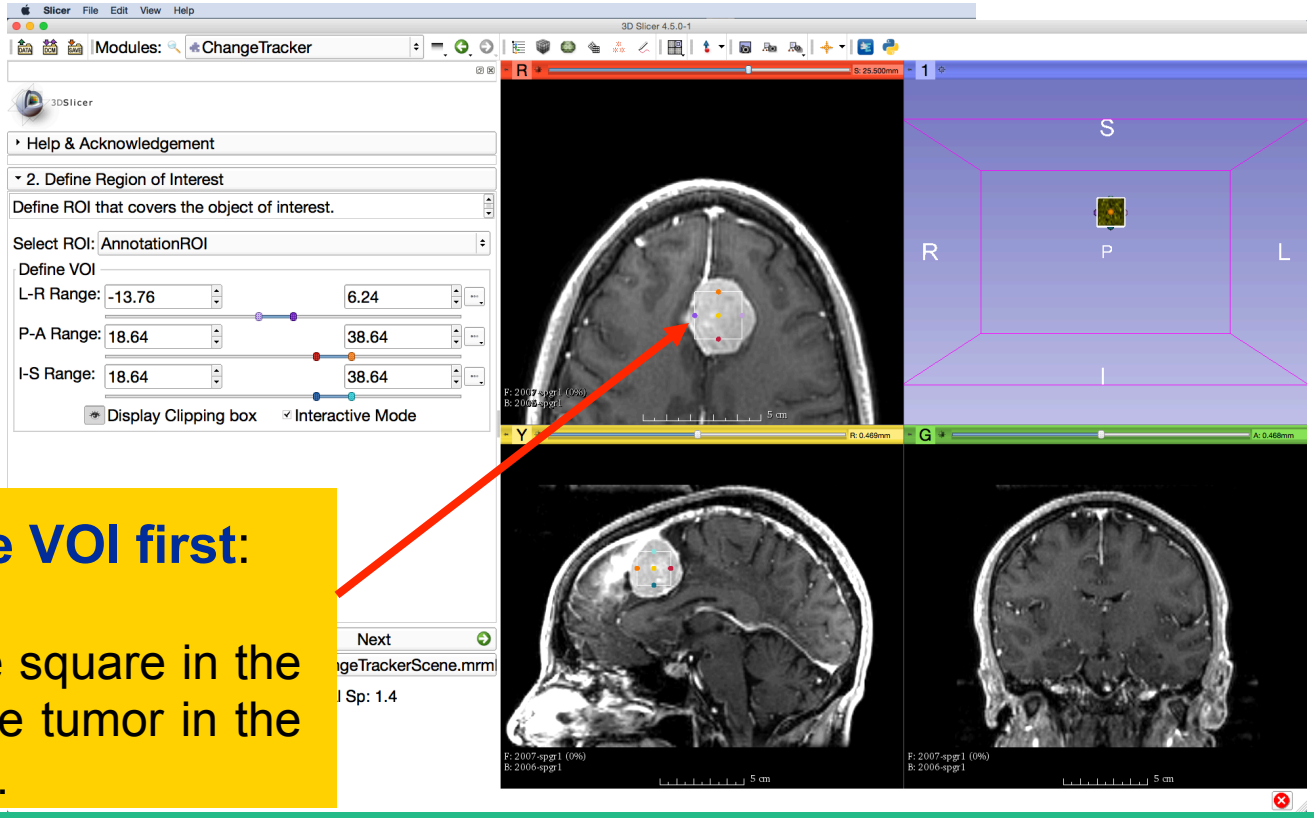
Browse through the Axial, Sagittal and Coronal slice viewers to get a close-up view of the tumor

Zoom in (Right mouse down and push/pull).

Pan (Middle mouse down and move)



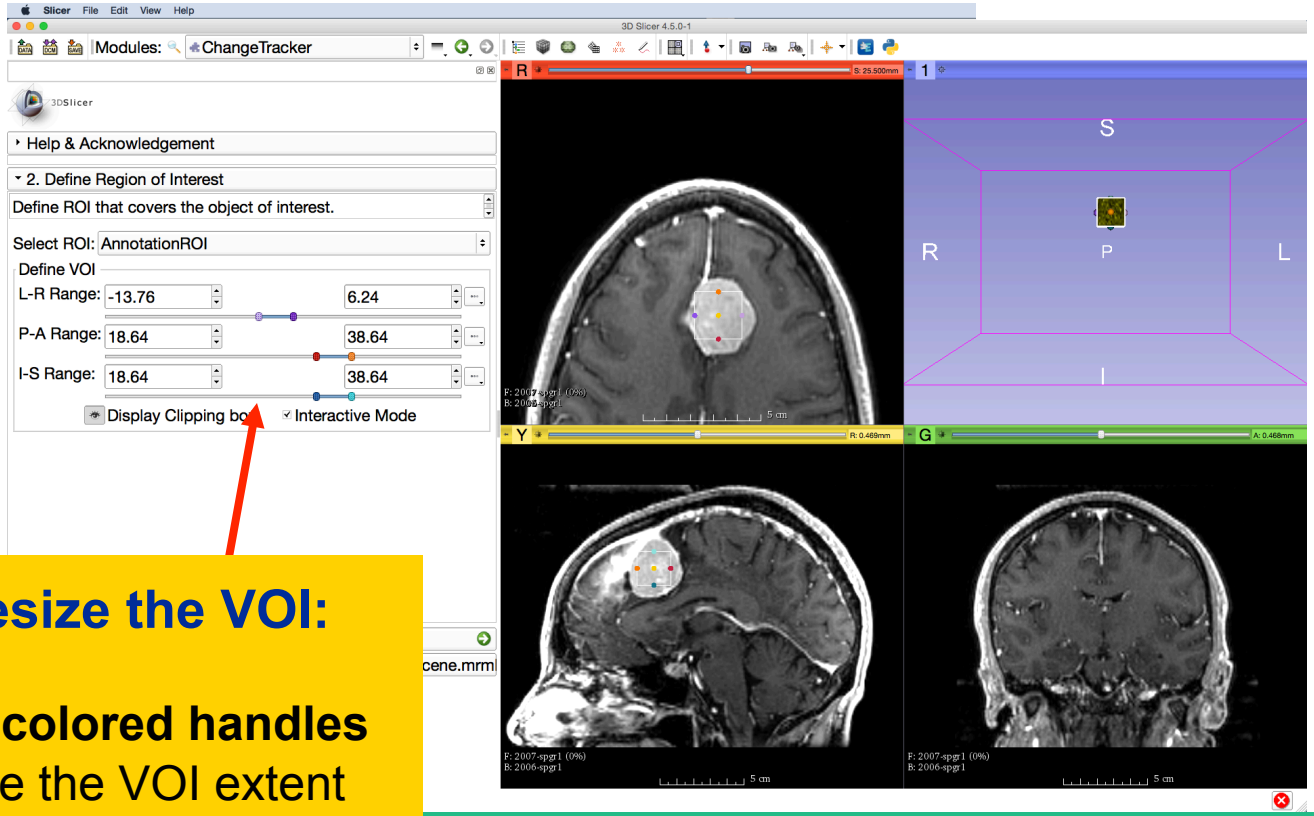
Step2: Define Region of interest



Center the VOI first:

Position the square in the center of the tumor in the slice viewer.

Step2: Define Region of interest

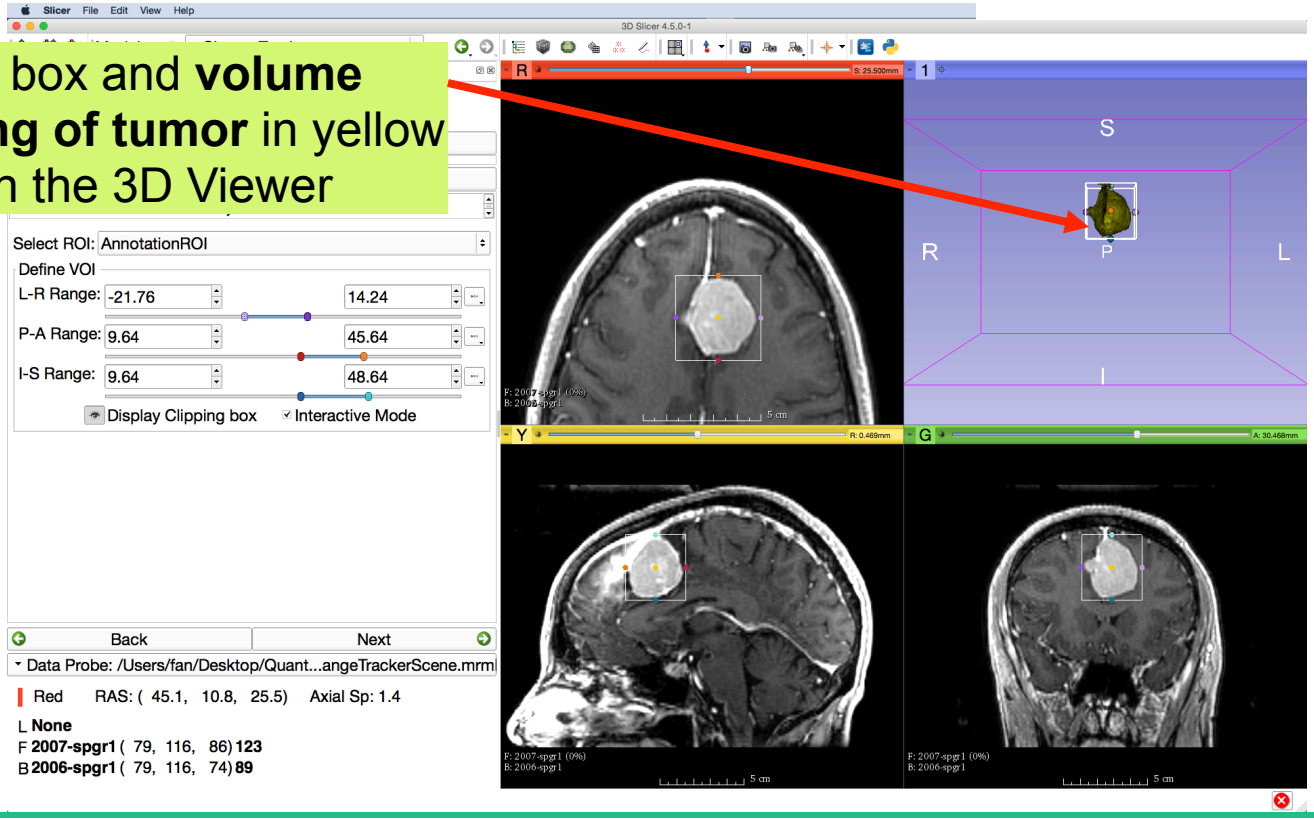


Next, resize the VOI:

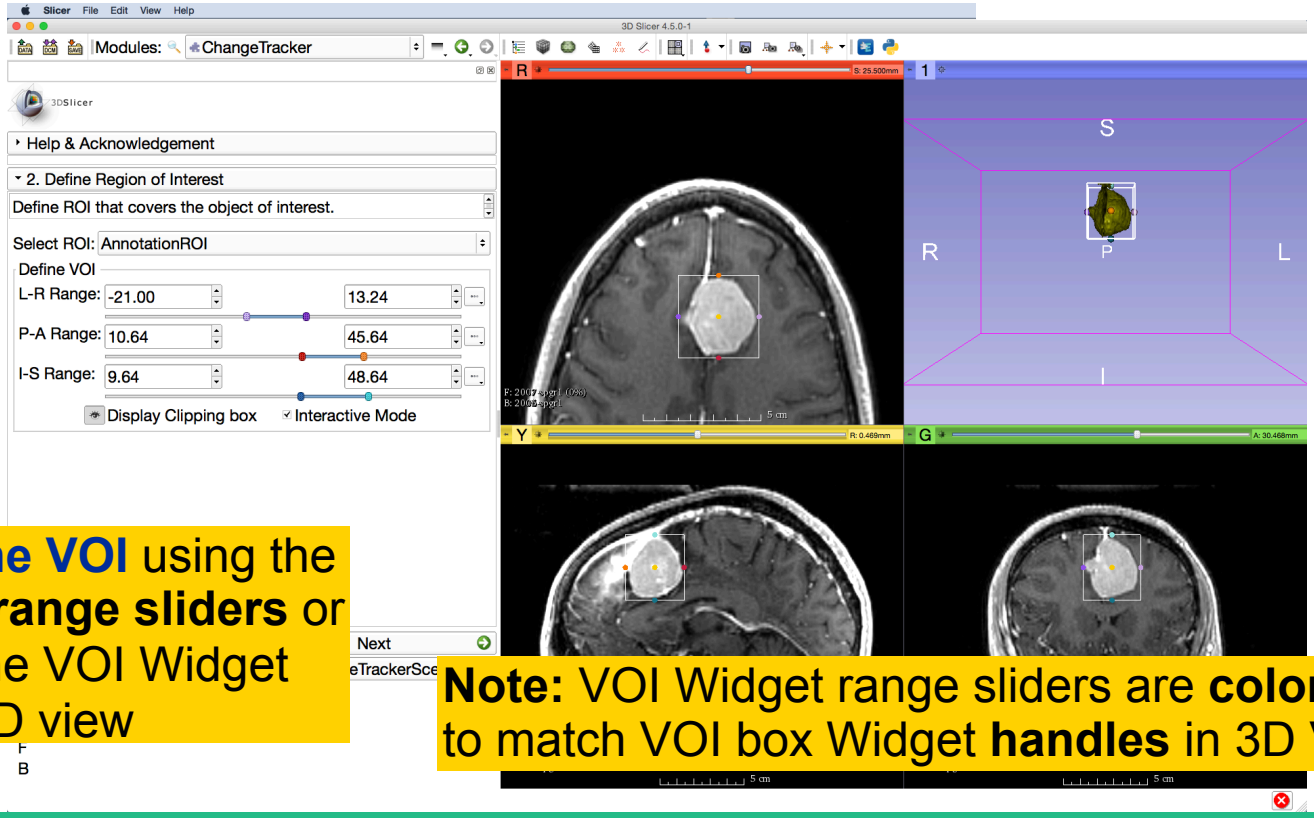
Use the colored handles to change the VOI extent

Step2: Define Region of interest

The VOI box and **volume rendering of tumor** in yellow appear in the 3D Viewer



Step2: Define Region of interest

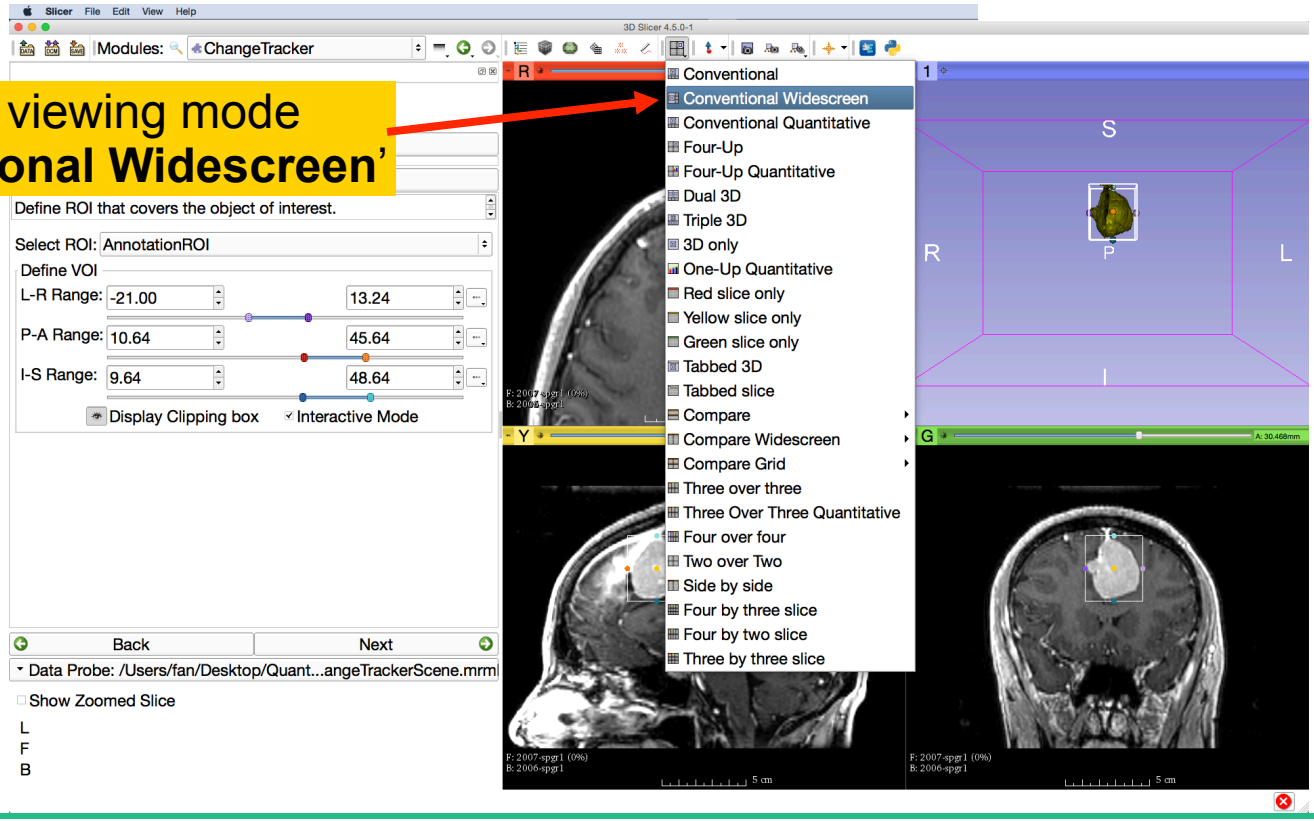


Fine-tune the VOI using the VOI Widget **range sliders** or by moving the VOI Widget handles in 3D view

Note: VOI Widget range sliders are **color-coded** to match VOI box Widget **handles** in 3D Viewer

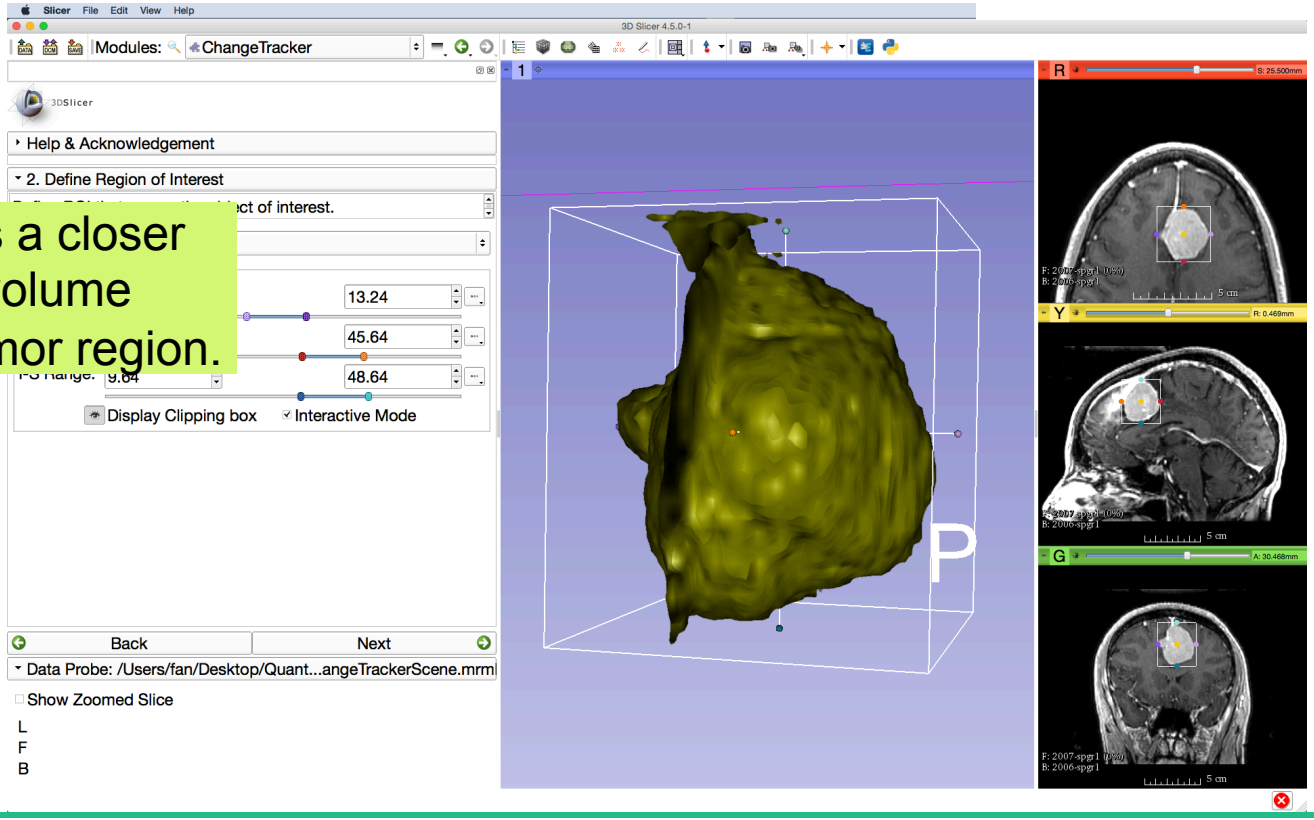
Step2: Define Region of interest

Select the viewing mode
‘**Conventional Widescreen**’

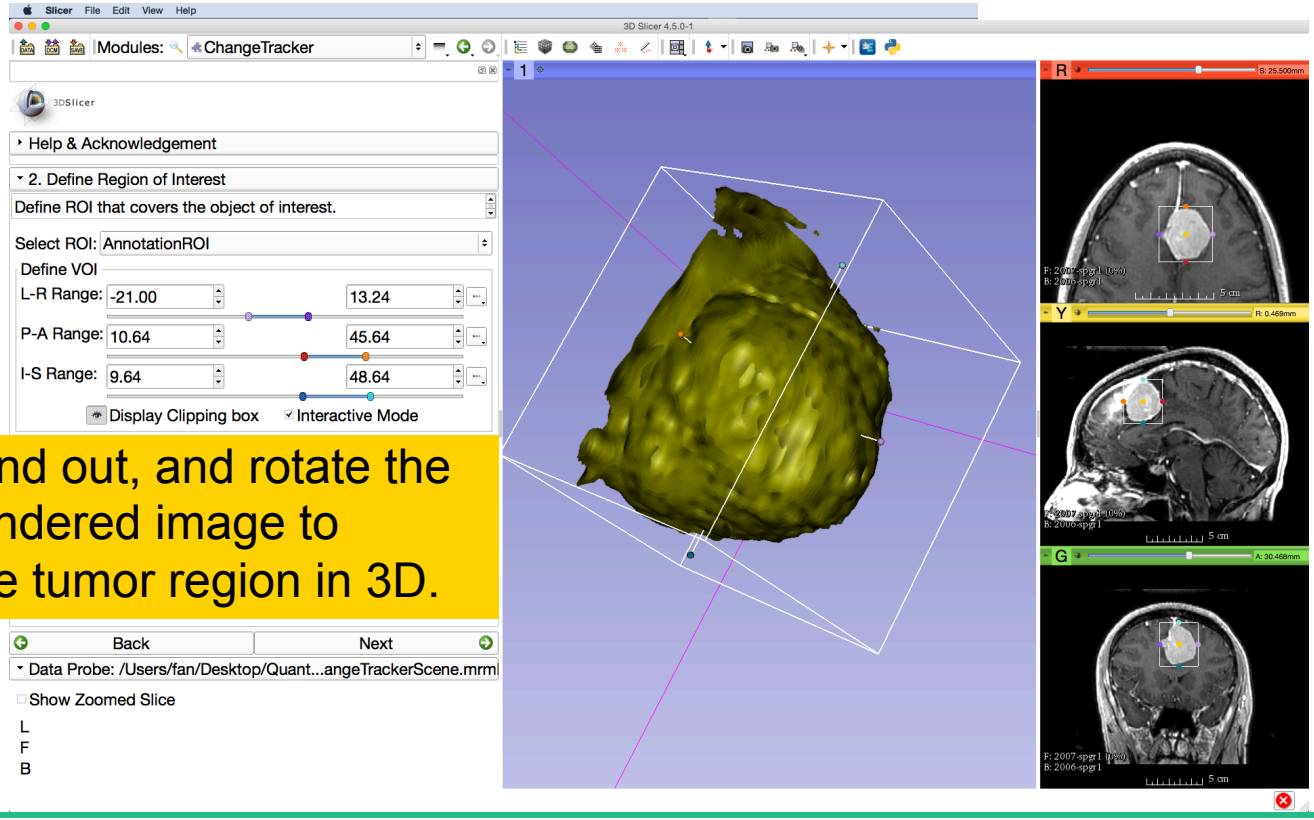


Step2: Define Region of interest

Slicer shows a closer view of the volume rendered tumor region.

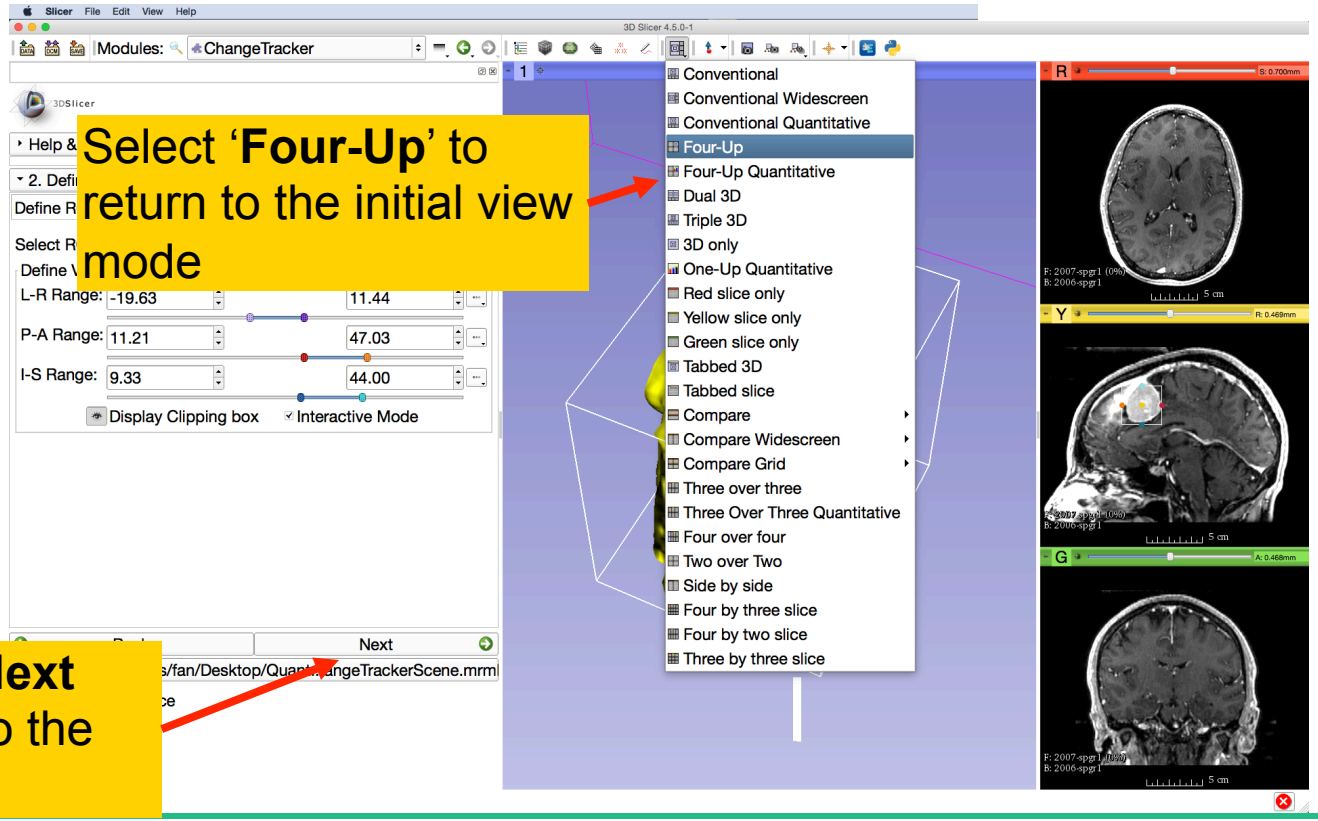


Step2: Define Region of interest

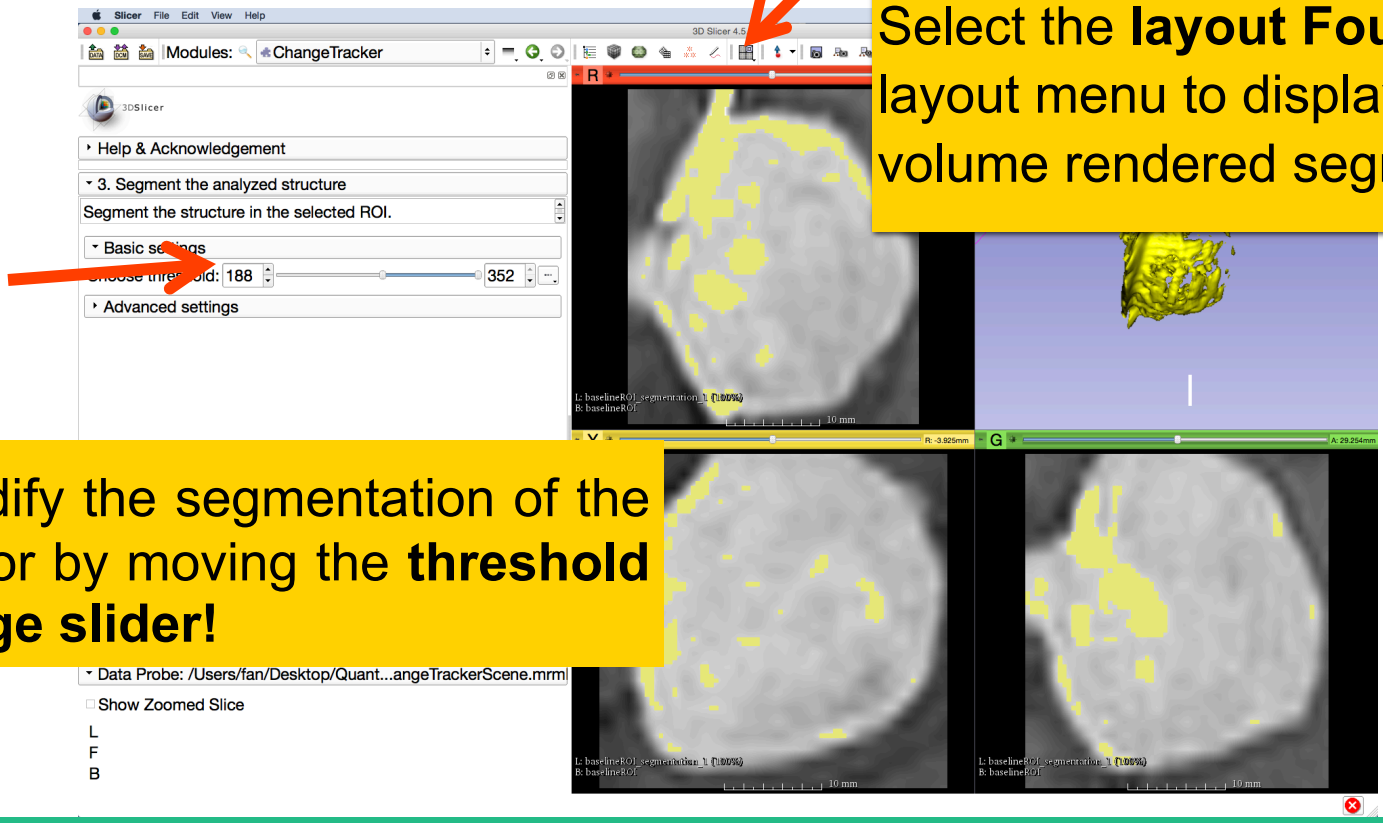


Zoom in and out, and rotate the volume rendered image to explore the tumor region in 3D.

Step2: Define Region of interest



Step3: Segment the tumor

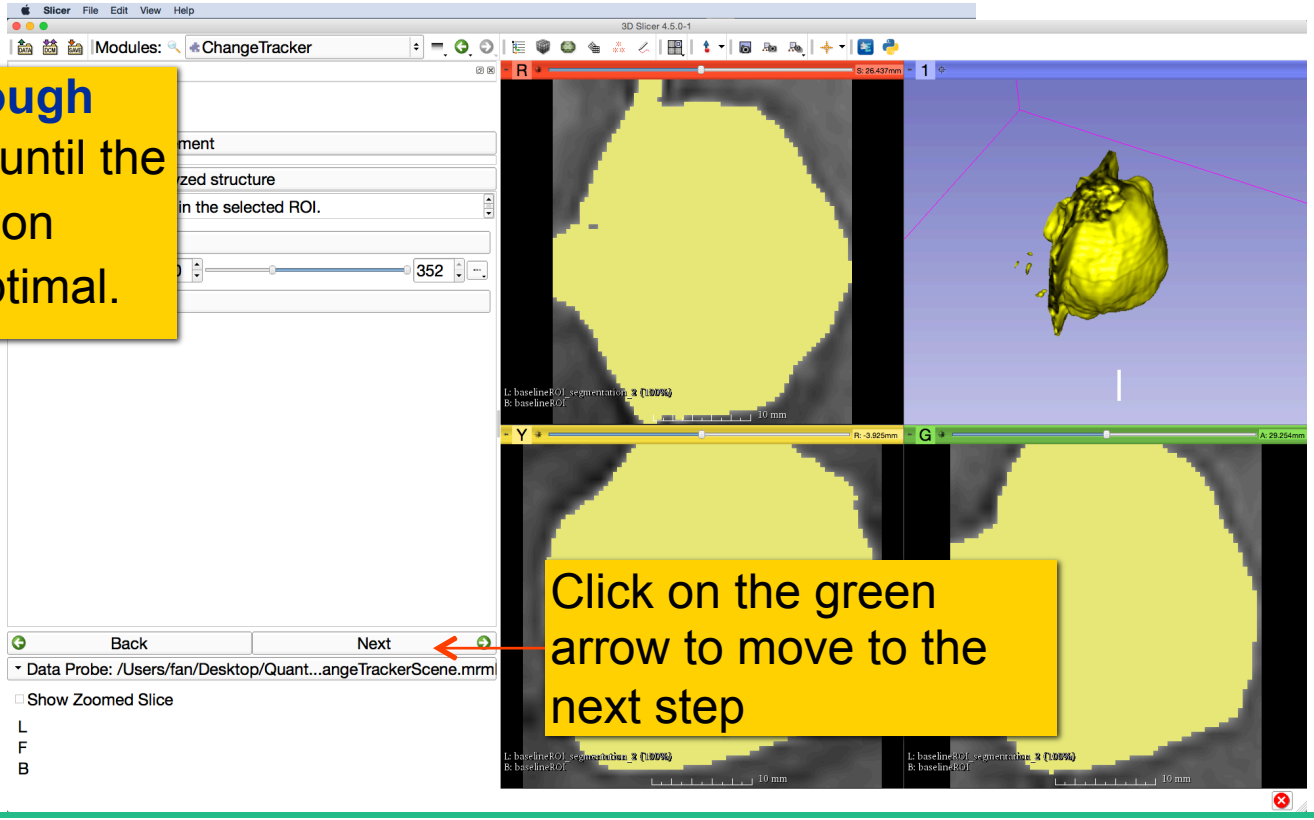


Select the **layout FourUp** in the layout menu to display the volume rendered segmentation

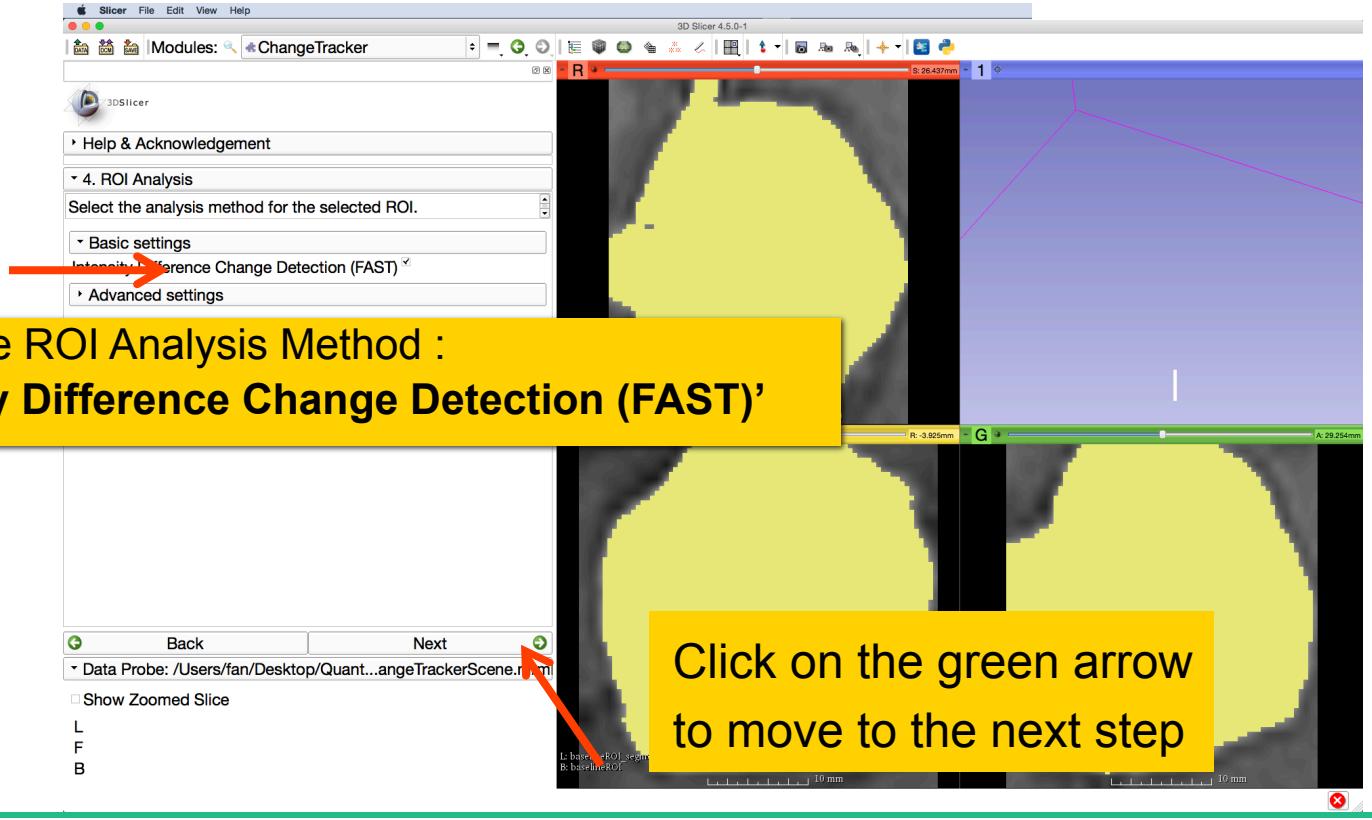
Modify the segmentation of the tumor by moving the **threshold range slider!**

Step3: Segment the tumor

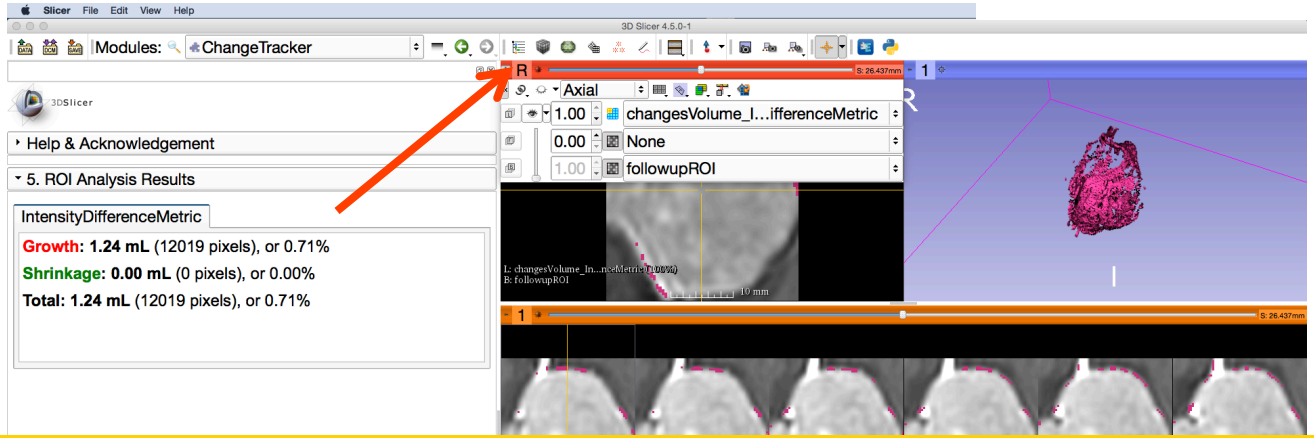
Scroll through the slices until the segmentation appears optimal.



Step4: Select the Analysis Method



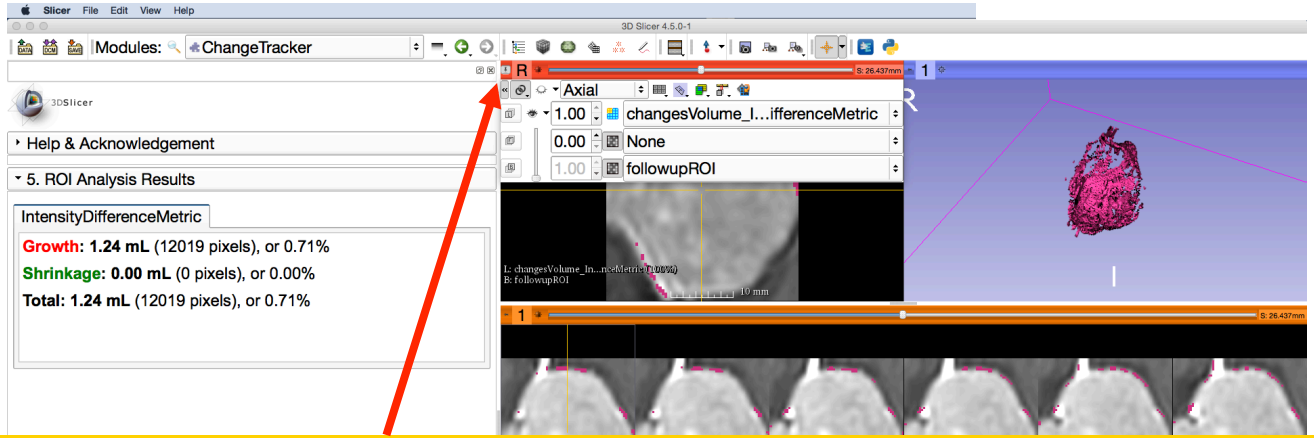
Step4: Select the Analysis Method



Left click on the slice menu to display the volumes that have been generated:

- **followupROI** correspond to the subvolume that has been extracted around the tumor in the 2007-spgr_1 dataset
- **changesVolume_IntensityDifferenceMetric** corresponds to the change between the 2006 and 2007 scans

Step4: Select the Analysis Method



Click on links icon in the Red Slice Viewer menu to link all three viewers.

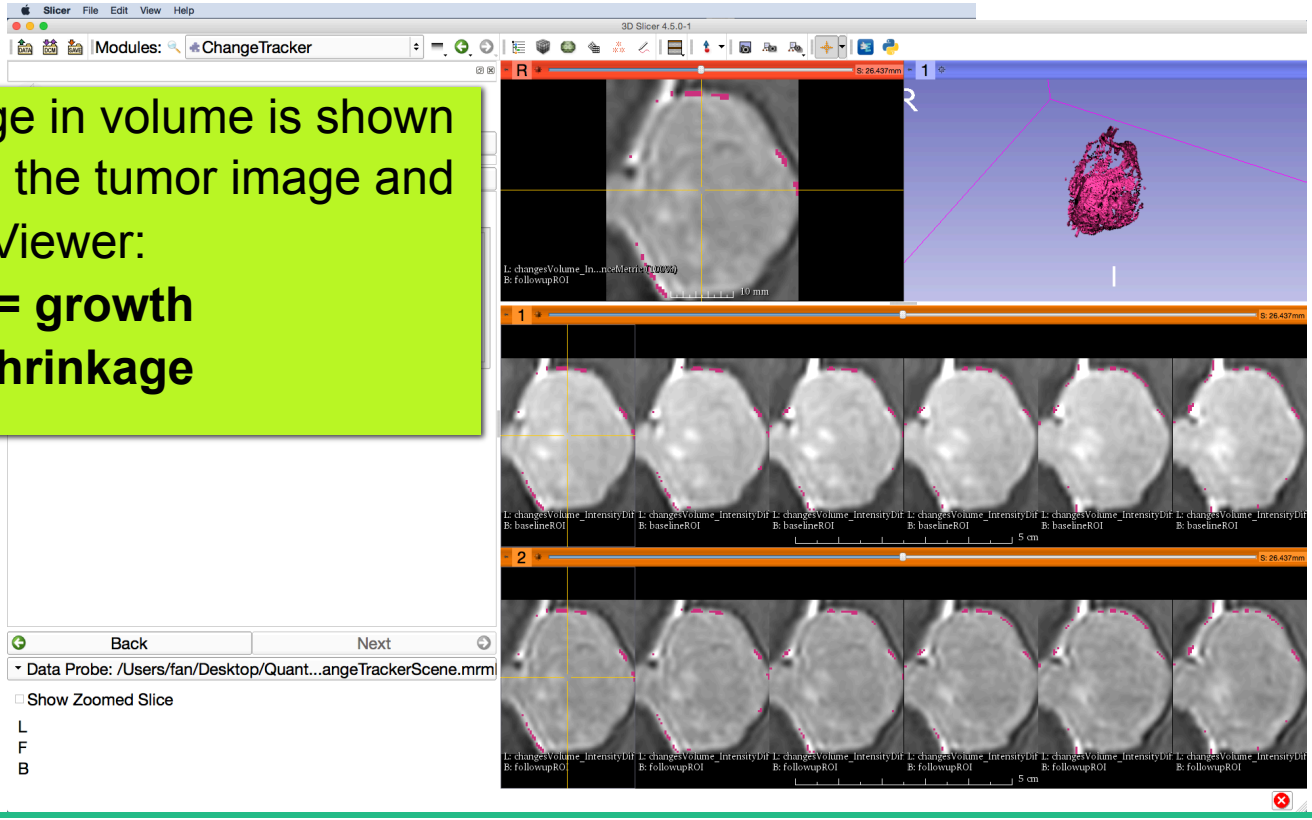
Click on the  icon to adjust the size of the image to the size of the window, and browse through the slices to display the images

Final Step: Change Tracker Results

The change in volume is shown overlaying the tumor image and in the 3D Viewer:

magenta = growth

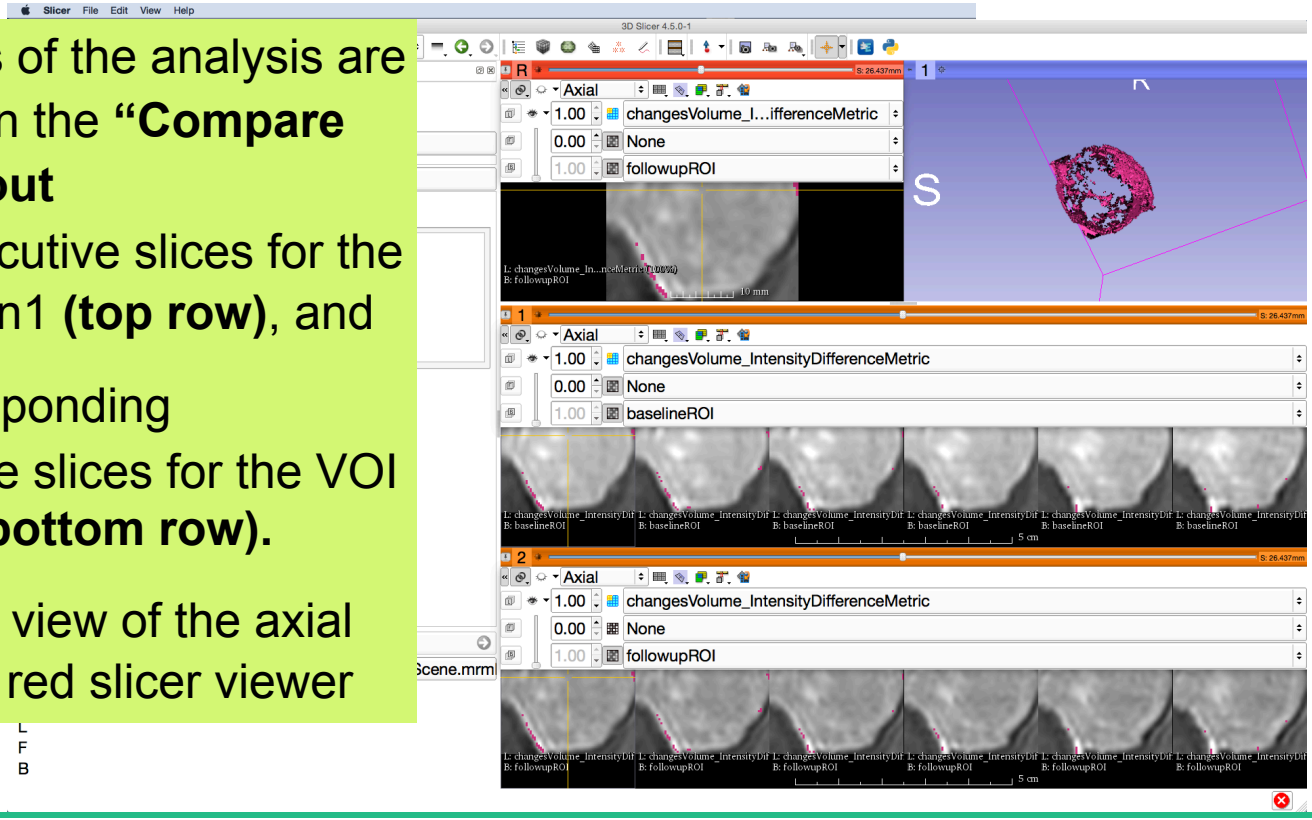
green = shrinkage



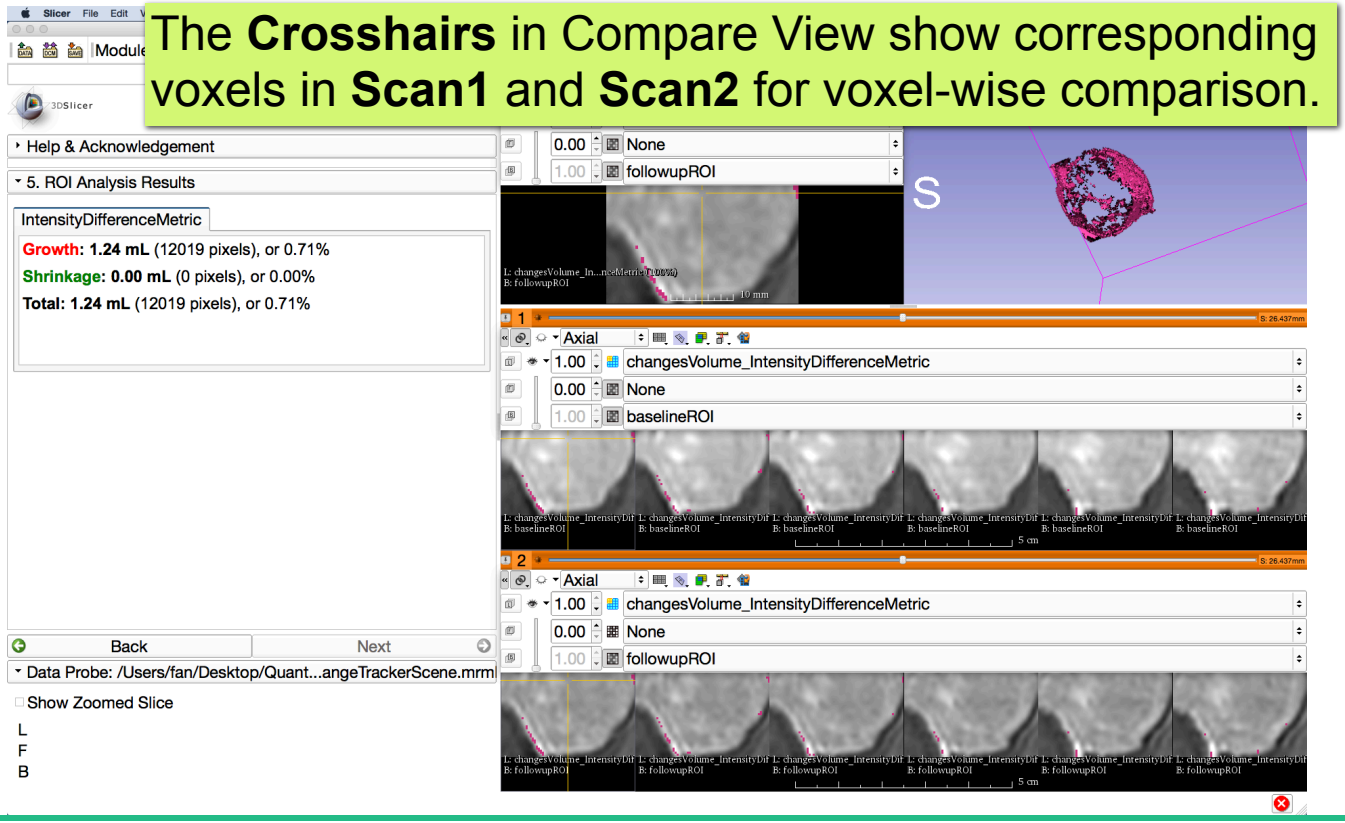
Visualization of the change in pathology

The results of the analysis are displayed in the **“Compare View” layout**

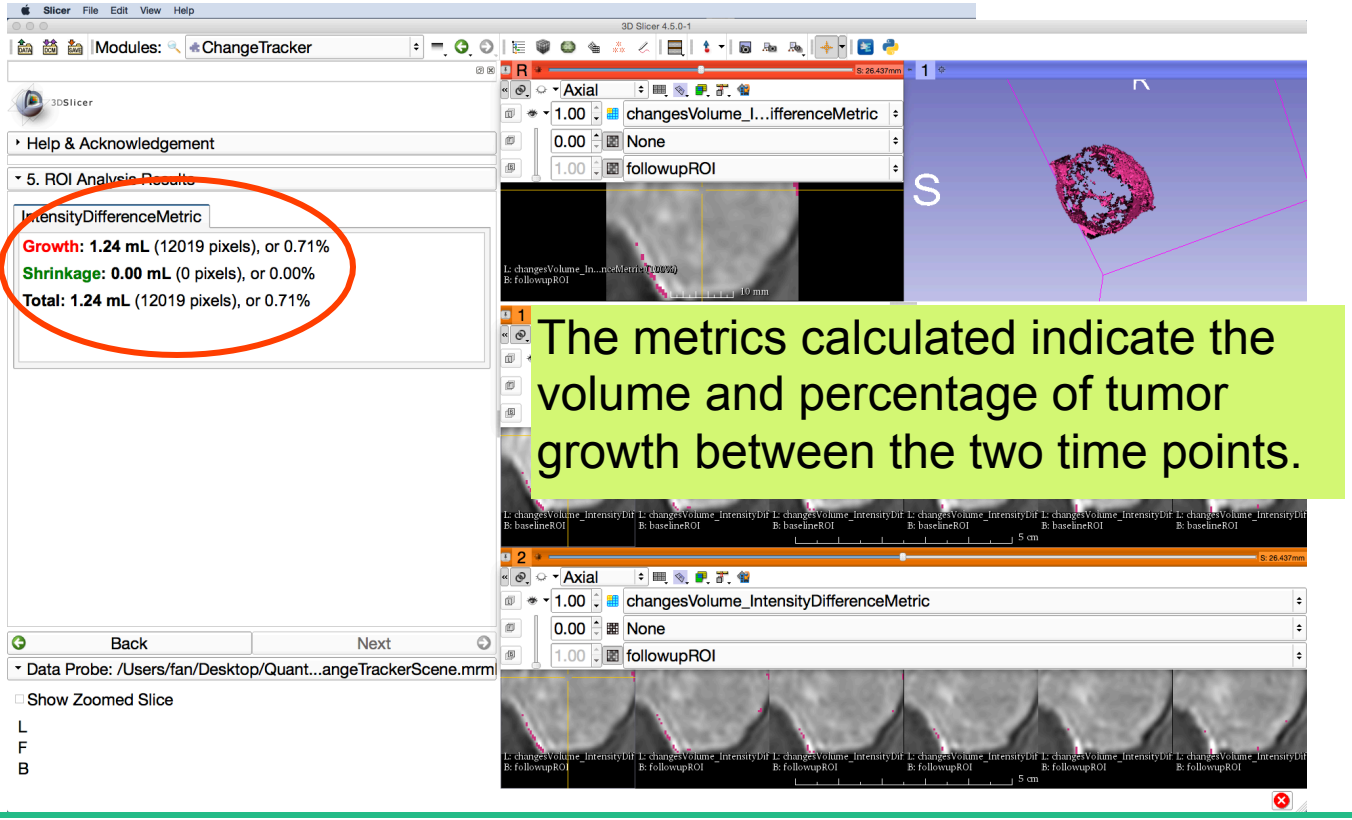
- Six consecutive slices for the VOI in Scan1 **(top row)**, and
- Six corresponding consecutive slices for the VOI in Scan2 **(bottom row).**
- A zoomed view of the axial slice in the red slicer viewer



Visualization of the change in pathology



Change Tracker Results



The metrics calculated indicate the volume and percentage of tumor growth between the two time points.

Change Tracker module

- This tutorial demonstrated the use of the change tracker module in Slicer on axial 3D SPGR T1 post Gadolinium scans

  ➢➢ **Tumor boundary should be clear**
  ➢➢ **Only for contrast enhanced images**
  ➢➢ **Need homogenous enhancement across timepoints.**

- The Change Tracker module has not been tested for tumors with changing necrosis.

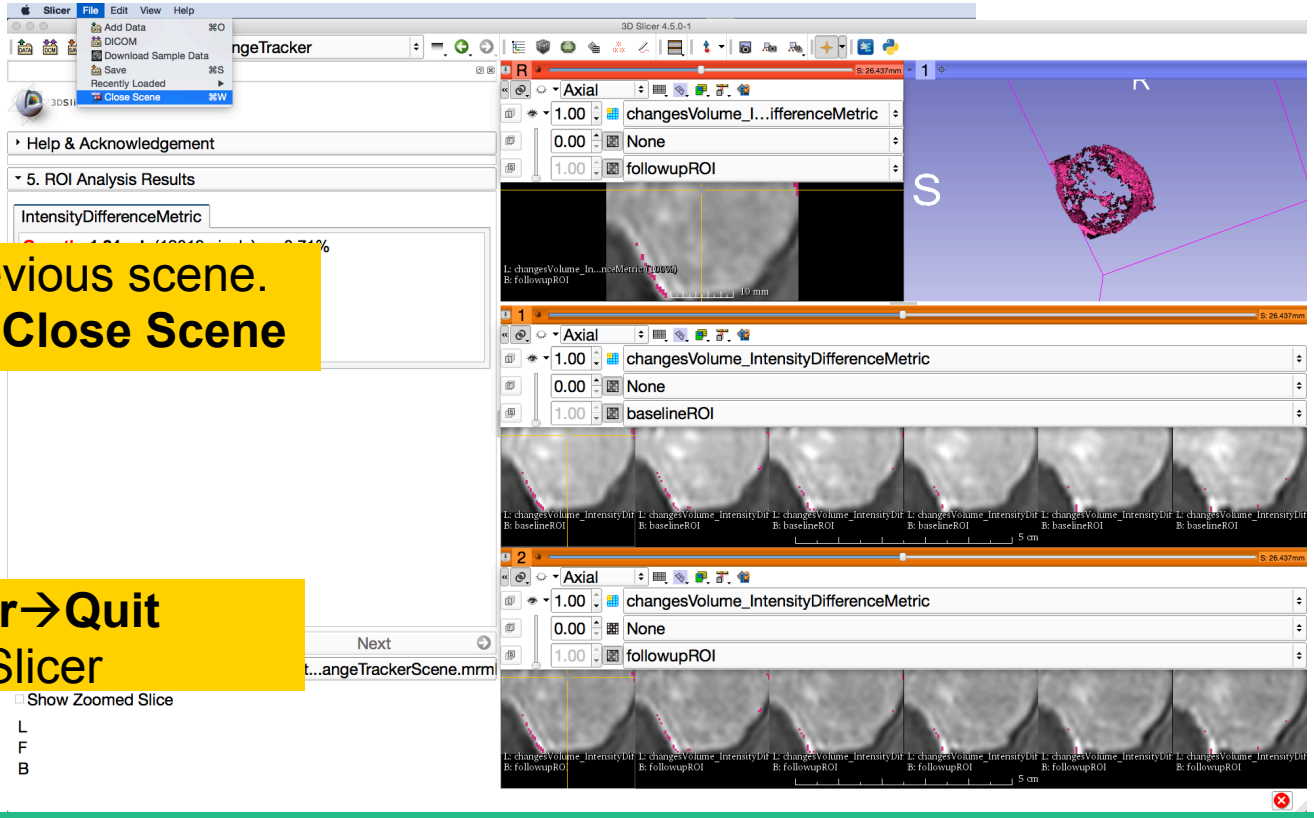
ChangeTracker: Exploring small volumetric changes

This tutorial demonstrated:

- a method to quantify small volumetric changes in pathology.
- visualization of these changes in the anatomical context
- use of Slicer's "**Compare Viewer**" to simultaneously explore
- baseline and followup studies.

Next, we will demonstrate combined visualization of PET/CT studies and SUV computation.

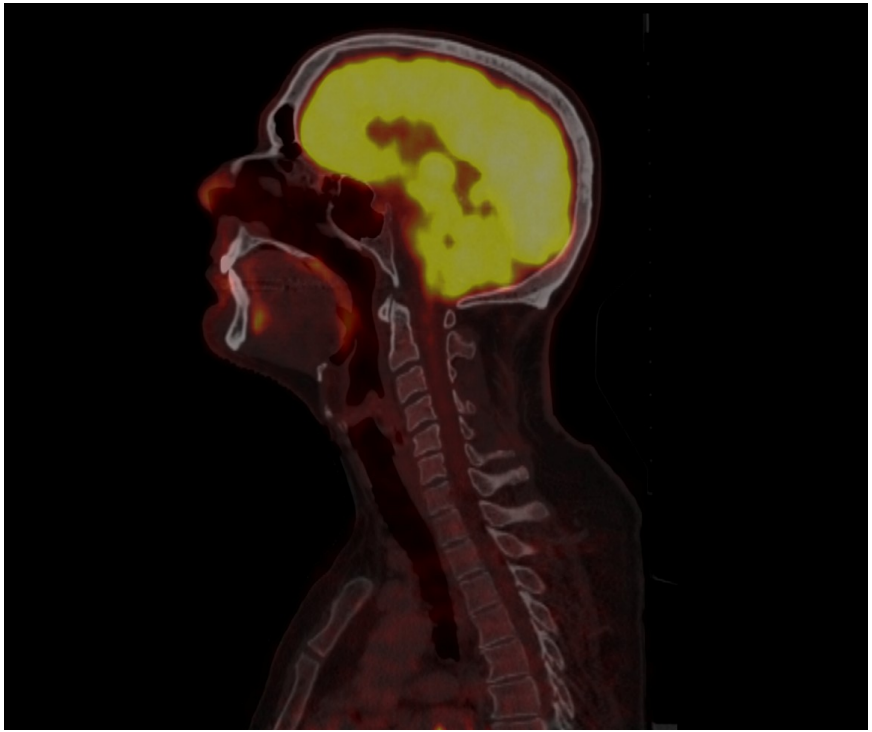
Clear the scene and its data



Clear the previous scene.
Select **File→Close Scene**

Select **Slicer→Quit**
and restart Slicer

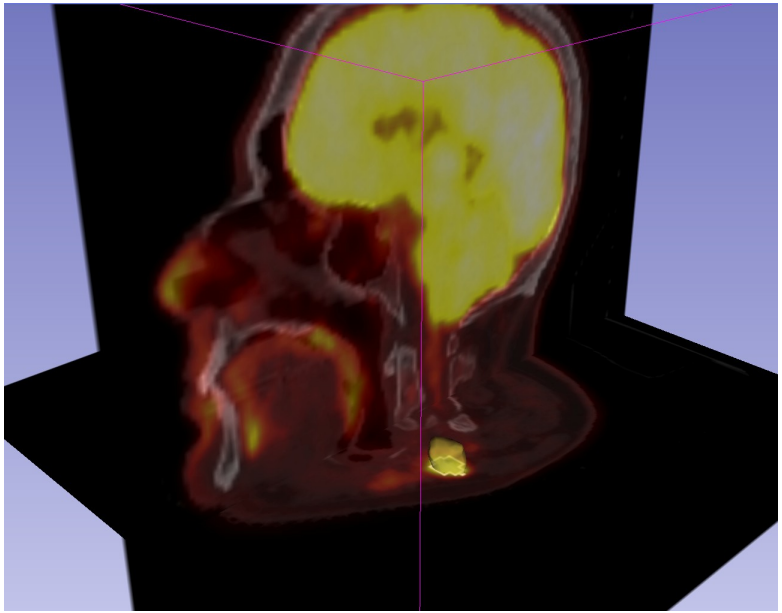
PET/CT Visualization and Analysis



Part II: PET/CT Analysis

Sonia Pujol, PhD
Kitt Shaffer, MD, PhD
Hatsuho Mamata, MD, PhD
Ron Kikinis, MD

Goal of the tutorial



The goal of this tutorial is to guide you step-by-step through the SUV computation of PETCT data of a squamous cell carcinoma case pre- and post-treatment

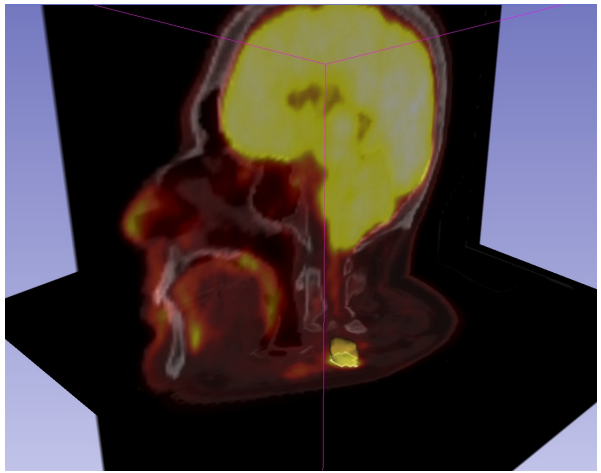
FDG-PET SUV

- Standardized Uptake Value (SUV) is a semi-quantitative measure derived from the determination of tissue activity obtained from a clinical PET study

SUV = Tissue Concentration of Radioactive Tracer x
Patient Weight / Injected Dose

- Under certain circumstances, 18-F Fluorodeoxyglucose (FDG) SUV correlates with metabolic rate of glucose and/or the number of viable tumor cells

Tutorial Case



- Pathology: poorly differentiated squamous cell carcinoma
- Treatment: radiotherapy and chemotherapy (weekly cis-platin)
- Two 18F-FDG PET and CT scans acquired within a 5-month interval.

PETCT tutorial: Clinical Case and Data

The datasets are located in

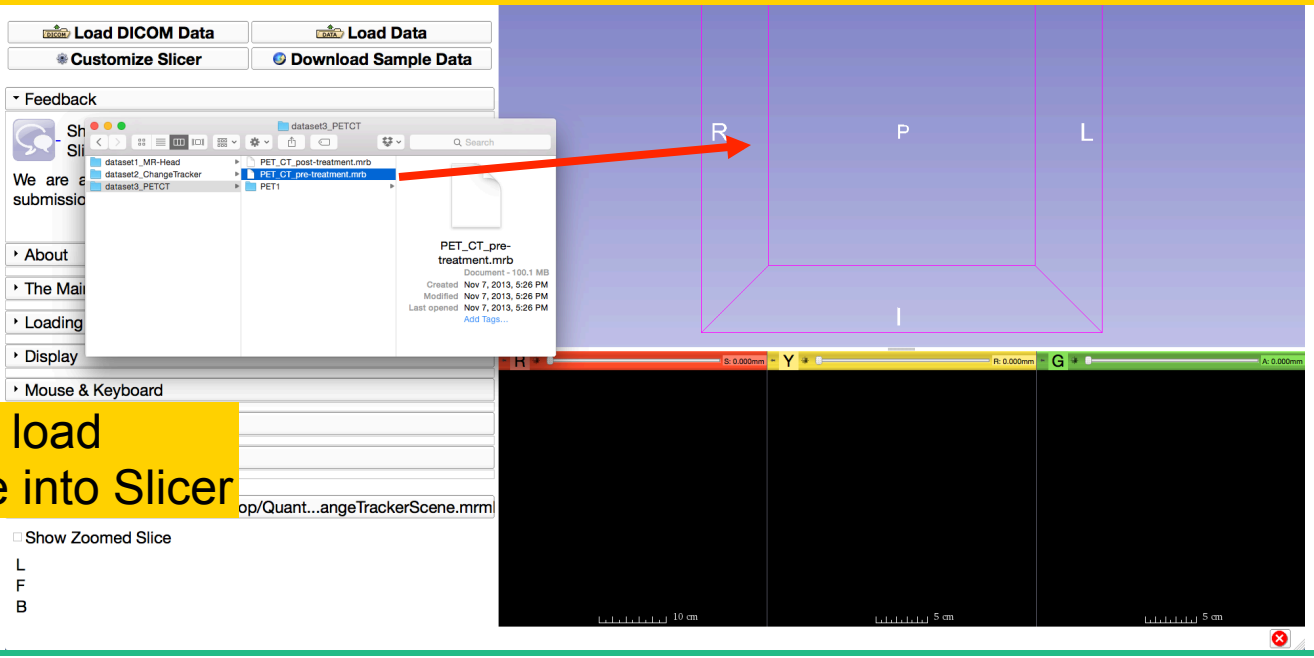
QuantitativeImaging/dataset3_PETCT

- **PETCT1 dataset** is located in the **pre-treatment directory** corresponds to the baseline
- **PETCT2 dataset** is located in the **post-treatment directory** corresponds to the follow-up scan.

Loading the PETCT scene

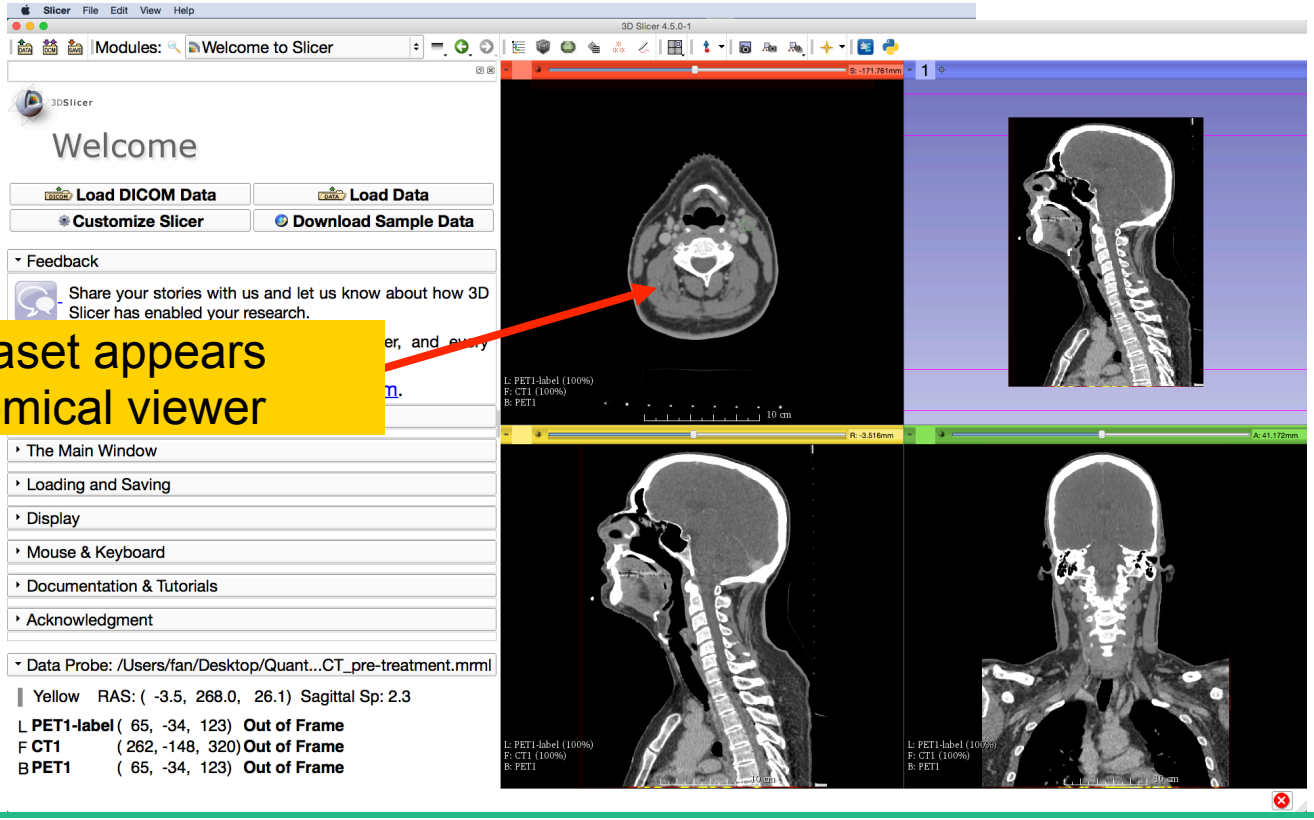
Drag and drop the file **PETCT_pre-treatment.mrb** located in

/Users/Desktop/QuantitativeImaging\dataset3_PETCT



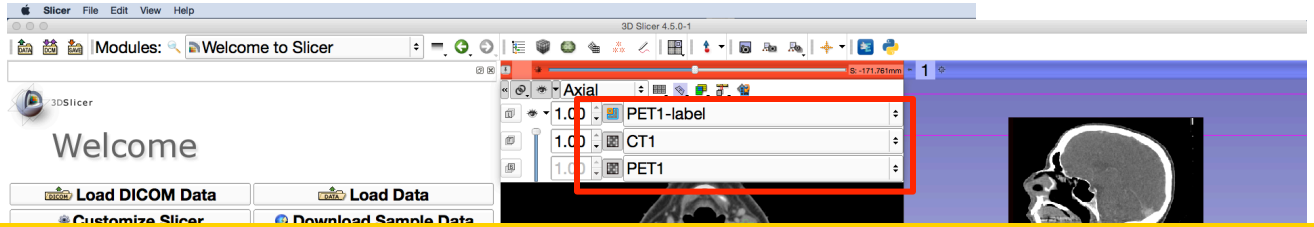
Click OK to load the .mrb file into Slicer

Loading the PETCT scene



The CT dataset appears in the anatomical viewer

Loading a PETCT dataset



Left click on the pin icon in the top left corner to display the red slice viewer menu.

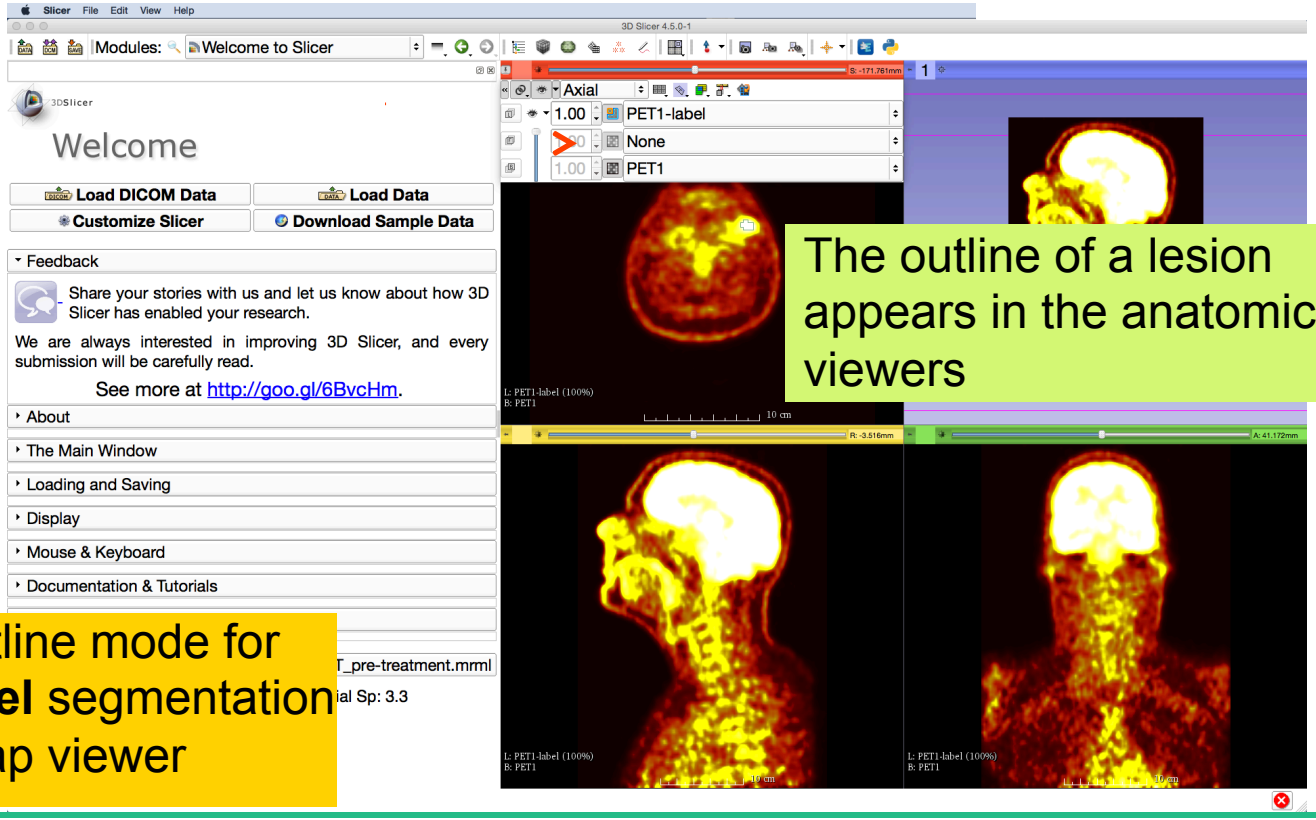
The **CT1** volume is displayed in the Foreground viewer

The **PET1** volume is displayed in the Background viewer

The **PET1-Label** is displayed in the Labelmap viewer

Use the slider to fade between the Bg viewer and the Fg viewer to display the PET volume overlaid on the CT volume

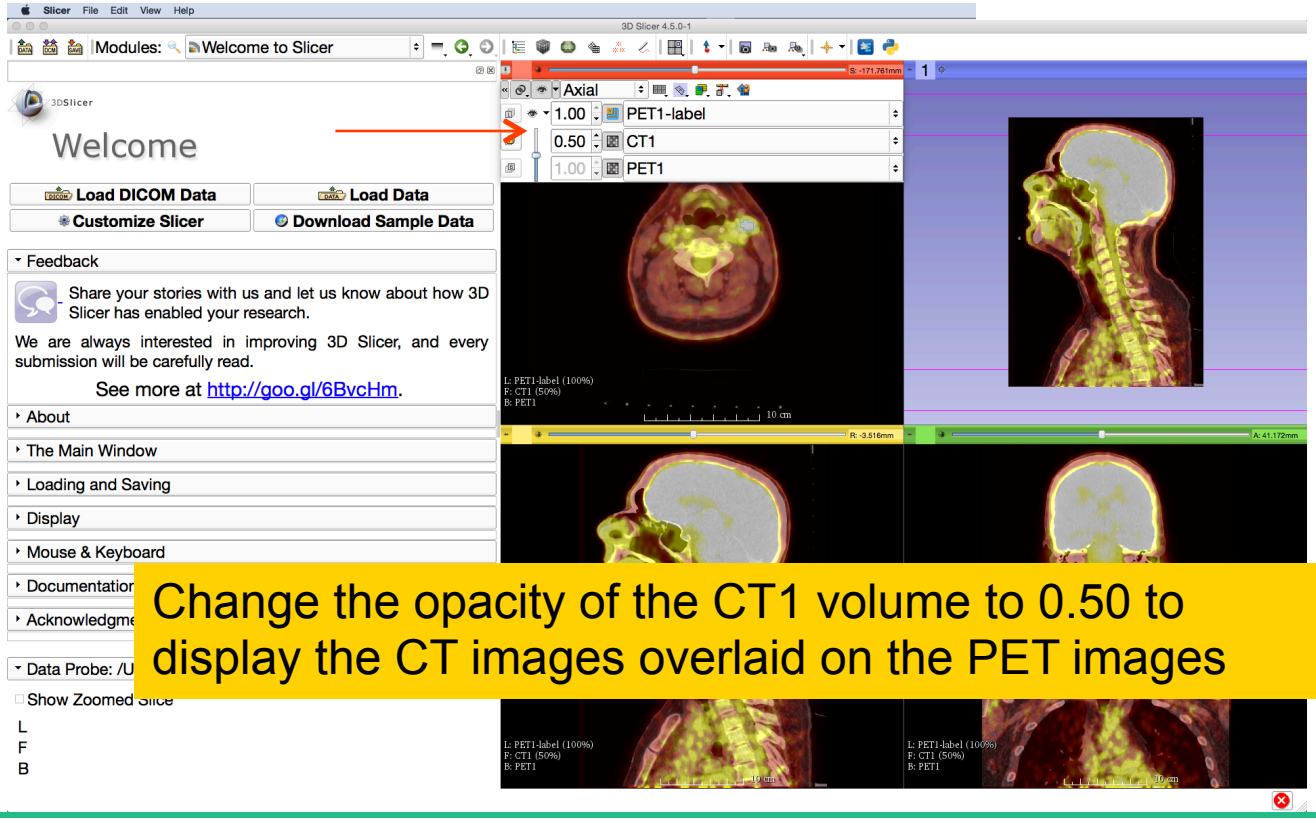
Visualization of PETCT data



The outline of a lesion appears in the anatomical viewers

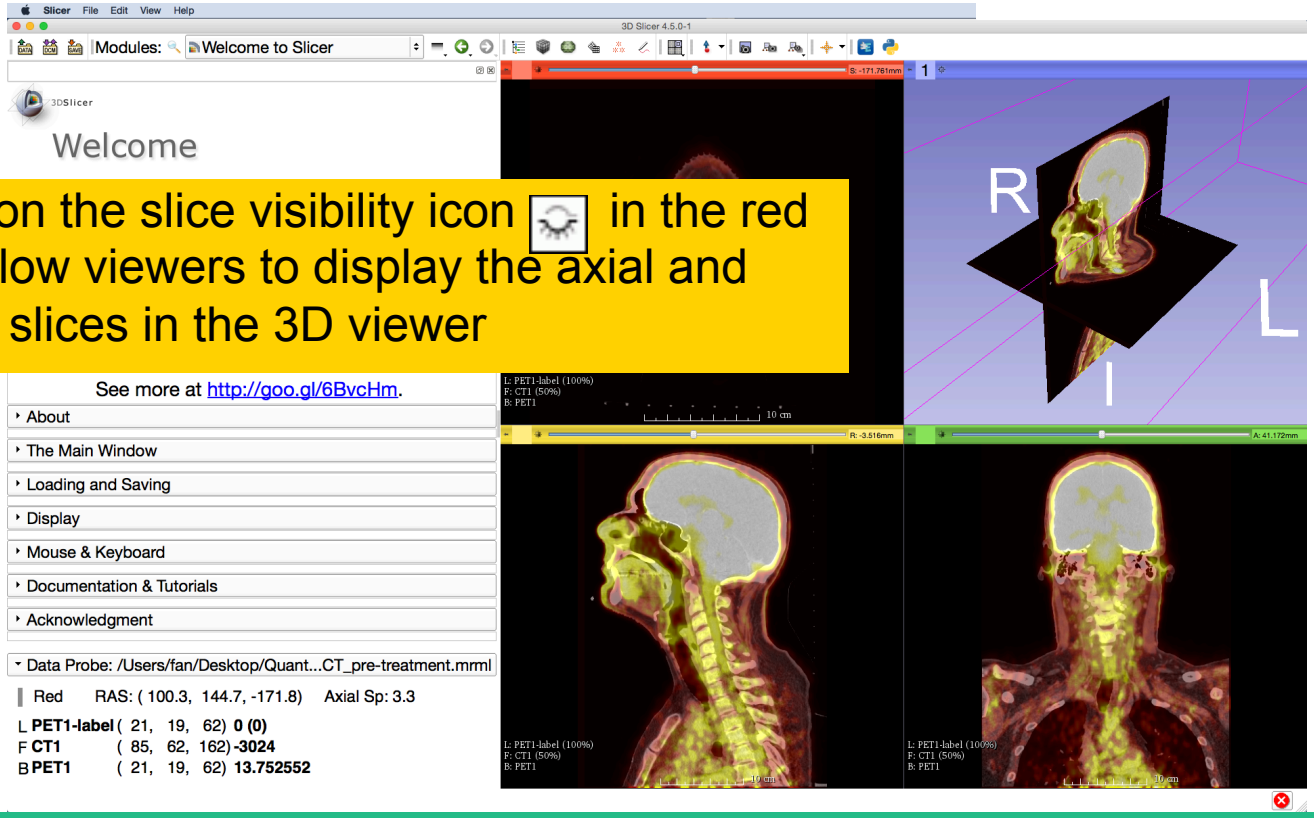
Select the outline mode for the **PET1-label** segmentation in the labelmap viewer

Visualization of PETCT data



Change the opacity of the CT1 volume to 0.50 to display the CT images overlaid on the PET images

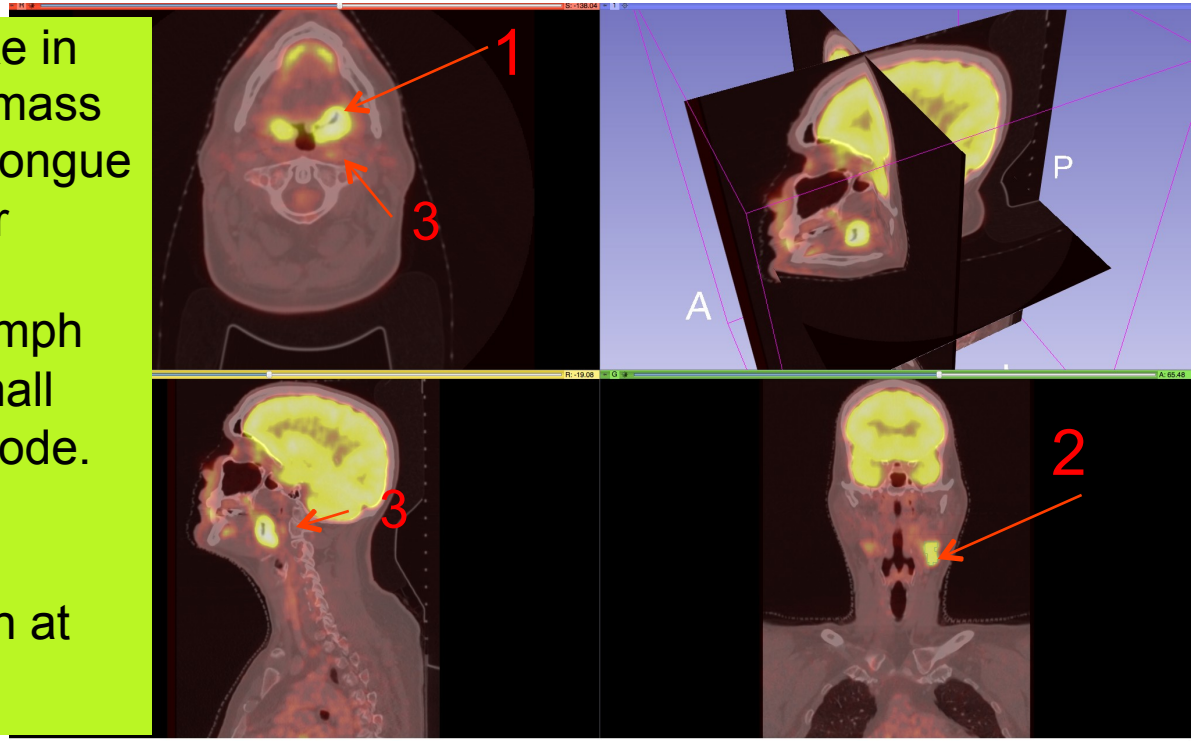
Visualization of PETCT data



Check on the slice visibility icon in the red and yellow viewers to display the axial and sagittal slices in the 3D viewer

PET uptake findings

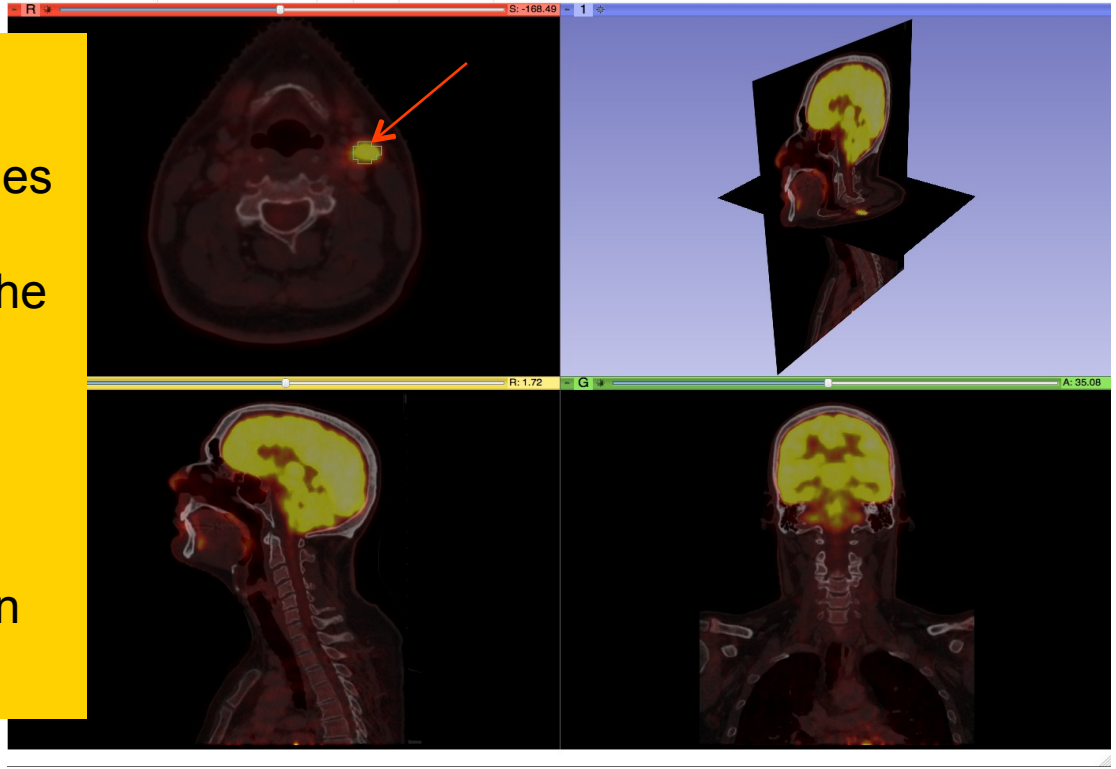
Note an intense uptake in
1) left oropharyngeal mass involving the base of tongue and left glossotonsillar fossa and,
2) in left level IIA/III lymph nodes as well as a small adjacent left level III node.
3) a possible small metastasis in the left retropharyngeal region at level of C1



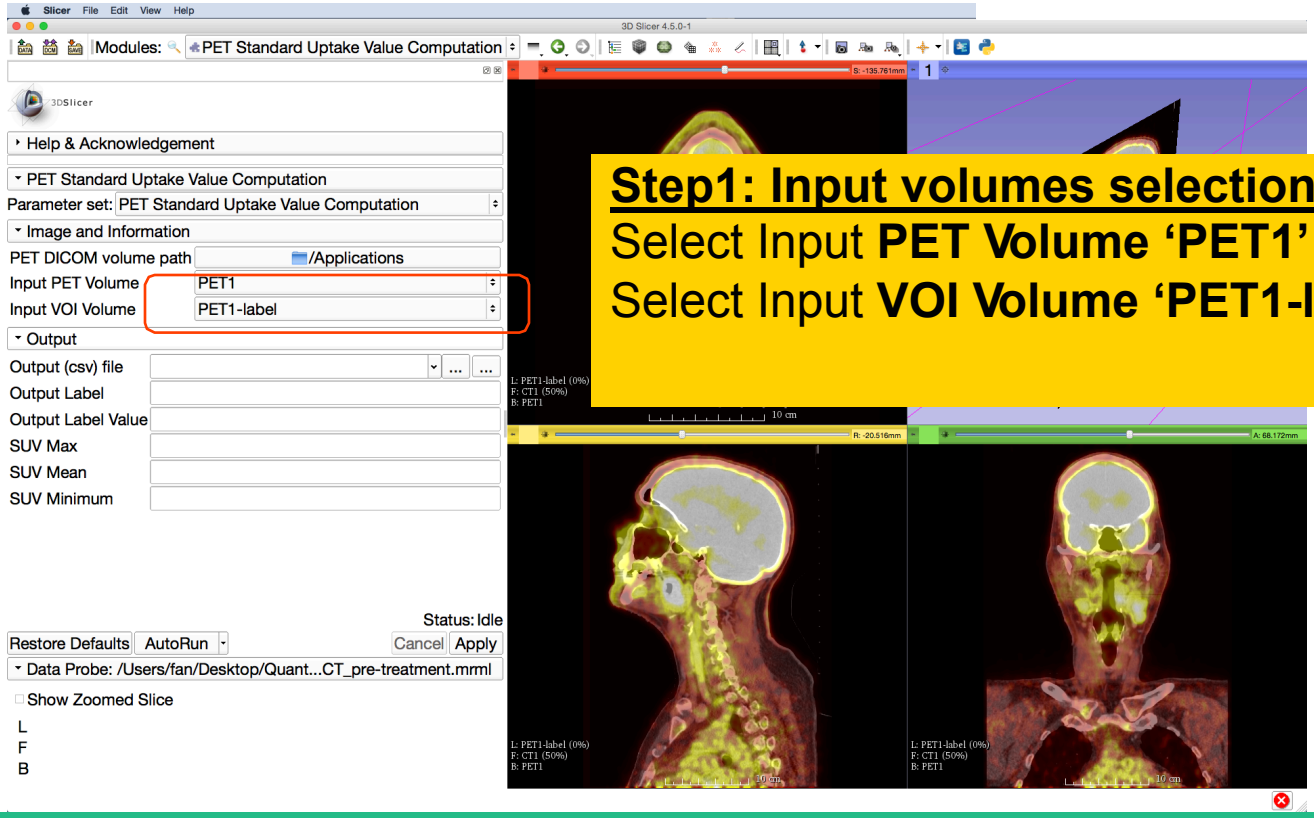
PET SUV Computation

For the purpose of this tutorial, we have pre-segmented the lymph nodes uptake region. In the next section, we will compute the SUV for this area.

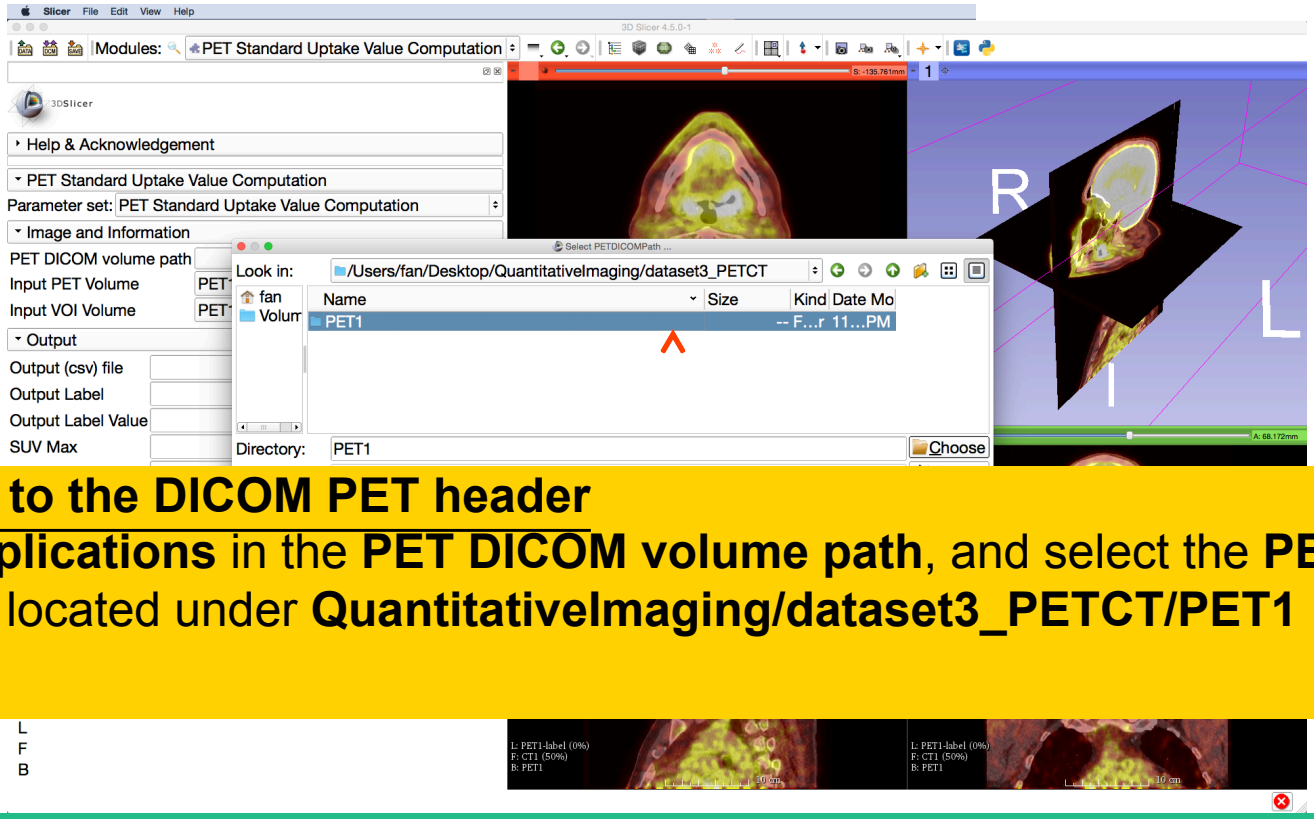
Select the module **PET Standard Uptake Value Computation** in the category **Quantification** in the modules' menu



PET SUV Computation



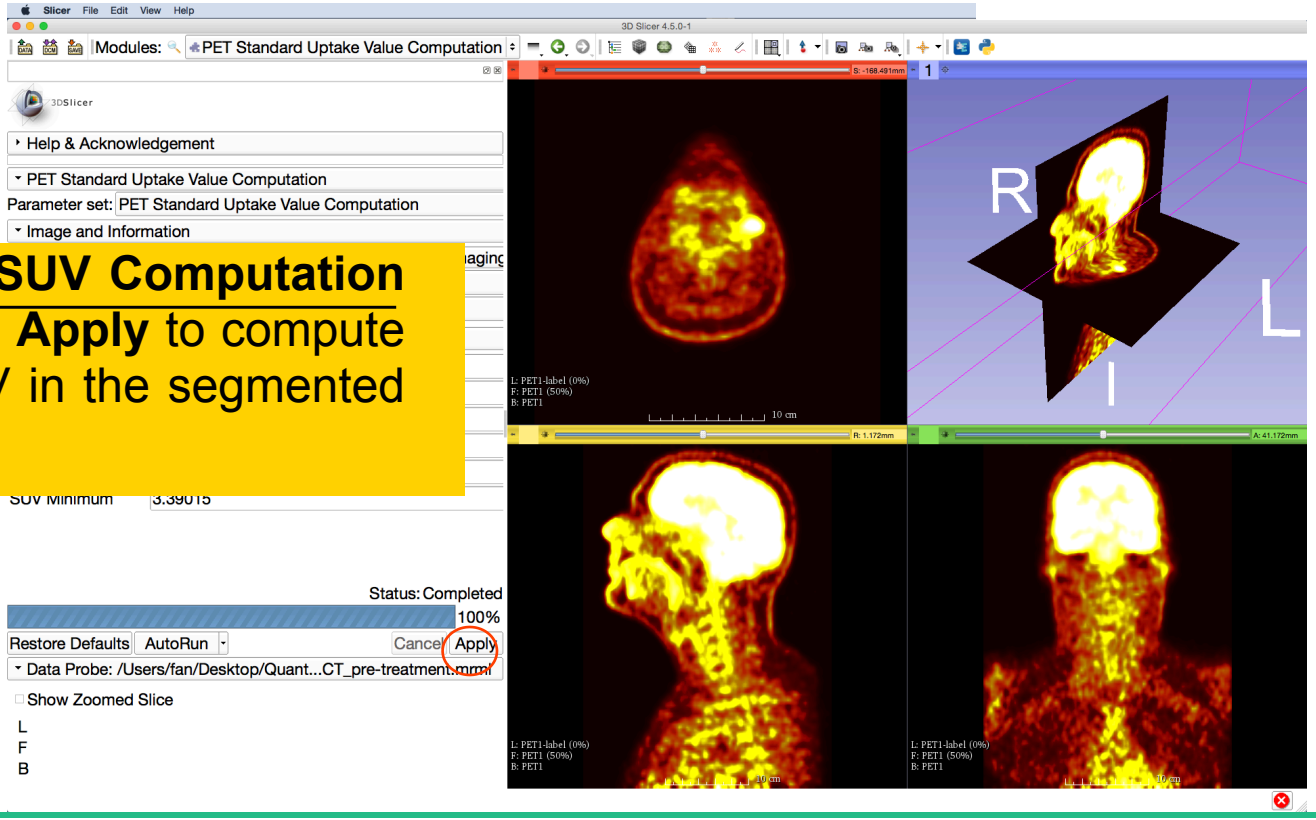
PET SUV Computation



Step2: Path to the DICOM PET header

Click on **/Applications** in the **PET DICOM volume path**, and select the **PET1** subdirectory located under **QuantitativeImaging/dataset3_PETCT/PET1**

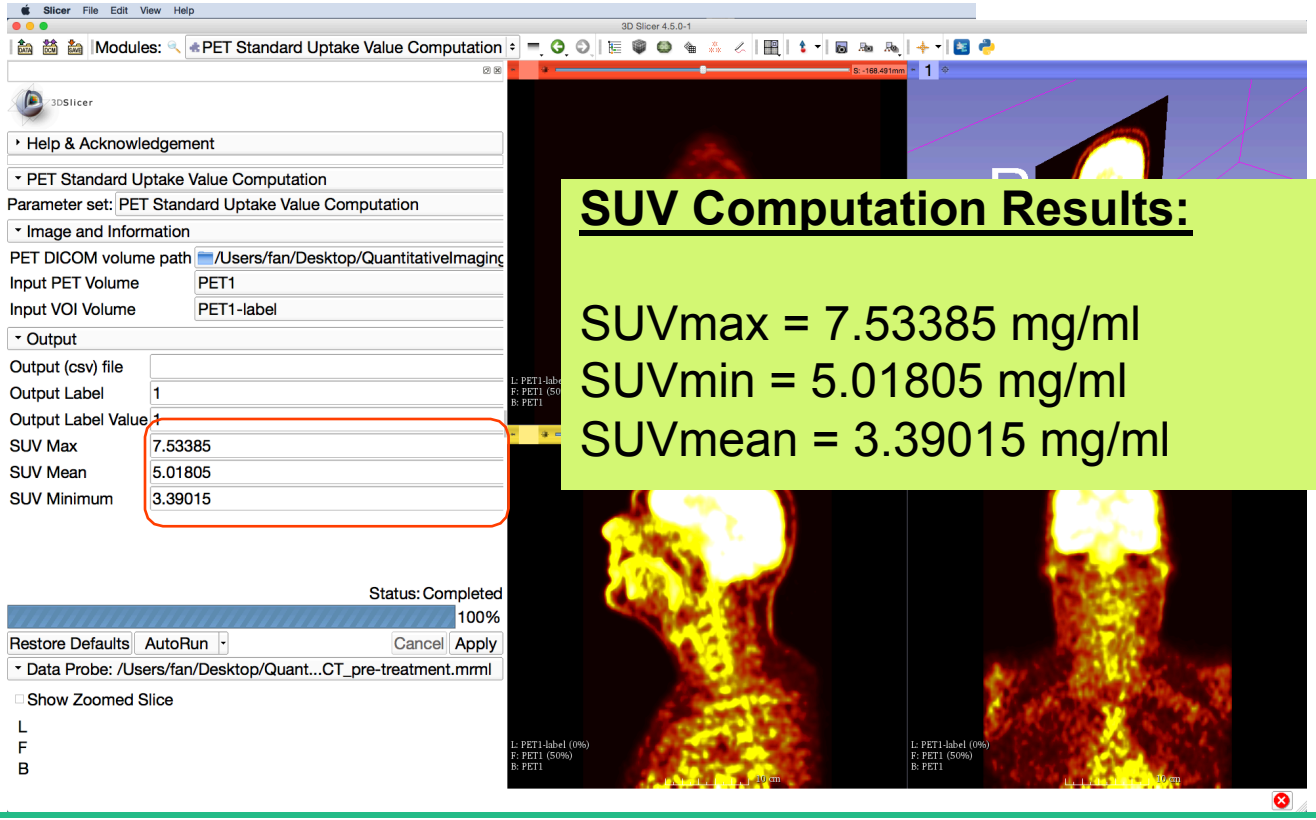
PET SUV Computation



Step3: SUV Computation

Click on **Apply** to compute the SUV in the segmented region

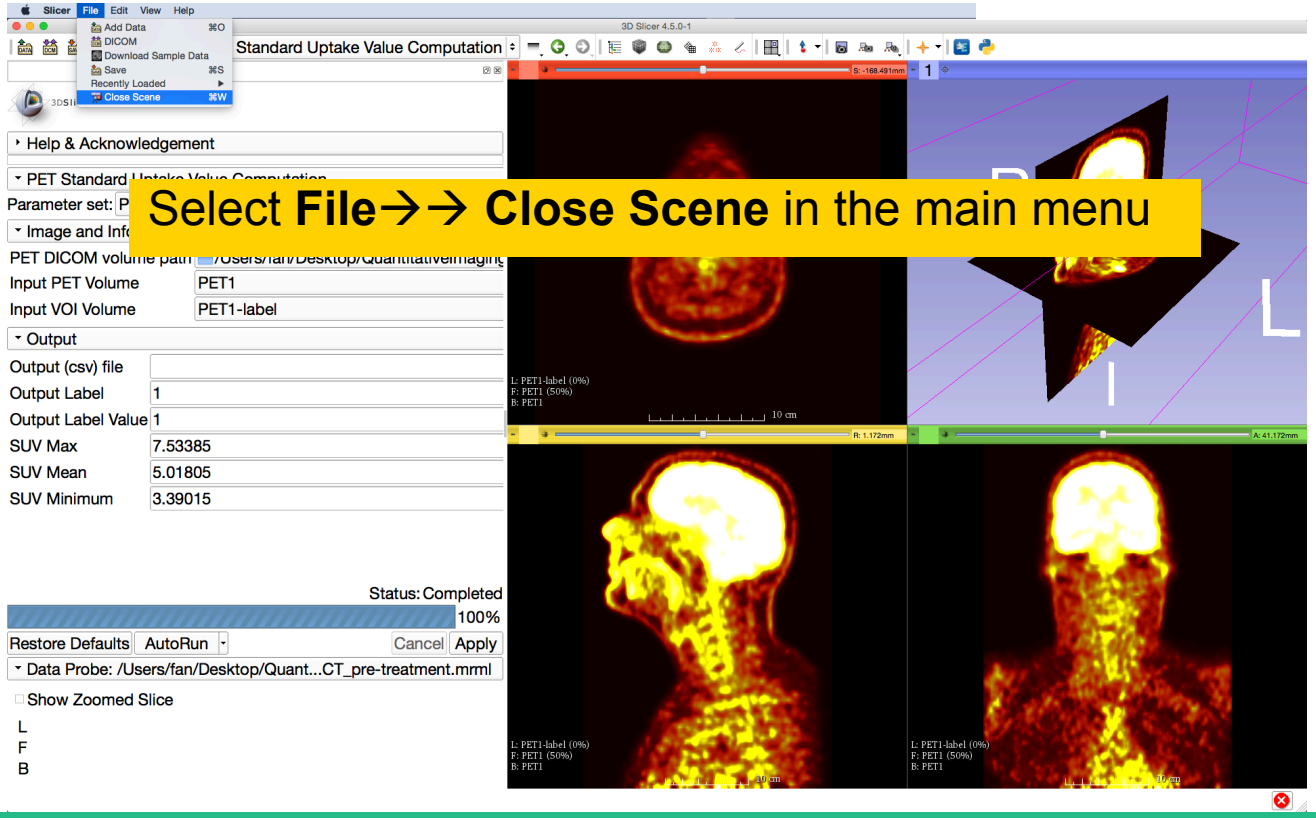
PET SUV Computation



SUV Computation Results:

SUVmax = 7.53385 mg/ml
SUVmin = 5.01805 mg/ml
SUVmean = 3.39015 mg/ml

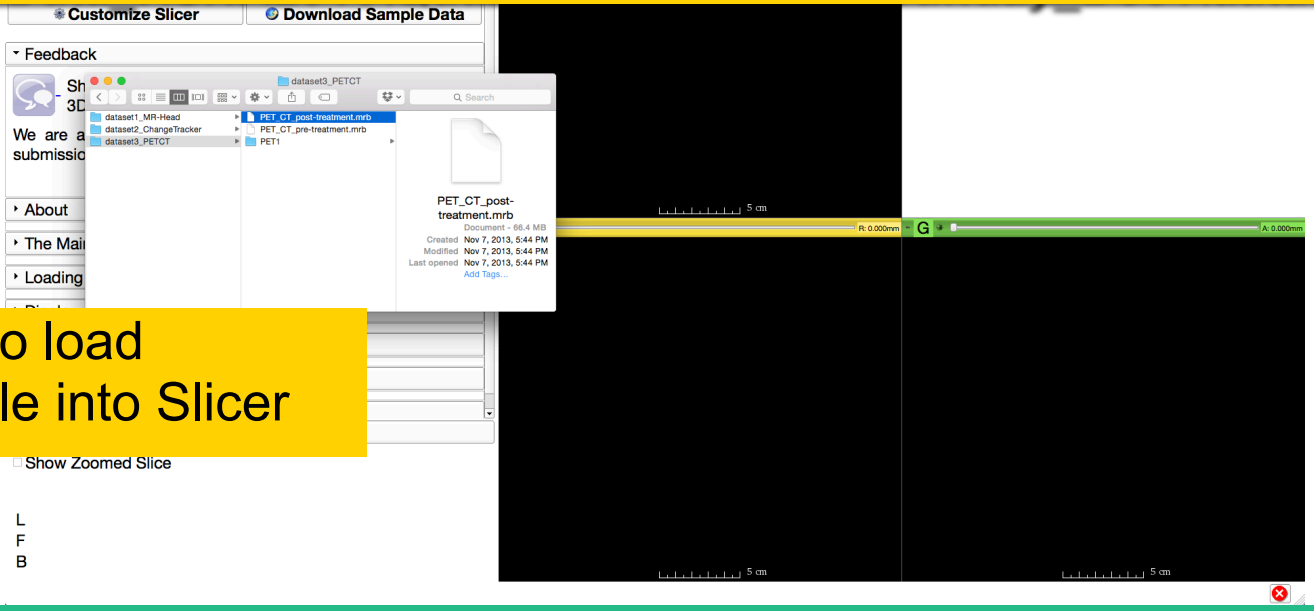
PET SUV Computation



Loading the PETCT scene

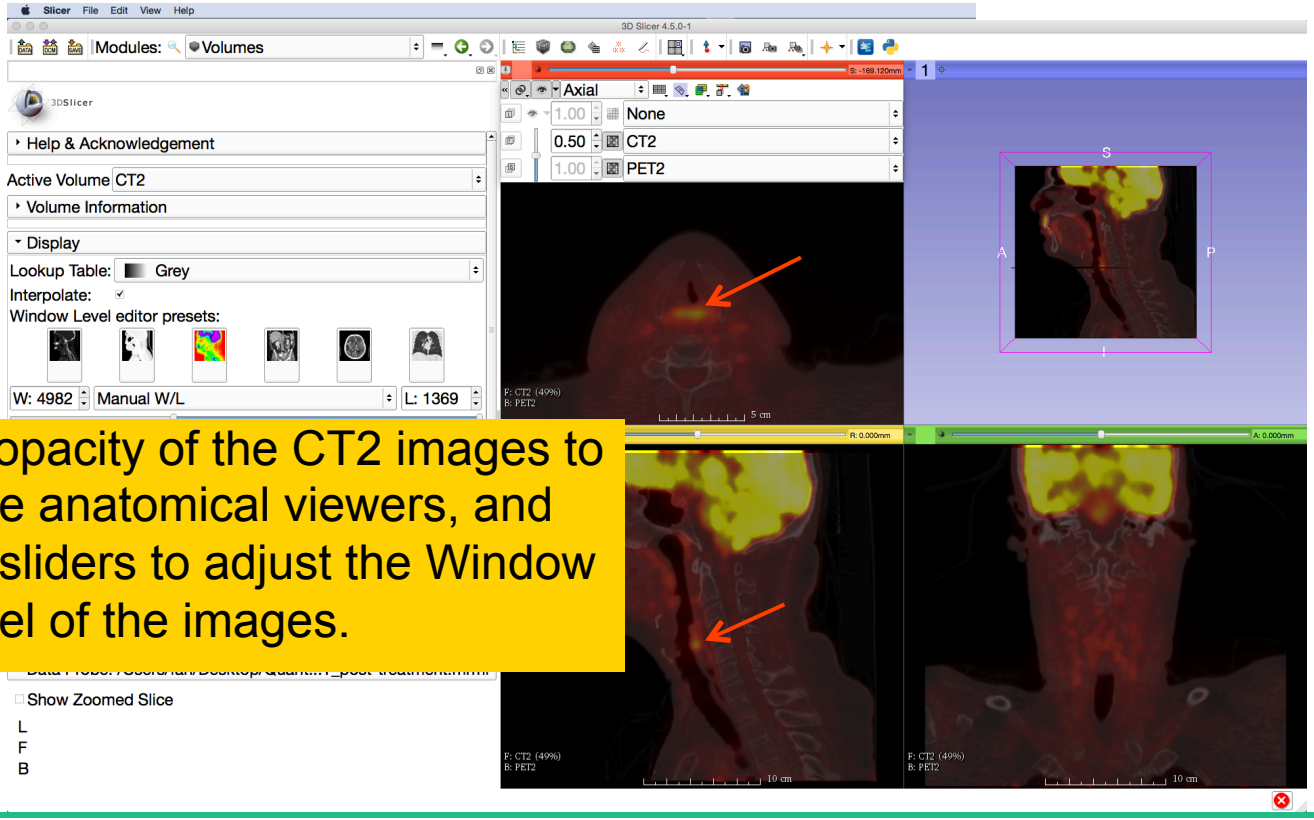
Drag and drop the file **PETCT_post-treatment.mrb** located in

QuantitativeImaging\dataset3_PETCT



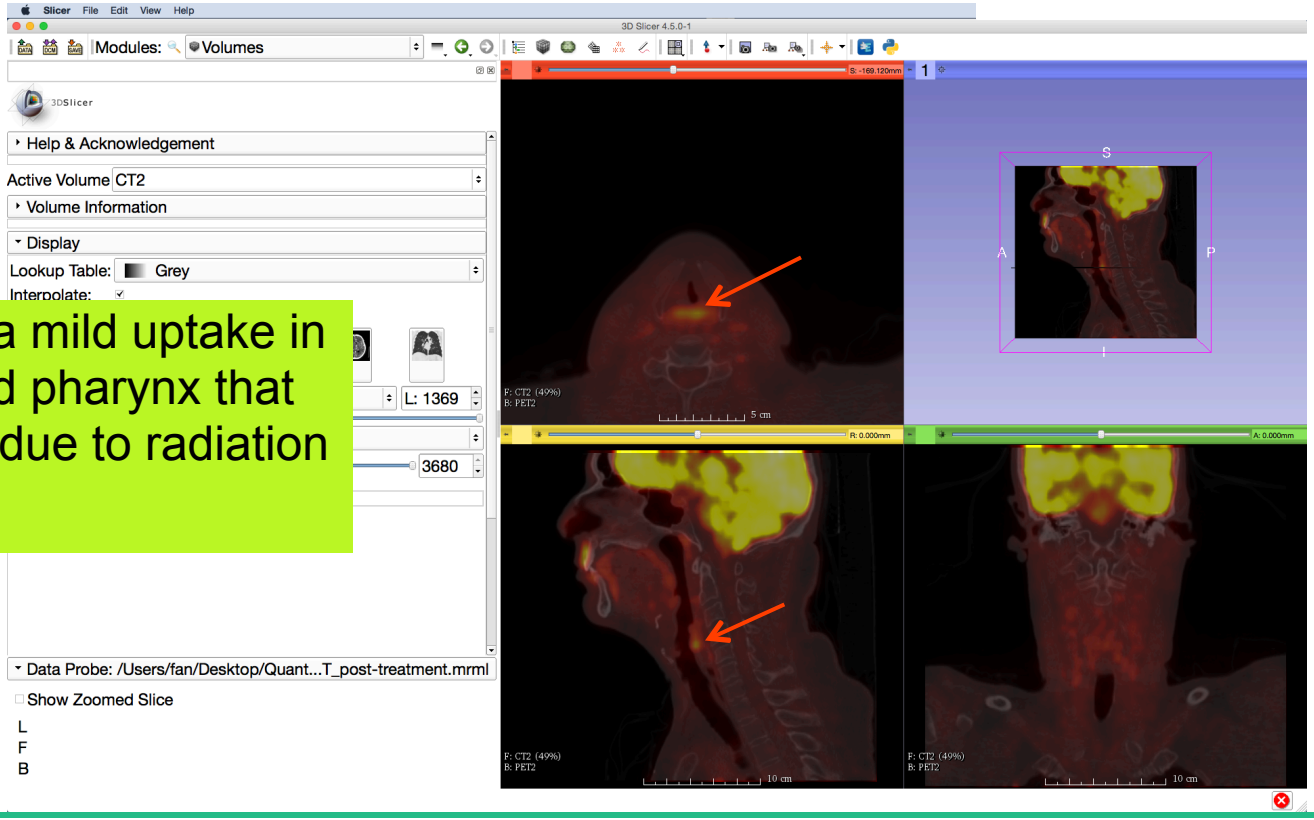
Click OK to load
the .mrb file into Slicer

PET uptake findings



Set the opacity of the CT2 images to 0.5 in the anatomical viewers, and use the sliders to adjust the Window and Level of the images.

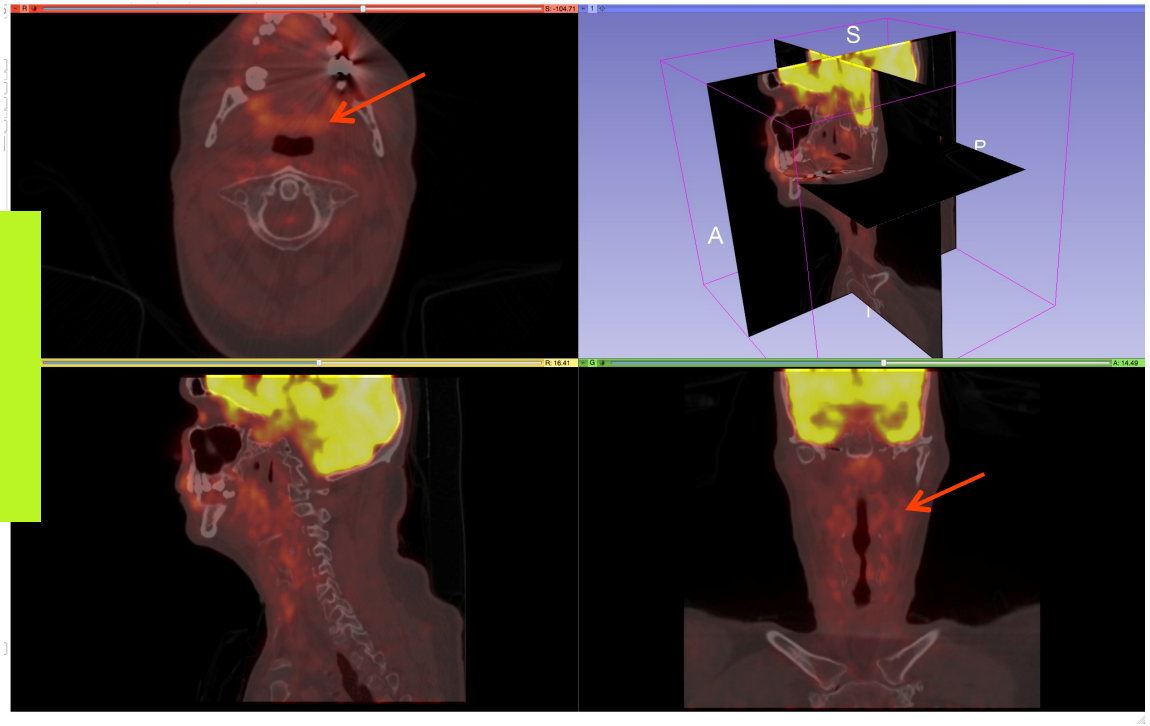
PET uptake findings



Observe a mild uptake in larynx and pharynx that are likely due to radiation effect.

PET uptake findings

Note that there is no remaining uptake in the area of the primary tumor or nodes after treatment



Conclusion

- This tutorial has demonstrated how to do 3D data visualization, quantitative measurement of small changes in tumor size, and PET/CT SUV computation in Slicer
- 3D Slicer is for research use only, and is not FDA approved
- 3D Slicer is a free open-source software for medical image computing supported by the NIH

Acknowledgments

National Alliance for Medical Image Computing (NA-MIC)
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- Marianna Jakab, MS, Brigham & Women's Hospital
- Fan Zhang, MSc, University of Sydney

3DSlicer at RSNA 2013

Quantitative Imaging Reading Room Exhibit QIRR 1028

- Sun. Dec.1-Fri. Dec.6, 8:00-6:00
- 3DSlicer: An Open Source Platform for Segmentation, Registration, Quantitative Imaging, and 3D Visualization of Multi-Modal Image Data.
- Sonia Pujol, PhD, Steve Pieper, PhD, Andriy Fedorov, PhD, Ron Kikinis, MD,

Additional Related Hands-on courses

All courses are in this Advanced Imaging Classroom: S401CD (except Monday when it is in S401AB)

Sunday 4:00 pm – Structured Annotation and Image Markup (AIM) Template and Toolsets (ICIW12)

Monday 4:30 pm – Clinical Trials Software for Clinical Trials and Research (ICIW24)

Wed 10:30 am – Open Access Imaging Data Resources: NIH Cancer Imaging Archive (ICIA41)

Wed 12:30 pm – Correlating Imaging with Human Genomics (ICIA42)

3DSlicer at RSNA

Sunday, December 1	Monday, December 2	Tuesday, December 3	Wednesday, December 4	Thursday, December 5	Friday, December 6
8:00am-11:00am: 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-11:00am:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-11:00am:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:15pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:15pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:45pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.
11:00am-12:30pm: RSNA Refresher Course: **"Quantitative Medical Imaging for Clinical Research and Practice: Hands-on Workshop."** **Sonia Pujol, Katarzyna Macura, Ron Kikinis** Room S401CD.	**12:30pm-1:30pm:** Meet-The-Experts Session, 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**12:30pm-2:00pm:** RSNA Refresher Course: **"3D Interactive Visualization of DICOM Images for Radiology Applications: Hands-on Workshop."** **Sonia Pujol, Kitt Shaffer, Ron Kikinis** Room S401CD.	**1:30pm-6:00pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center, Hall E, Exhibit LL-QRR3007.	**12:30pm-1:30pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	
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Questions: spujol@bwh.harvard.edu