

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

a teaching affiliate of Harvard Medical School

3D VISUALIZATION OF DICOM IMAGES FOR RADIOLOGICAL APPLICATIONS

Sonia Pujol, PhD

Brigham and Women's Hospital, Harvard Medical School

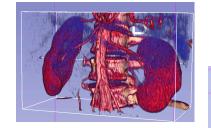
Kitt Shaffer, MD, PhD Boston University School of Medicine

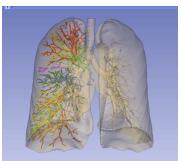
Ron Kikinis, MD, Brigham and Women's Hospital, Harvard Medical School

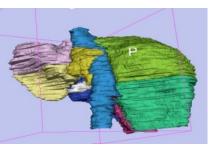


3D Visualization of DICOM images for Radiological applications

Following this tutorial, you will be able to load and visualize DICOM volumes with 3D Slicer, and to interact in 3D with structural images and models of the anatomy.





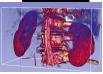




Overview

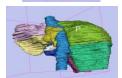


Part I: Introduction to the 3D Slicer software



Part II: 3D Data Loading and visualization of DICOM images

- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data



Part III: 3D interactive exploration of the anatomy

- Exploration of the Segments of the liver
- Exploration of the Segments of the lung





Overview

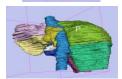


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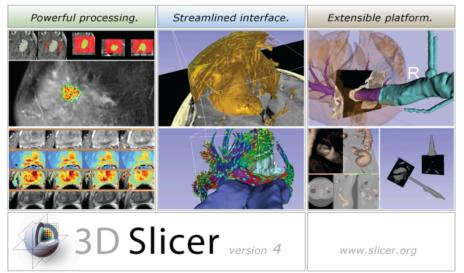




Introduction to the 3D Slicer software



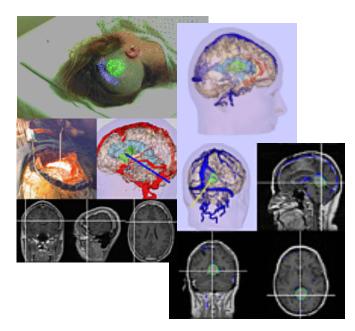




3D Slicer is a freely available open-source platform for segmentation, registration and 3D visualization of medical imaging data.

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





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

Image Courtesy of the CSAIL, MIT



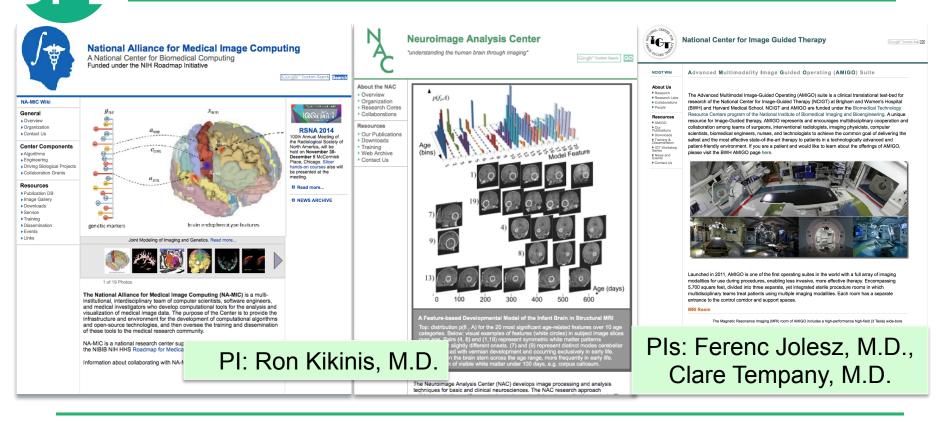
3D Slicer History

Date range	Region	Country
i Nov 28, 2011 - Nov 17, 2014 →	Northern America (32811)	United States (27813)
/ersion	Western Europe (17791)	China (8240)
version	Eastern Asia (14629)	Germany (7878)
4.0 (9%)	Southern Europe (11182)	Italy (5645)
4.1 (16%)	Eastern Europe (7103)	Canada (4998)
4.2 (26%)	Northern Europe (6966)	United Kingdom (4281)
4.3 (47%)	South America (4786)	France (3765)
4.4 (2%)	Southern Asia (3946)	Spain (3523)
0 10,000 20,000 30,000 40,000 50,000	Australia, New Zealand (2475)	Japan (3380)
Operating system	Western Asia (2115)	India (2849)
	South-Eastern,Asia (1966)	Australia (2167)
Linux (1496)	Northern Africa (910)	Poland (2163)
Mac (17%)	Central America (860)	Russian Federation (2040)
Windows (69%)	unknown (319)	Netherlands (1883)
0 20,000 40,000 60,000	Southern Africa (318)	Brazil (1830)
	Caribbean (129)	Austria (1666)
Stability	Eastern Africa (92)	Switzerland (1624)
nightly (20%)	Western Africa (44)	South Korea (1611)
release (80%)	Others (54)	Others (21140)
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1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)

 2014: Slicer is a multiinstitution effort to share the latest advances in image analysis with the clinical & scientific community

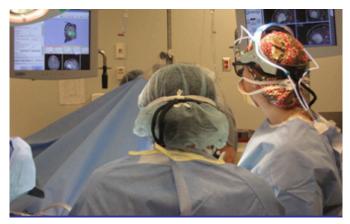
A multi-institution: NA-MIC, NAC, NCIGT



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

Slicer: Behind the scenes

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P Slicer Training events



- Hands-on training workshops at national and international venues
- More than 3,500 clinicians, clinical researchers and scientists trained since 2005

Slicer Training events



Major international conferences

- **RSNA** 2008, 2009, 2010, 2011, 2012, 2013, 2014
- MICCAI 2008, 2009, 2011, 2012, 2013, 2014
- **SfN** 2009, 2011
- **SPIE** 2012, 2013
- **CAOS** 2010
- CARS 2010, 2012, 2013

An extensible platform

AIRWAY SEGMENTATION

AirwaySegmentation

INSTALL



CleaverExtension Ionathan Bronson (SCI ... (0)

++++ (0)

CarreraSlice

Ivan Kolesov, Liangjia ...

INSTALL

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ARC Marcel Prastawa (Unive... (0)





INSTALL



GelDosimetry GelDosimetryAnalysis Fotis Drakopoulos (CR... Csaba Pinter (PerkLab. (0) (0)



Andrey Fedorov (SPL), ... (0)

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Pietro Nardelli (Univers. ******* (0) INSTALL



ErodeDilateLabel



DiceComputation





CornerAnnotation

(0)

Atsushi Yamada (Shiga.

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GvroGuide Ruifeng Chen, Luping F. (0)

ImageMaker

(0)

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UNINSTALL



CurveMaker

Junichi Tokuda (BWH)

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FastGrowCutEffect Liangjia Zhu, Ivan Kole. (0)

INSTALL



IASEM Julien Finet (Kitware) Bradley Lowekamp (0) INSTALL



Distance ******** (0)

CMFrea

Vinicius Boen (Univ of M.

INSTALL

FinslerTractography

Antonio Tristan-Vega,...

INSTALL

(0)



- 3D Slicer supports plugins called Slicer extensions available from the Extension Manager
- Allows end-users to select extensions useful to them. without having to download the entire extension archive
 - Built Nightly with Slicer



LAScarSegmenter

(0)

Liangjia Zhu (SBU), Yi G.

INSTALL



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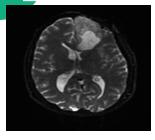
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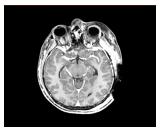
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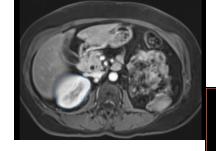
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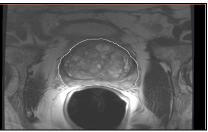
Slicer clinical applications



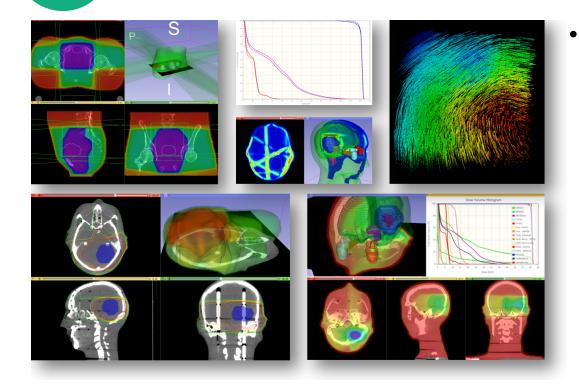


- Applied science oriented toward patient-specific analysis in the presence of pathology
- Driving Biological Projects leading to the development of new tools





Examples of clinical applications



Radiotherapy: RT-specific analysis dose accumulation and dose comparison (G.Fichtinger et al. Queen's University, Canada)

Examples of clinical applications

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3D Slicer 4.4.0

Diffusion Tensor Imaging tractography for neurosurgical planning



Overview

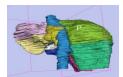


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Welcome to Slicer4

3D Slicer 4.4.0					-	
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🛞 Customize Slicer	🕑 Download Sample Data					
▼ Feedback						
- Share your stories with us and let us k	know about how 3D Slicer has enabled your research.					
We are always interested in improving 3D Slicer, and every	submission will be carefully read.					
See more at http:	://goo.gl/6BvcHm.					
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To start Slicer, double-click on the **Slicer-shortcut** icon on the Desktop (bottom left)

Navigating the Application GUI

The Graphic User Interface (GUI) of Slicer4 integrates four components:

- the Menu & Toolbar
- the Module GUI Panel
- the 3D Viewer
- the Slice Viewers

● ● ●	3D Slicer 4.4.0	t • 6 a a + • 2 🐣
Bosticer Welcome Customize Slicer Feedback Share your stories with us and let us know - about how 3D Slicer has enabled your research. Wa are alwayse interseted in improving 3D Slicer and	Slice Viewers	3D Viewer
We are always interested in improving 3D Slicer, and every submission will be carefully read. > About Moodupe Courter. >	Slice	Viewers

Welcome to Slicer4.4

B 3D Slicer 4.4.0 RCPC Transform File Edit View Help Real Add Scalar Volumes 🚵 🚵 Modules: 🔍 💽 Welcome to Slicer Annotation AtlasTests Annotations RAINS Strip Rotation A Data E DataStore RAINSDWICleanup A DICOM M Cameras Markuns Rest Scalar Volume Load DICOM Models tharting Scene Views ReckerBoard Filter Customize Six Subject Hierarch Colors Transforms Feedback View Controllers Compare Volumes Volume Rendering Share your stories 🔘 Volumes @ Cron Volume Welcome to Slicer We are always interested in improv Wizards A Data Se Informatics 🔹 🖈 DataProbe About Registration DataStore Segmentation The Main Window Ouantification M DICOM Diffusion Loading and Saving IGT Filtering Display Surface Models 🖌 🌸 DTJexport DTEmport Mouse & Keyboard Converters Endoscom Documentation & Tutorials Utilities DWI Rician LMMSE Filter Developer Tools DWI to DTI Estimation Acknowledgment

a AddManyMarkupsFiducialTest RAINS Transform Convert Repline to deformation field ColorsScalarBarSelfTest Reate a DICOM Series Curvature Anisotropic Diffusion Demon Registration (BRAINS) at Diffusion Tensor Scalar Measurements 🗼 🚓 Diffusion Weighted Volume Masking DW/ Joint Rician LMMSE Filter 🔭 🌲 DWI to Full Brain Tractography

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🔺 Resample Scalar Volume Resample Scalar/Vector/DWI Volume Resize Image (BRAINS) Robust Statistics Segmenter RSNA2012ProstateDemo RSNAQuantTutorial RSNAVisTutorial Sample Data Rene Import (Issue 2428) Scene Performance Re Scene Views & SelfTests Itk Simple Filters 🚓 Simple Region Growing Segmentation Received SliceLinkLogic A Slicer4Minute slicerCloseCrashBug2590 Subject Hierarchy SubjectHierarchyCorePluginsSelfTest SubjectHierarchyGenericSelfTest Internet Scalar Volumes Surface Toolbox 🚓 Test Tractography Display Restriction of the second state of the second 🚓 Tractography Display at Tractography Interactive Seeding Real Tractography Label Map Seeding RTransform MRML Files to New EMSegmenter Standard In Transforme Vector Demon Registration (BRAINS) Rector to Scalar Volume Wiew Controllers



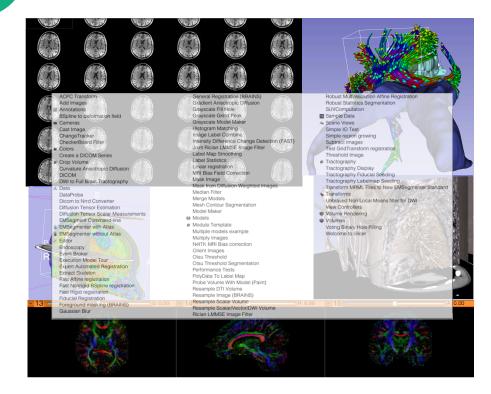
- 6 -

Click on **Welcome to Slicer** to display the list of modules of Slicer in the Modules menu and click on All Modules

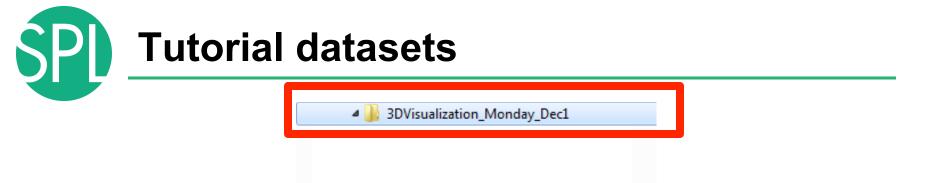
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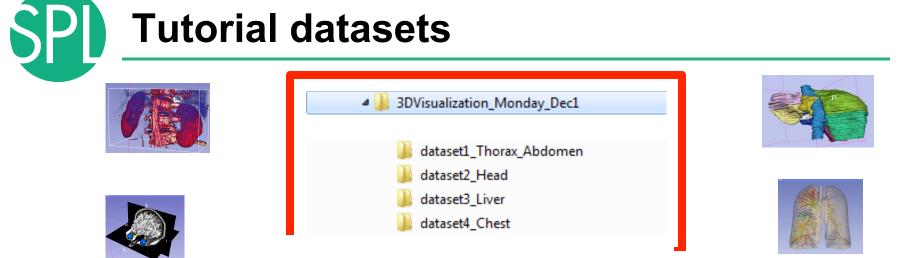


Slicer4.4 contains more than 100 modules for image segmentation, registration and 3D visualization of medical imaging data



The tutorial datasets are located on the directory **3DVisualization_Monday_Dec1** on the desktop

Double-click on the directory to expand it



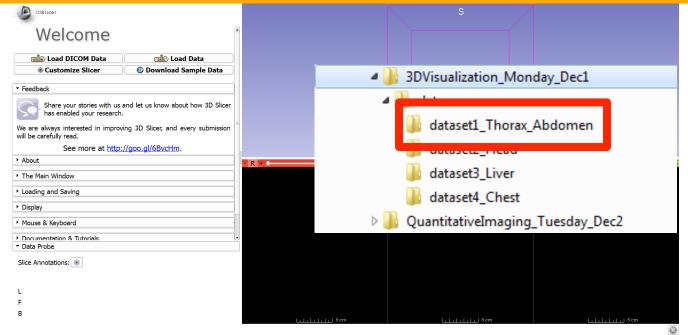
The directory contains 4 datasets that we prepared for this course.





Part 1:

Drag and drop the directory 'dataset1_Thorax_Abdomen' into Slicer



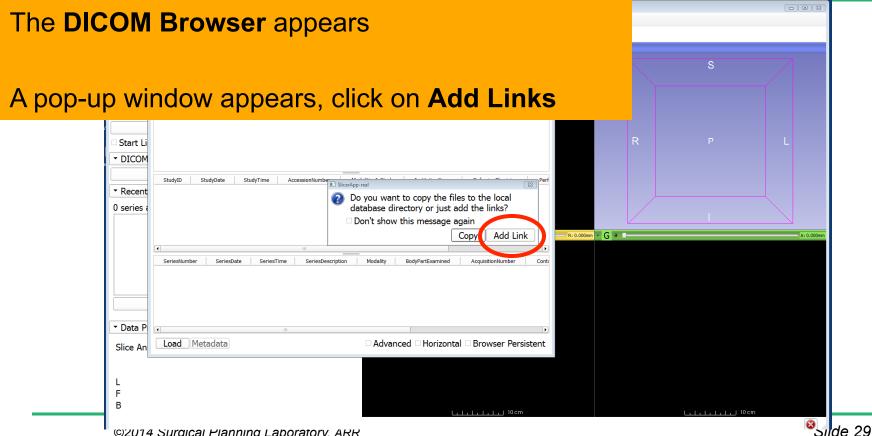
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See more at <u>http:</u>	<u>//goo.gl/6BvcHm</u> .	Cancel G +	A: 0.000mm
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A pop-up window to select the DICOM reader appears: the option **Load directory into DICOM database** is selected by default. Click on **OK**

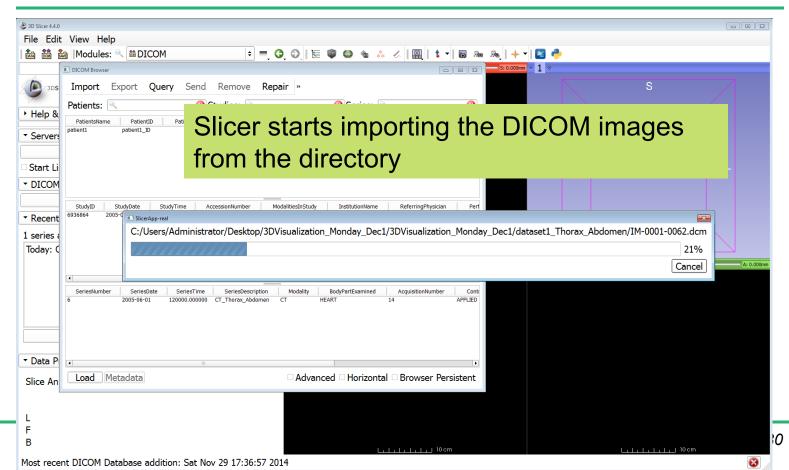
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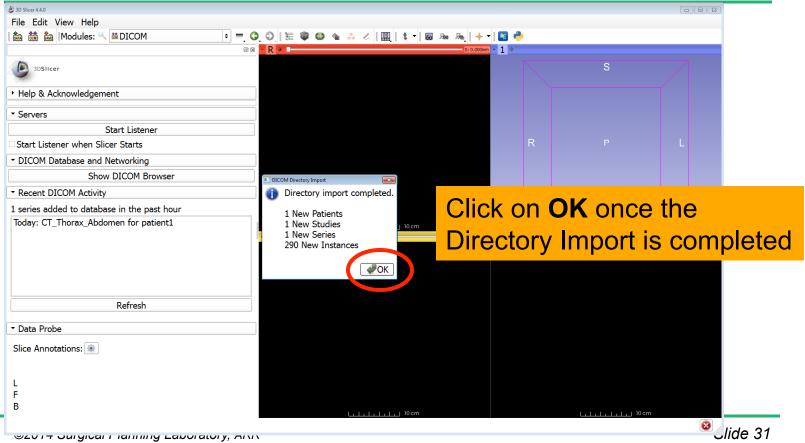
A DICOM pop-up window appears to inform the user where Slicer will store the DICOM Database.

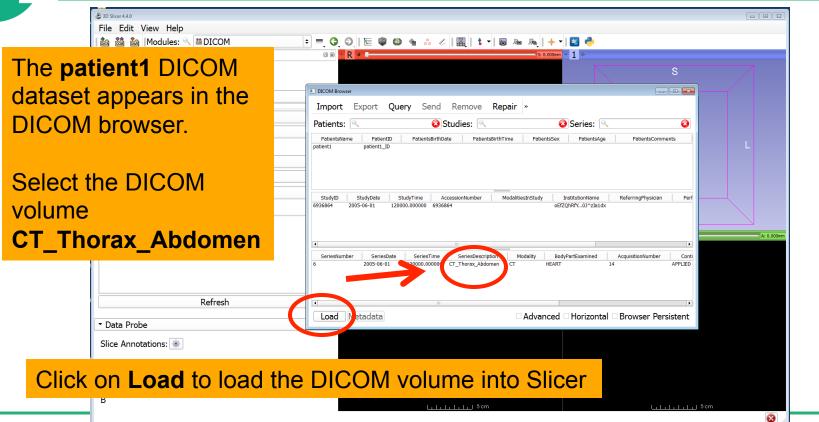
Click on **OK**



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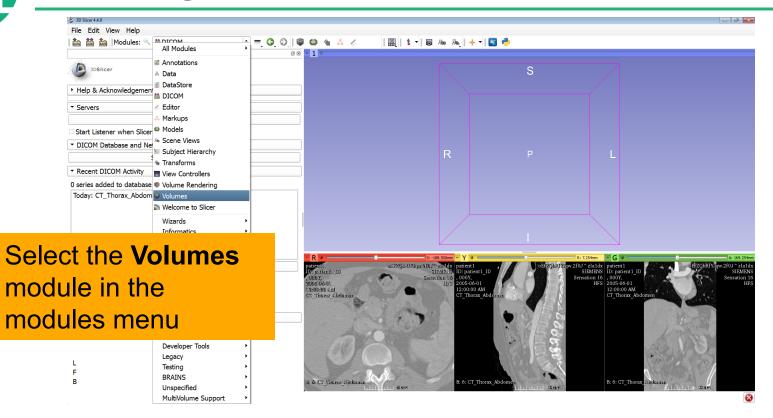
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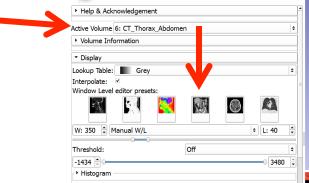
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Select the Active Volume 6:CT_Thorax_Abdomen

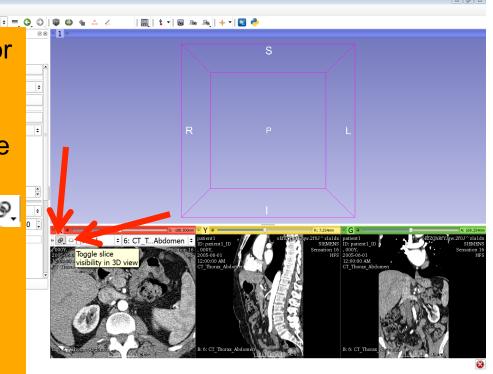


Slicer has a series ofwindow/level presetsavailable

Click on the Window Level Preset **CT-abdomen**, or adjust manually the Window and Level using the Manual W/L slider



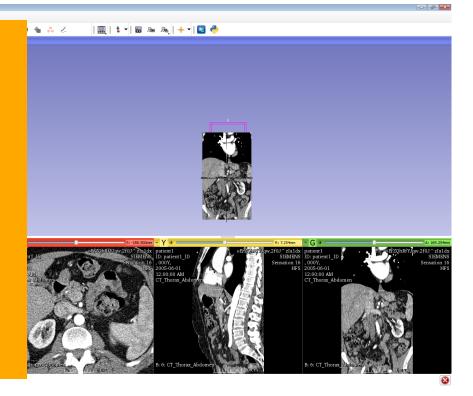
- Position the mouse cursor over the pin icon (left to the letter R) in the Red Viewer to display the slice menu.
- Click on the Links icon to link the slice controls across all Slice Viewers.
- Click on the Eye icon to display the three anatomical slices in the 3D Viewer



The three anatomical slices appear in the 3D viewer.

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Hold the right-mouse button down in the 3D Viewer, and move to the cursor up and down to zoom in and out



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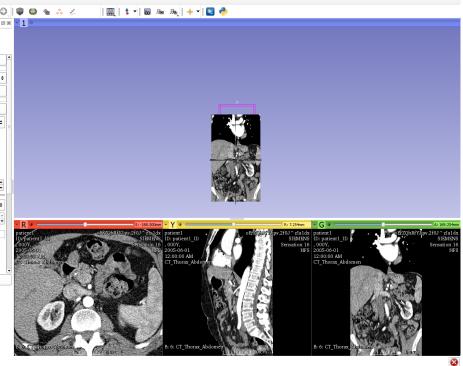
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Hold the left-mouse button down in the 3D Viewer and move the cursor lefft and right to rotate the volume

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Center the 3D view on the scene

 Help & Acknowledgement Position the mouse over the pin icon (left to number 1) in the blue banner to display the 3DView controller, and click on the top left icon to center the 3D view on the scene

3D Slicer 4.4

File Edit View Help

3DSlicer

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Note: a shortcut to this functionality is available through the icon next to the number '1' in the blue banner

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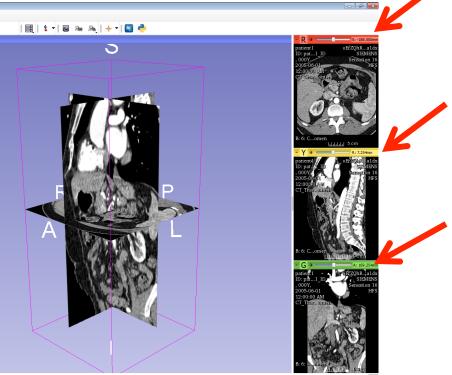
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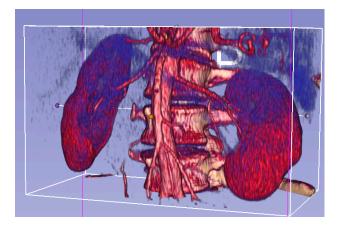
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Use the sliders in the red view, yellow view and green view to slice through the volume in all three anatomical directions

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3D Interactive exploration of thoraco-abdominal CT data using Volume Rendering

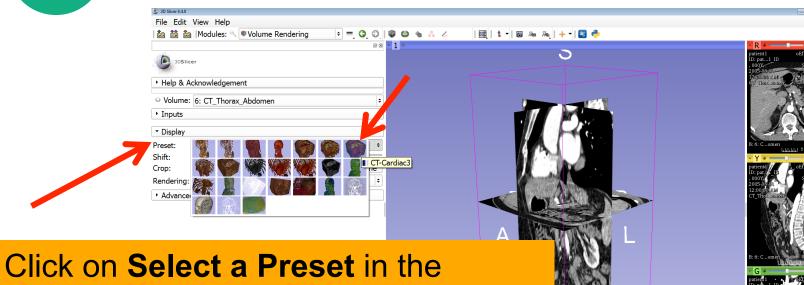
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Display tab to display the list of available presets for the transfer function (first row, top right) Select the Preset **CT-Cardiac3**

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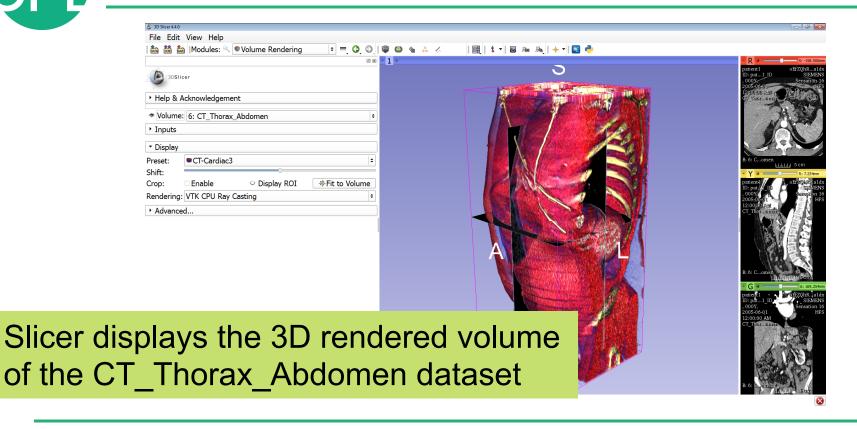
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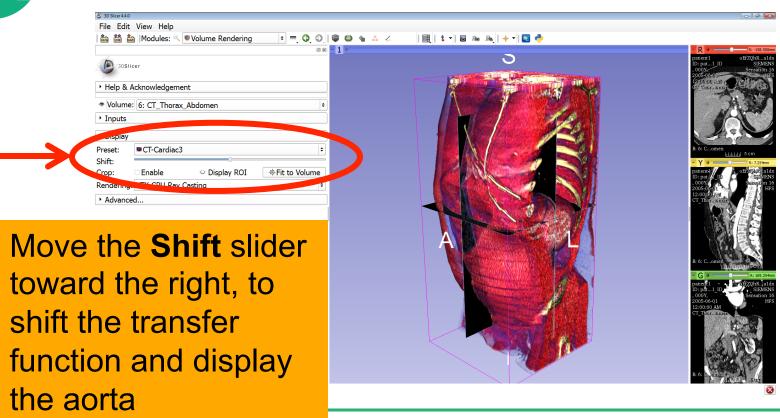
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Select the Rendering VTK GPU Ray Casting, and click on the eye icon in the Volume tab to display the Volume rendered volume in the 3D viewer (FIX)

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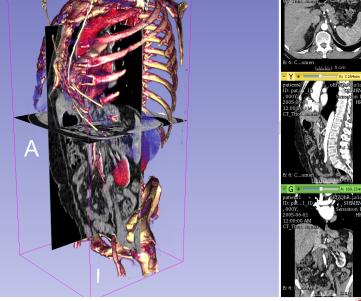
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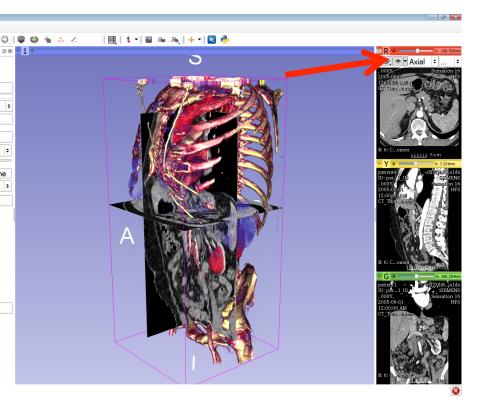
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The volur of the aorta and rib cage appears in the 3D viewer



Click on the eye icon in the red viewer to turn off the visibility of the anatomical slices in the 3D viewer

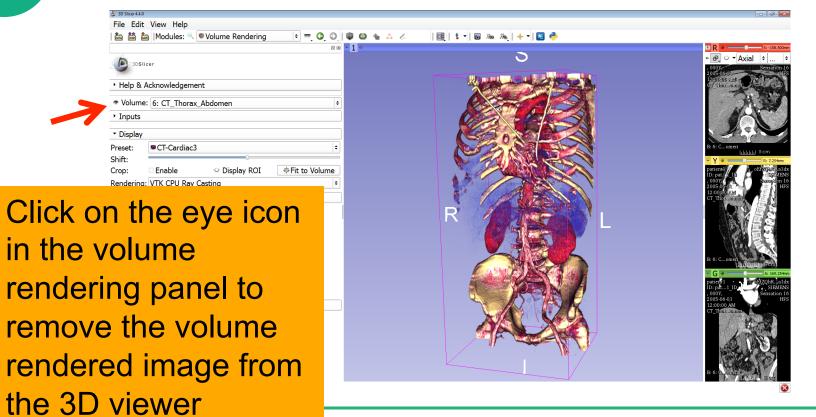
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inte dataset, and make sure the option Crop is selected ('Enable' should be checked)



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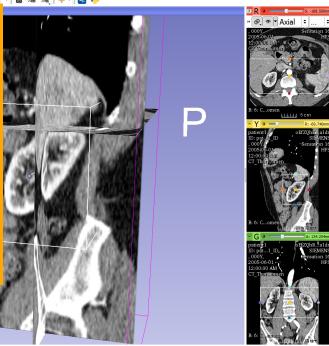
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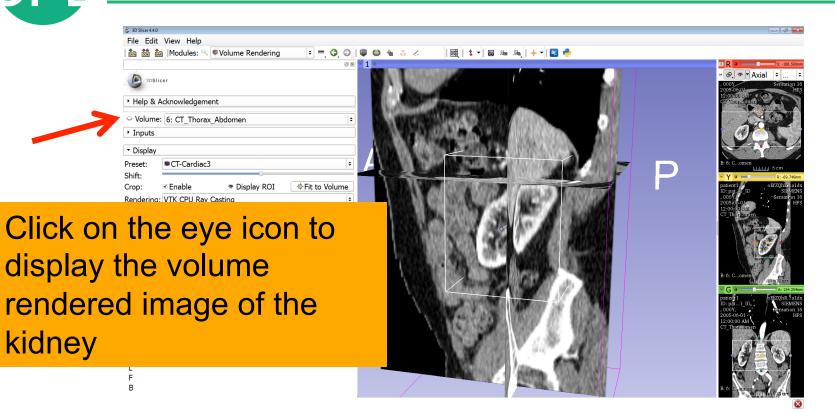
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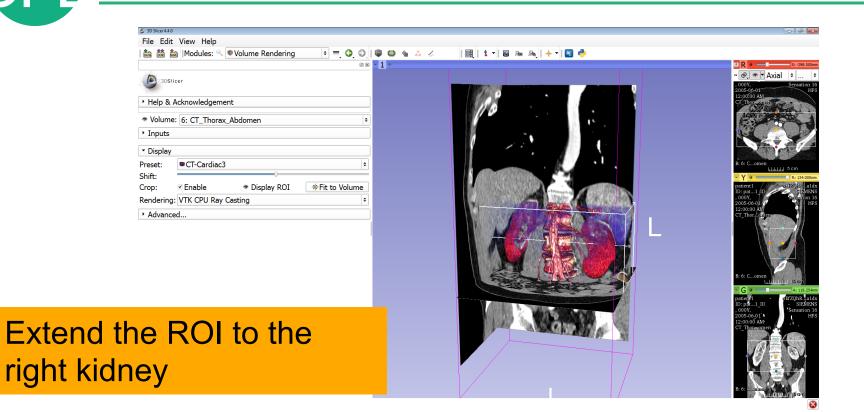
Click on the eye icon in the red viewer to turn on the visibility of the grayscale images, and position the ROI around the left and right kidneys using the ROI controls in the 2D anatomical views and in the 3D viewer





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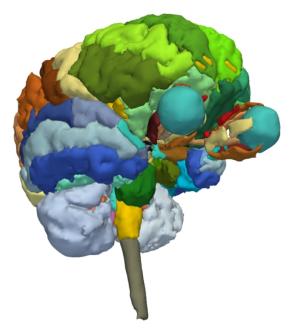


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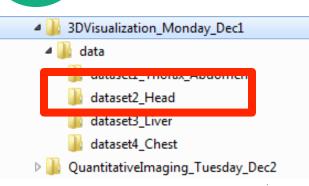
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Part 2: 3D visualization of surface models of the brain

3D Data Loading and Visualization



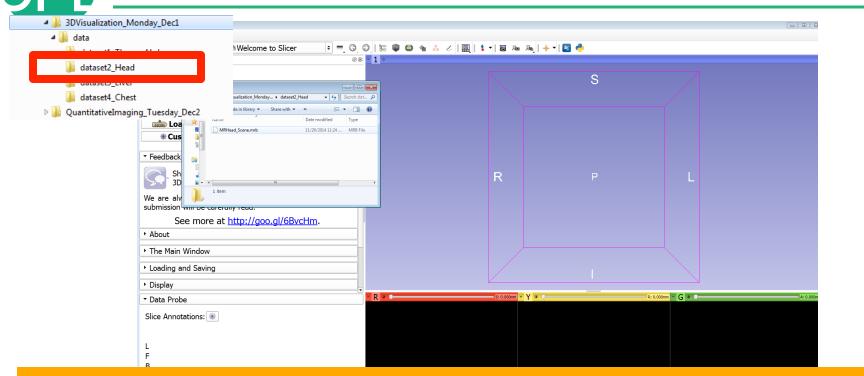


- Open the directory **3DVisualization_Monday_Dec1** on the Desktop
- Select the directory dataset2_Head
- Select the file **MRHead_Scene.mrb** This file is composed of an MR scan of the brain and 3D surface reconstructions of anatomical structures.

The data are part of the SPL-PNL Brain Atlas developed by Talos, Jakab, Kikinis et al. The atlas is freely available for download at:

http://www.spl.harvard.edu/publications/item/view/2037

3D visualization of surface models of the brain



Drag and drop the file Head_Scene.mrb into Slicer

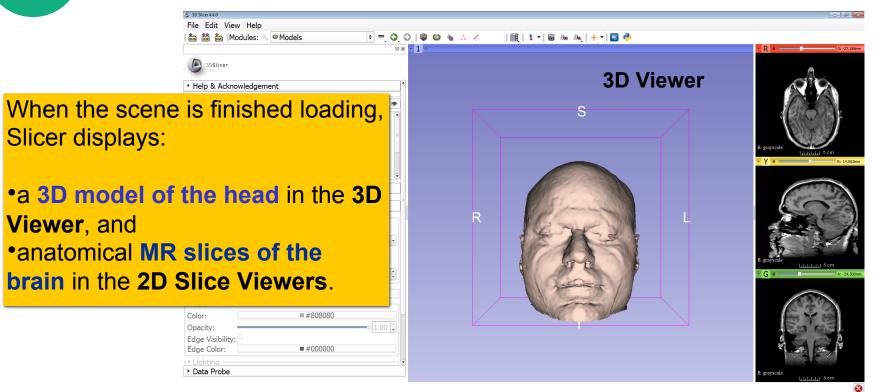


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Click on **OK** to load the file **MRHead_Scene.mrb** into Slicer

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3D visualization of surface models of the brain : <u>Viewing the Scene</u>



3D visualization of surface models of the brain : Exploring Slicer's functionality

Linear Registration



Diffusion

Filtering

Converters

Endoscopy

Litilities

Legacy

Testing

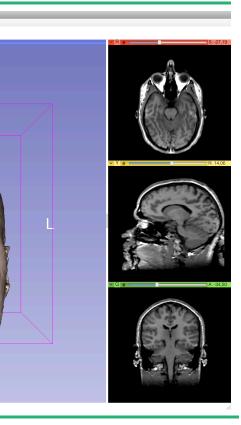
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To access the **Models** module, browse through the list of modules.

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ACPC Transform

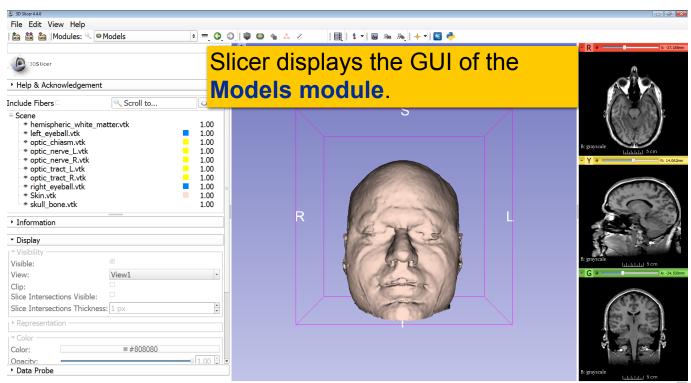
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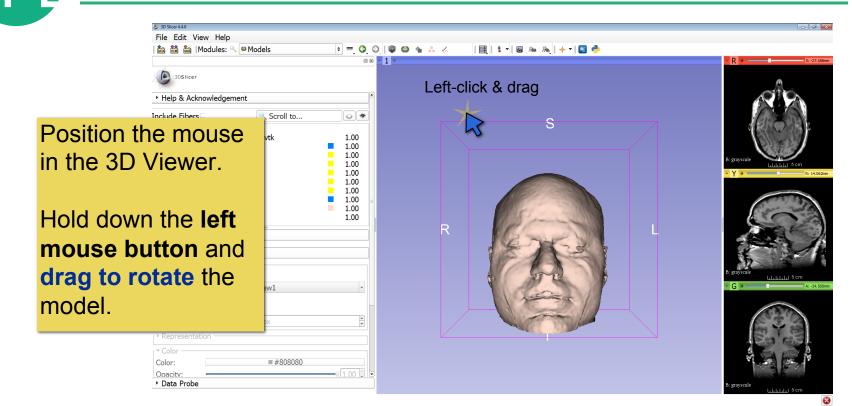
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3D visualization of surface models of the brain : Switching to the Models Module



3D visualization of surface models of the brain : Basic 3D Interaction





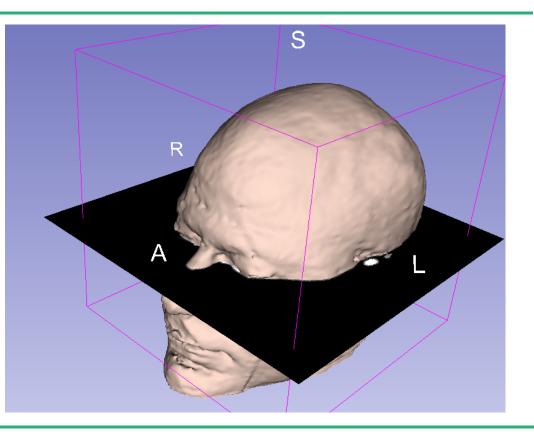
3D visualization of surface models of the brain : Viewing Slices in the 3D Viewer

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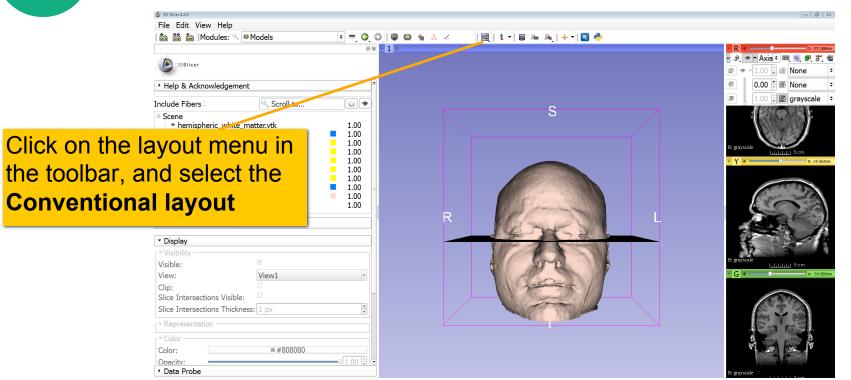


3D visualization of surface models of the brain

Slicer adds a view of the **Axial slice** in the 3D View.









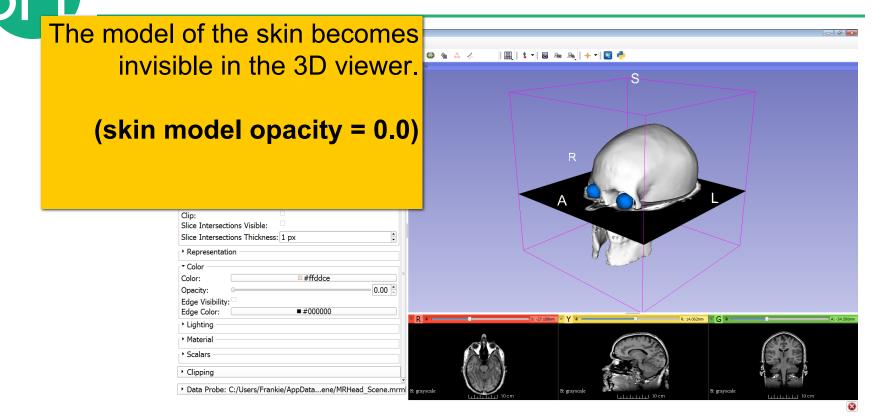
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Click to expand the

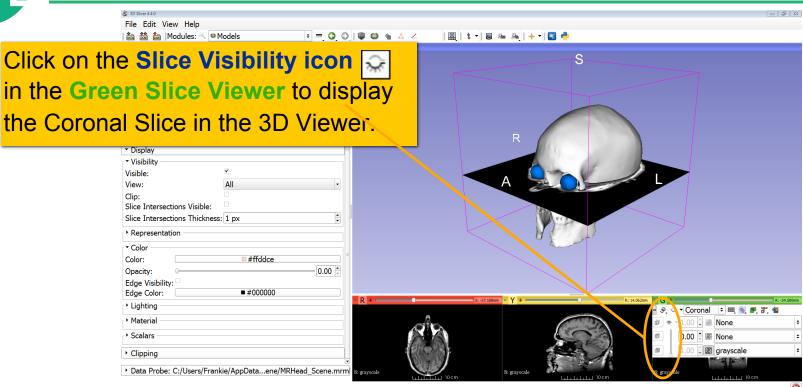
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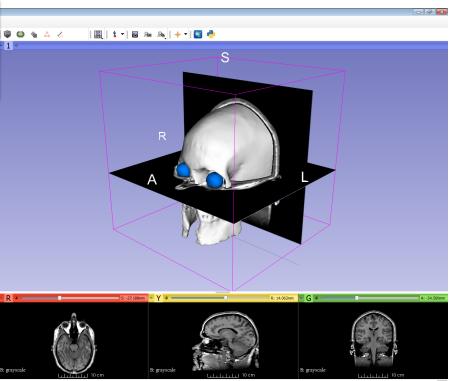






The Axial and Coronal Slices are displayed in the 3D Viewer.

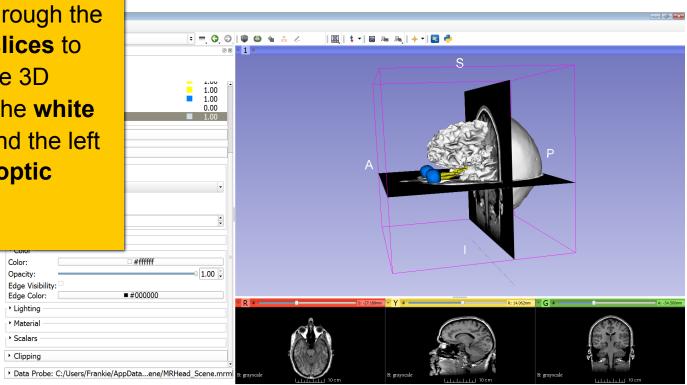
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Browse through the coronal slices to expose the 3D model of the white matter, and the left and right optic nerves.



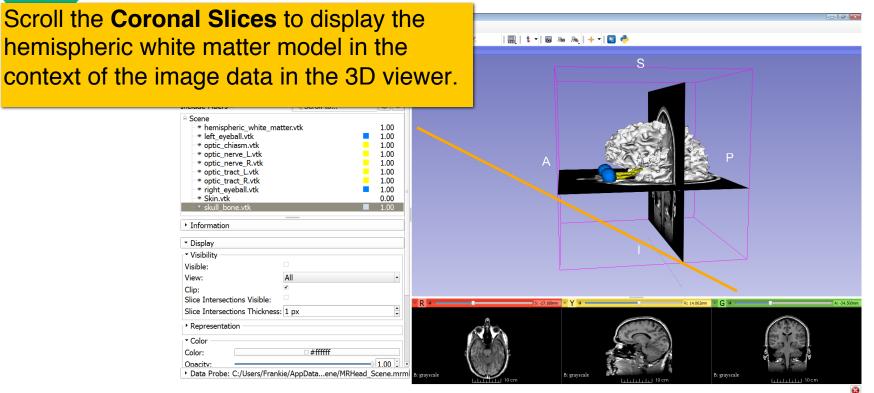
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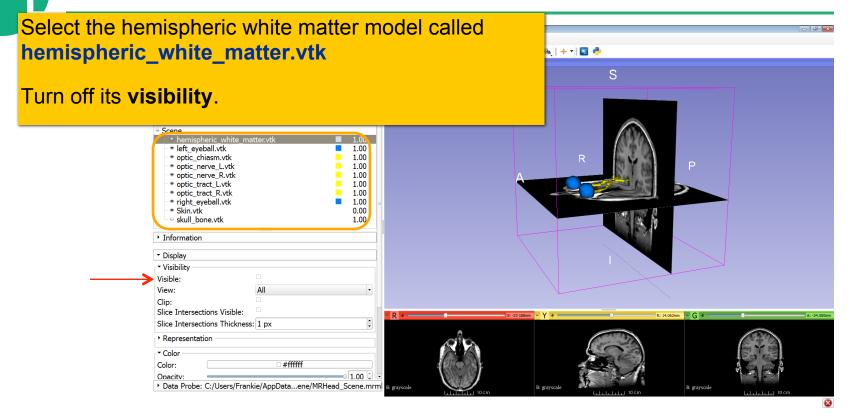
Uncheck the option '**visible'** to make the skull invisible.

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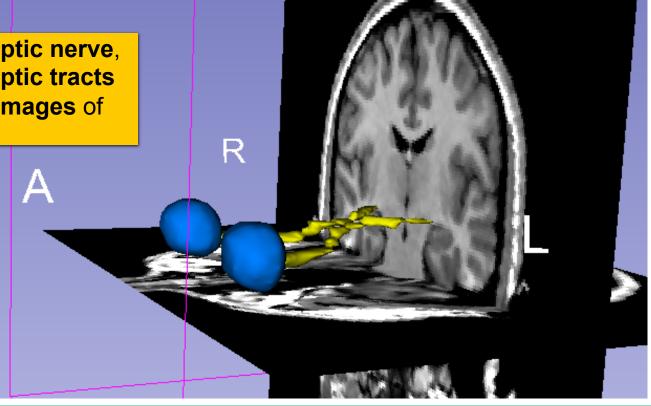








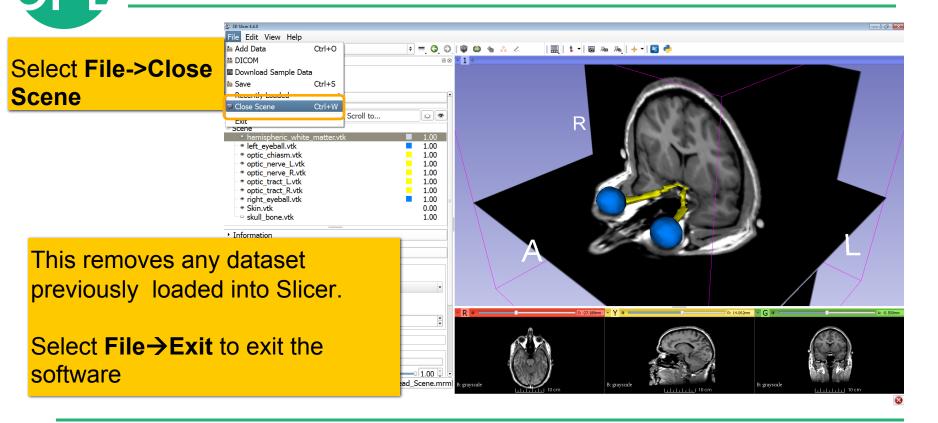
Slicer displays the **optic nerve**, **optic chiasm** and **optic tracts** overlaid on the **MR images** of the brain.





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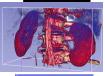




Overview



Part I: Introduction to the 3DSlicer software



Part II: 3D Data Loading and visualization of DICOM images

- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data

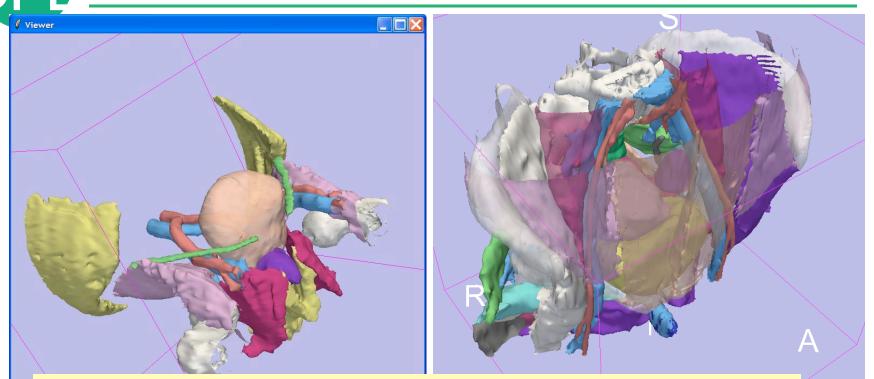


Part III: 3D interactive exploration of the anatomy

- Exploration of the Segments of the liver
- Exploration of the Segments of the lung



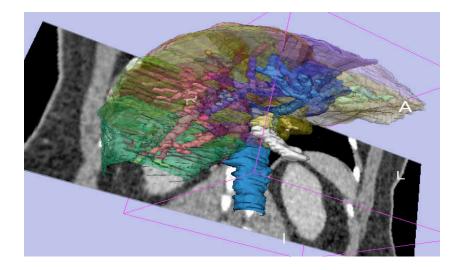
Slicer for Radiology Education



Slide 88

Models completed as 'virtual dissection' by a medical student who is now a radiology resident



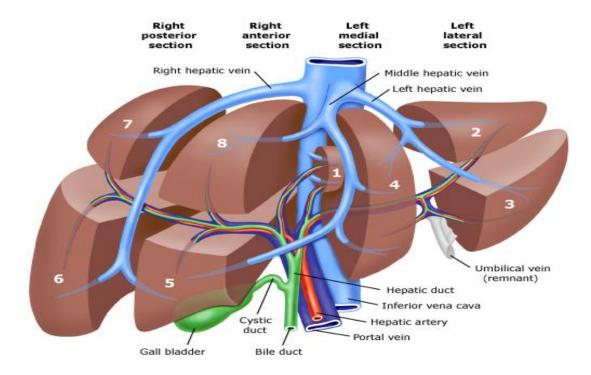


Part Illa:

Interactive 3D Visualization of the segments of the liver



Anatomy of the liver

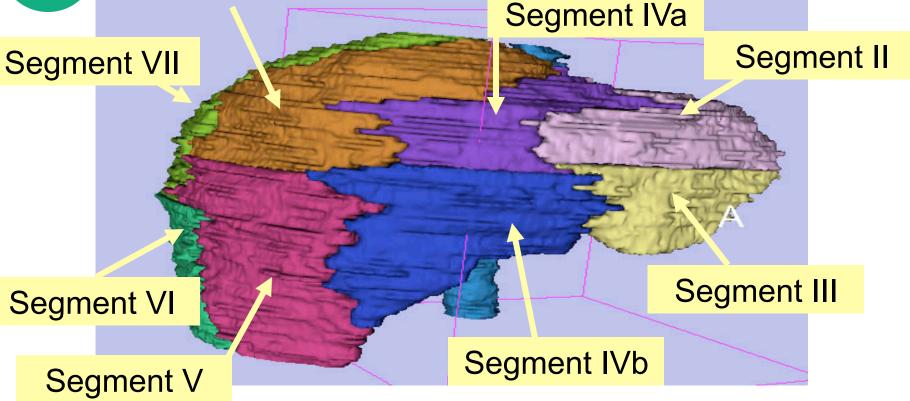


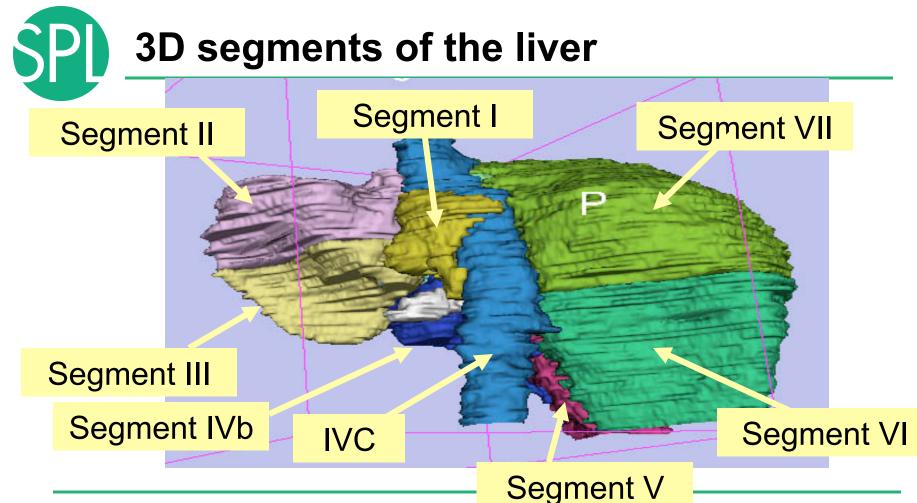




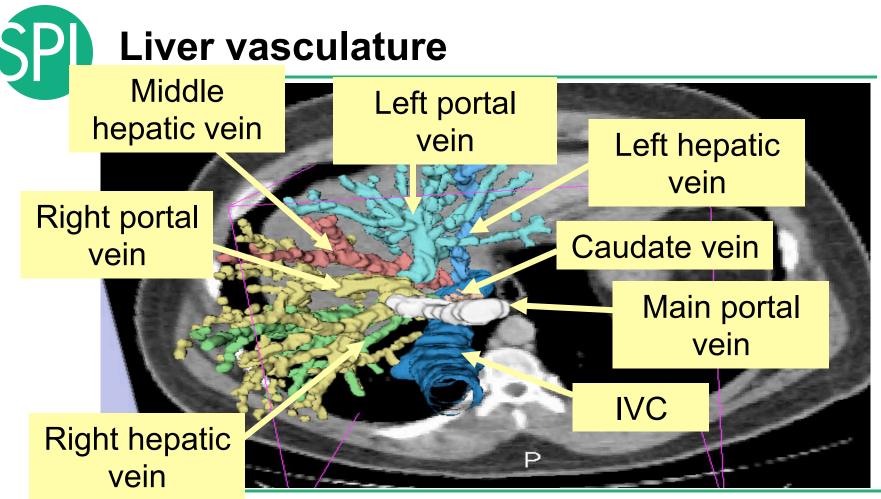
The liver dataset is a contrast-enhanced CT abdominal scan of a healthy 36 year-old male.





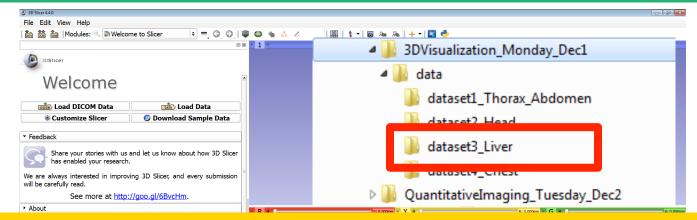


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Loading the Liver Scene



Browse to the directory 3DVisualization_Monday_Dec1

Select the directory dataset3_Liver

Drag and drop the file LiverSegments_Scene.mrb into Slicer

Click on OK to load the scene into Slicer

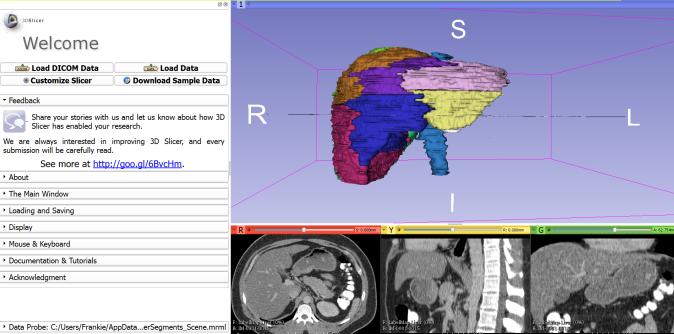


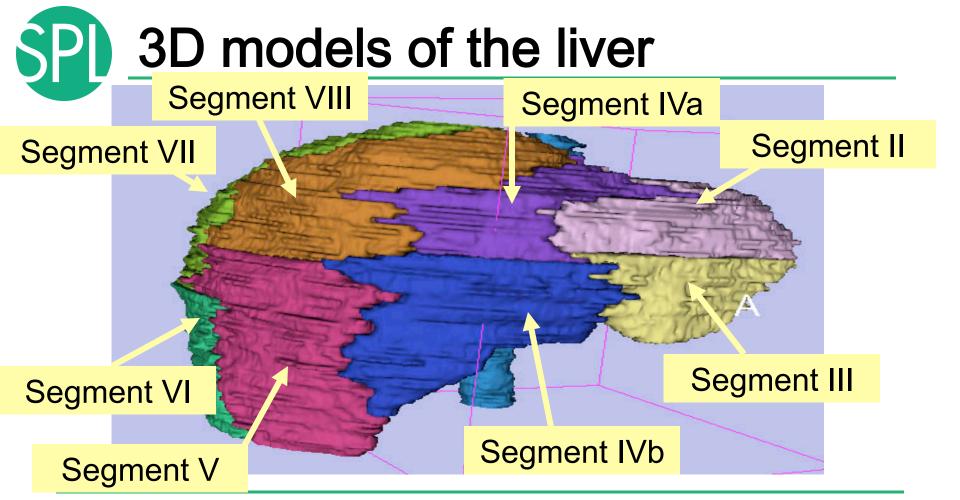
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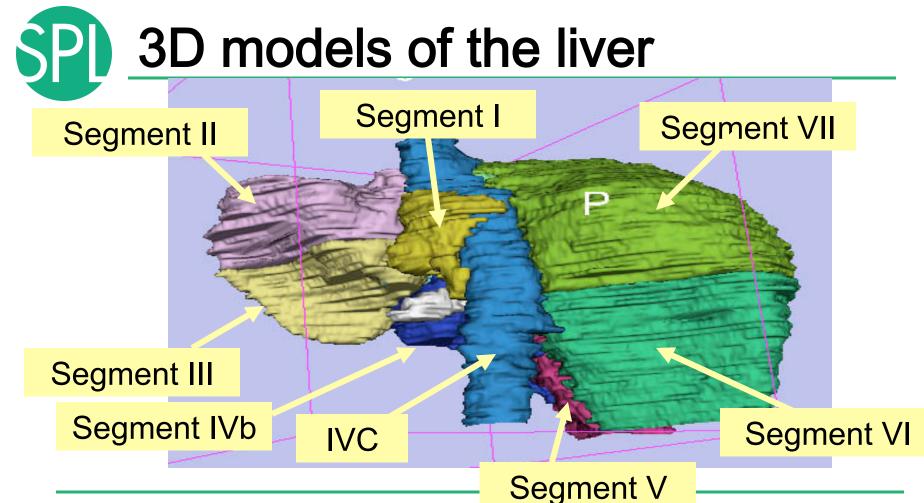
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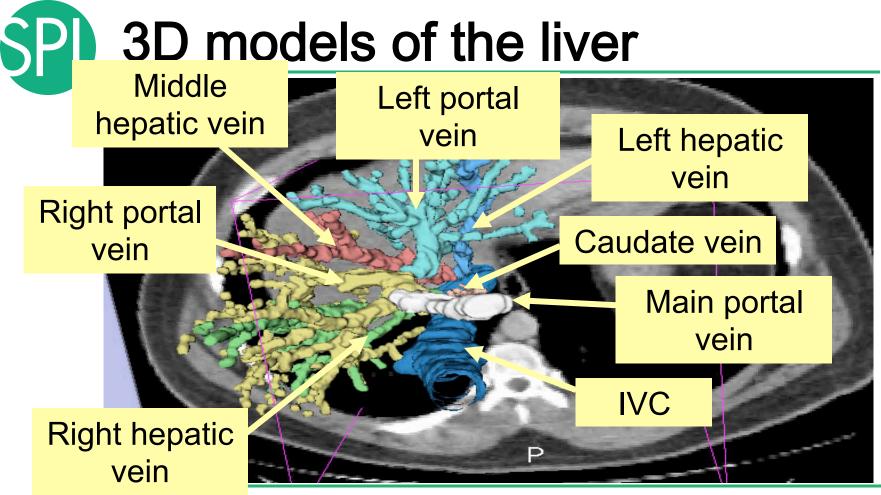
Liver Segments Scene

The elements of the scene appear in the Viewer

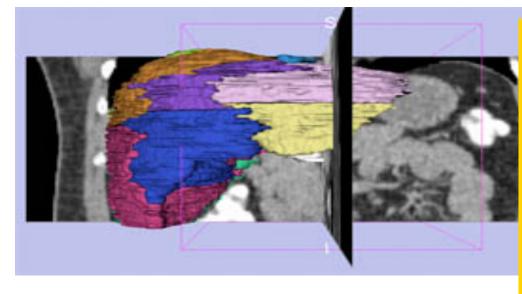




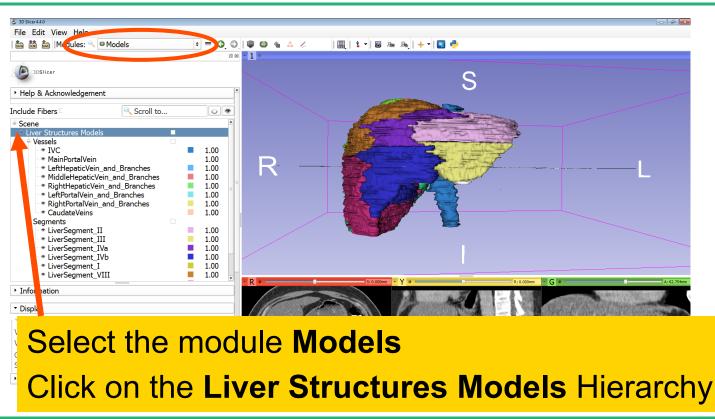


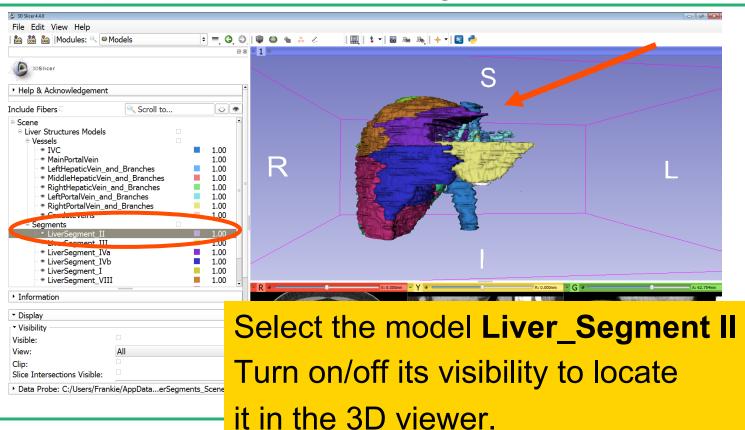






Example: What organ abuts the left-most margin of segment II in this patient ?





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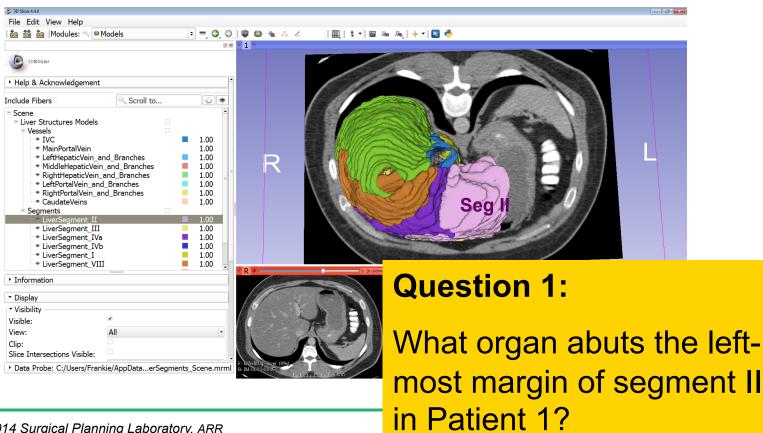
Position the mouse in the 3D Viewer, hold down the left mouse button and drag to orient the 3D model to a superior view.

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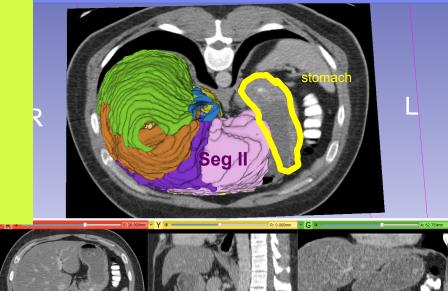
Question 1:

What organ abuts the leftmost margin of segment II in this patient?

Answer 1: Stomach

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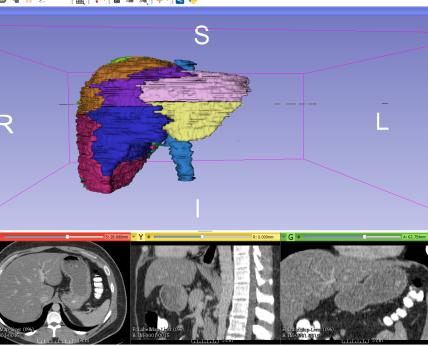
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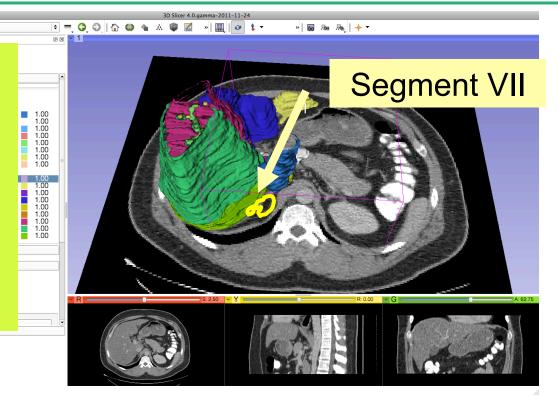
Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland ?



Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland ? Answer 2: <u>Segment VII</u>



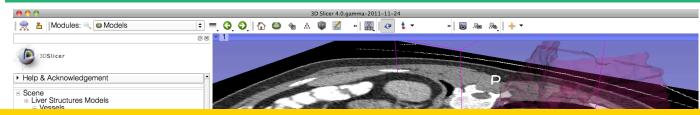
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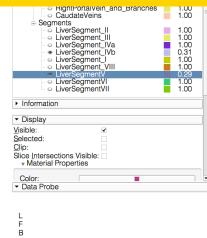
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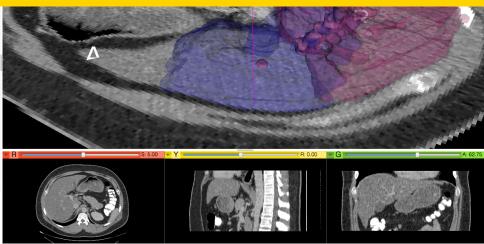


Closing the Liver Scene

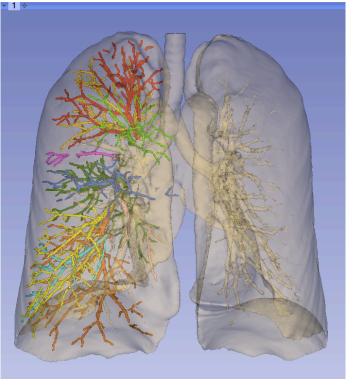


Select File → Close Scene and File→Exit



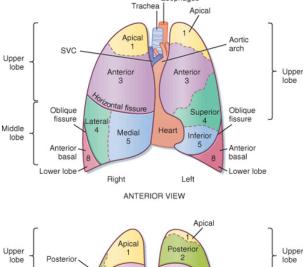






Part IIIb: Interactive 3D Visualization of the segments of the lungs

Bronchopulmonary Segments



Upper lobe Superior Superior Lower Lower Lateral Anterior Posterior lobe lobe basal basal basal Posterior Lateral 10 basal basal Left Right

POSTERIOR VIEW

Source: Koeppen & Stanton: Berne and Levy Physiology, 6th edition

Right Lung (10 segments) Right Upper Lobe (RUL)

- RUL Apical
- RUL Posterior
- RUL Anterior

Right Middle Lobe (RML)

- RML Lateral
- RML Medial

Right Lower Lobe (RLL)

- RLL Superior
- RLL Medial Basal
- RLL Anterior Basal
- RLL Lateral Basal
- RLL Posterior Basal

Left Lung (8 segments): Left Upper Lobe (LUL)

- LUL Apical Posterior
- LUL Anterior

Left Upper Lobe Lingula (LUL Lingula)

- LUL Superior Lingula
- LUL Inferior Lingula

Left Lower Lobe (LLL)

- LLL Superior
- LLL Anteromedial Basal
- LLL Lateral Basal
- LLL Posterior Basal

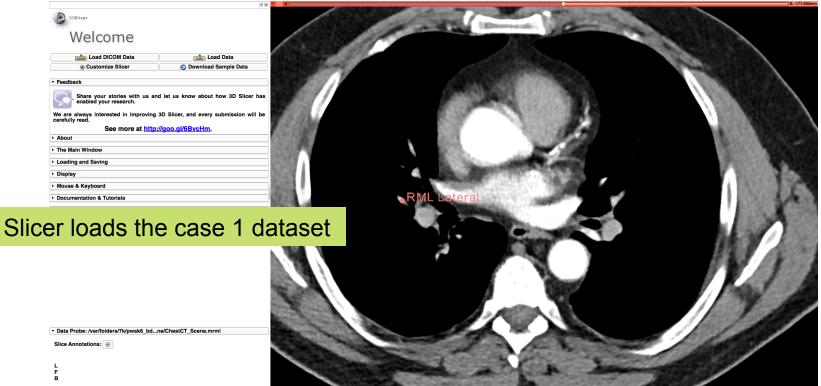
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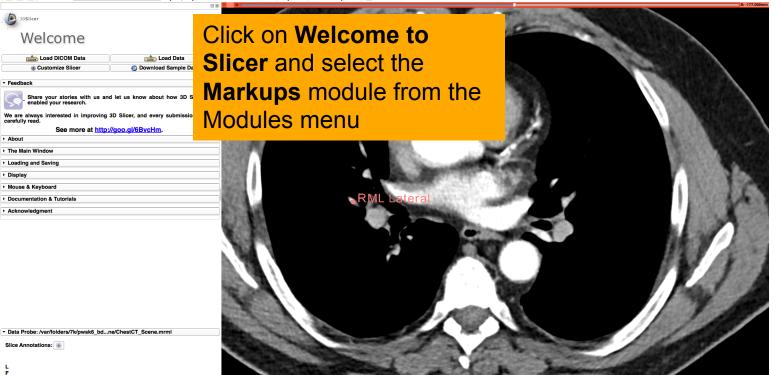
Select the subdirectory dataset4_Chest/case1

Drag and drop the file ChestCT_Scene.mrb into Slicer

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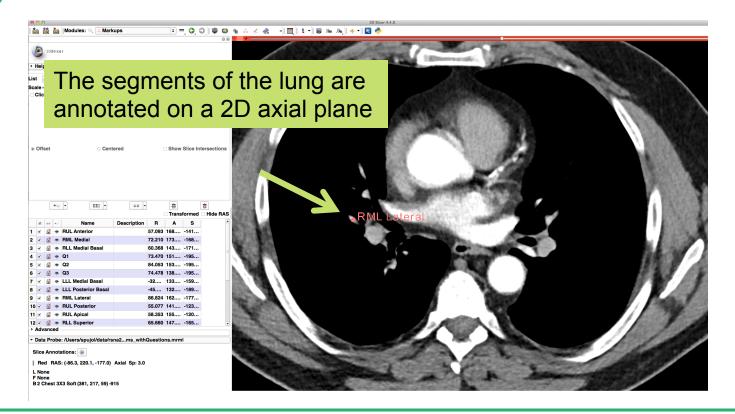
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Lung Segments: Answer 1

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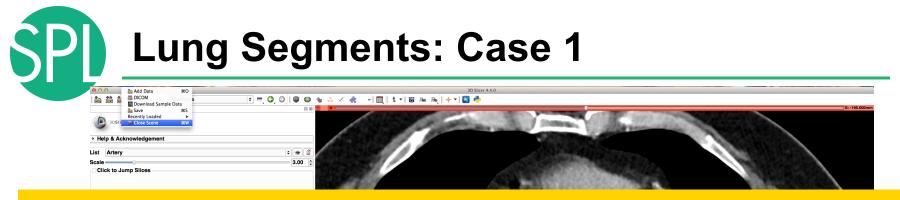
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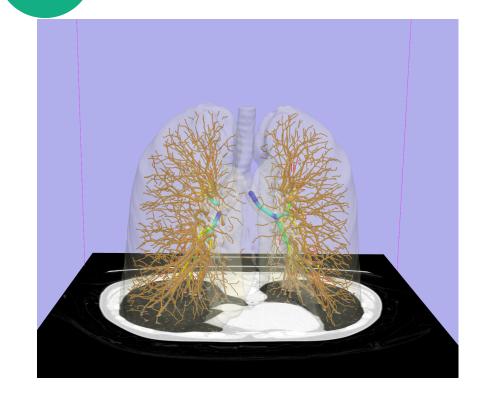


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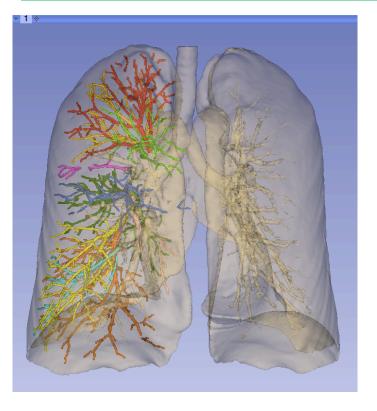






Segmentation and 3D surface reconstruction of the lung and pulmonary vessels from a Chest CT dataset

3D Segments of the lung

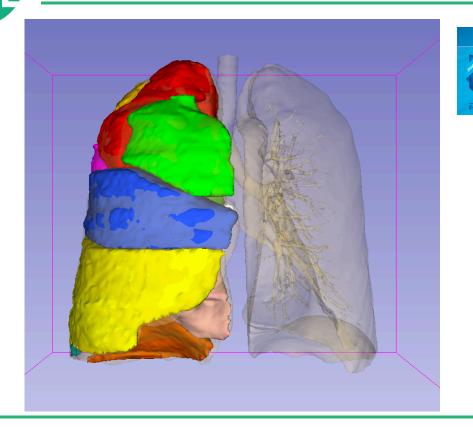


©2014 Surgical Planning Laboratory, ARR

3D parcellation of arteries and veins from original model of pulmonary vessels (Right Lobe)

- Upper Lobe (RUL)
 - RUL Pulmonary Vein
 - RUL Anterior Segment
 - RUL Apical Segment
 - RUL Posterior Segment
- Middle Lobe (RML)
 - RML Pulmonary Vein 1 & 2
 - RML Lateral Segment
 - RML Medial Segment
- Lower Lobe (RLL)
 - RLL Pulmonary Vein 1,2,3
 - RLL Anterior Basal Segment
 - RLL Medial Basal Segment
 - RLL Lateral Basal Segment
 - RLL Posterior Basal Segment

3D Segments of the lung



Educational research project supported by the RSNA Research & Education Foundation, through the Education Scholar Grant program

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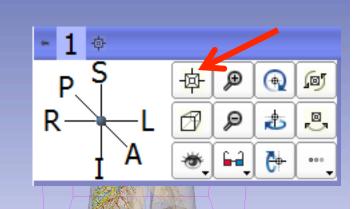
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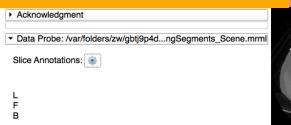
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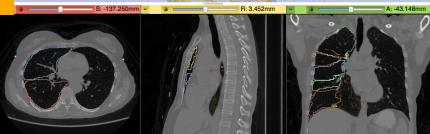
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Position the mouse over the blue banner in the 3D viewer window to display the 3DView controller, and **click on the top left icon** to center the 3D view on the scene









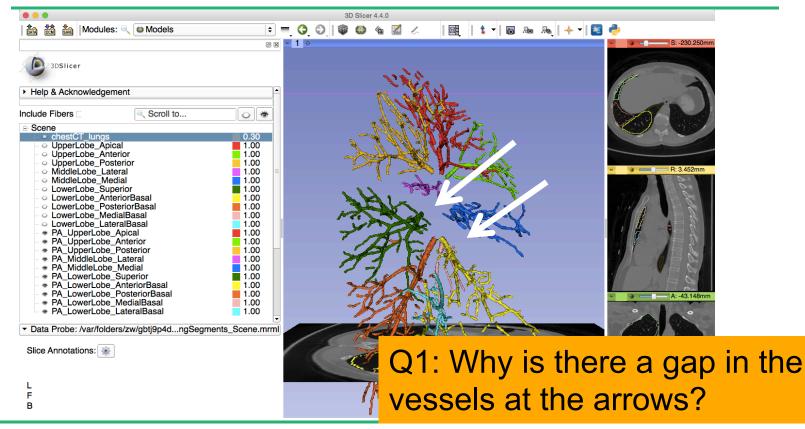
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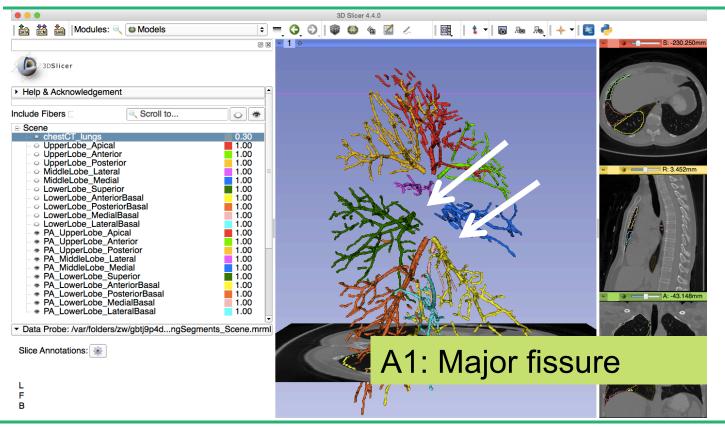
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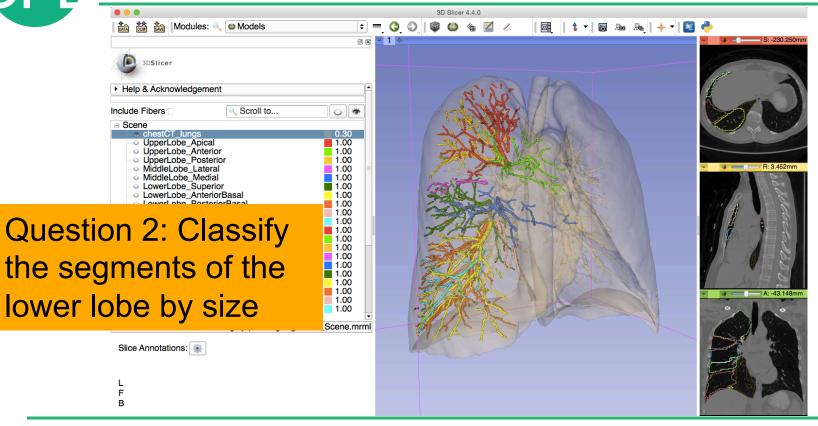
Lung Segments – Case 2: Question 1



Lung Segments – Answer 1



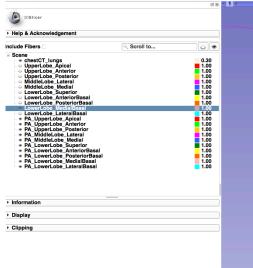
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Lung Segments – Answer 2

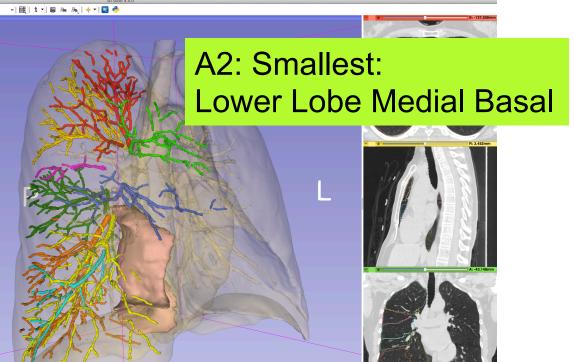
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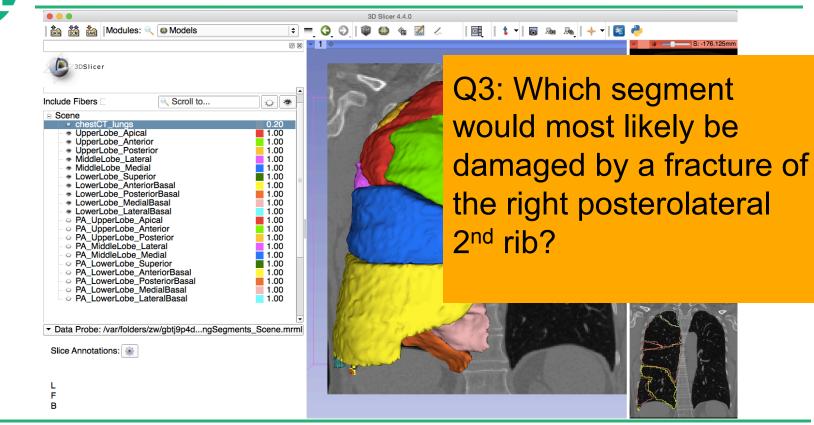
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Lung Segments – Answer 3

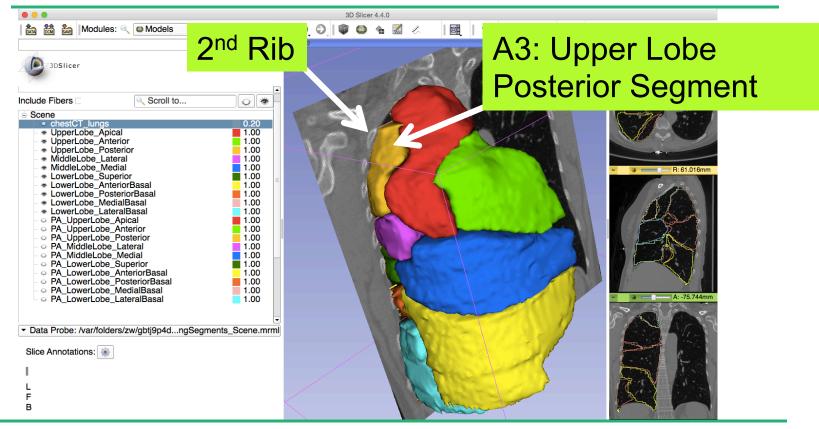
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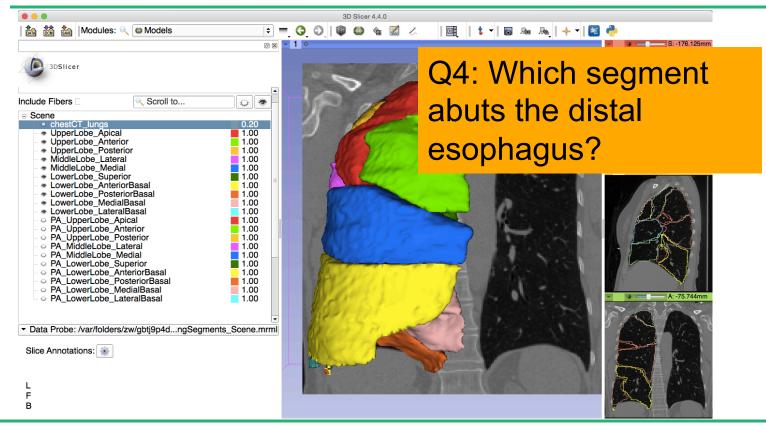
Lung Segments – Question 3



Lung Segments – Answer 3



Lung Segments – Question 4

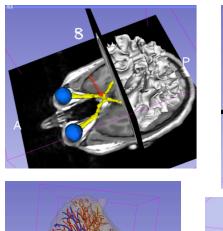


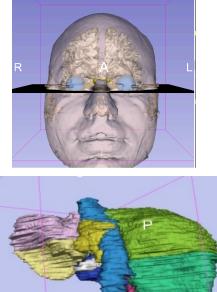
Lung Segments – Answer 5

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3D Visualization of DICOM images



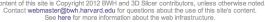


- Interactive user-interface to load and manipulate DICOM volumes, labelmaps and 3D models
- User-defined 3D view of the anatomy



www.slicer.org









Get Slicer 4.

Slicer 4 is the latest version of 3D Slicer, a free, comprehensive software platform for medical image analysis and visualization developed with NIH support. 3D Slicer is distributed under a permissive BSD-style open source license. It has a thriving user and developer community.

Pre-compiled binaries



3D Slicer at RSNA 2014

Quantitative Imaging Reading Room, Exhibit LL-QRR002

- Daily meet the experts session, 12:15-1:15 pm
- 3D Slicer: 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



Acknowledgments



RSNA Resarch and Education Foundation



National Alliance for Medical Image Computing (NA-MIC) (NIH Grant U54EB005149)



Neuroimage Analysis Center (NAC) (NIH Grant P41 RR013218)

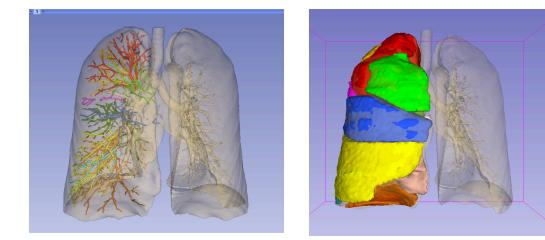
Marianna Jakab, Brigham and Women's Hospital (BWH) Franklin King, Queen's University, Kingston, Ontario Sidong Liu, University of Sydney Australia/BWH Ye Li, PLA General Hospital, Beijing/BHW



3DSlicer at RSNA

Sunday, November 30	Monday, December 1	Tuesday, December 2	Wednesday, December 3	Thursday, December 4	Friday, December 5
8:00am-12:30pm: 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. 8:30am-10:00am: RSNA Refresher Course: "Quantitative Medical Imaging for Clinical Research and Practice: Hands-on Workshop." & Sonia Pujol, Katarzyna Macura, Ron Kikinis Room S401CD. 12:15pm-1:16pm: Meet-The- Exhibit: Quantitative Imaging Reading Room. & Lakeside Learning Center Hall E, Exhibit LL-QRR3007 1:16pm-6:00pm: 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. 12:15pm-1:15pm: 3D Slicer Exhibit: Quantitative Imaging Reading Room. @ Lakeside Learning Center Hall E, Exhibit LL-QRR3007. 1:15pm-6:00pm: 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.
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Questions and comments:

Sonia Pujol, Ph.D spujol@bwh.harvard.edu