



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

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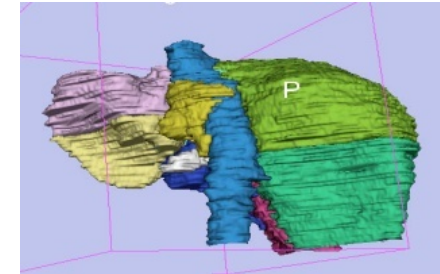
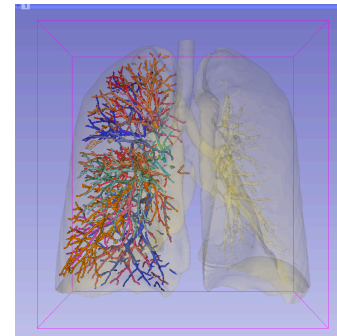
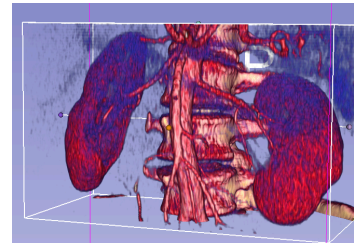
Kitt Shaffer, MD, PhD, Boston University
Vice-Chairman for Education, Boston University School of Medicine

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



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.

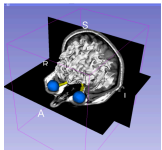
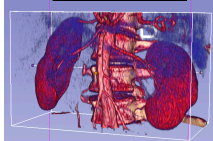




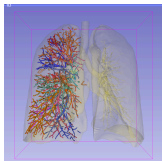
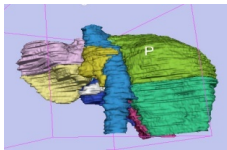
Overview



- Part I:** 3D Data Loading and visualization of DICOM images
- Volume Rendering of thoraco-abdominal CT data



- Part II:** 3D interactive exploration of the anatomy
- Exploration of the Segments of the liver
 - Exploration of the Segments of the lung

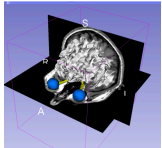
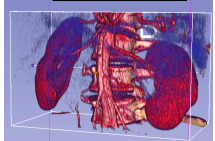




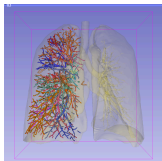
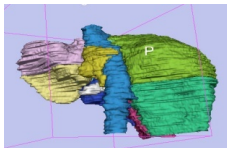
Overview



- Part I: 3D Data Loading and visualization of DICOM images**
- Volume Rendering of thoraco-abdominal CT data

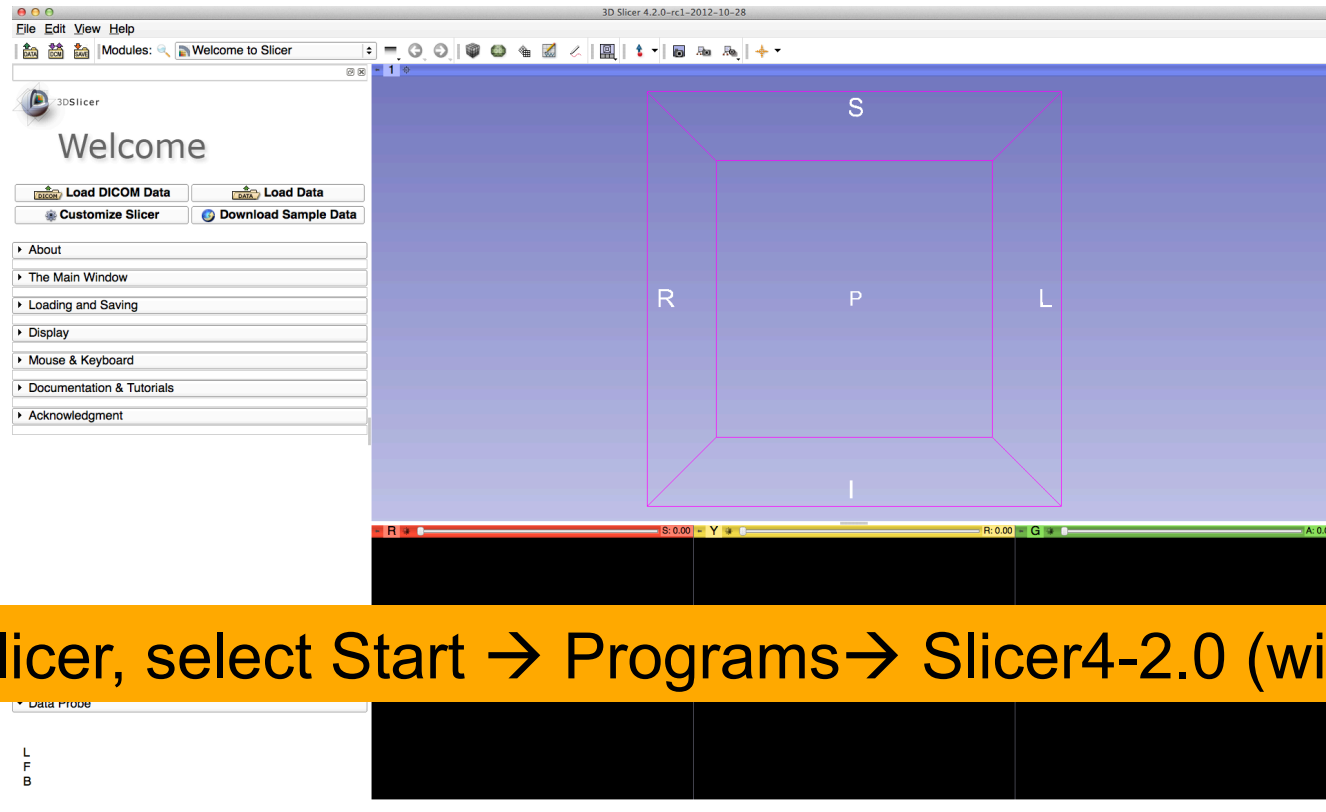


- Part II: 3D interactive exploration of the anatomy**
- Exploration of the Segments of the liver
 - Exploration of the Segments of the lung





Welcome to Slicer4



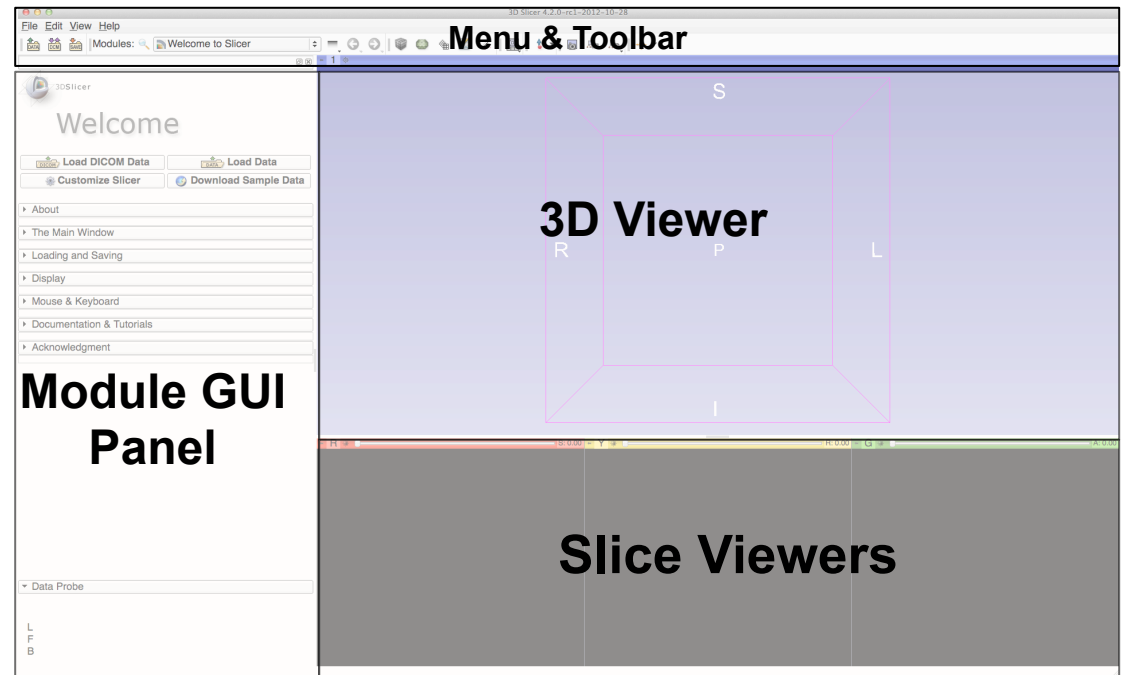
To start Slicer, select Start → Programs → Slicer4-2.0 (win64)



Navigating the Application GUI

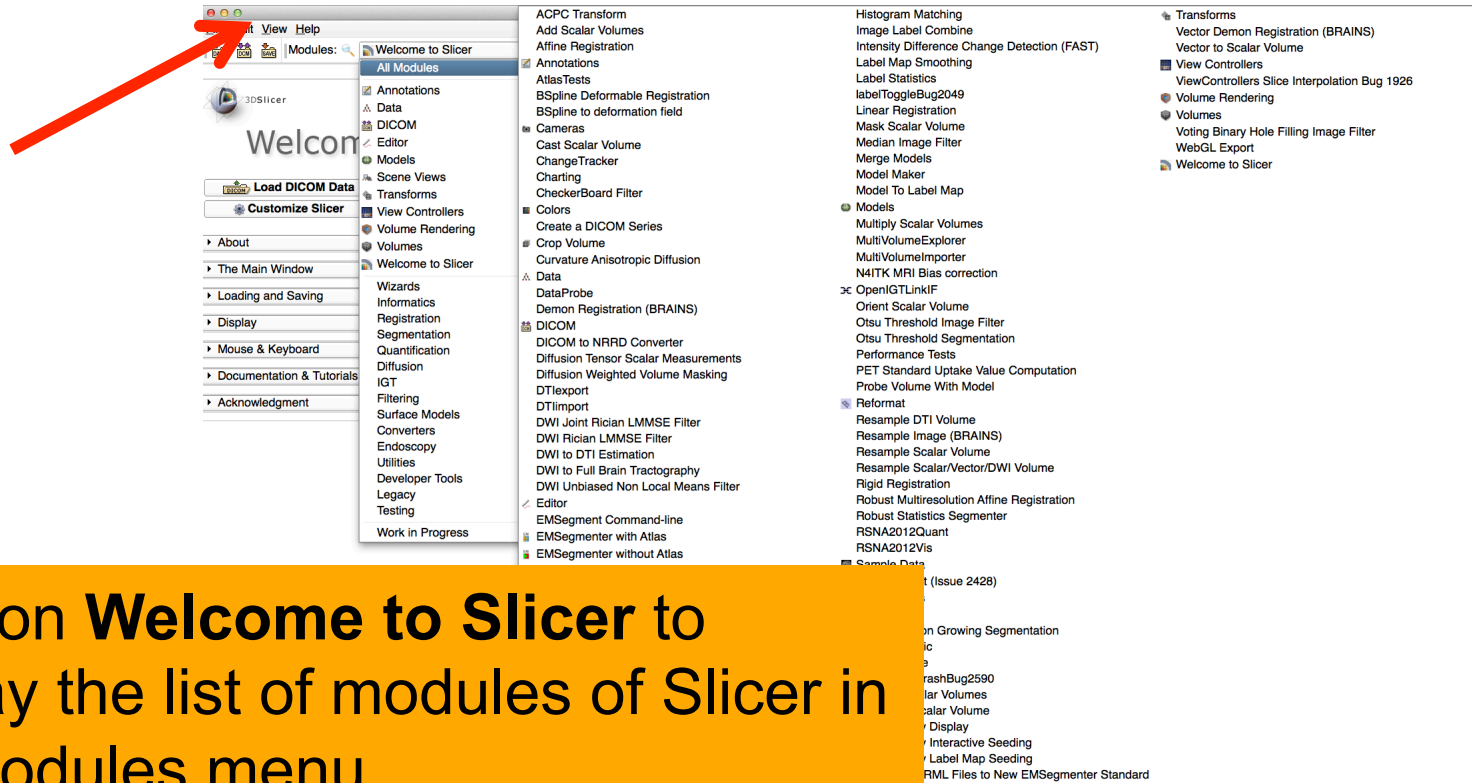
The Graphic User Interface (GUI) of Slicer4 integrates **four components**:

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





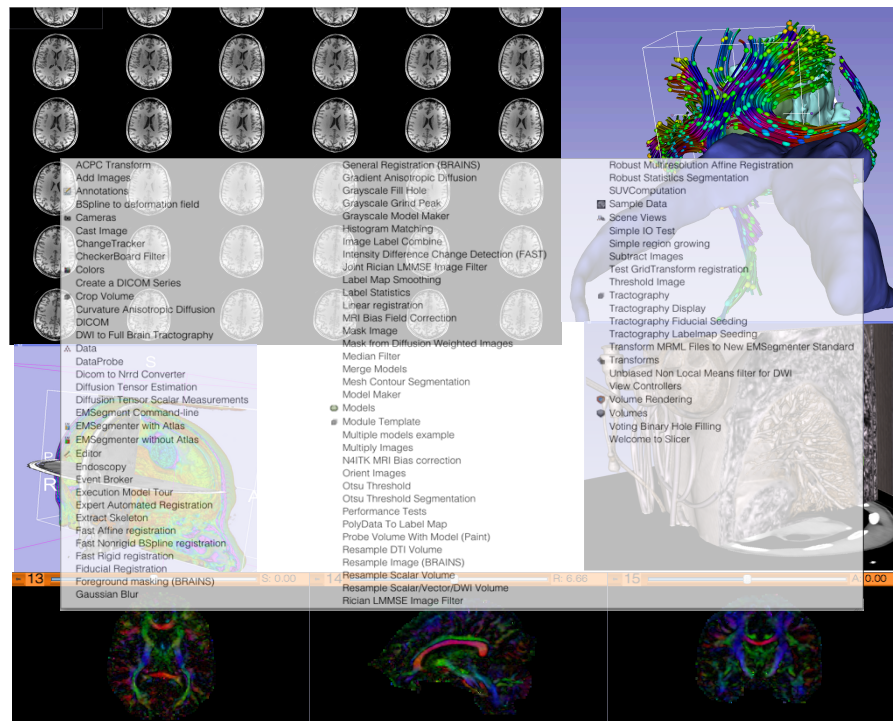
Welcome to Slicer4.2



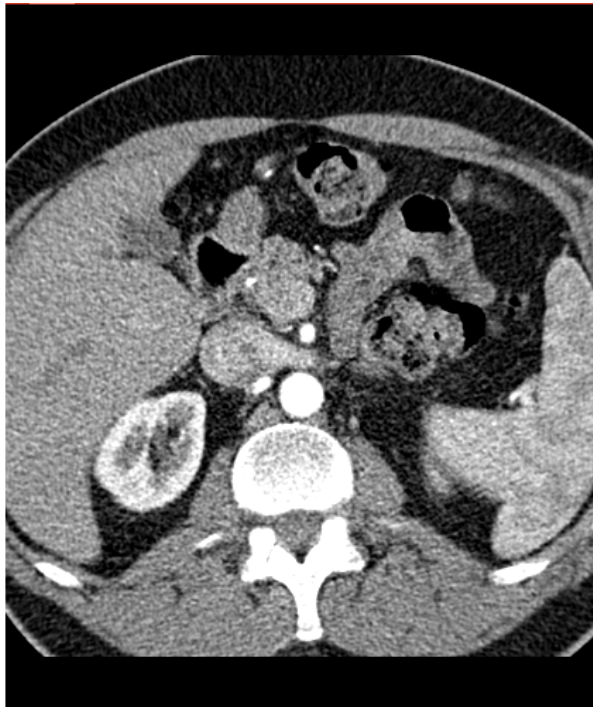
Click on **Welcome to Slicer** to display the list of modules of Slicer in the Modules menu



Welcome to Slicer4



Slicer4.2 contains more than 100 modules for image segmentation, registration and 3D visualization of medical imaging data

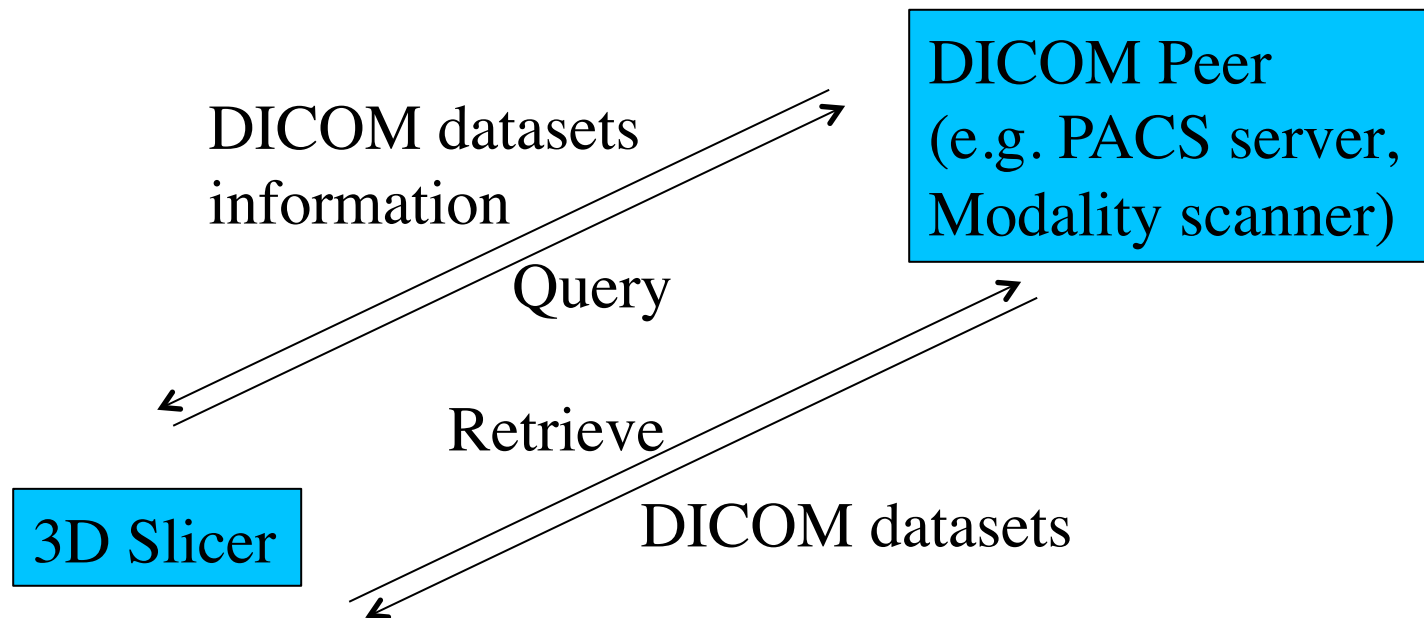


Part 1:

Retrieving a DICOM Volume
from a DICOM Peer

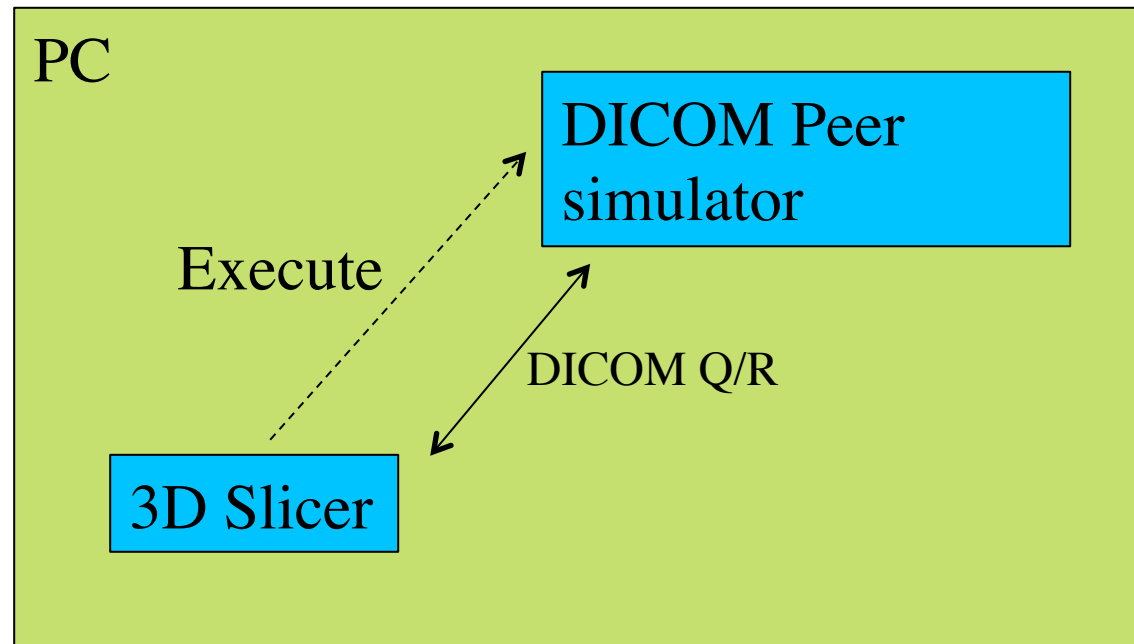


DICOM Query/Retrieve



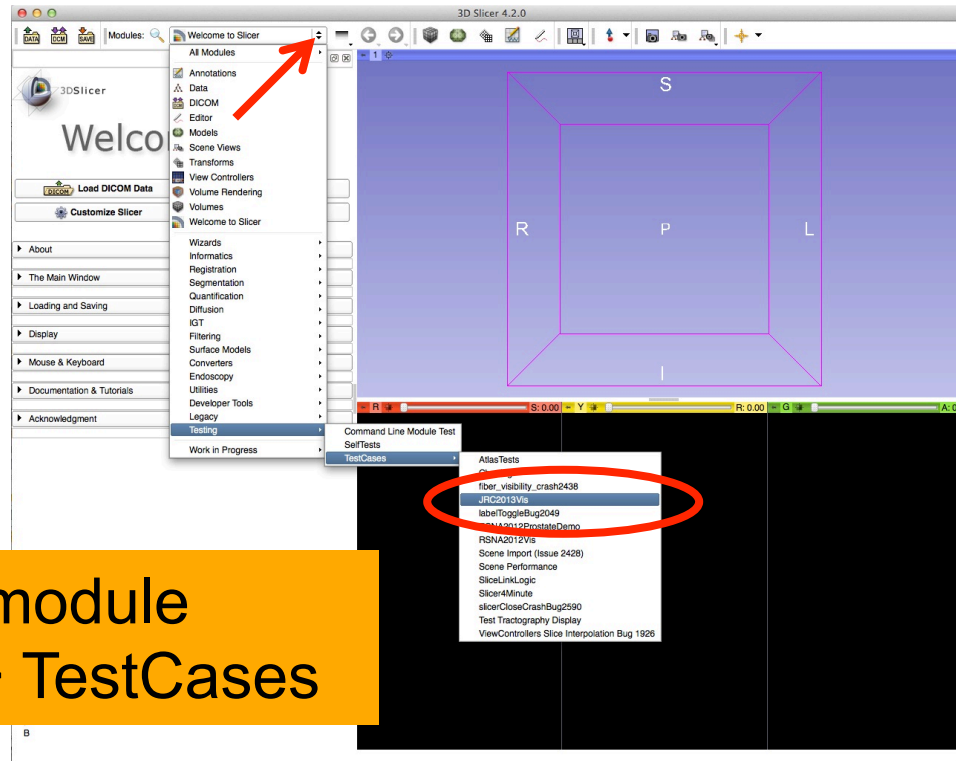


Using Local DICOM Peer Simulator





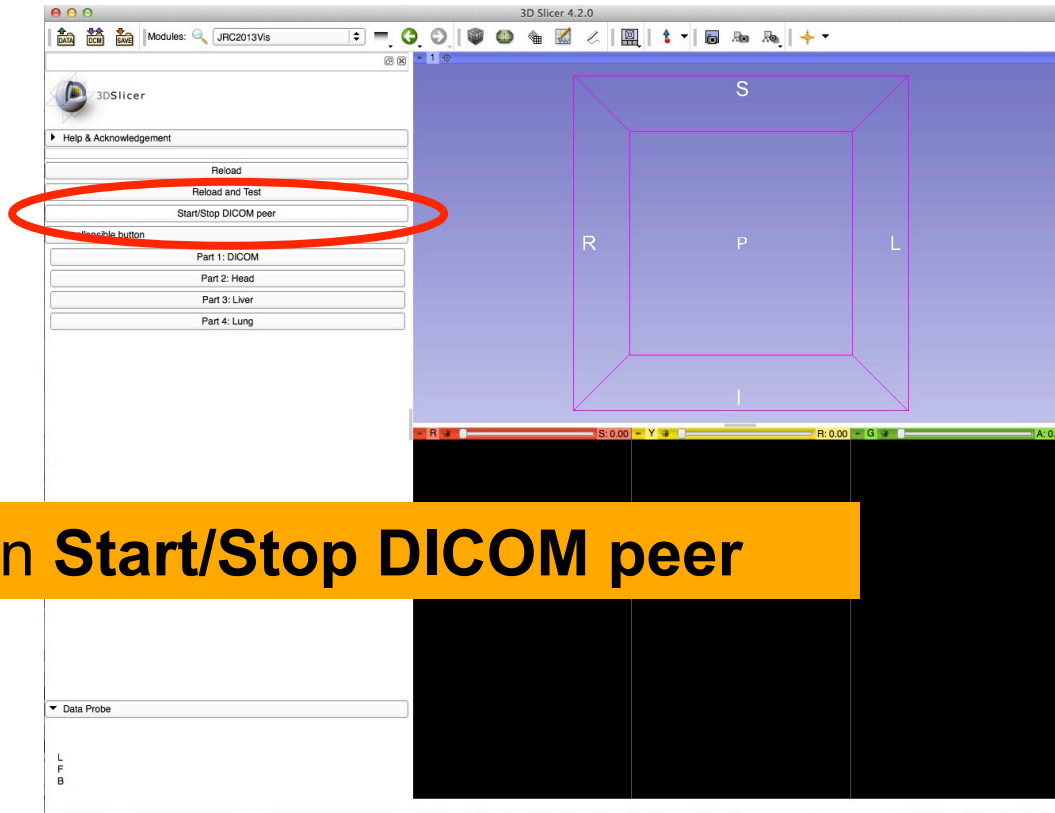
Start a DICOM Peer Simulator



Go to **JRC2013Vis** module
Module -> Testing -> TestCases



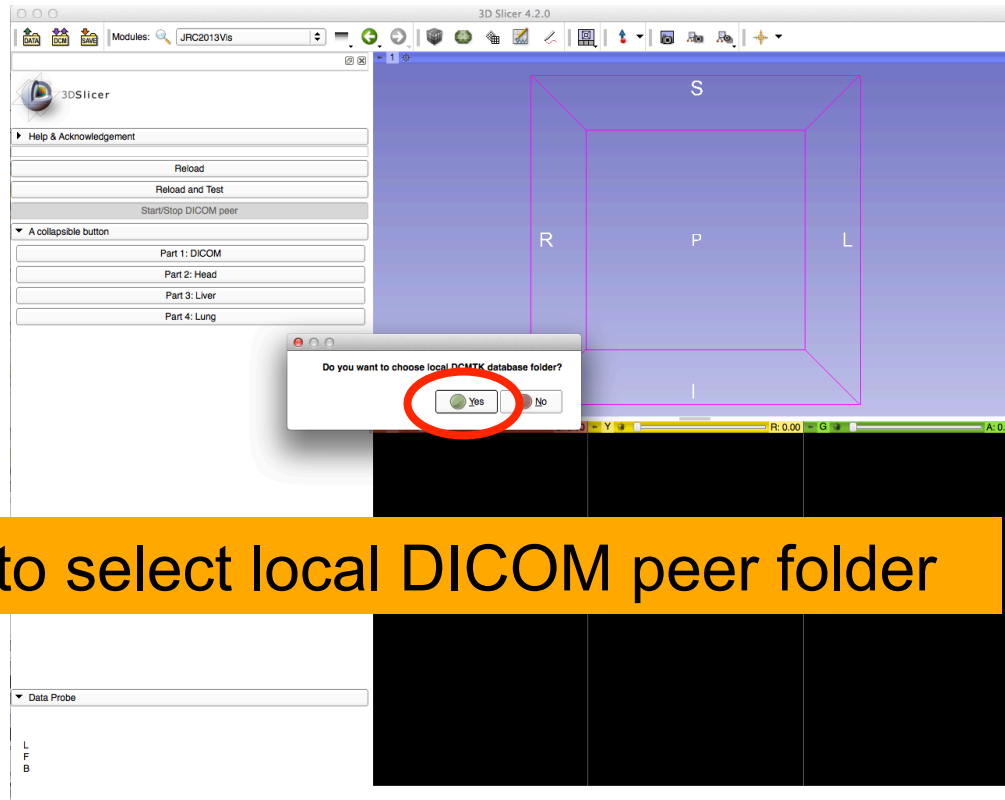
Start a DICOM Peer Simulator



Click on **Start/Stop DICOM peer**



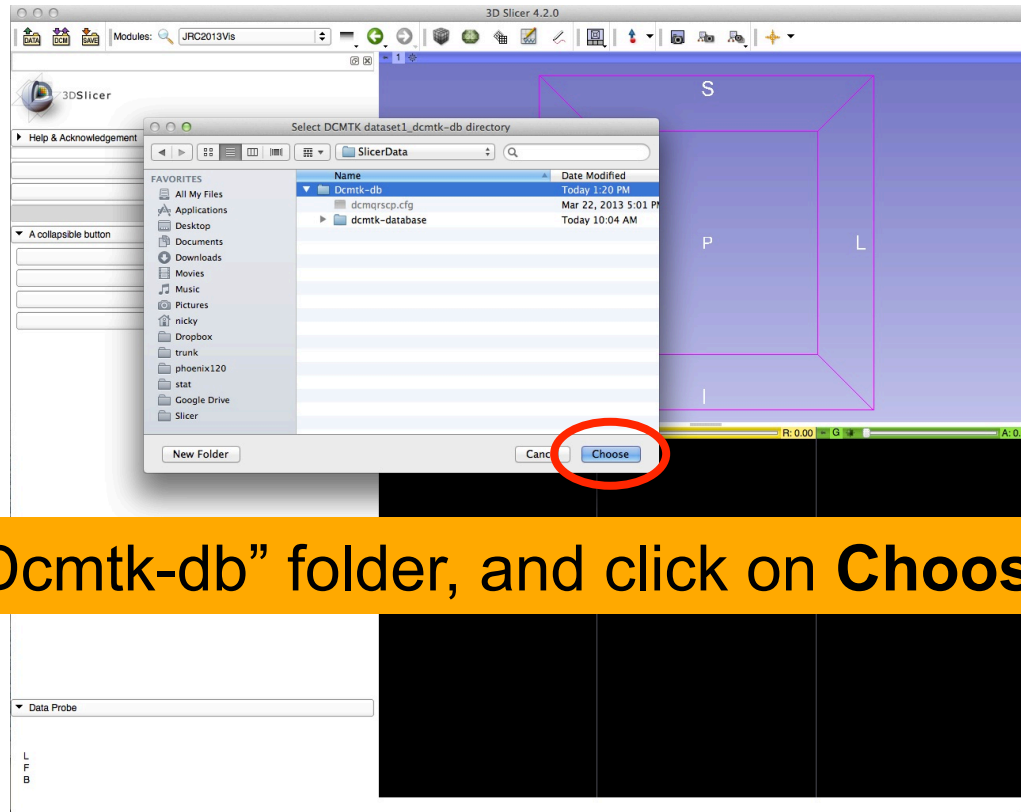
Start a DICOM Peer Simulator



Click **Yes** to select local DICOM peer folder



Start a DICOM Peer Simulator



Select "Dcmk-db" folder, and click on **Choose**

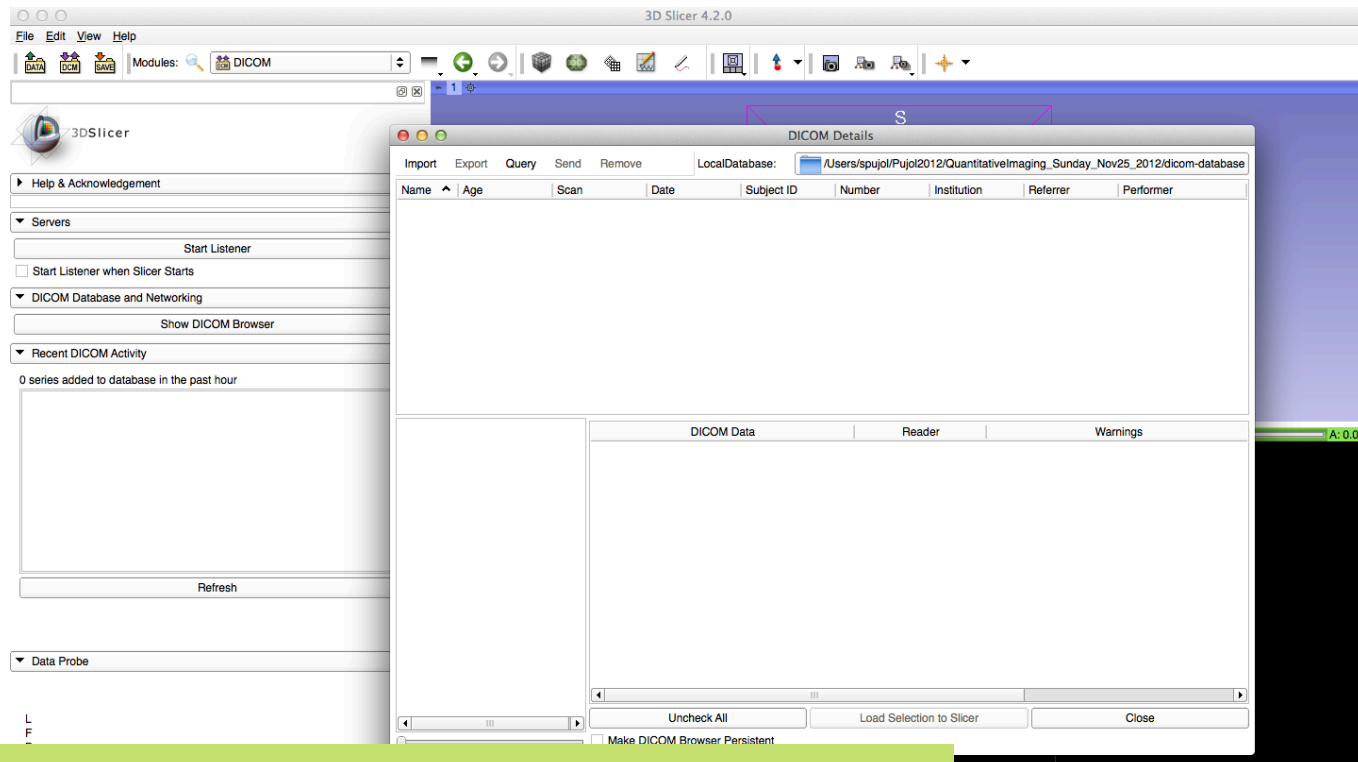


Loading a DICOM volume

The screenshot shows the 3D Slicer software interface. The title bar reads "3D Slicer 4.2.0-rc1-2012-10-28". The menu bar includes "File", "Edit", "View", and "Help". The "Modules" dropdown menu is set to "Welcome to Slicer". The main window is titled "1". On the left, the "Welcome" panel is visible, featuring a red circle around the "Load DICOM Data" button. Other buttons in the panel include "Load Data", "Customize Slicer", and "Download Sample Data". Below these are several expandable sections: "About", "The Main Window", "Loading and Saving", "Display", "Mouse & Keyboard", "Documentation & Tutorials", and "Acknowledgment". At the bottom of the panel, there is a "Data Probe" section with "L", "F", and "B" options, and a "None RAS: (125.0, -125.0, 1.0)" label. The main 3D view area is currently empty, with a coordinate system at the bottom showing "R", "Y", "G", and "A" axes with values "S: 0.00", "R: 0.00", and "A: 0.00". A large yellow text box is overlaid on the 3D view area, containing the instruction: "Click on **Load DICOM Data** in the panel of the Welcome to Slicer module".



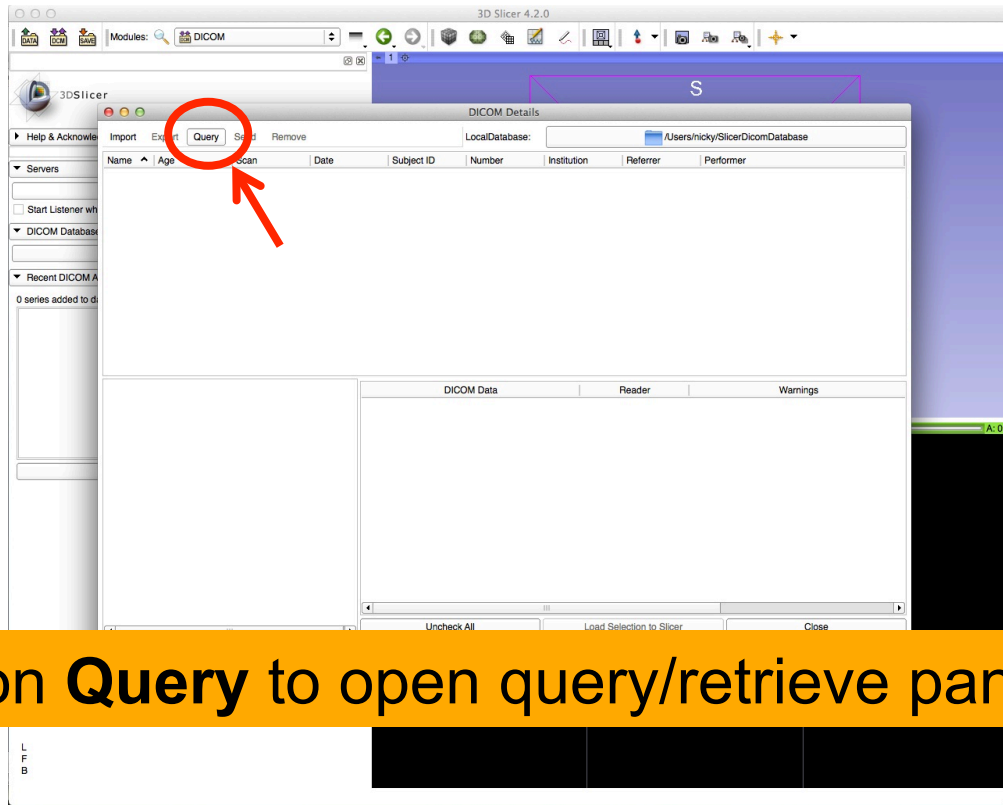
Show DICOM browser window



The GUI of the DICOM browser window appears



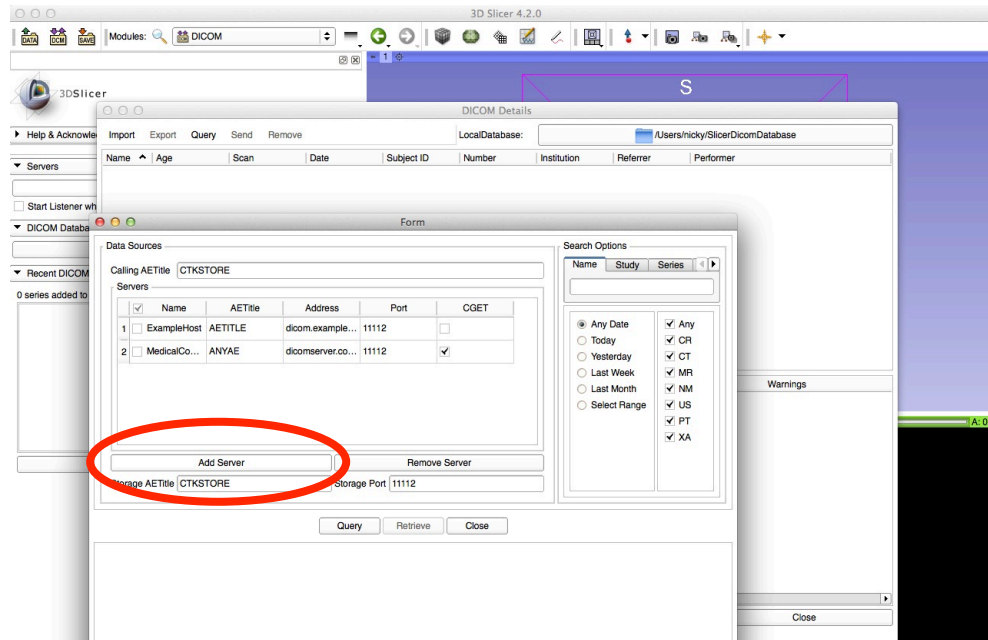
Show query/retrieve panel



Click on **Query** to open query/retrieve panel



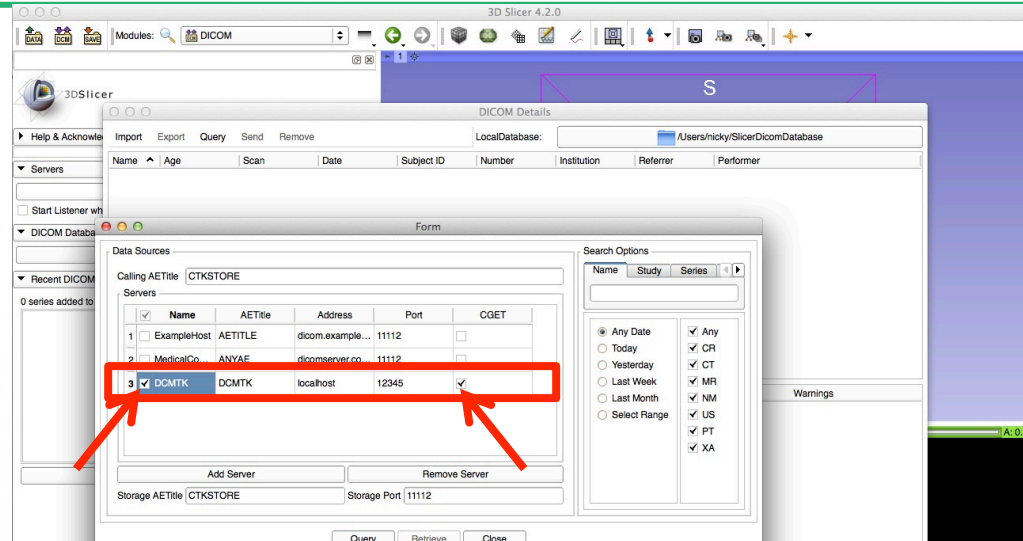
Add a DICOM peer



Click on **Add Server** to add a DICOM peer



Add a DICOM peer



Fill DICOM peer info:

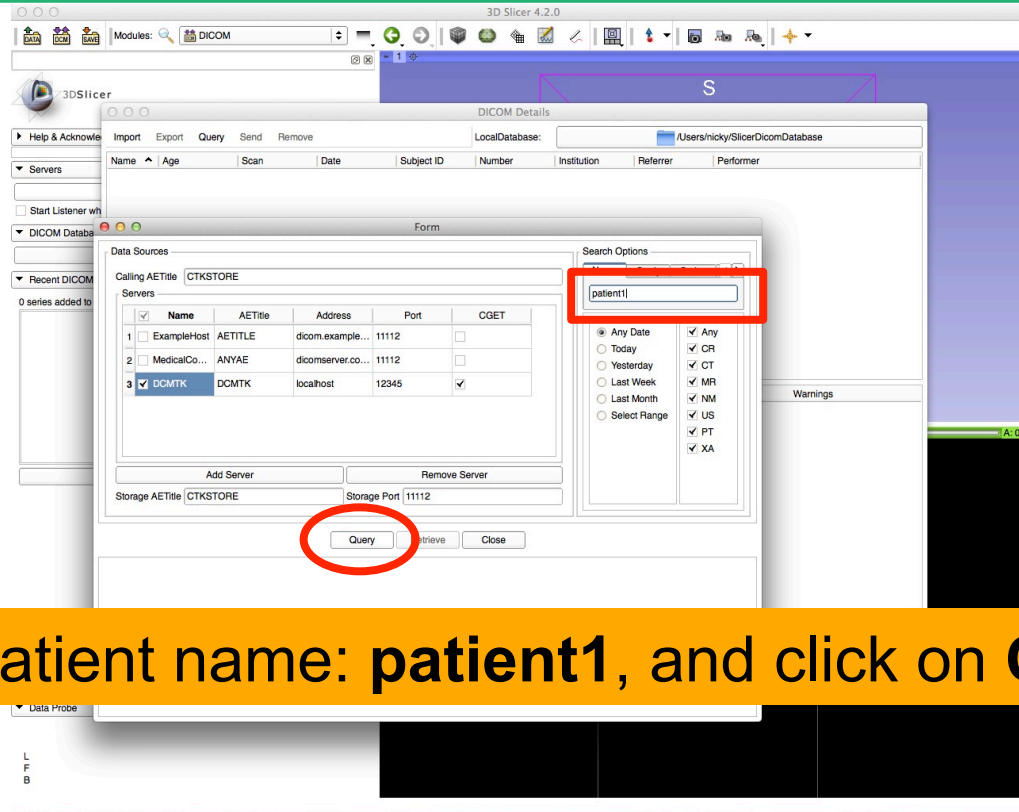
Name: **DCMTK**, AETitle: **DCMTK**, Address: **localhost**, Port: **12345**

Check to **enable CGET**

Check to **activate**



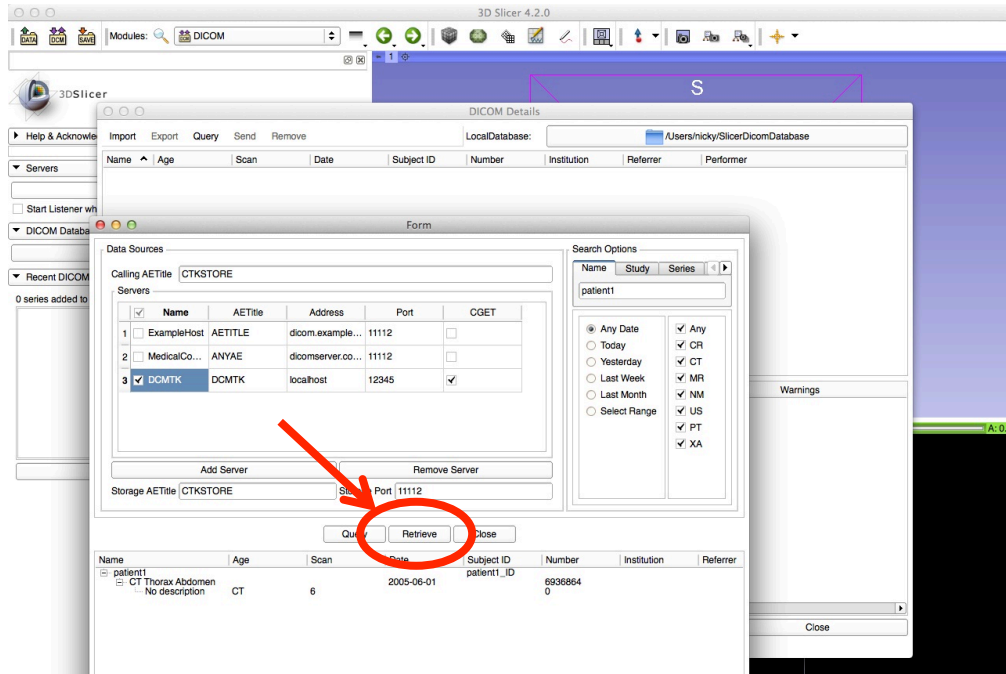
Query DICOM volumes



Type patient name: **patient1**, and click on **Query**



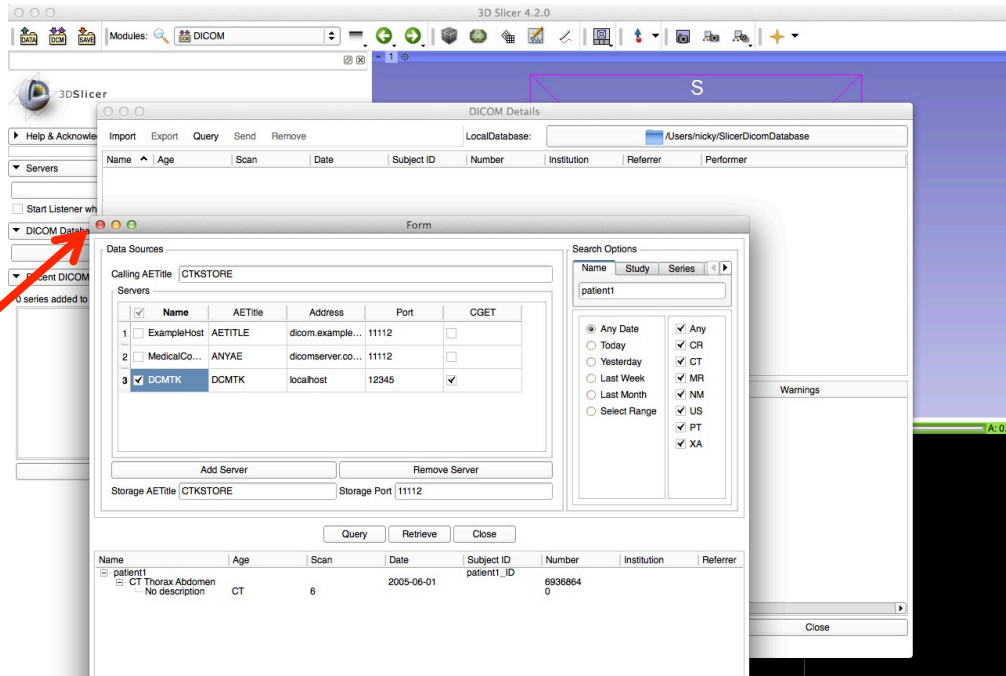
Retrieve DICOM volumes



Click on **Retrieve** to retrieve DICOM volume



Close query/retrieve panel



Click on close button to close query/retrieve panel



Loading a DICOM volume

The screenshot shows a DICOM browser window titled 'DICOM Details'. The window has a menu bar with 'Import', 'Export', 'Query', 'Send', and 'Remove'. Below the menu bar is a text field for 'LocalData:' containing the path '/Users/spujol/workshop/RSNA2012/data/DICOM-database'. The main area is a table with columns: Name, Age, Scan, Date, Subject | Number, Institution, Referrer, and Performer. The table contains the following data:

Name	Age	Scan	Date	Subject Number	Institution	Referrer	Performer
patient1				patien...			
CT Thorax Abdomen			2005-...	6936864	oEfZQ...		
CT_Thorax_Abdomen CT		6	2005-...	HEART	14		

A red arrow points to the 'CT_Thorax_Abdomen CT' entry. Below the table is a scroll bar. At the bottom of the window, there are three tabs: 'DICOM Data', 'Reader', and 'Warnings'. Below the tabs are three buttons: 'Uncheck All', 'Load Selection to Slicer', and 'Close'. At the very bottom, there is a checkbox labeled 'Make DICOM Browser Persistent'.

The patient1 DICOM dataset appears in the DICOM browser. Click on 'patient1' to display the file hierarchy, select the DICOM volume **CT_Thorax_Abdomen_CT**



Loading a DICOM volume

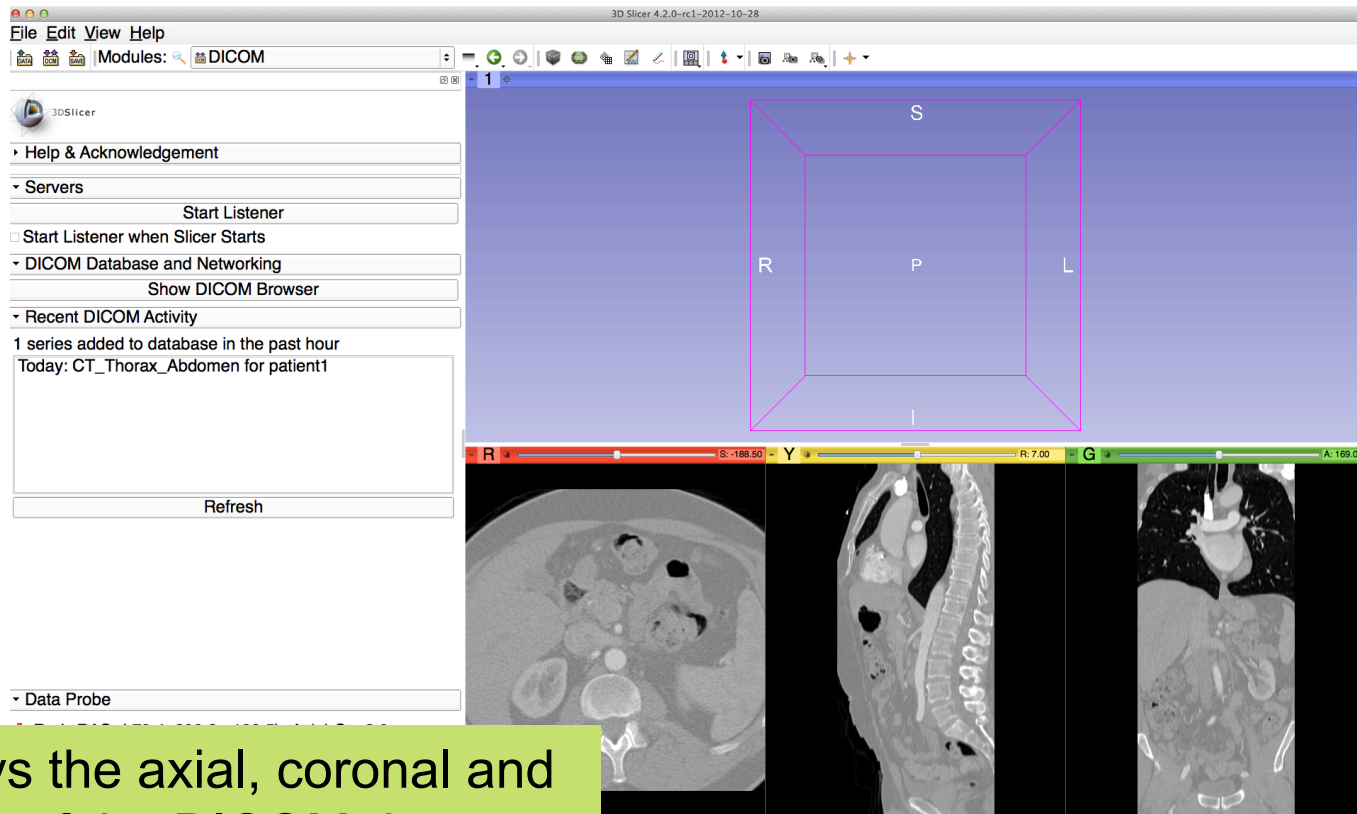
The screenshot shows the Slicer DICOM browser interface. At the top, there is a menu bar with 'Import', 'Export', 'Query', 'Send', and 'Remove'. Below the menu is a table with columns: Name, Age, Scan, Date, Subject I Number, Institution, Referrer, and Performer. The table contains one main entry for 'patient1' with a sub-entry for 'CT_Thorax_Abdomen CT'. Below the table is a grid of 20 image thumbnails labeled 'Image 0' through 'Image 19'. A red arrow points to the 'Image 1' thumbnail. To the right of the image grid is a 'DICOM Data' panel with columns for 'DICOM Data', 'Header', and 'Warnings'. The 'DICOM Data' column contains multiple entries for '6: CT_Thorax_Abdo...'. At the bottom of the DICOM Data panel are buttons for 'Uncheck All', 'Load Selection to Slicer', and 'Close'. Below these buttons is a checkbox labeled 'Make DICOM Browser Persistent'.

Click to expand the DICOM Browser window.

Slicer displays the snapshots of the DICOM images of the **CT_Thorax_Abdomen_CT** dataset



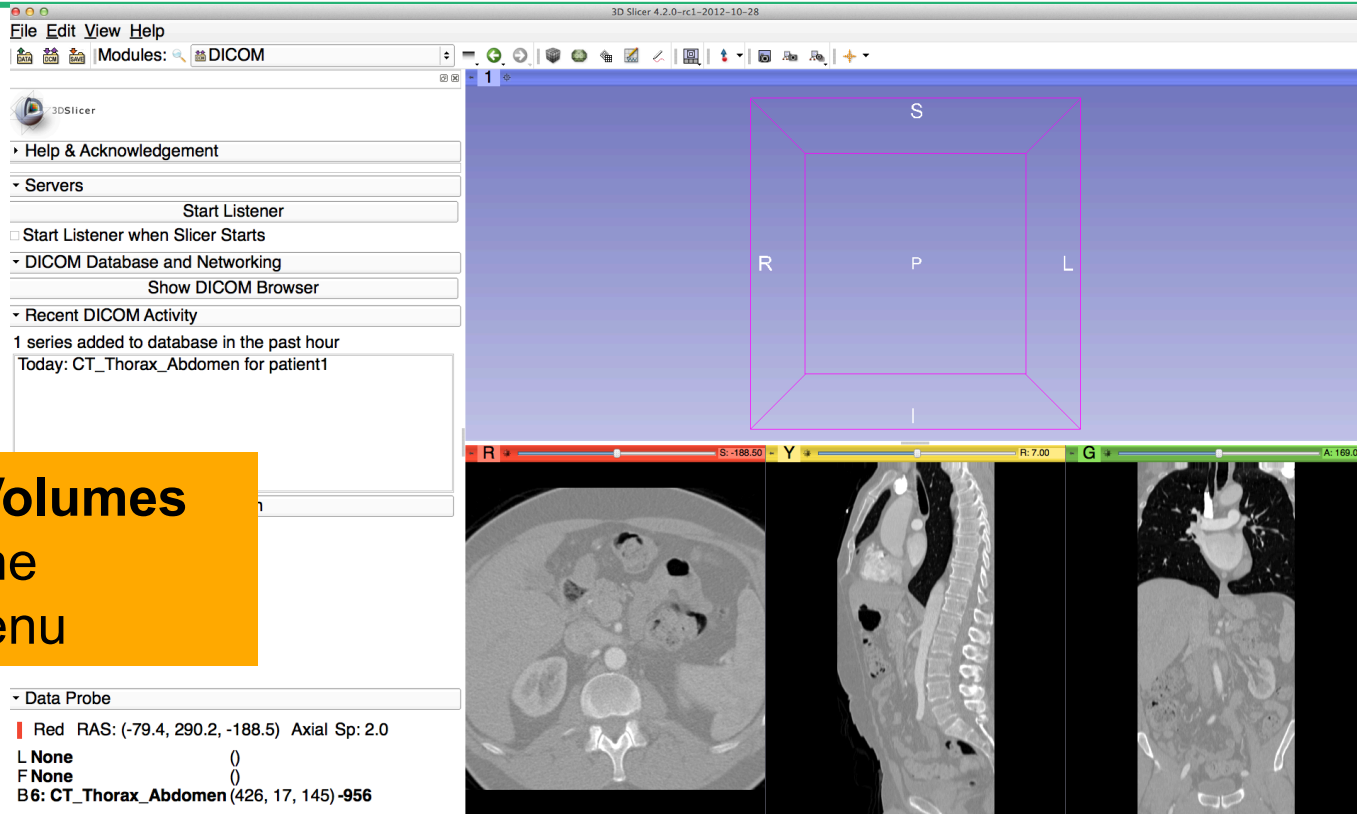
Loading a DICOM volume



Slicer displays the axial, coronal and sagittal slices of the DICOM dataset



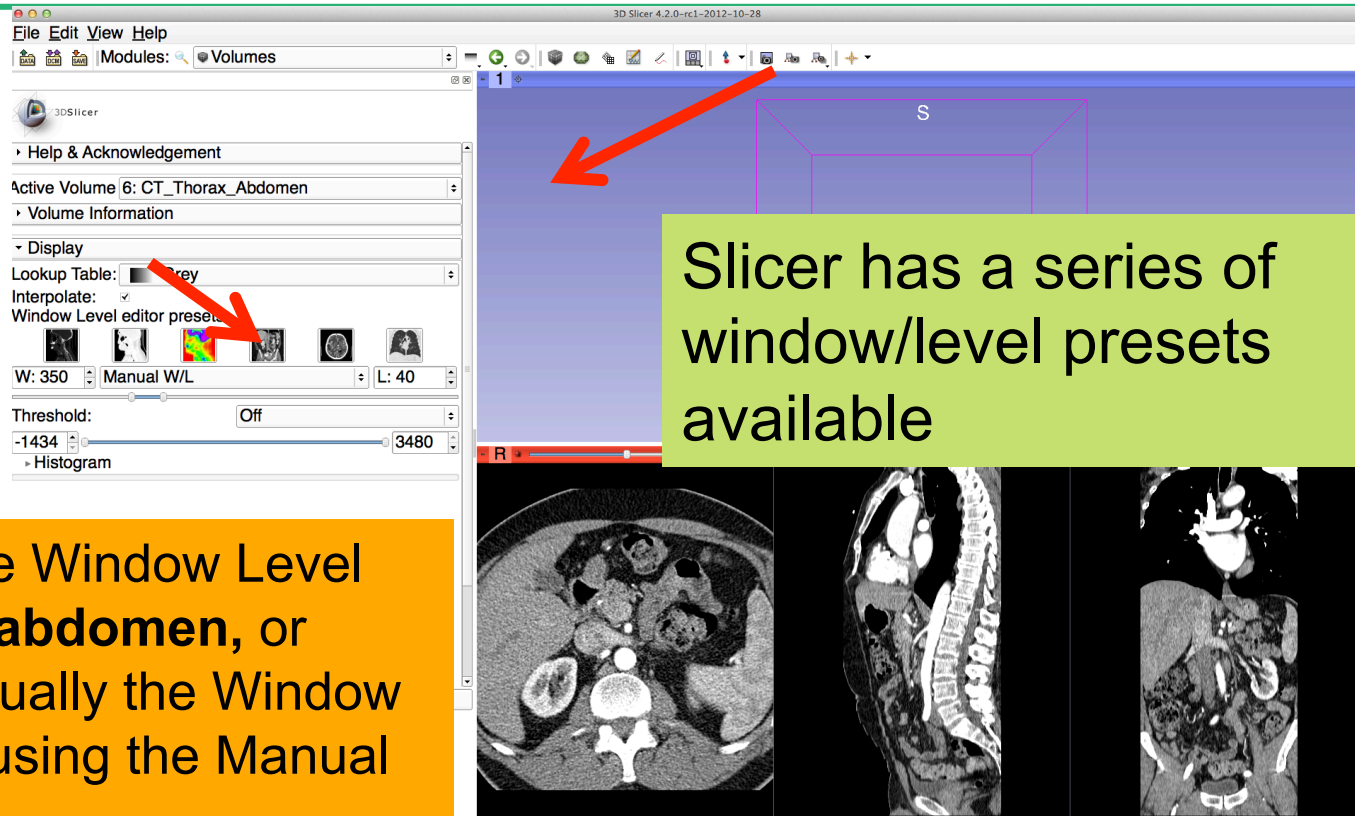
Loading a DICOM volume



Select the **Volumes** module in the modules menu



Loading a DICOM volume




Slicer has a series of window/level presets available

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

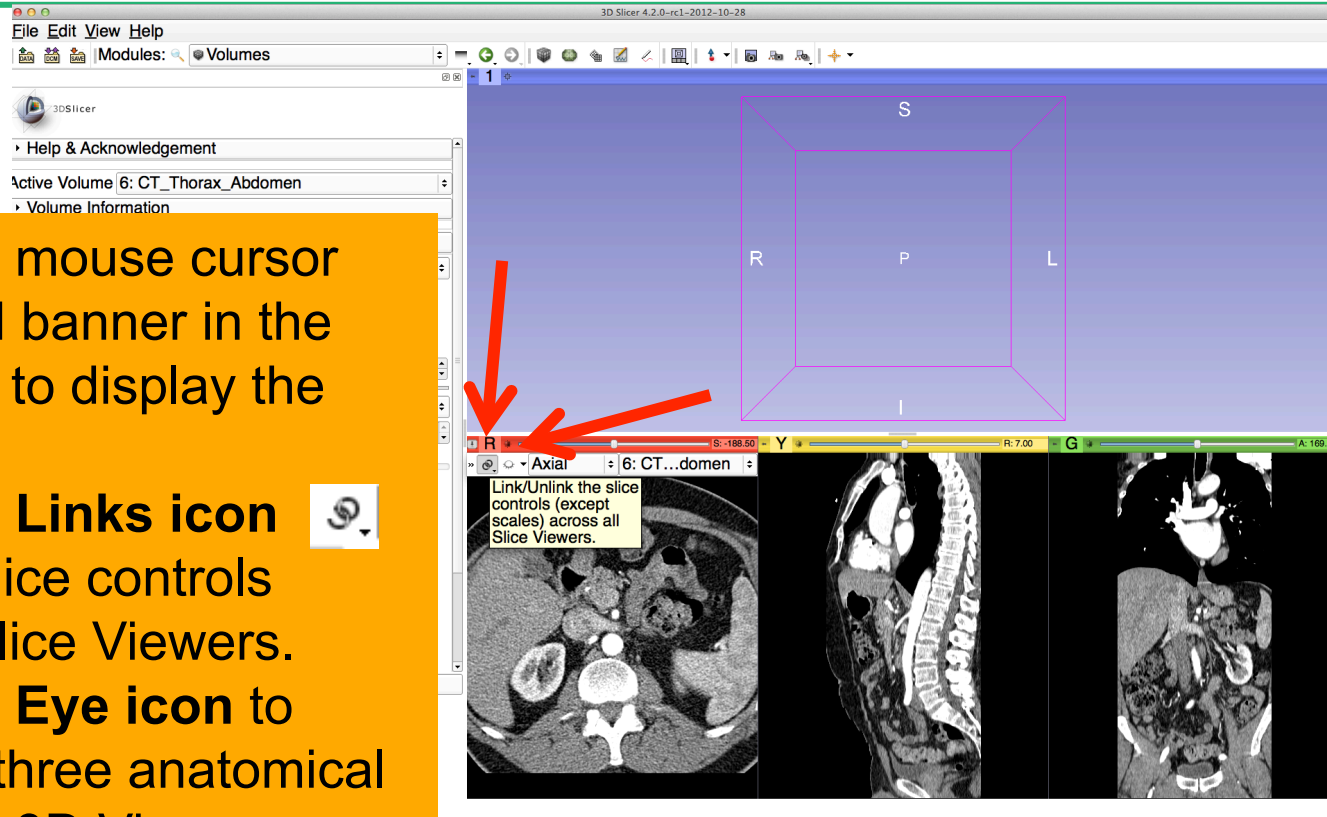


Loading a DICOM volume

Position the mouse cursor over the red banner in the Red Viewer to display the slice menu.

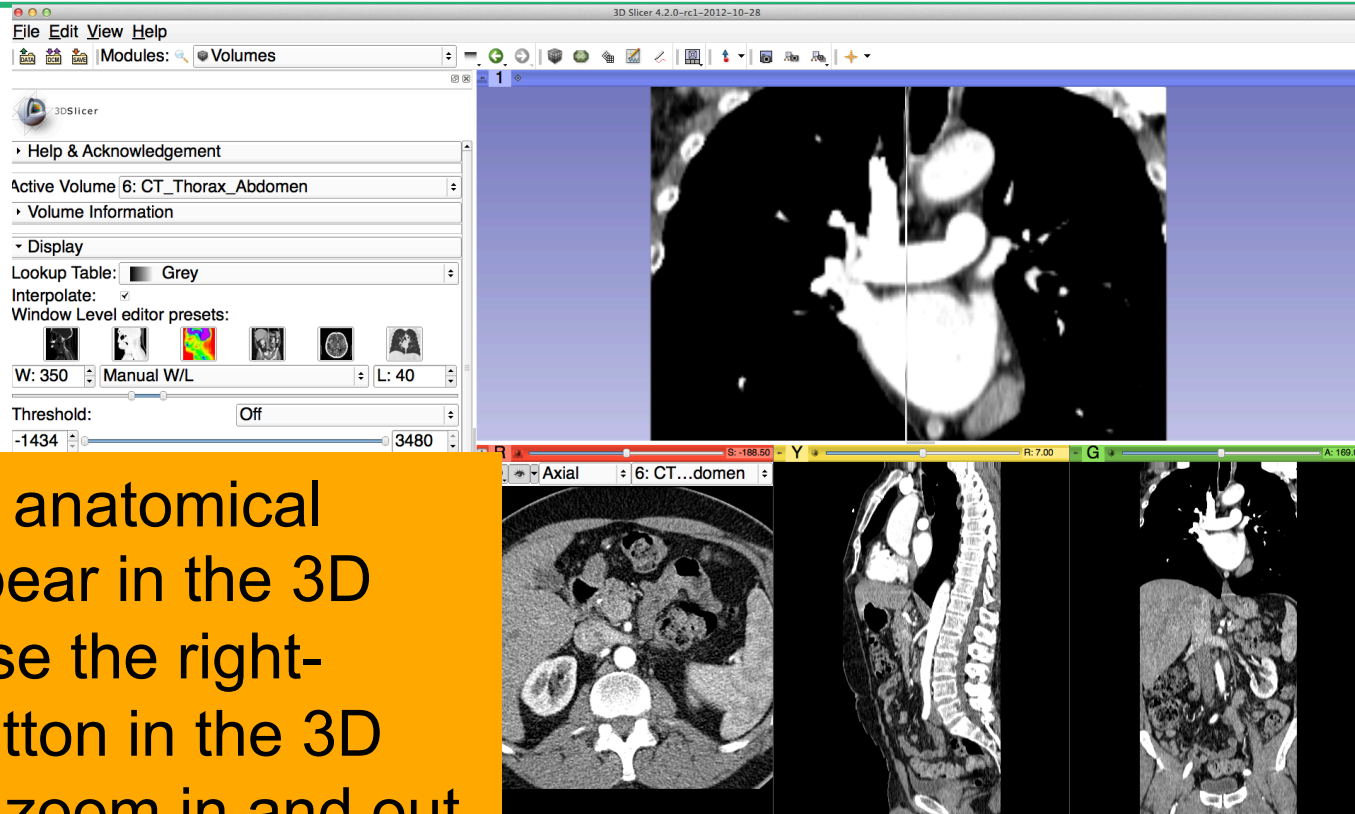
Click on the **Links icon**  to link the slice controls across all Slice Viewers.

Click on the **Eye icon** to display the three anatomical slices in the 3D Viewer





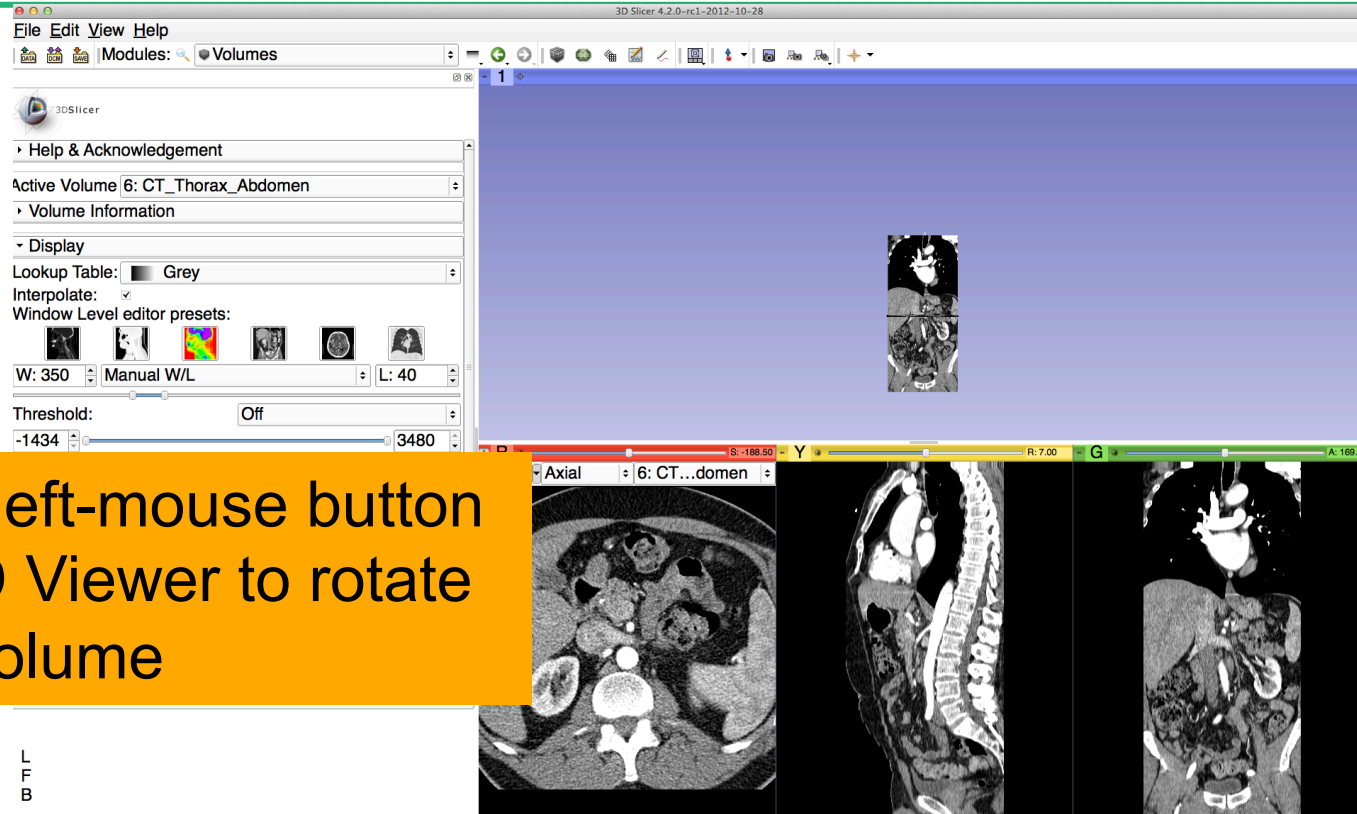
Loading a DICOM volume



The three anatomical slices appear in the 3D viewer. Use the right-mouse button in the 3D Viewer to zoom in and out



Loading a DICOM volume



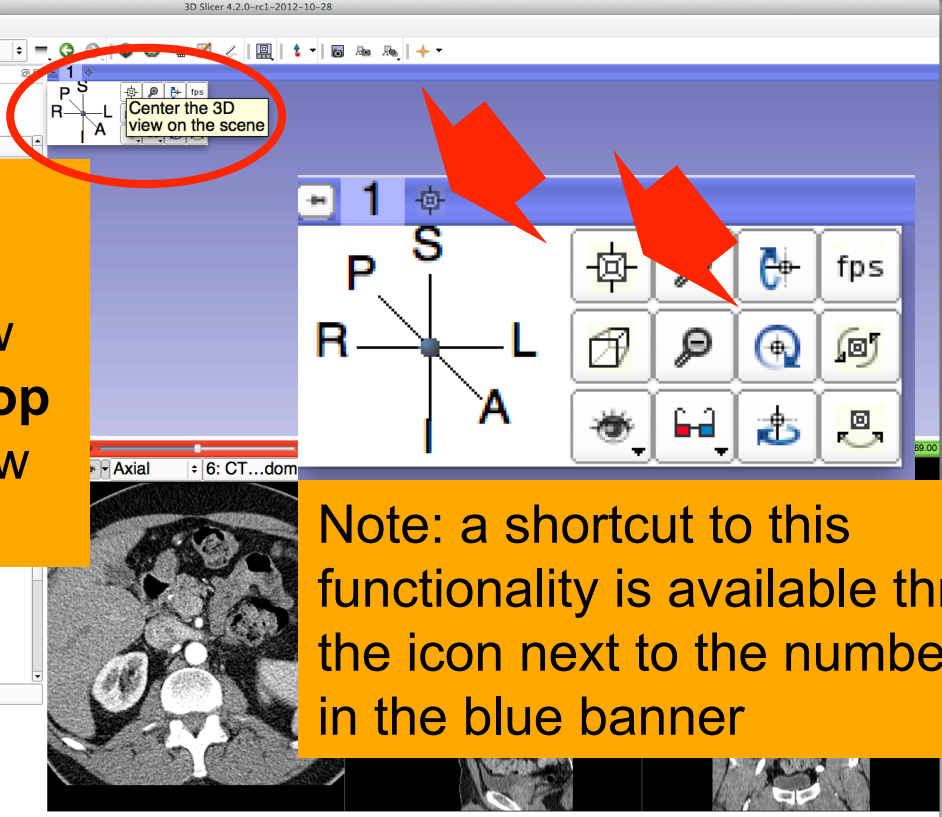
Use the left-mouse button in the 3D Viewer to rotate the 3D volume

L
F
B



Loading a DICOM volume

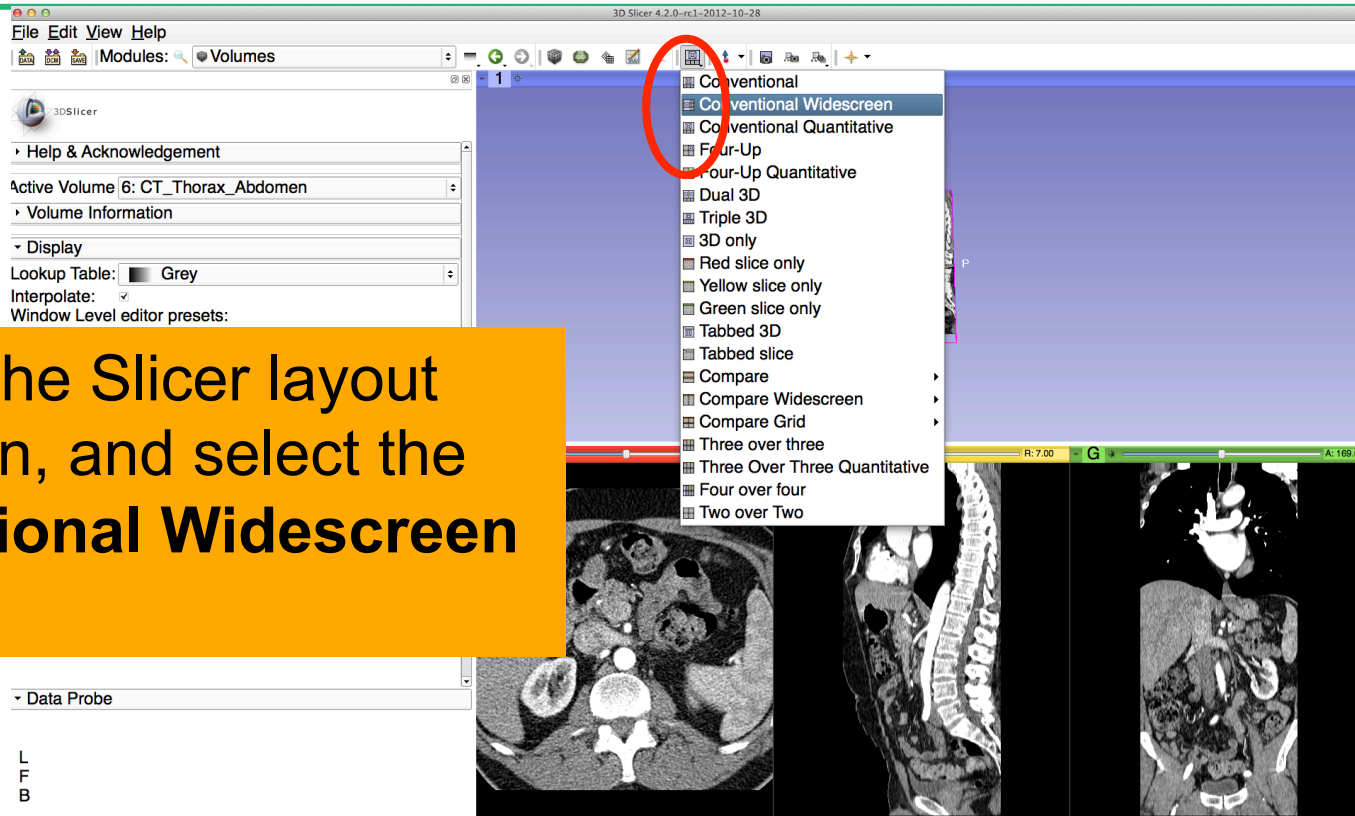
Position the mouse over the blue banner in the 3D viewer window to display the 3DView controller, and **click on the top left icon** to center the 3D view on the scene



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



Loading a DICOM volume



Click on the Slicer layout menu icon, and select the **Conventional Widescreen** layout

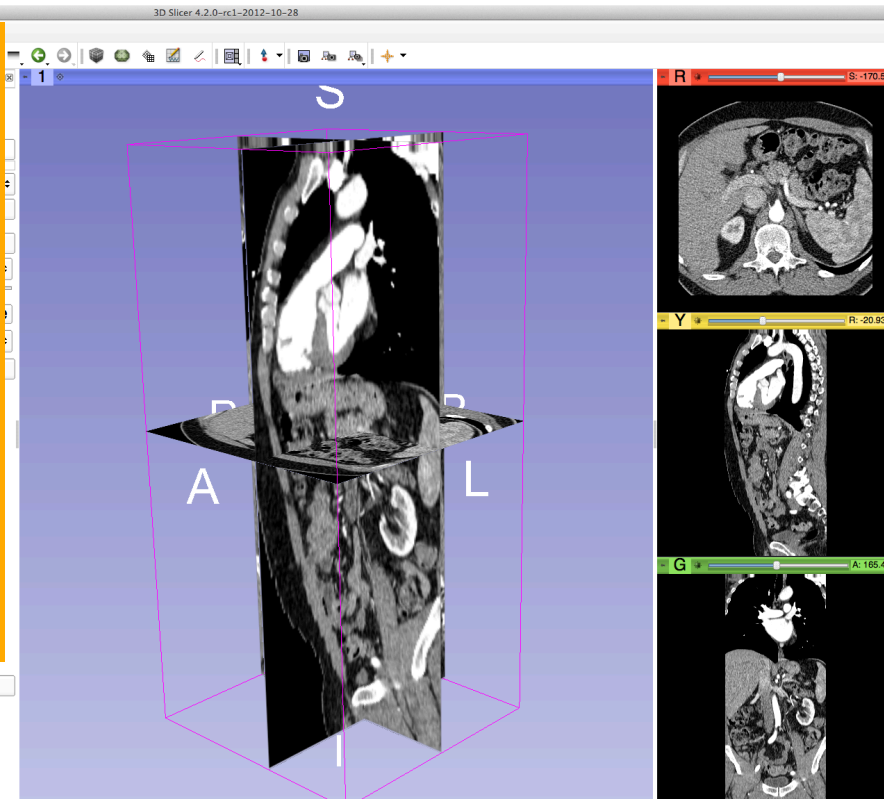


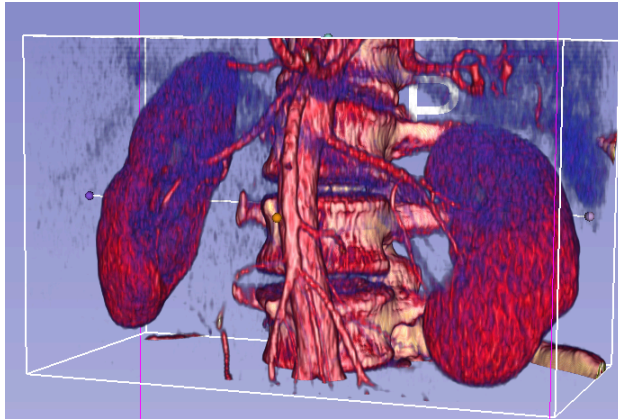
Loading a DICOM volume

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

Data Probe

L
F
B



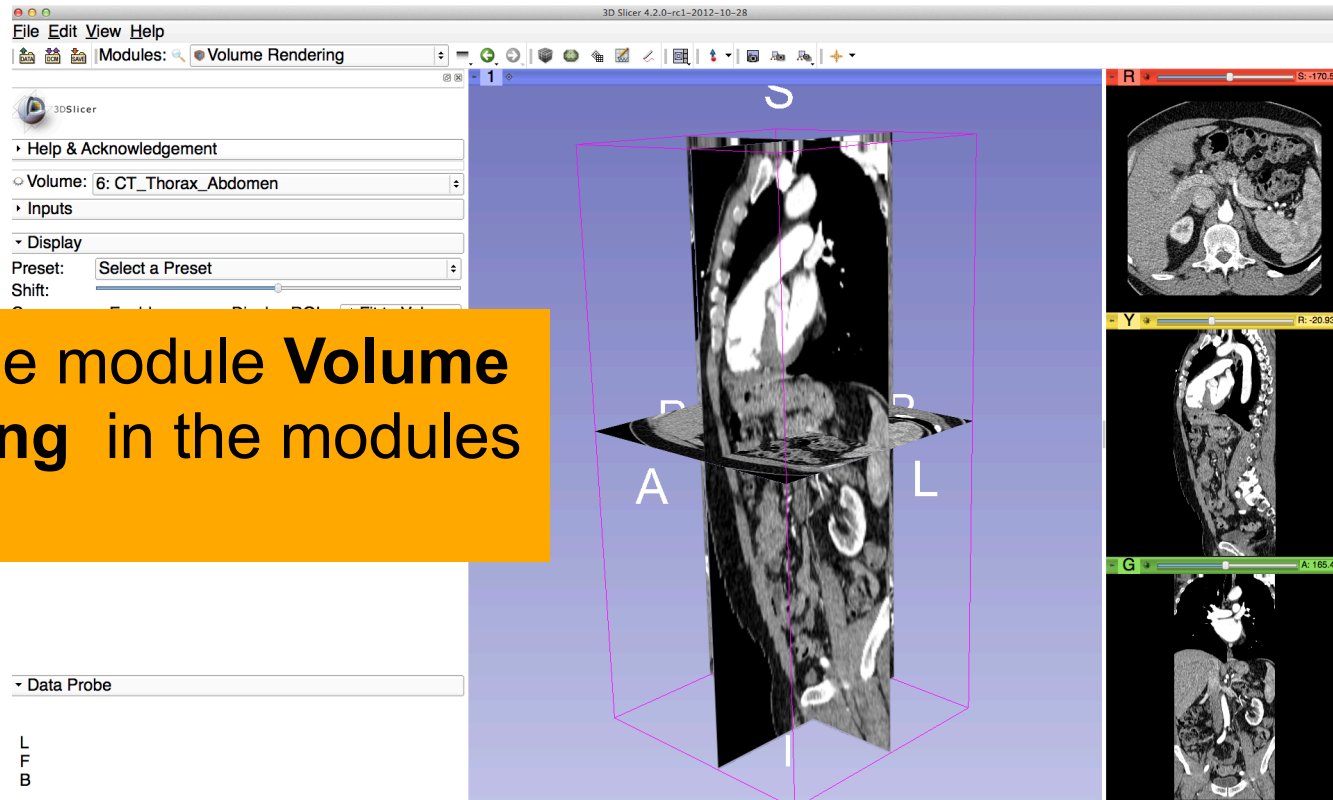


3D Interactive exploration of
thoraco-abdominal CT data
using Volume Rendering



Volume Rendering

Select the module **Volume Rendering** in the modules menu

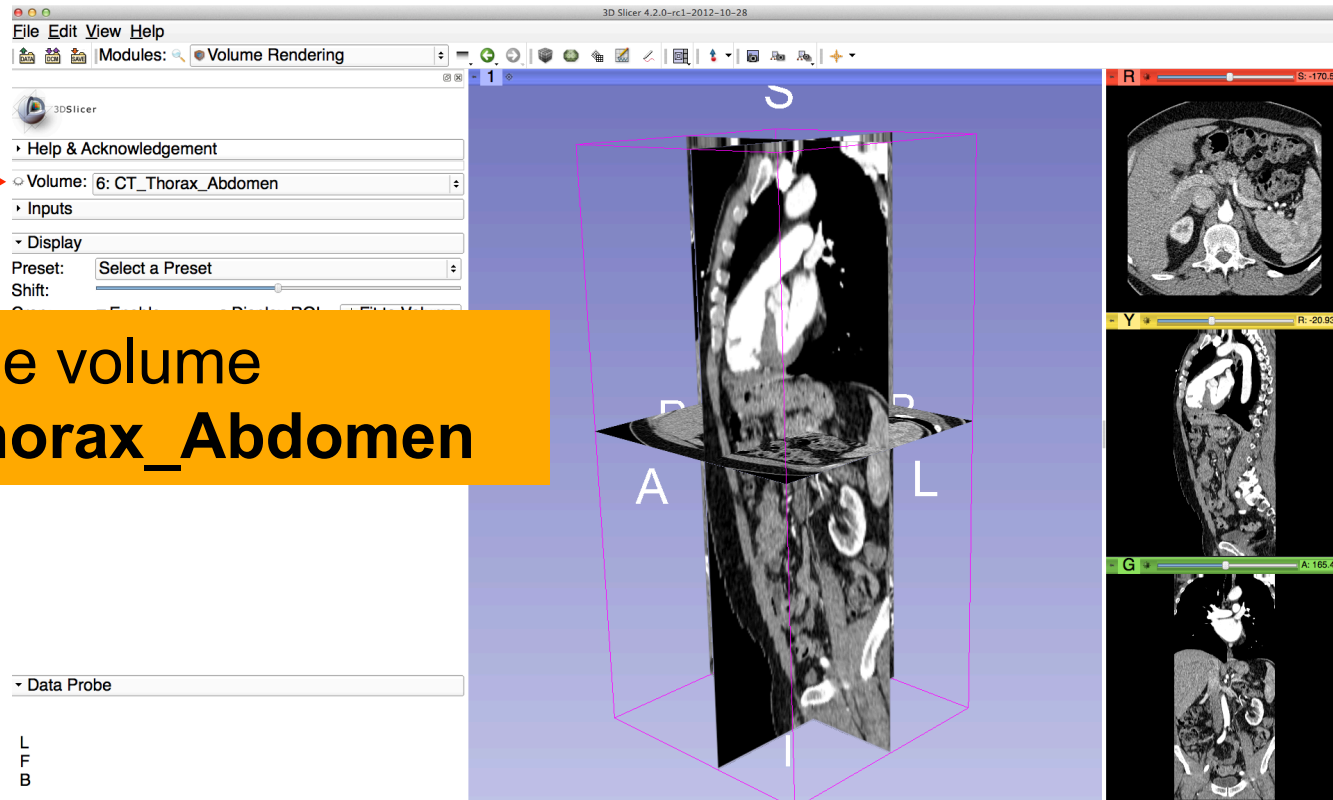




Volume Rendering

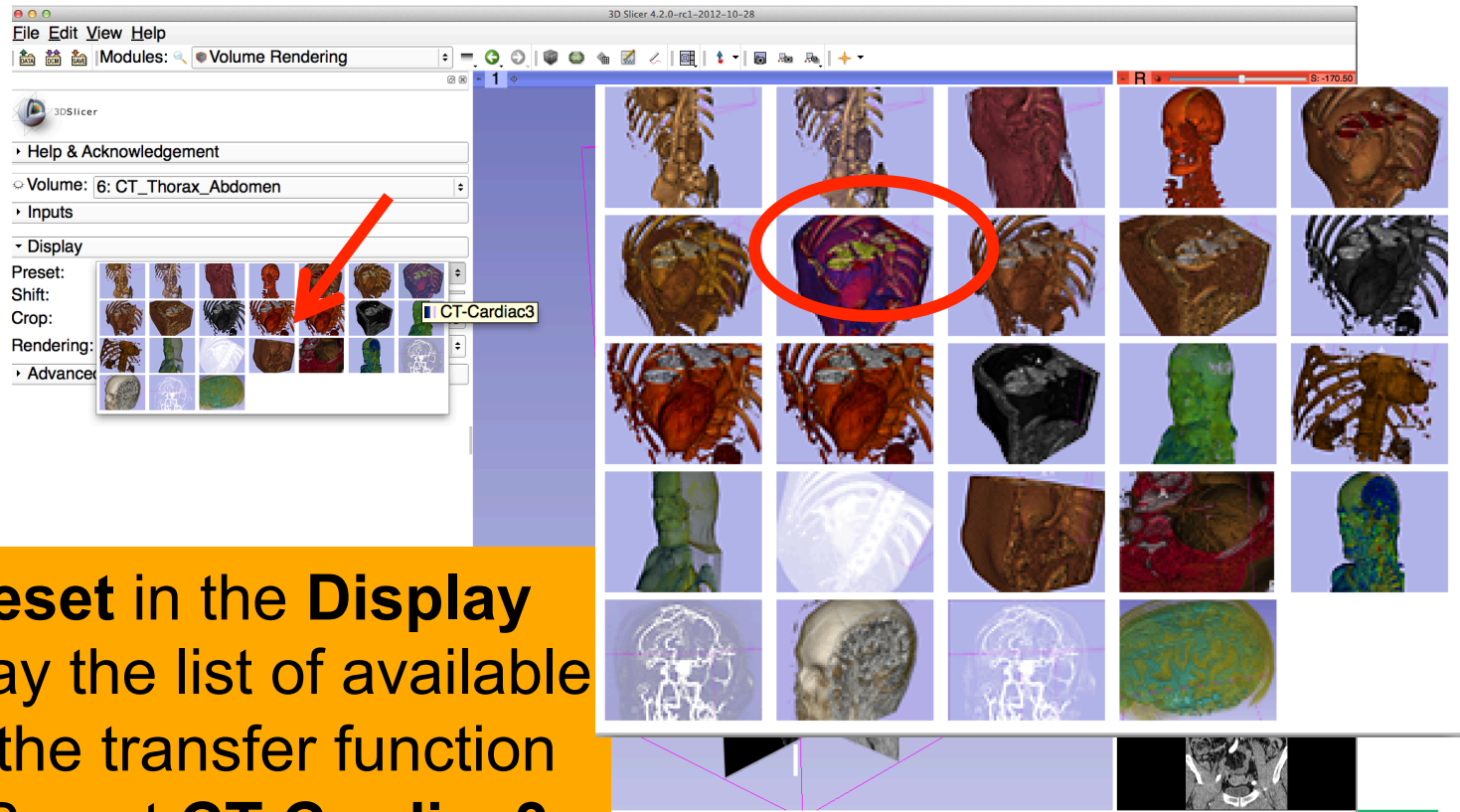


Select the volume
6:CT_Thorax_Abdomen





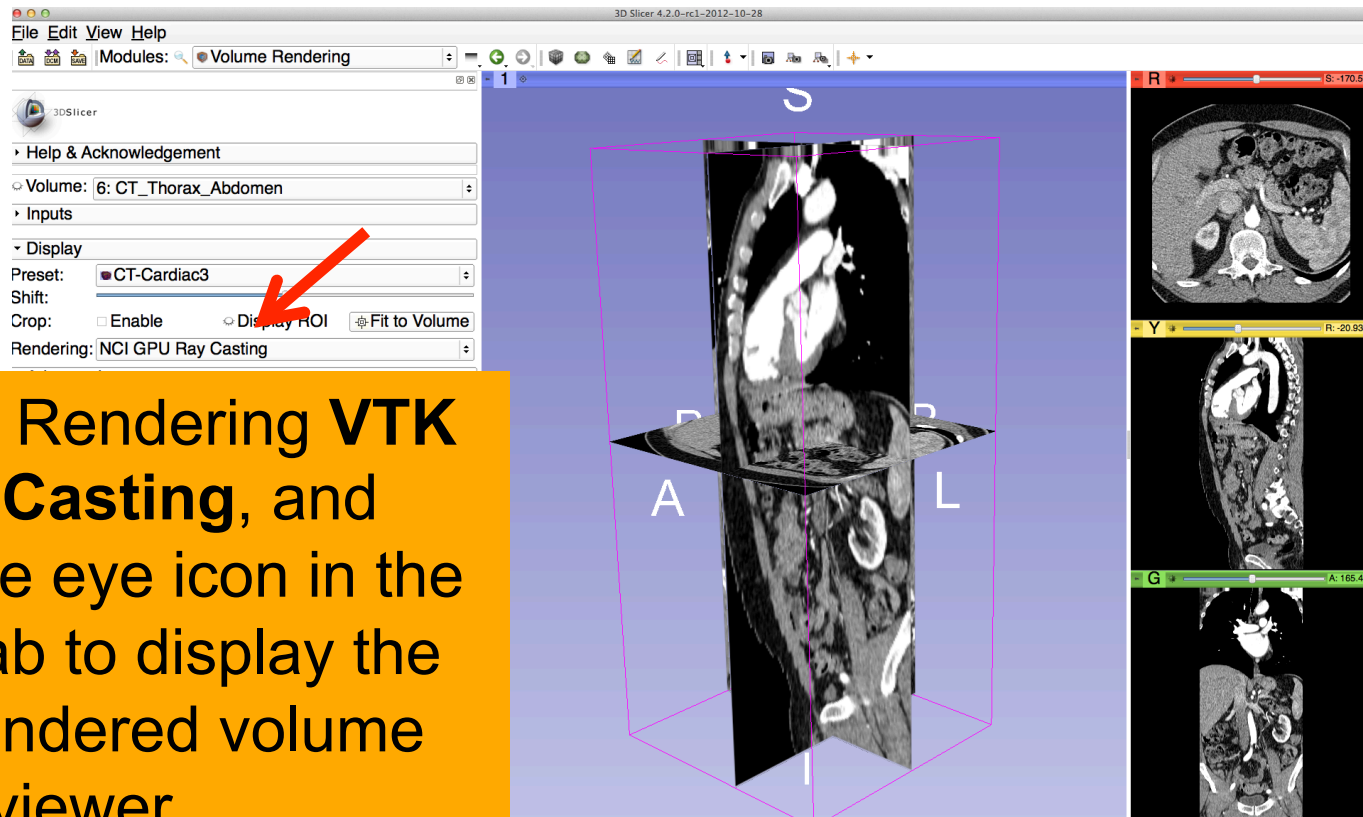
Volume Rendering



Click on **Preset** in the **Display** tab to display the list of available presets for the transfer function
Select the Preset **CT-Cardiac3**



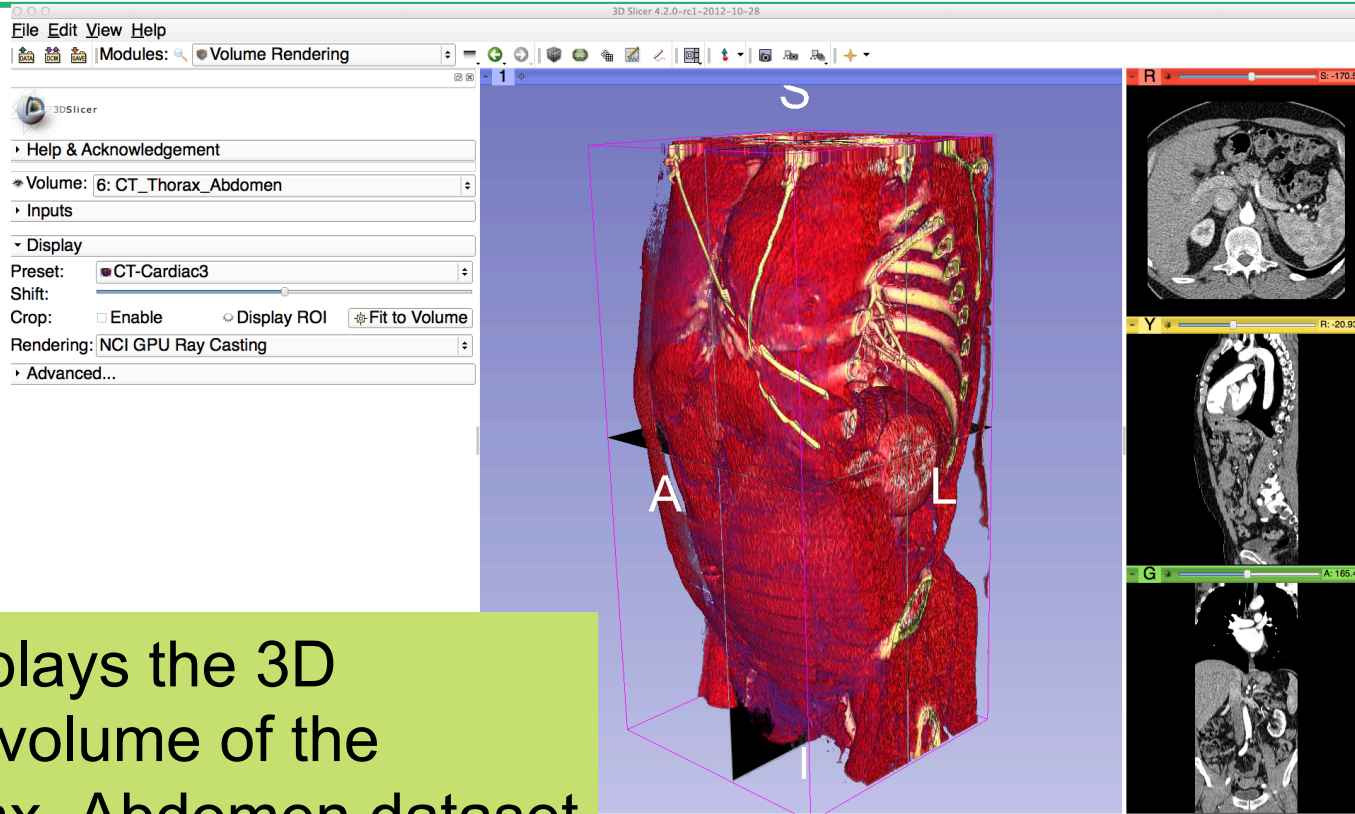
Volume Rendering



Select the Rendering **VTK CPU Ray Casting**, and click on the eye icon in the **Volume** tab to display the Volume rendered volume in the 3D viewer



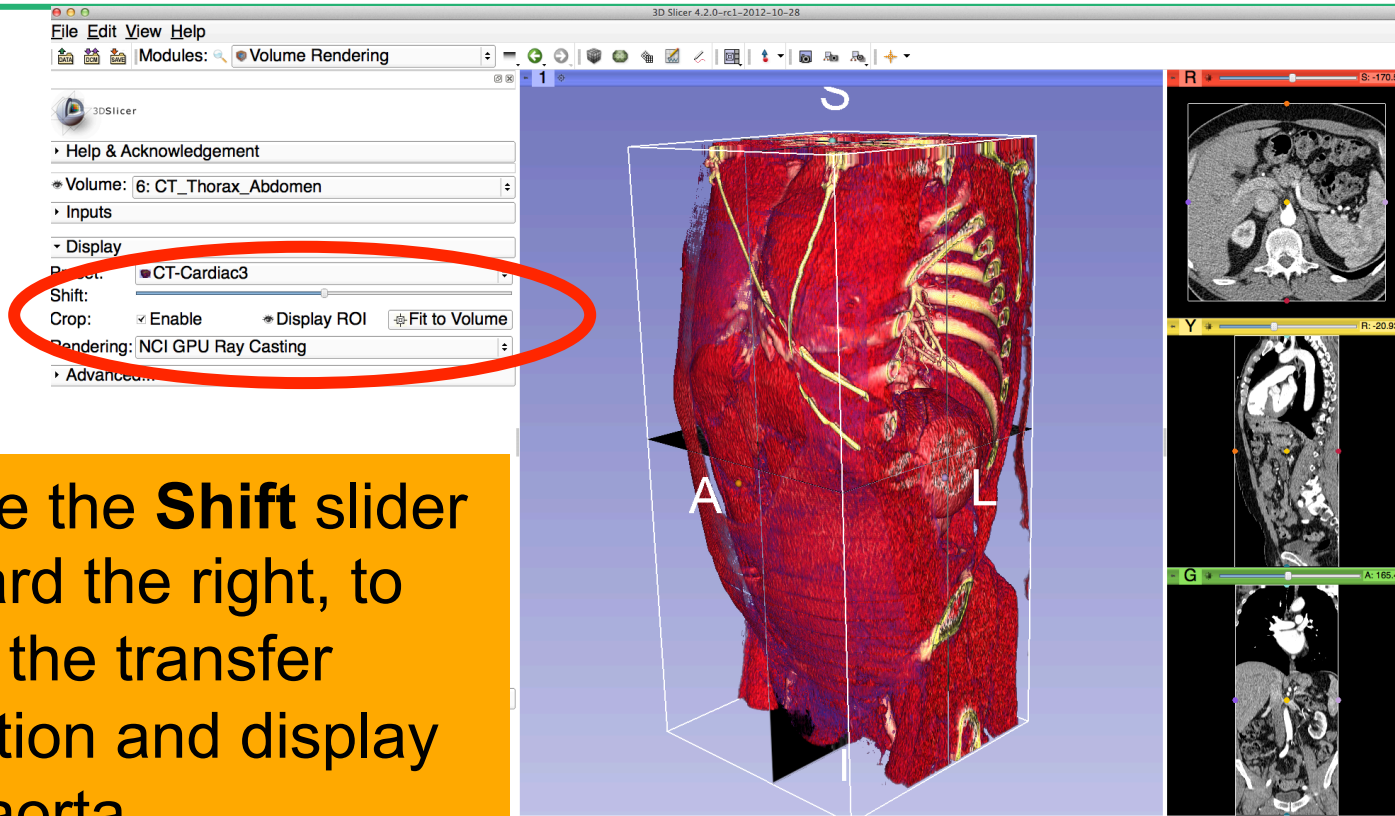
Volume Rendering



Slicer displays the 3D rendered volume of the CT_Thorax_Abdomen dataset



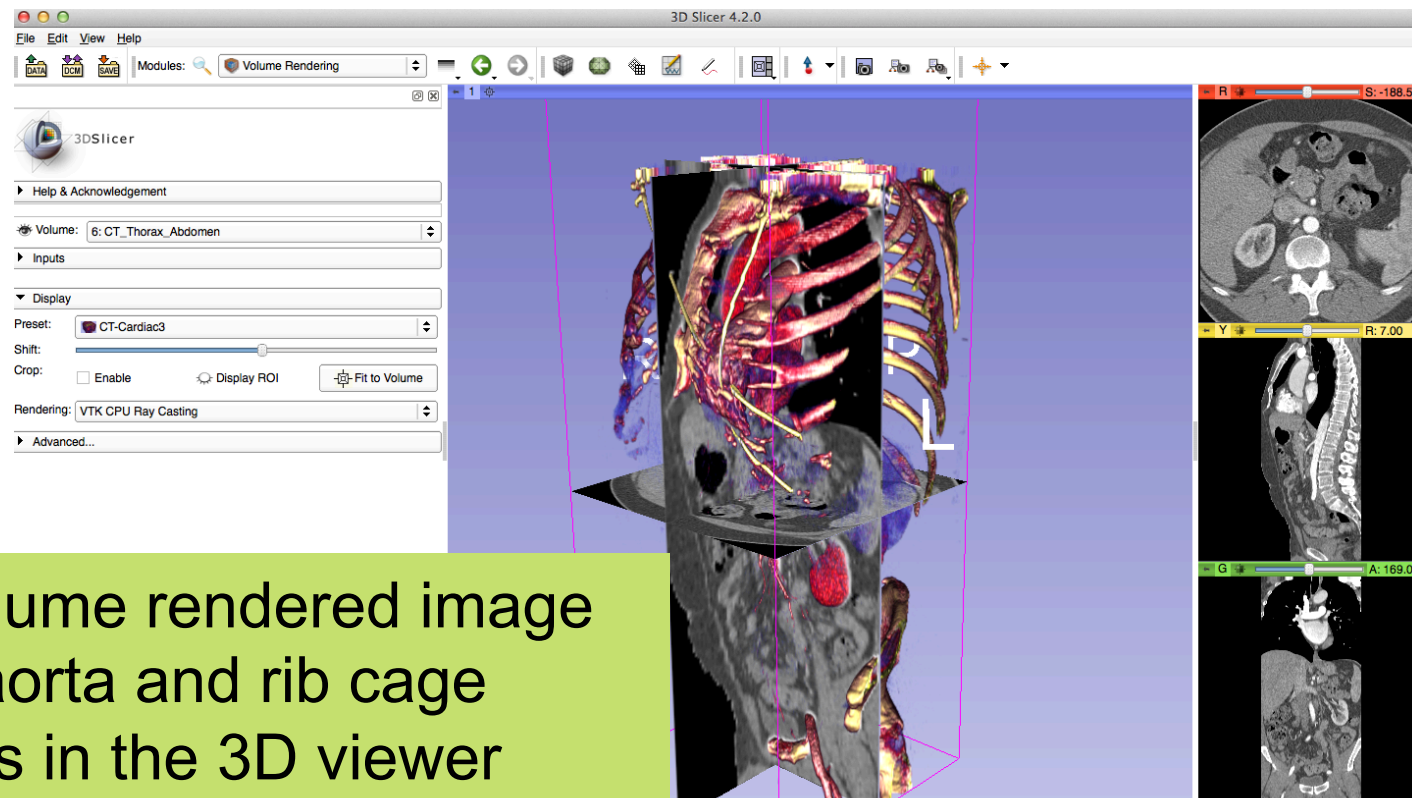
Volume Rendering



Move the **Shift** slider toward the right, to shift the transfer function and display the aorta



Volume Rendering

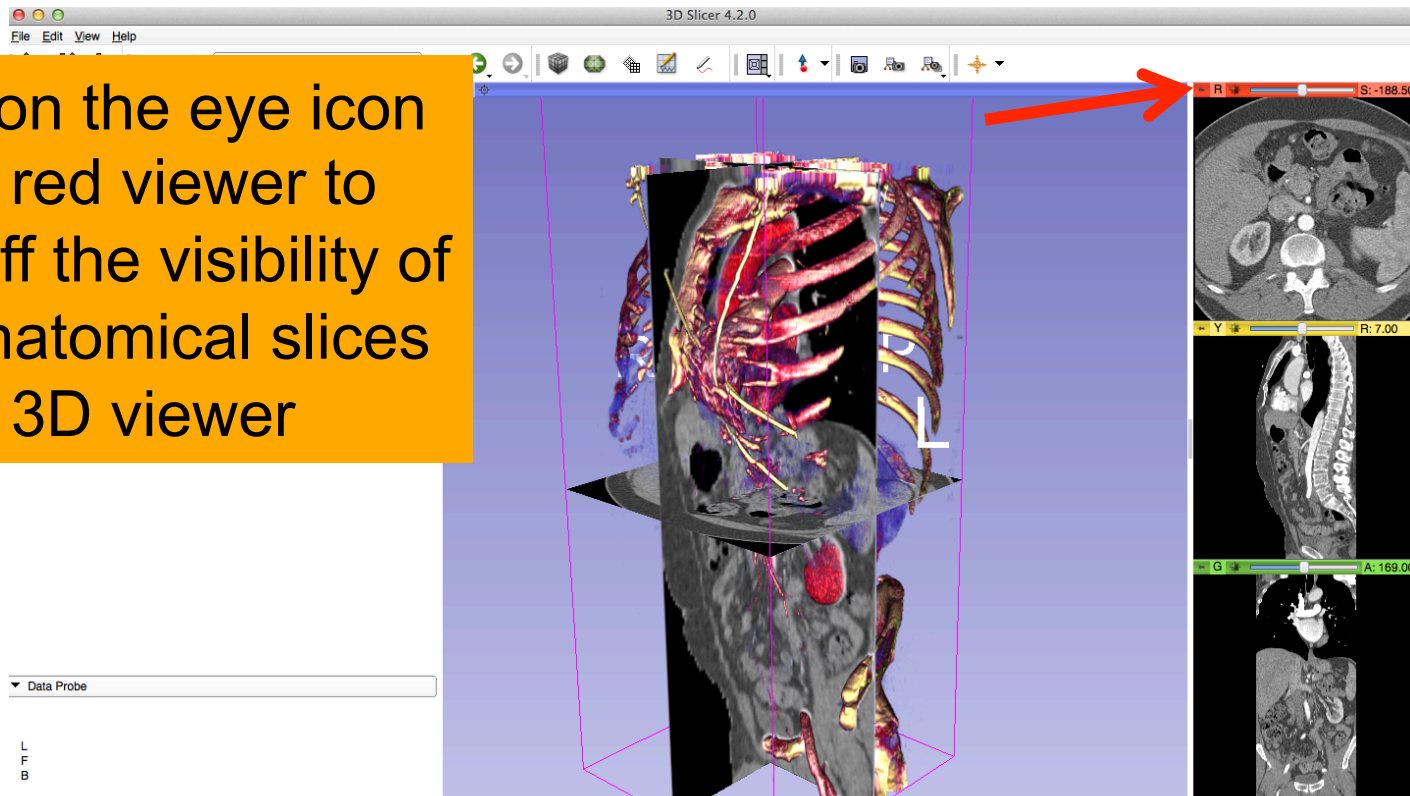


The volume rendered image of the aorta and rib cage appears in the 3D viewer



Volume Rendering

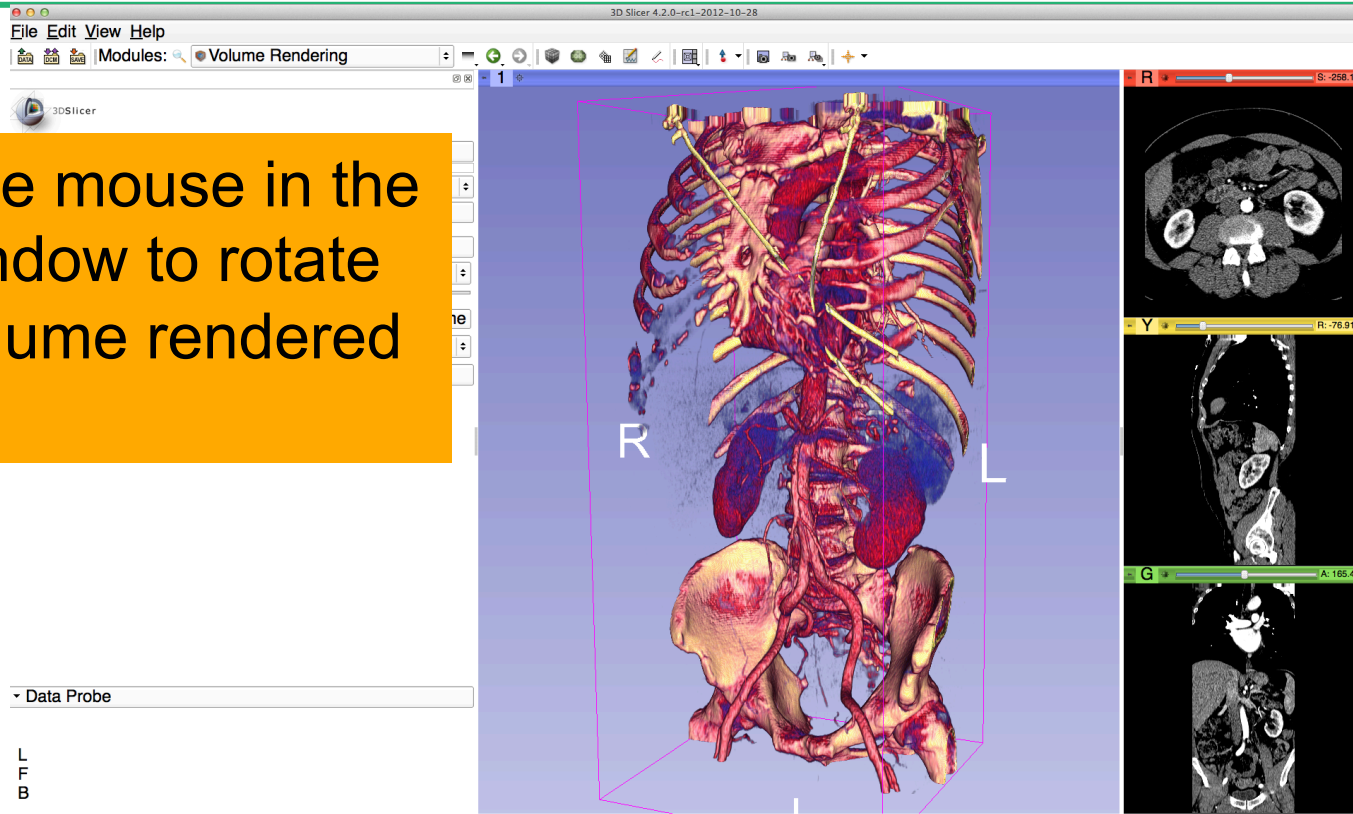
Click on the eye icon in the red viewer to turn off the visibility of the anatomical slices in the 3D viewer





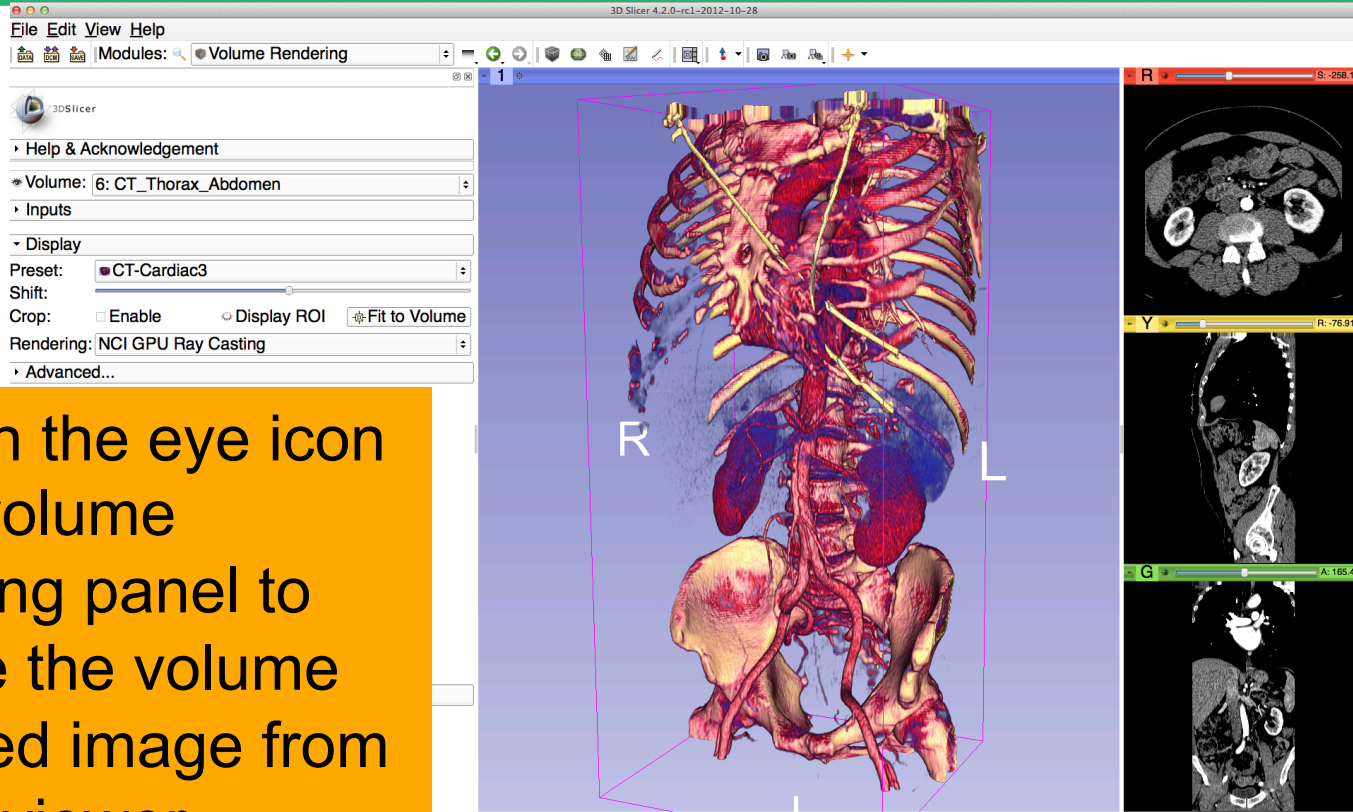
Volume Rendering

Use the mouse in the 3D window to rotate the volume rendered image





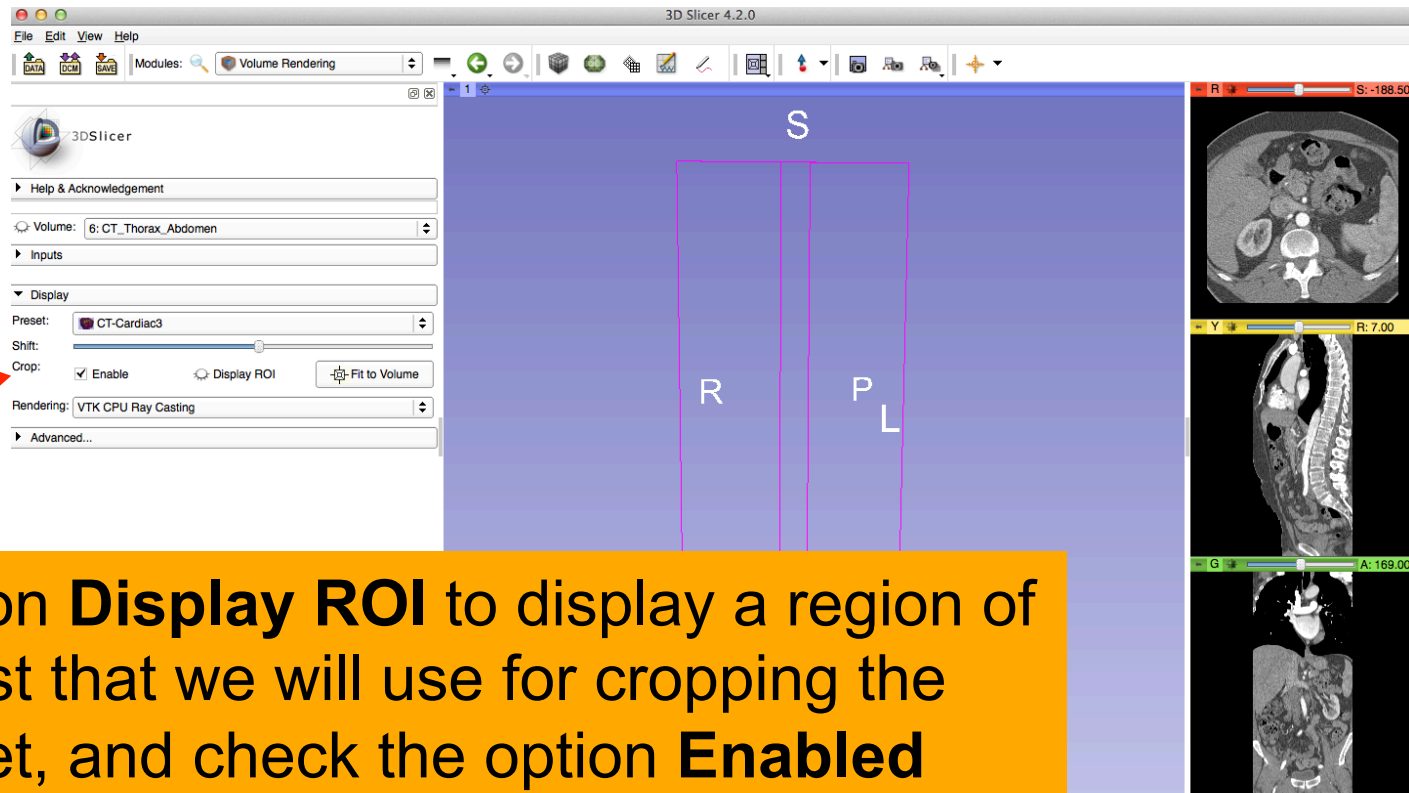
Volume Rendering



Click on the eye icon in the volume rendering panel to remove the volume rendered image from the 3D viewer



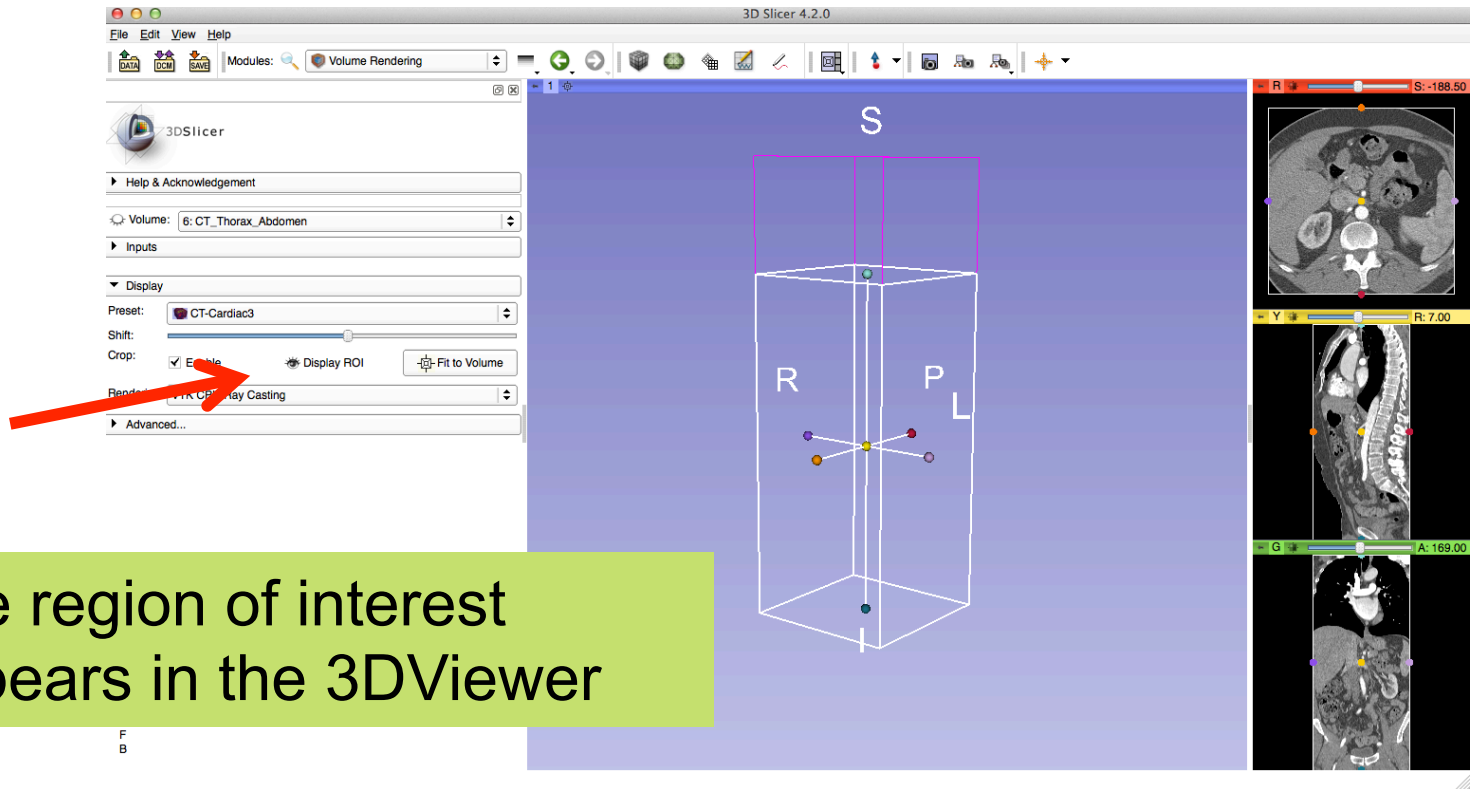
Volume Rendering



Click on **Display ROI** to display a region of interest that we will use for cropping the dataset, and check the option **Enabled**



Volume Rendering

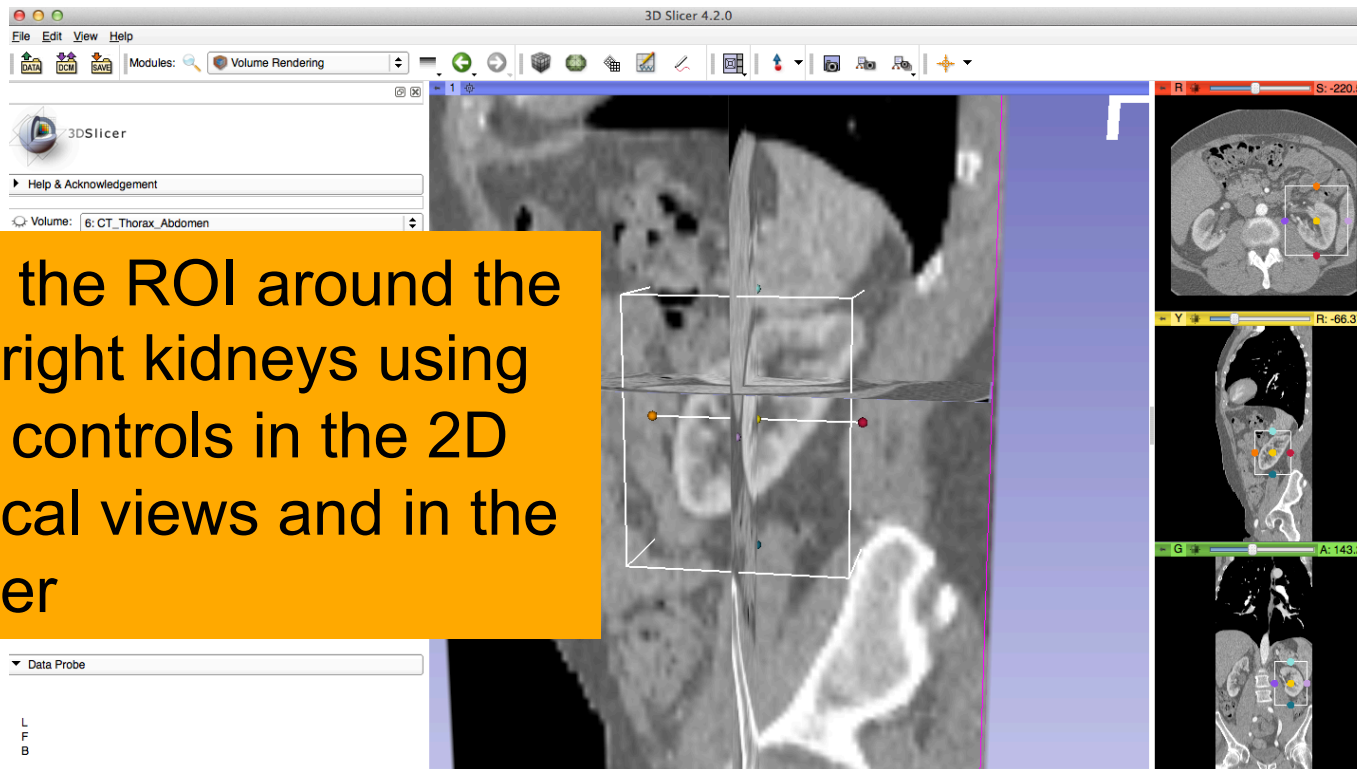


The region of interest appears in the 3DViewer



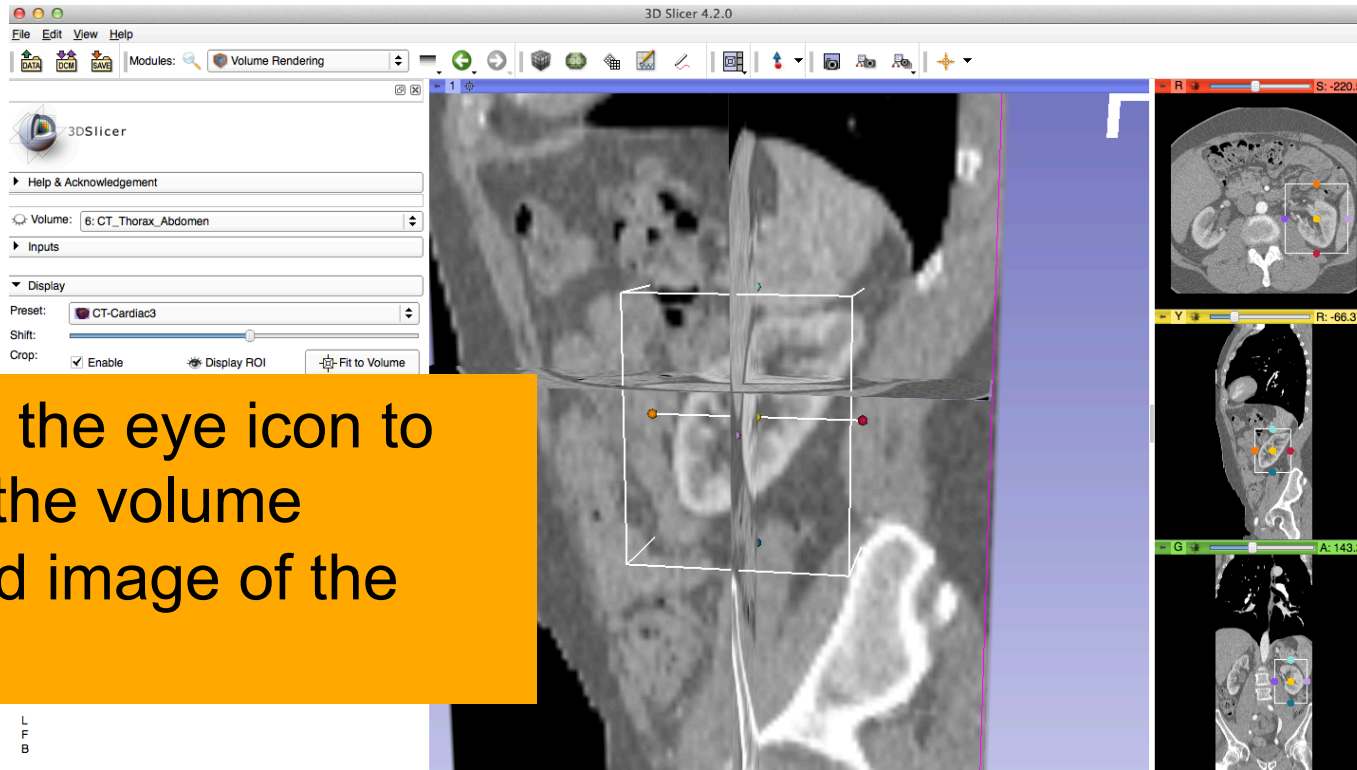
Volume Rendering

Position the ROI around the left and right kidneys using the ROI controls in the 2D anatomical views and in the 3D viewer





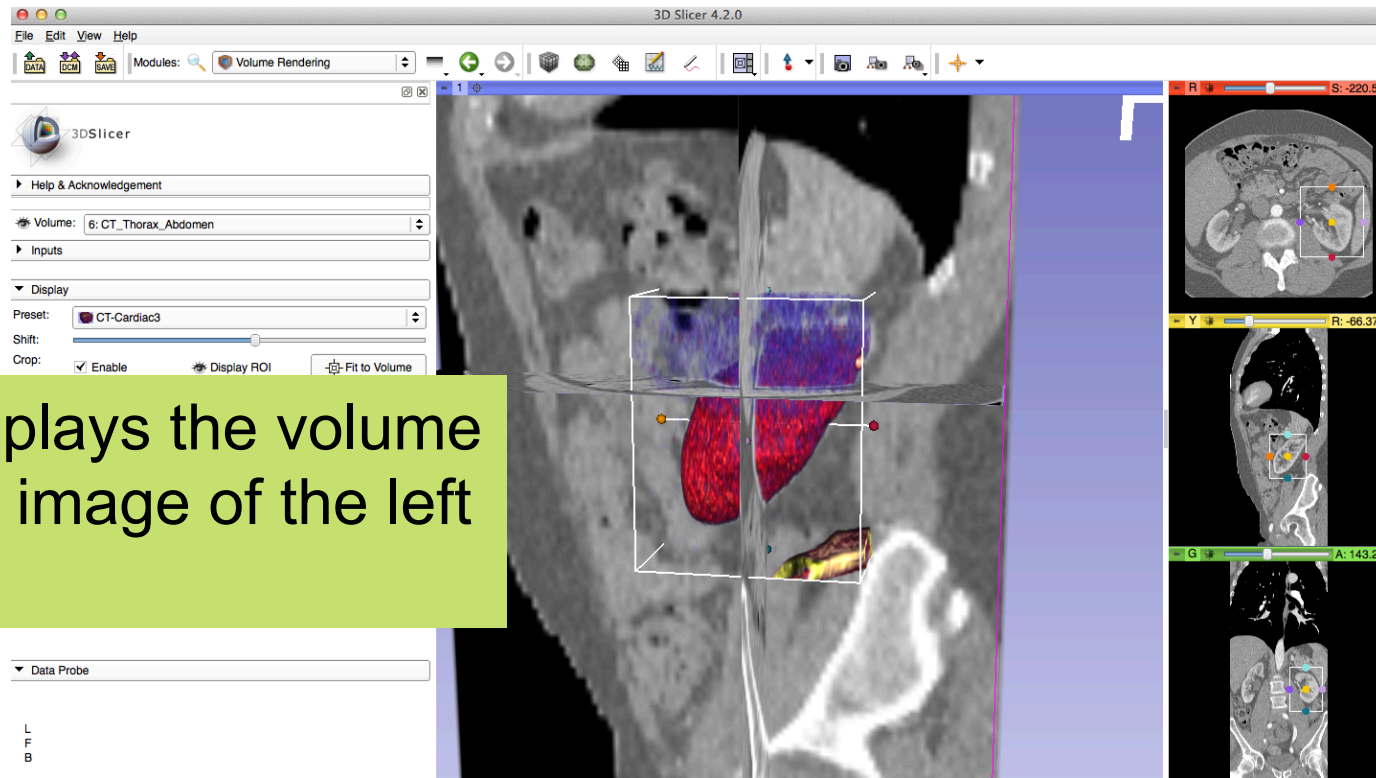
Volume Rendering



Click on the eye icon to display the volume rendered image of the kidney



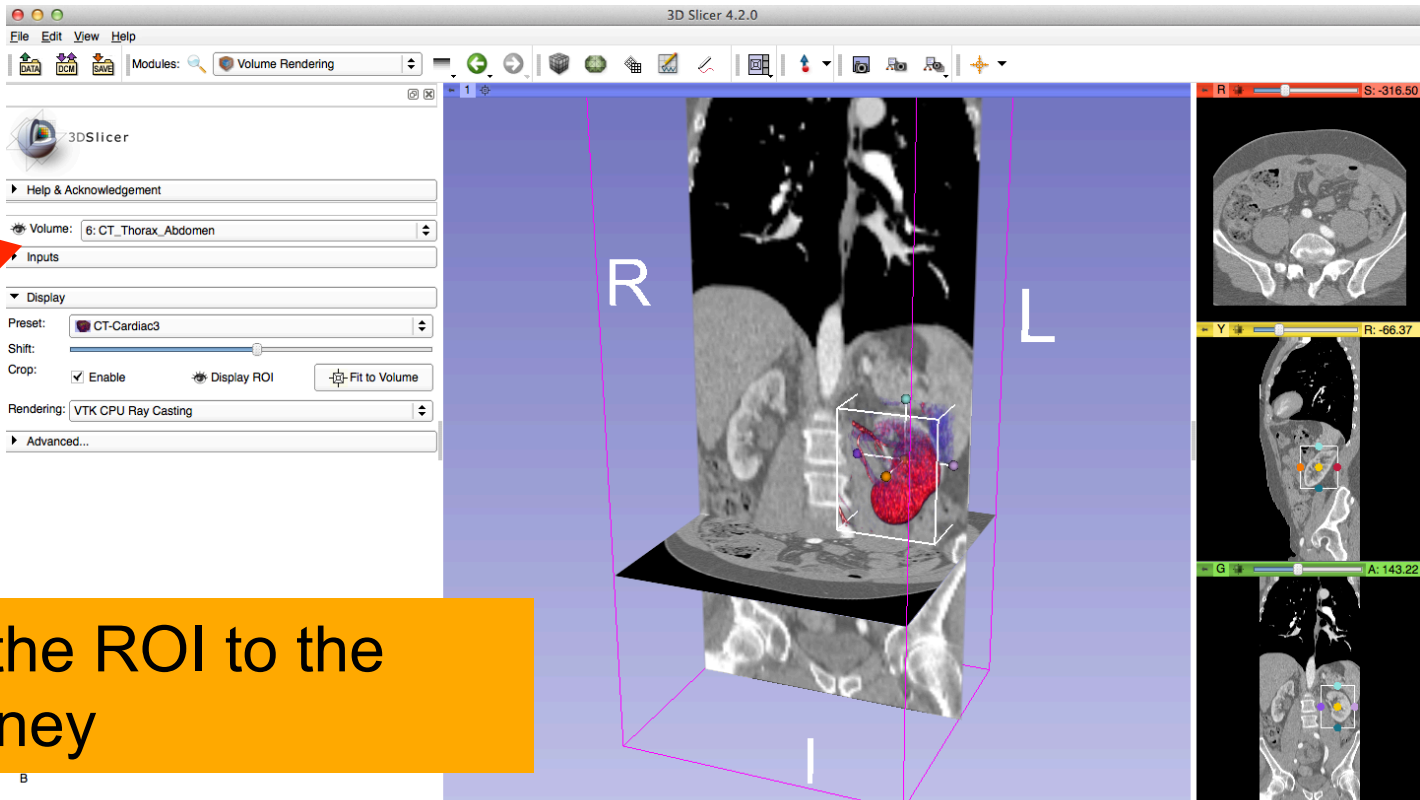
Volume Rendering



Slicer displays the volume rendered image of the left kidney



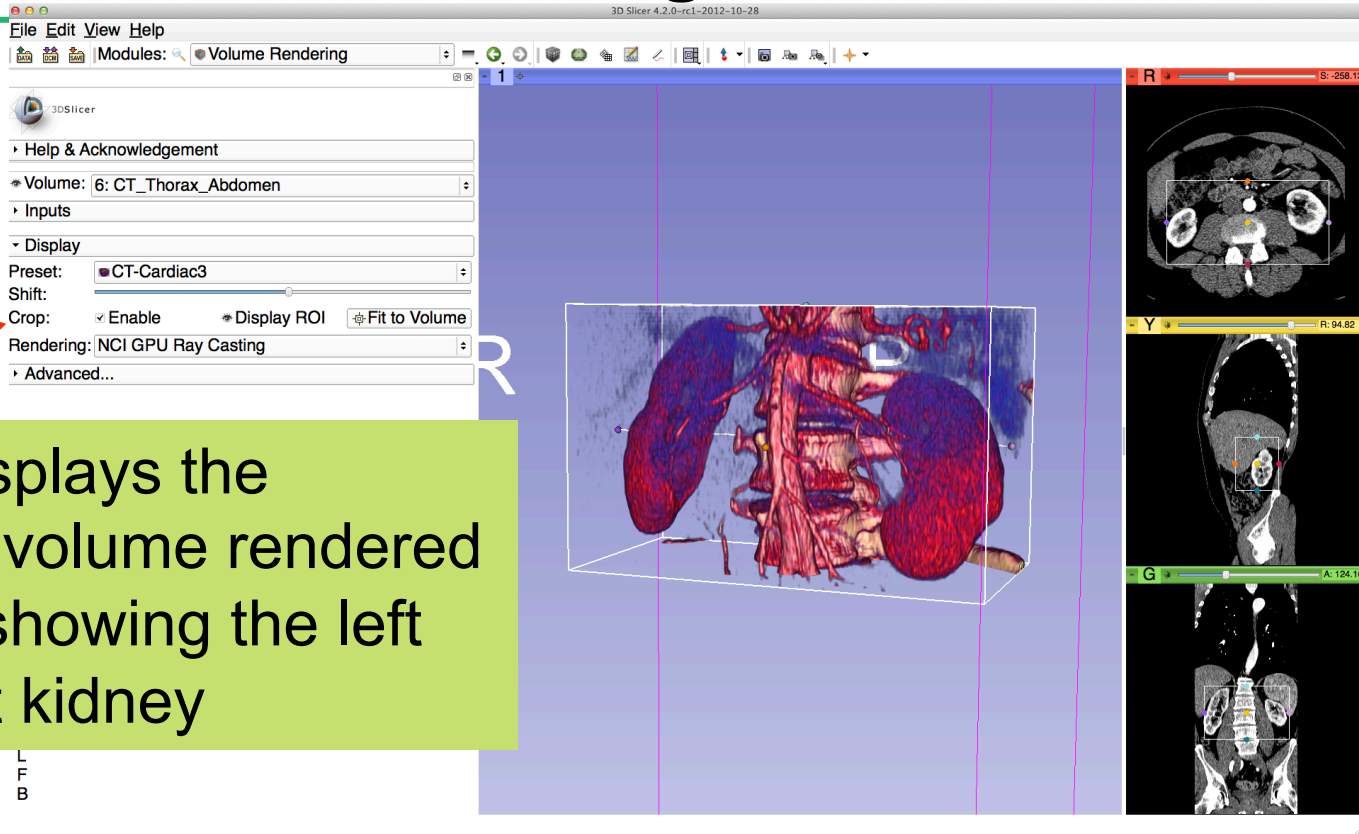
Volume Rendering



Extend the ROI to the right kidney



Volume Rendering



Slicer displays the cropped volume rendered images showing the left and right kidney



Volume Rendering

File Edit View Help
Modules: Volume Rendering

3DSlicer

- Help & Acknowledgement
- Volume: 6: CT_Thorax_Abdomen
- Inputs
- Display
 - Preset: CT-Cardiac3
 - Shift: [Slider]
 - Crop: Enable Display ROI Fit to Volume
 - Rendering: NCI GPU Ray Casting
 - Advanced...
- Data Probe

L
F
B

R

R: -258.13
Y: R: 94.82
G: A: 124.16

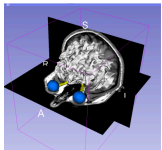
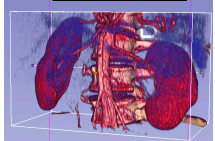
Click on File → Exit to quit Slicer



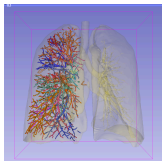
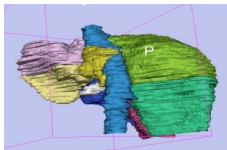
Overview

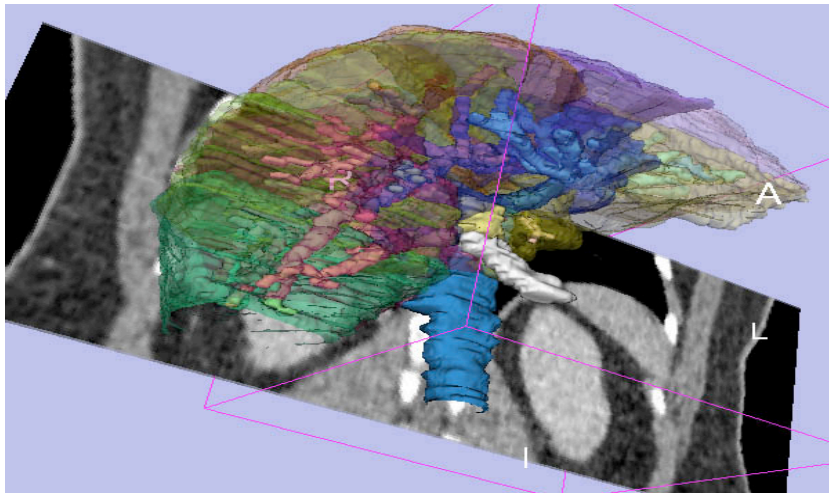


Part I: 3D Data Loading and visualization of DICOM images
- Volume Rendering of thoraco-abdominal CT data



Part II: 3D interactive exploration of the anatomy
- Exploration of the Segments of the liver
- Exploration of the Segments of the lung



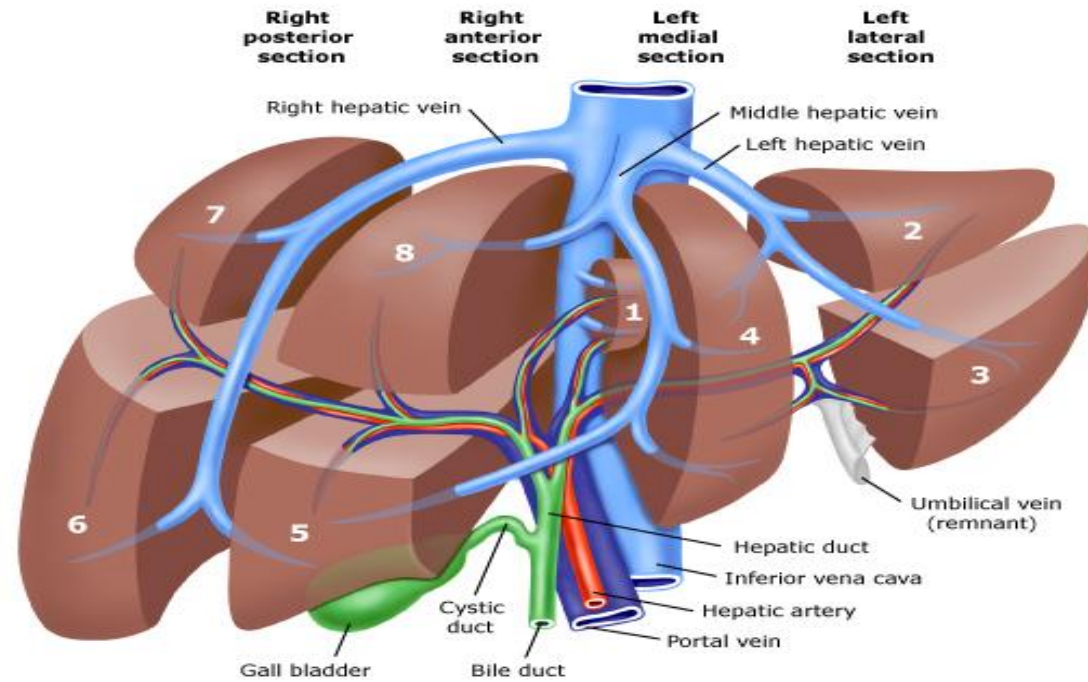


Part II:

Interactive 3D Visualization
of the segments of the liver

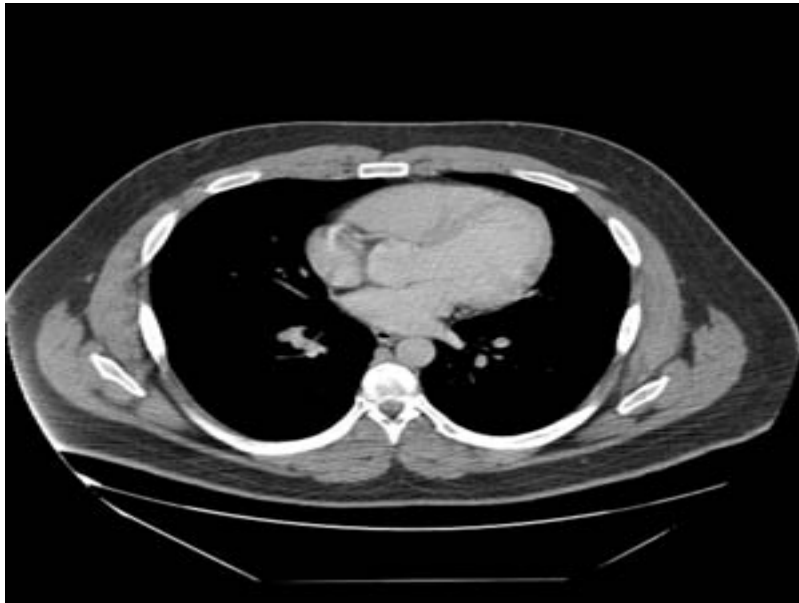


Anatomy of the liver





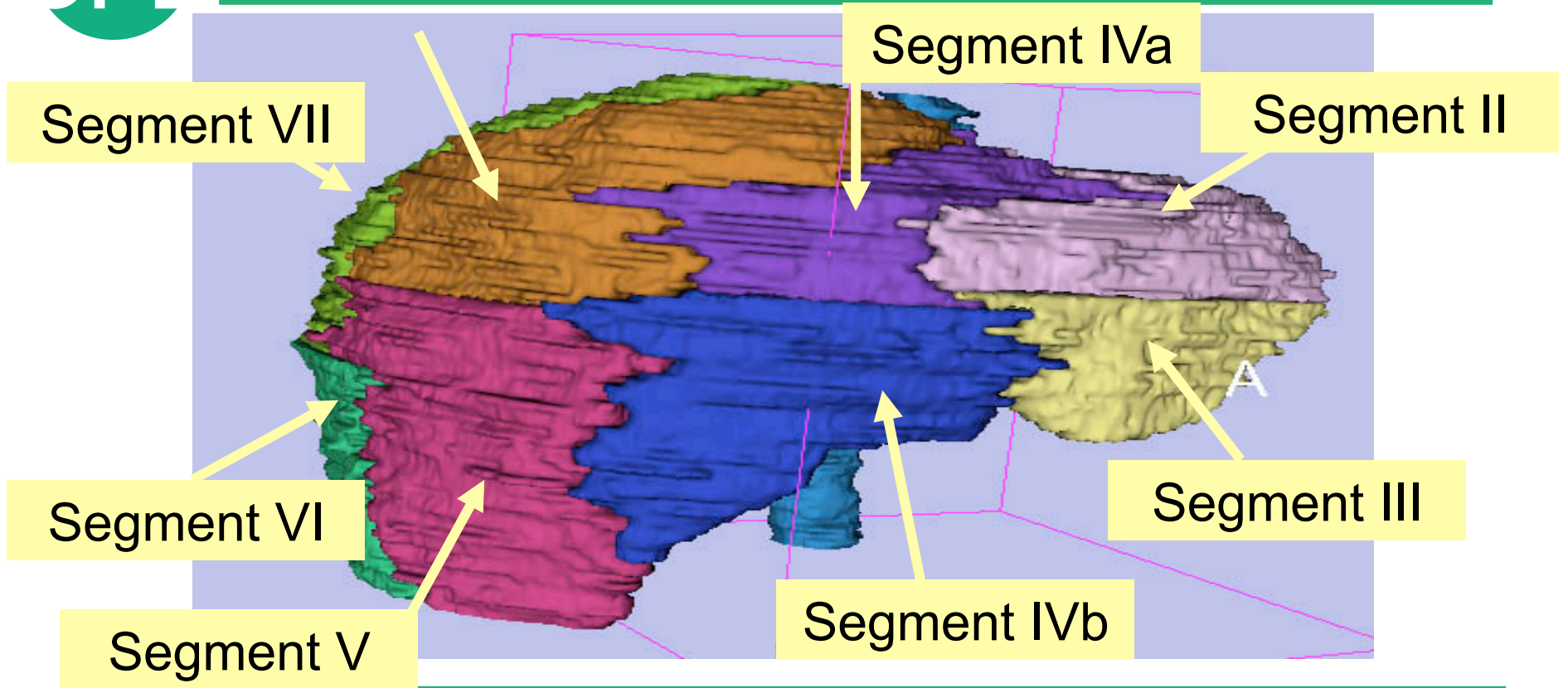
Liver dataset



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

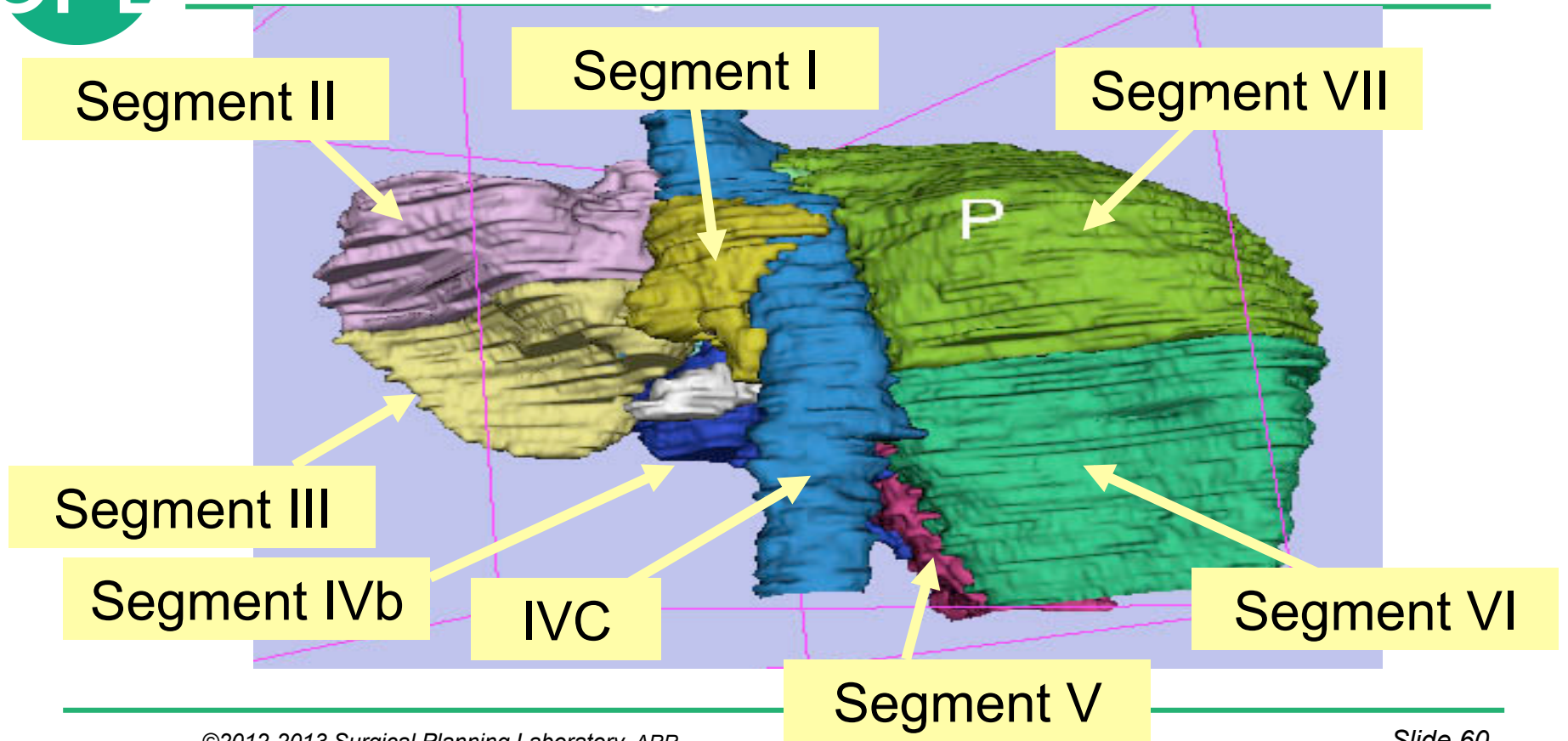


3D segments of the liver



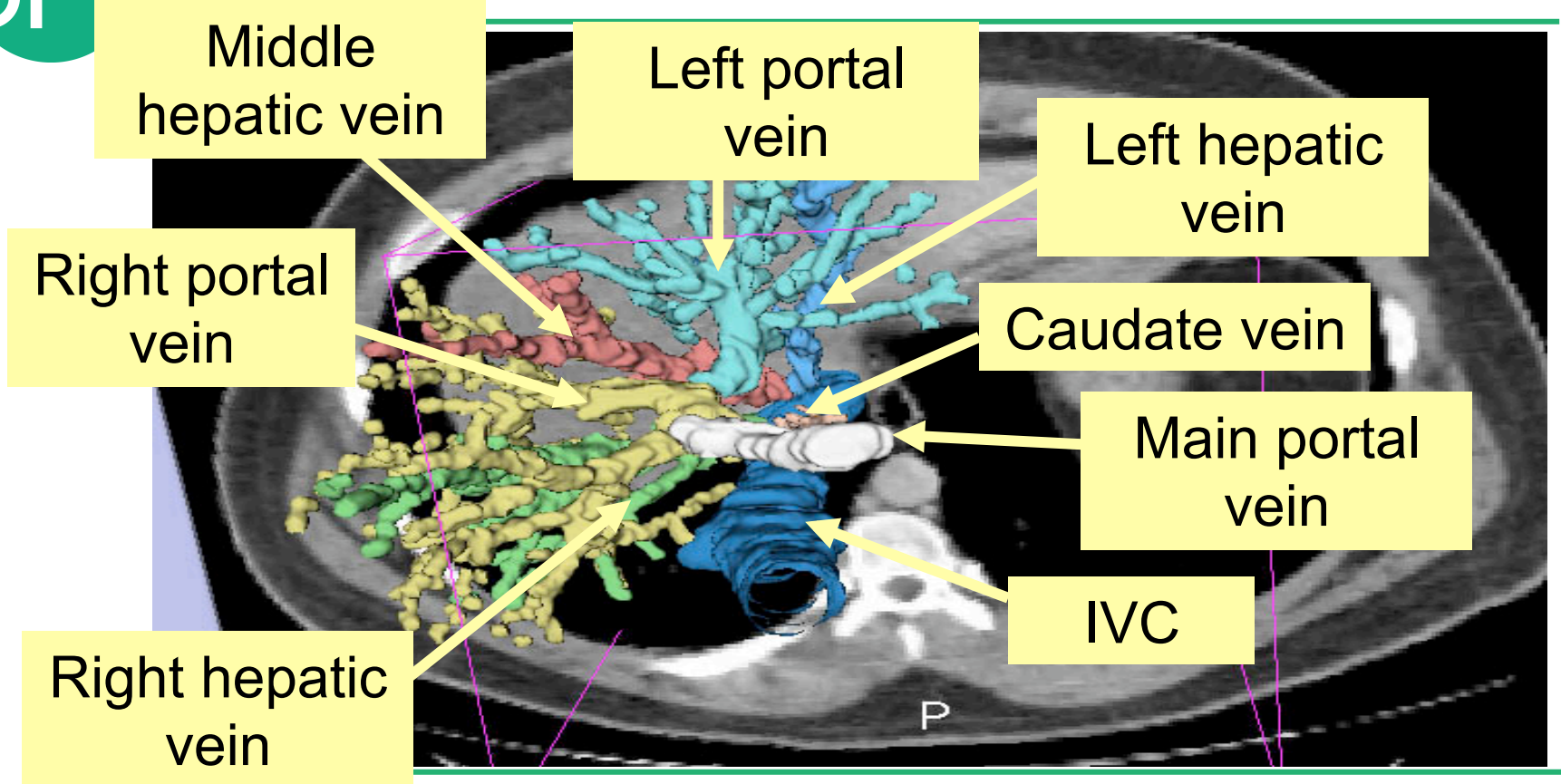


3D segments of the liver



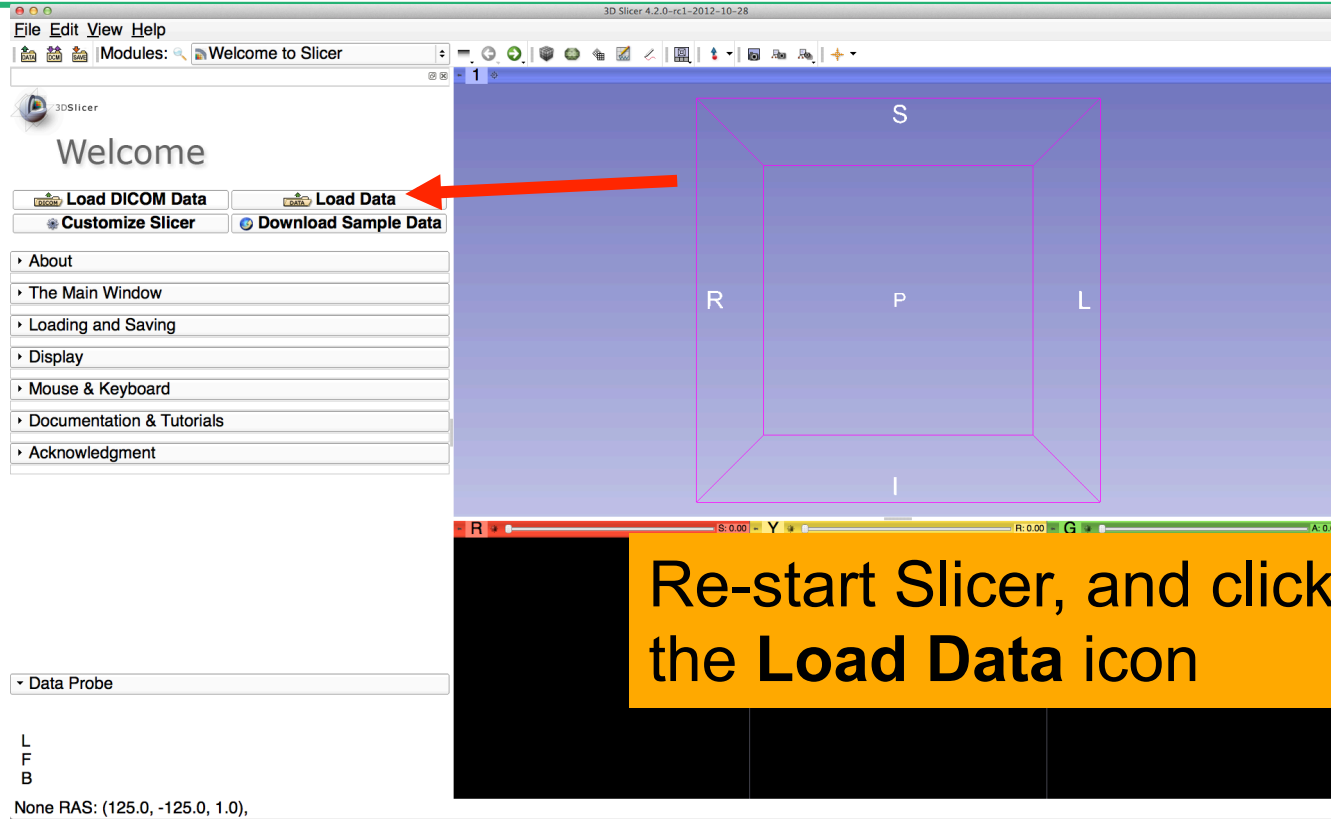


Liver vasculature



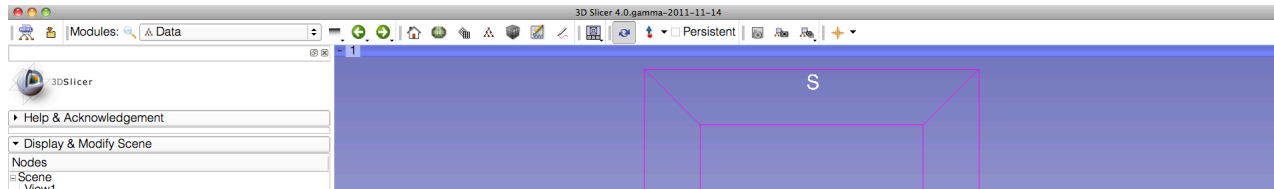


Loading the Liver Data Scene





Loading the Liver Scene



Browse to the directory

C:\Pujol2012\3Dvisualization_Tuesday_Nov27_2012

Select the directory **dataset3_CT-Liver**

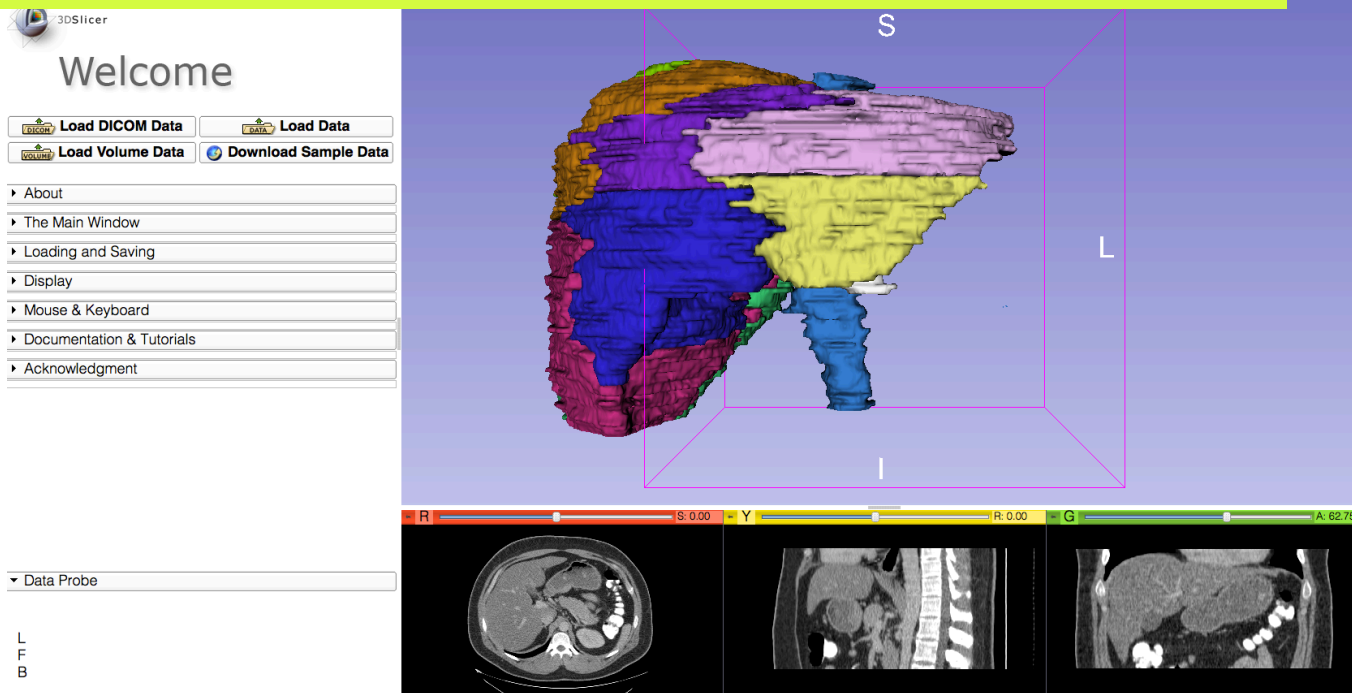
Select the file **LiverSegments_Scene.mrml**

Click on OK to load the scene into Slicer



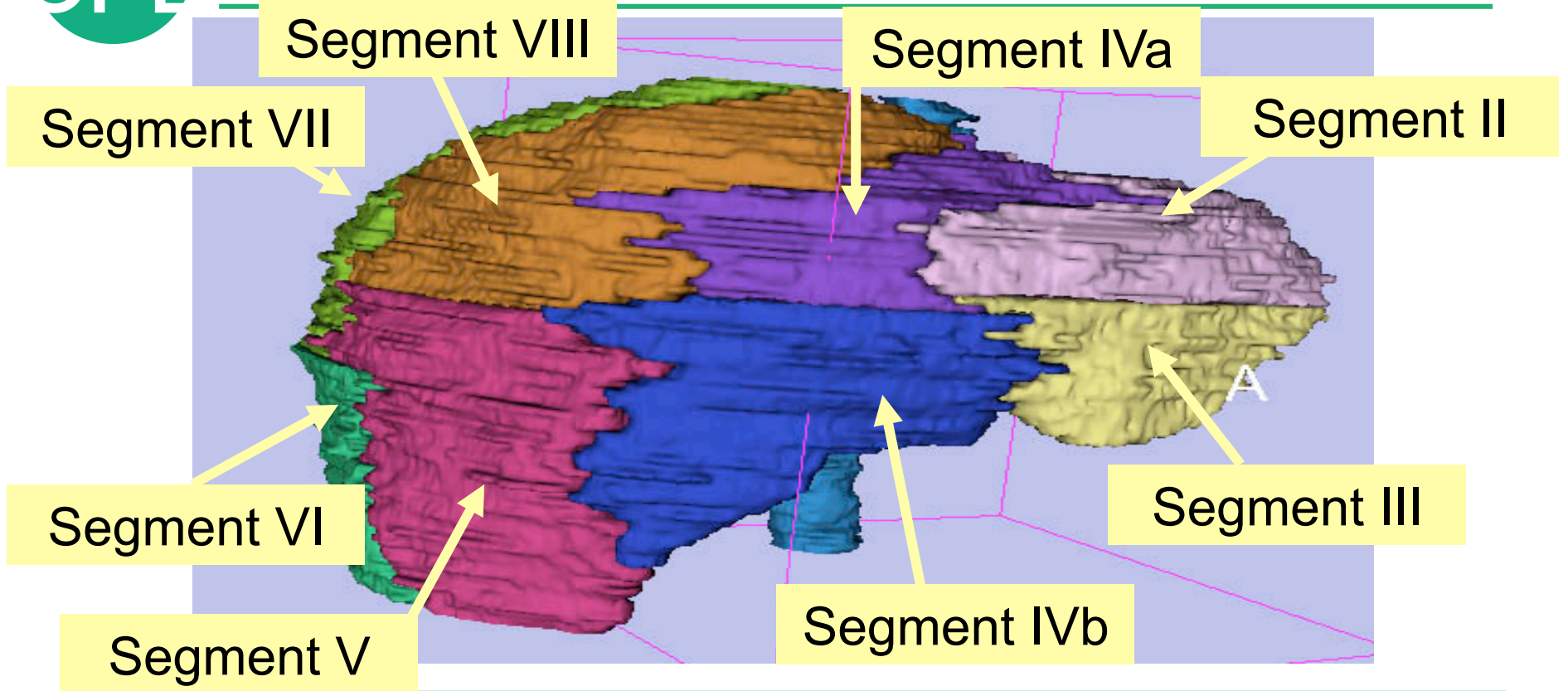
Liver Segments Scene

The elements of the scene appear in the Viewer



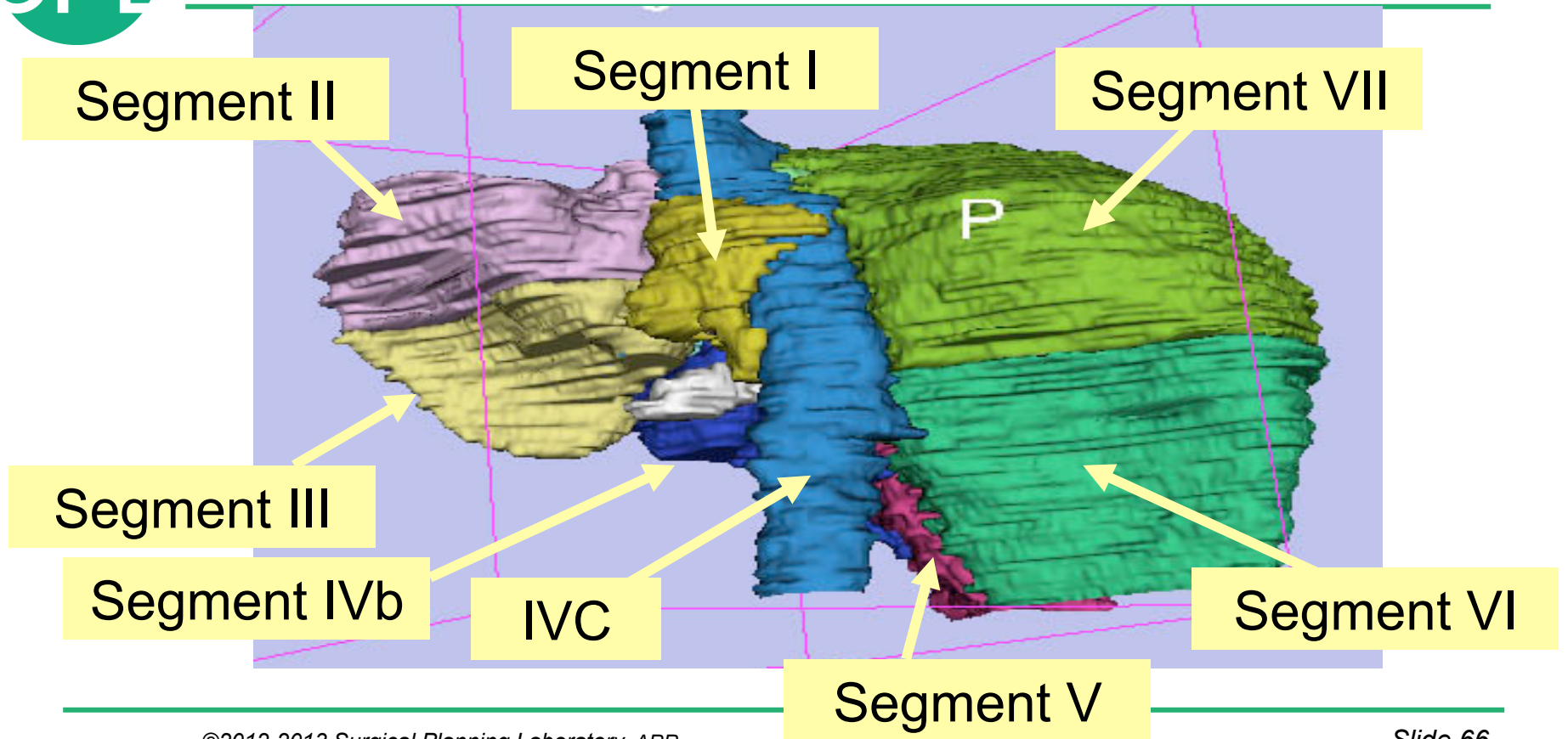


3D models of the liver



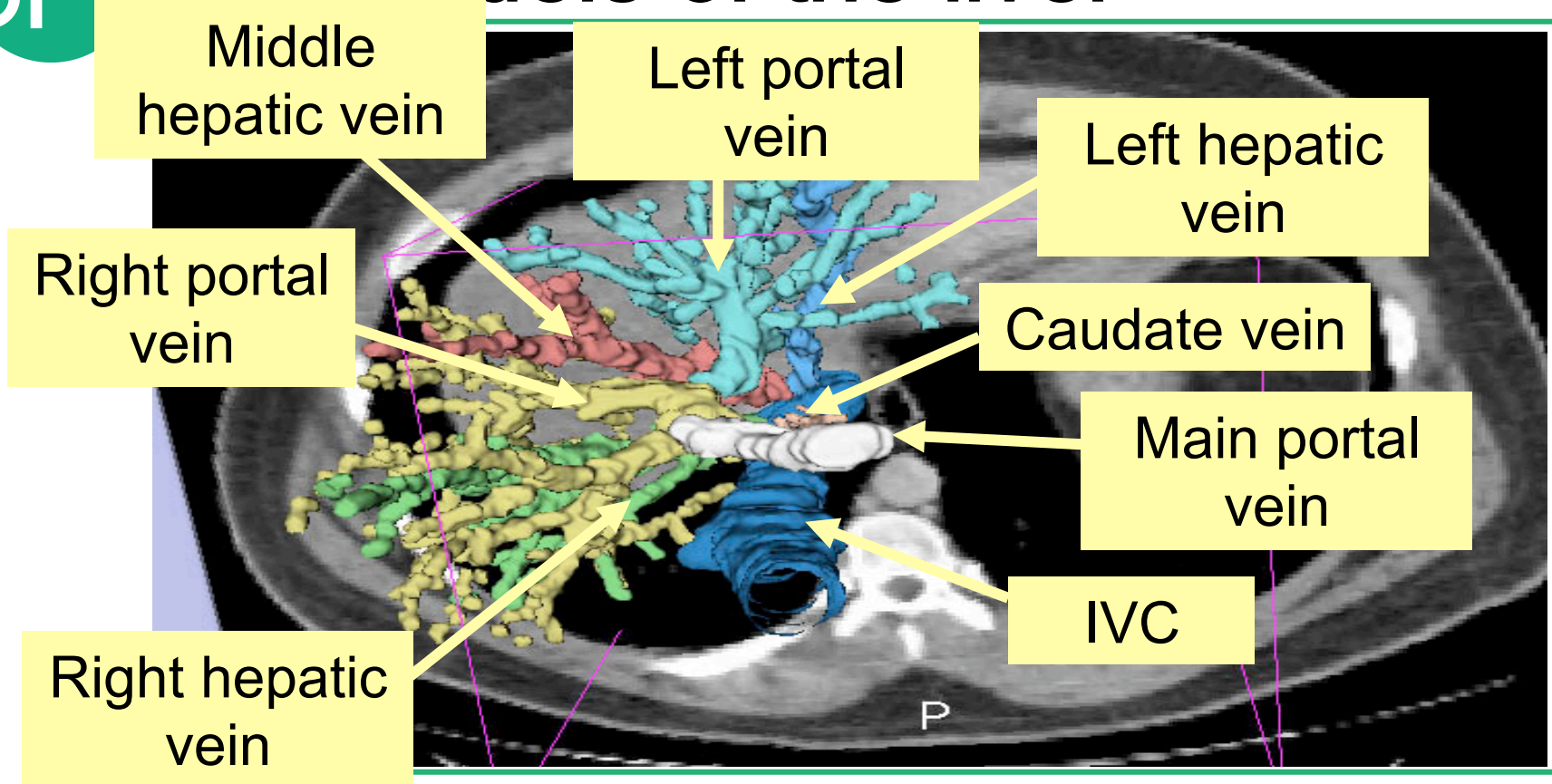


3D models of the liver



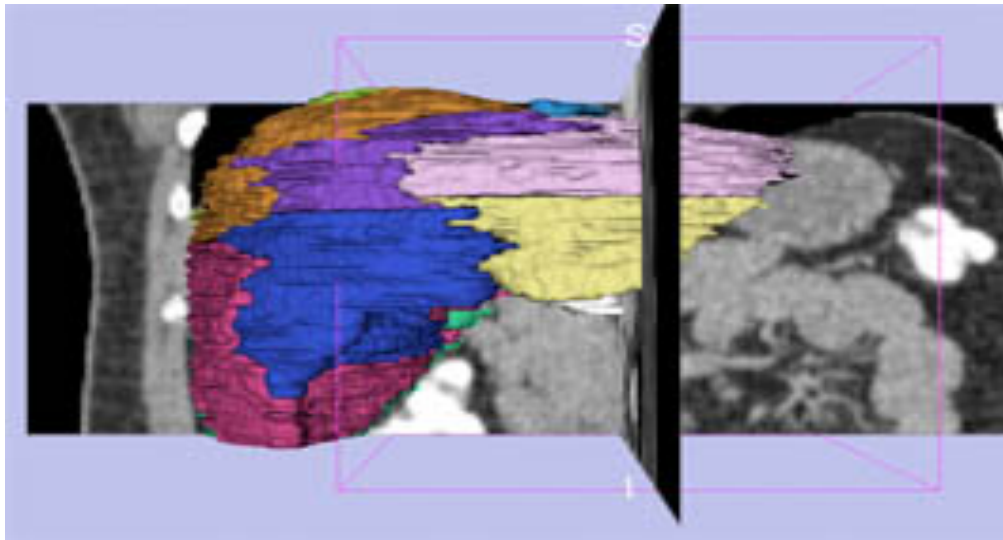


3D models of the liver





3D Exploration of Liver Segments

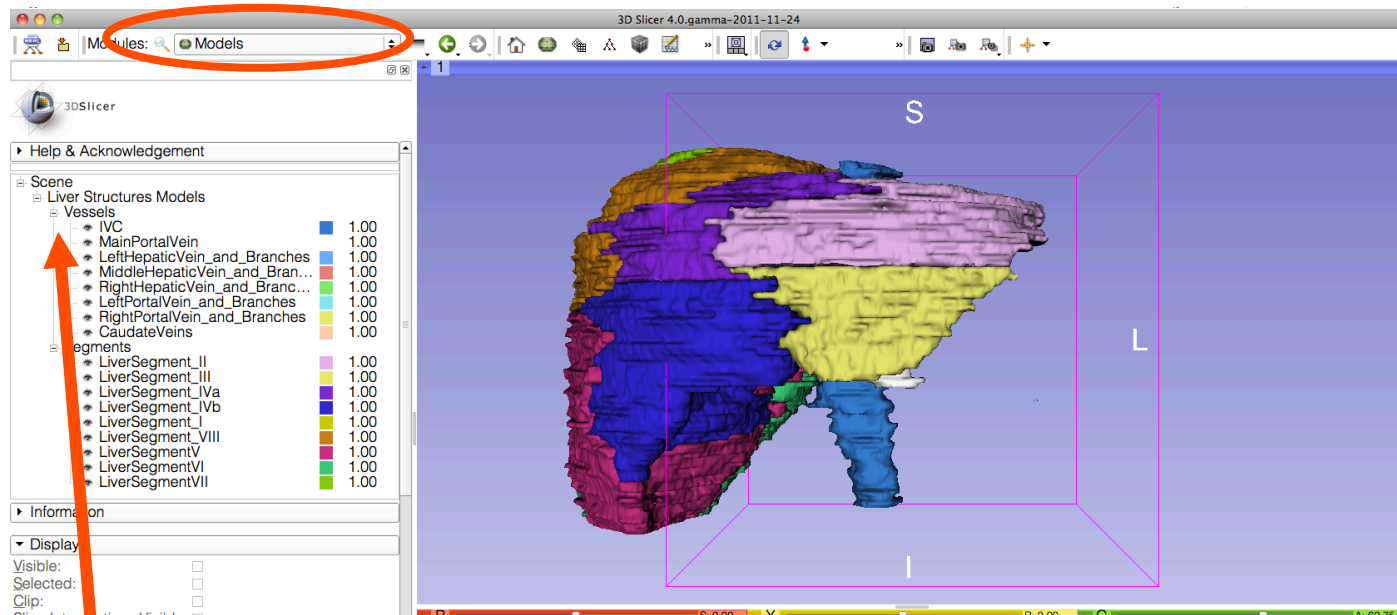


Example:

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



3D Exploration of Liver Segments

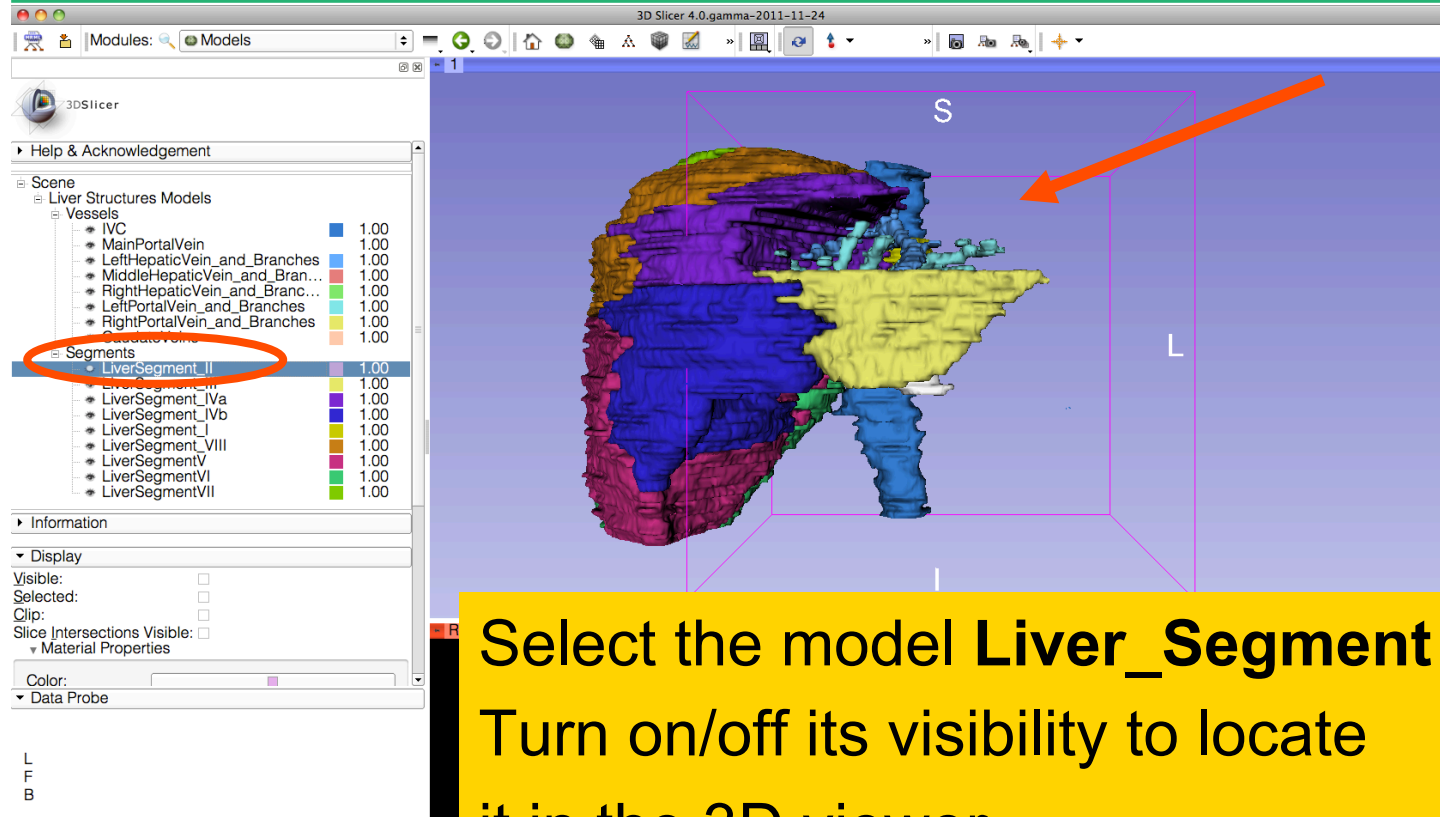


Select the module **Models**

Click on the Liver Structures Models Hierarchy



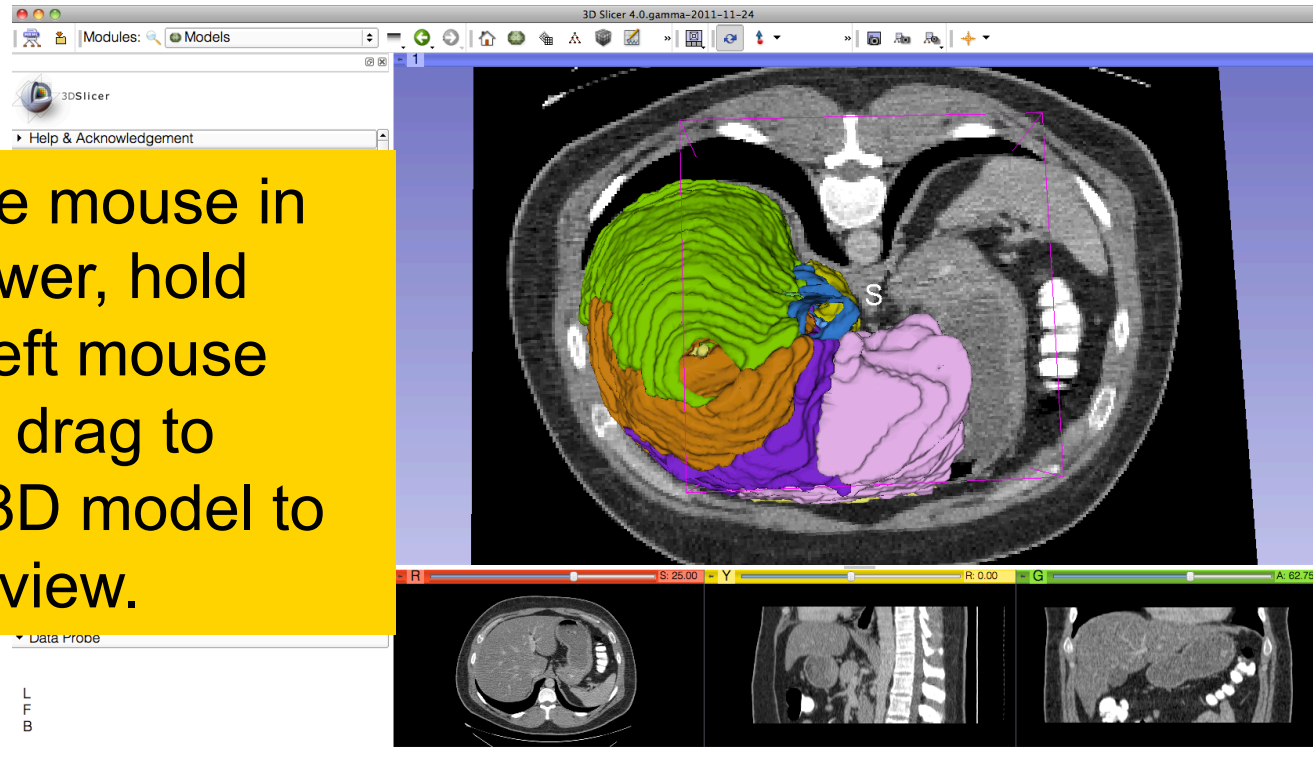
3D Exploration of Liver Segments





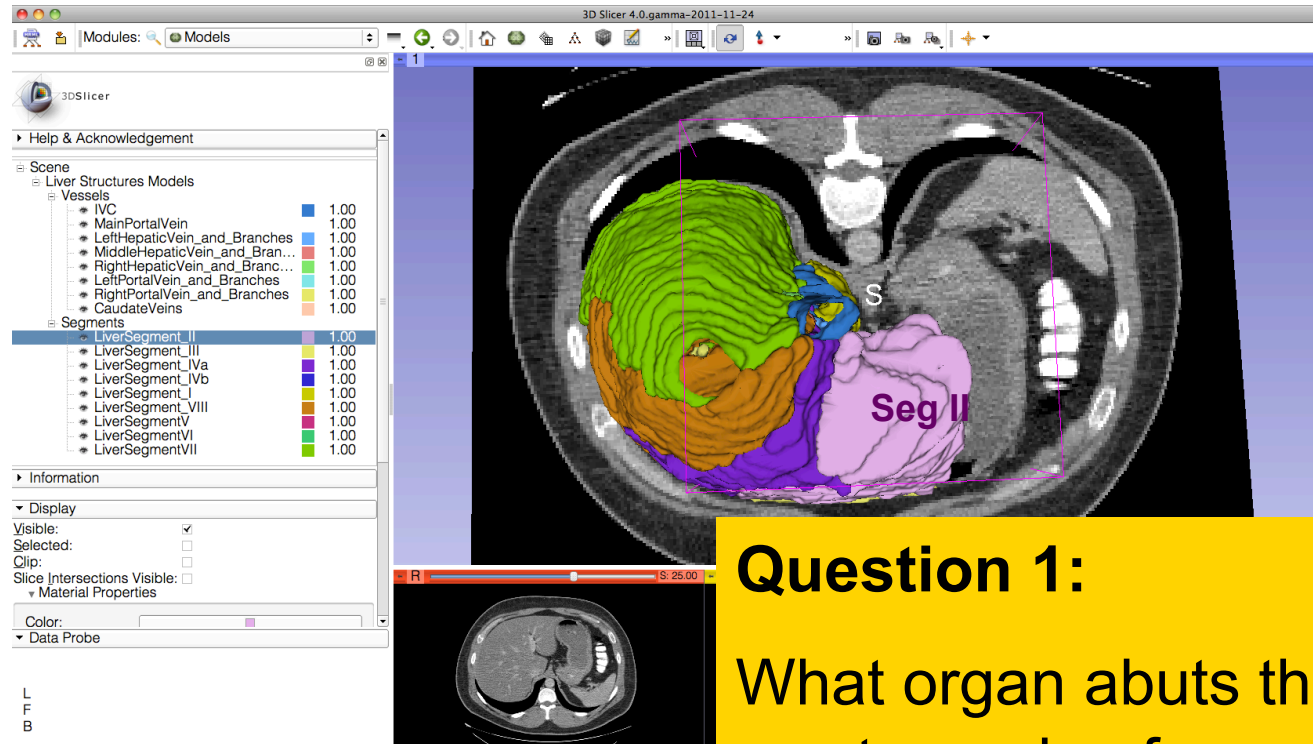
3D Exploration of Liver Segments

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





3D Exploration of Liver Segments



Question 1:

What organ abuts the left-most margin of segment II in Patient 1?

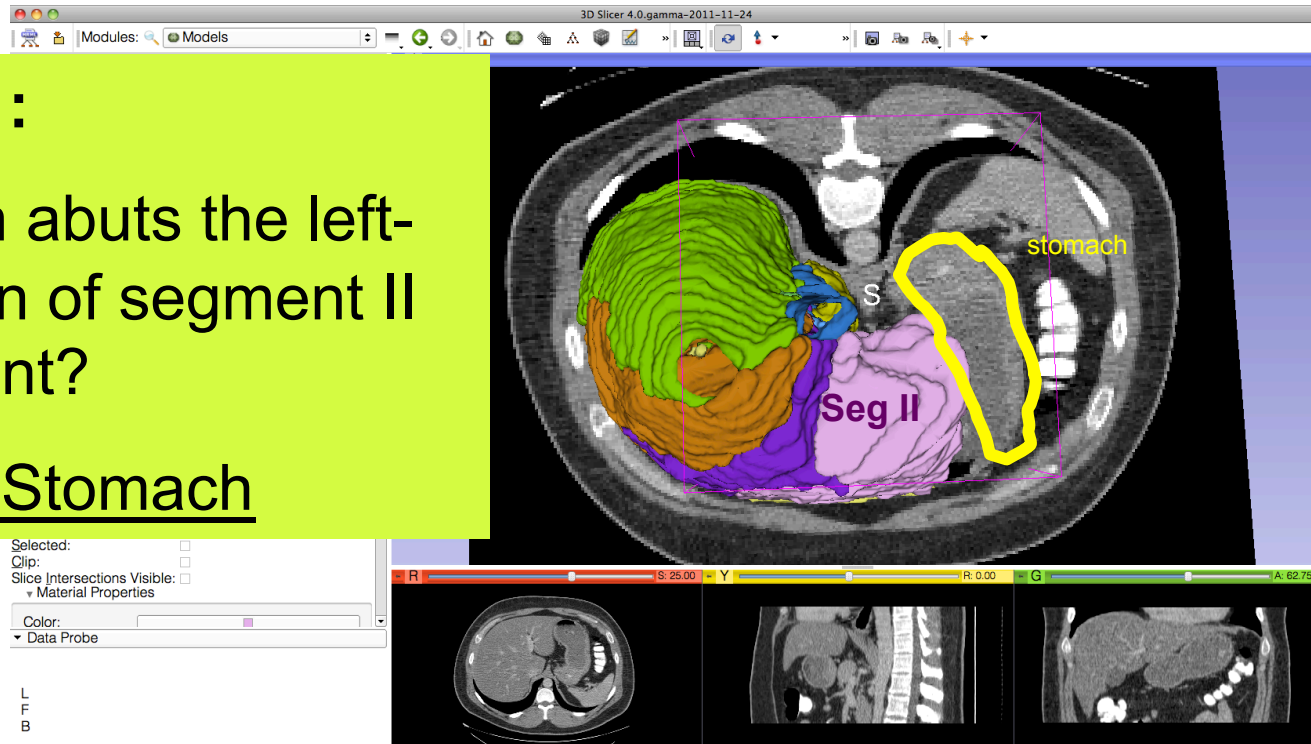


3D Exploration of Liver Segments

Question 1:

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

Answer 1: Stomach

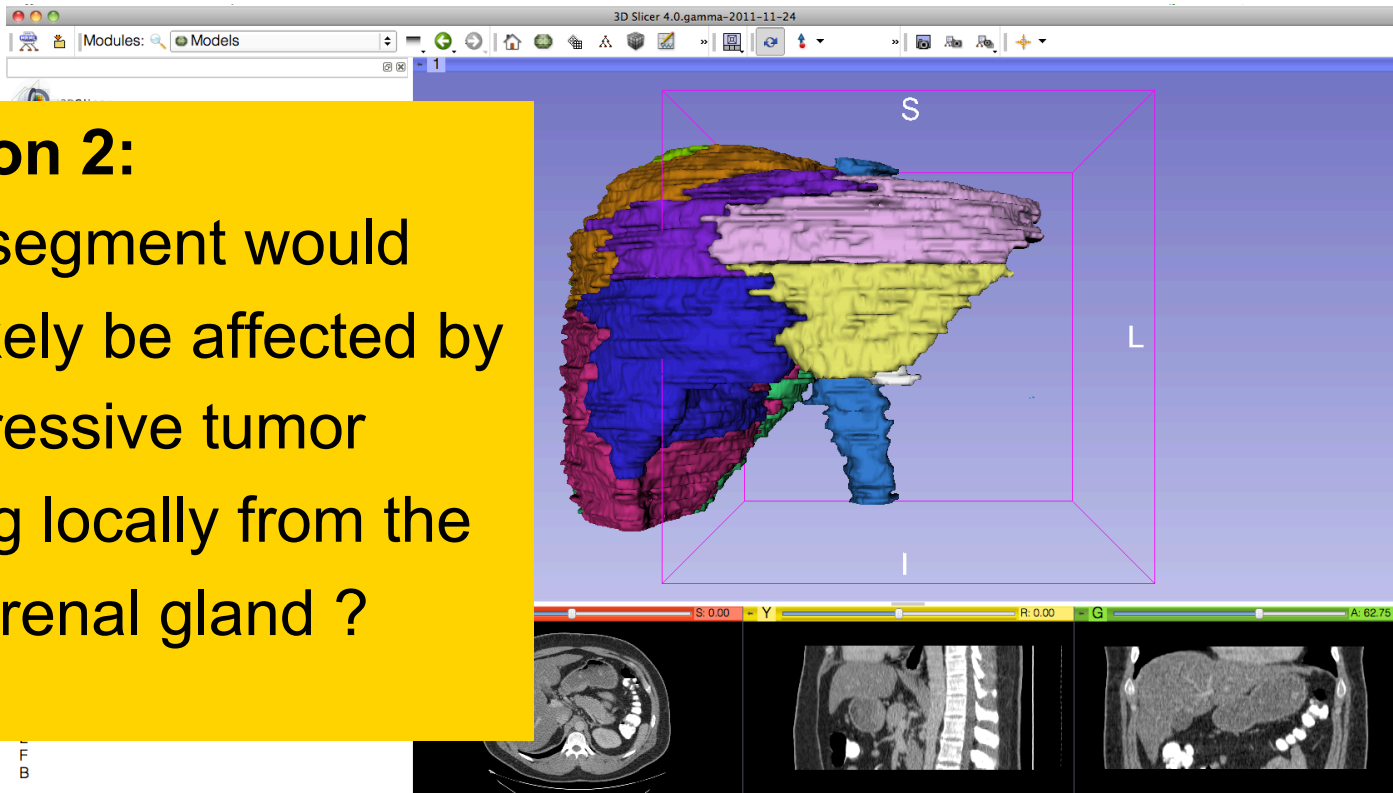




3D Exploration of Liver Segments

Question 2:

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





3D Exploration of Liver Segments

Question 2:

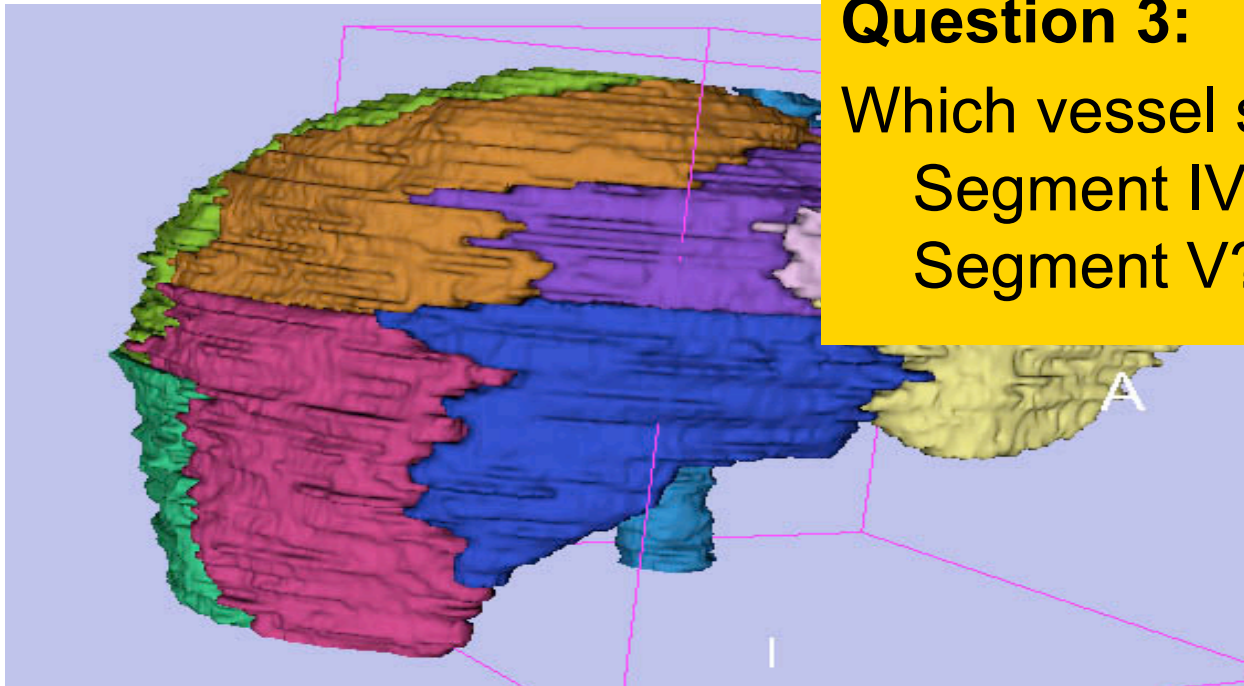
Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland ?

Answer 2: Segment VII





3D Exploration of Liver Segments

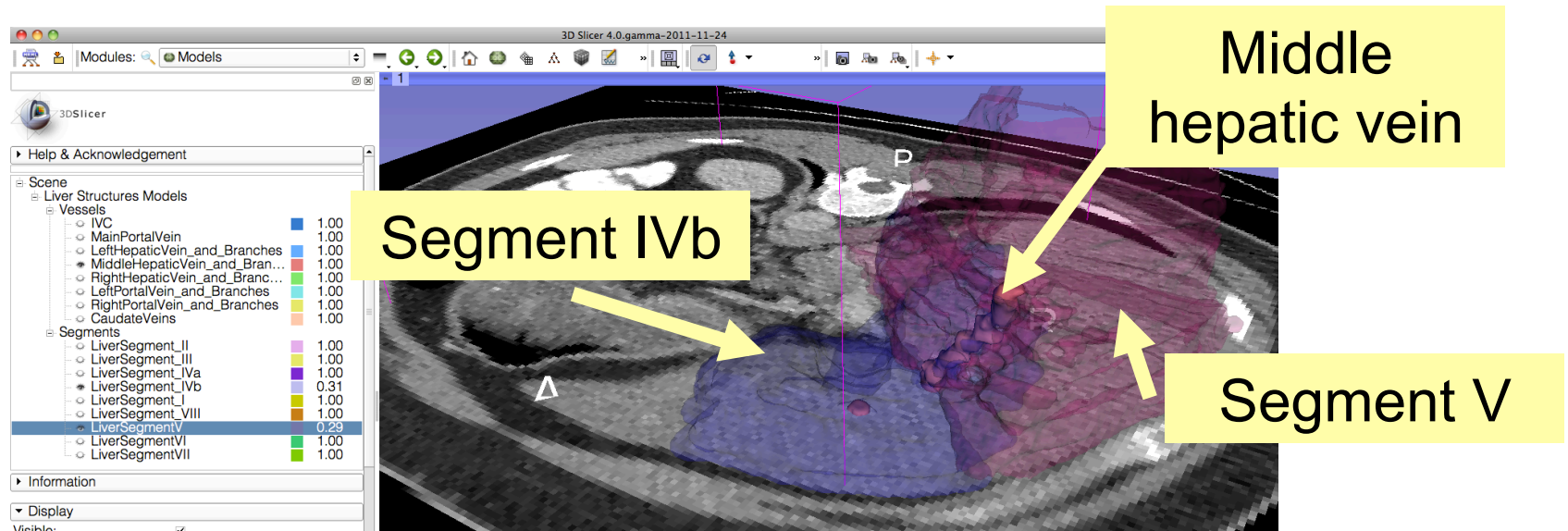


Question 3:

Which vessel separates Segment IVb and Segment V?



Middle Hepatic Vein



Question 3:

Which vessel separates Segment IVb and Segment V?

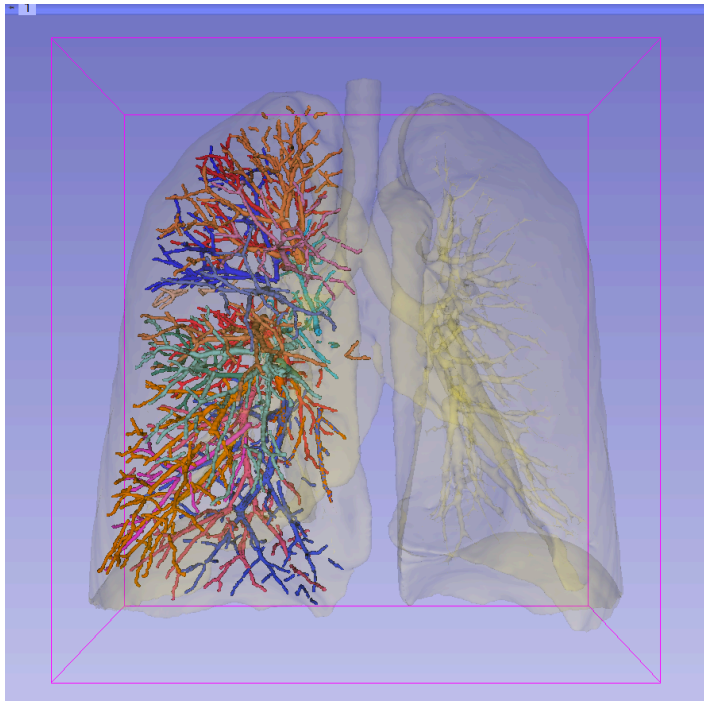
Answer 3: The middle hepatic vein



Closing the Liver Scene

Select **File** → **Exit** to close the Liver Scene and exit Slicer

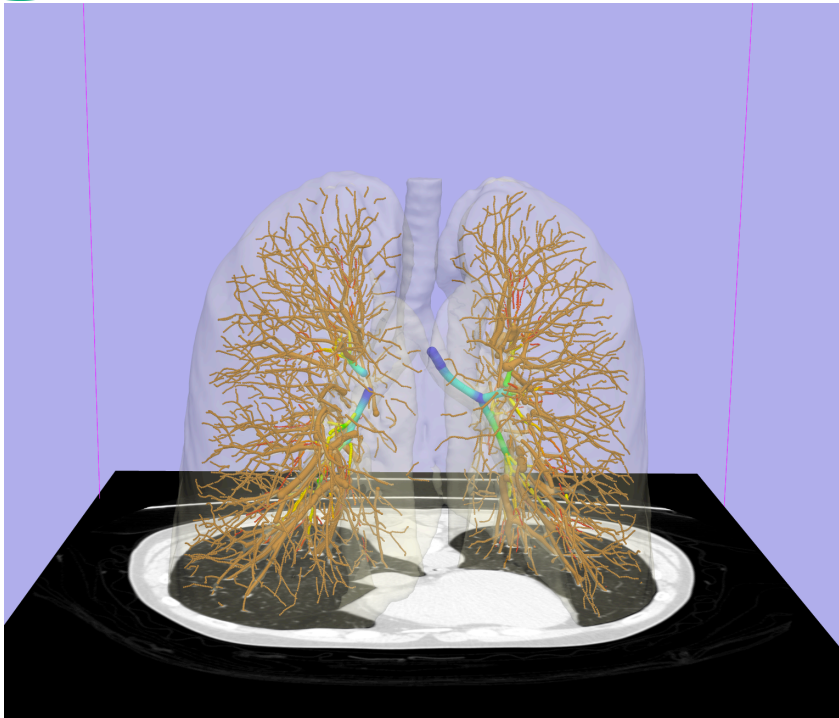




Interactive 3D Visualization of the segments of the lungs



Segments of the lung



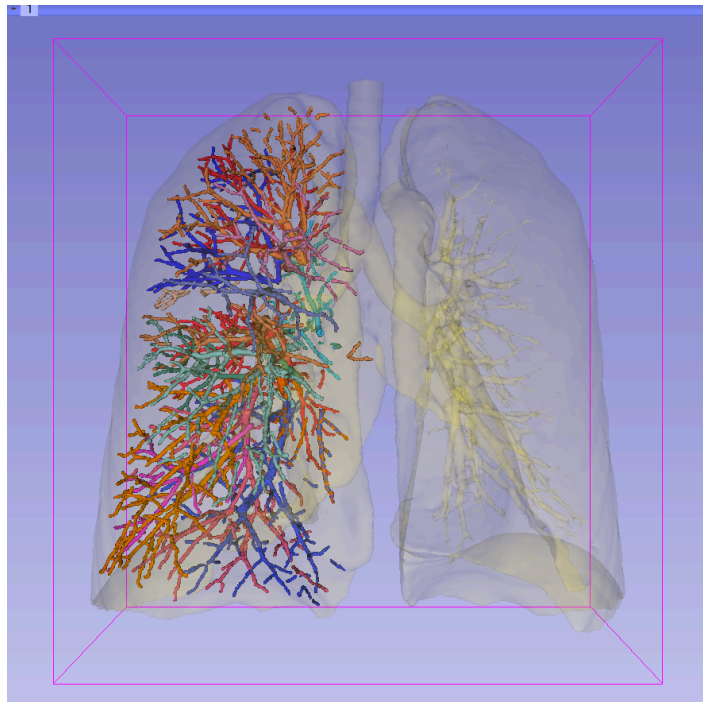
Segmentation and 3D surface reconstruction of the lung and pulmonary vessels

Acknowledgment:

Segmentation of the lung surface and vasculature: Raul San Jose Estepar, Ph.D., George Washko, M.D., Ed Silverman, M.D. and James Ross, MSc. Brigham and Women's Hospital (K25 HL104085) and COPDGene (01 HL089897 and U01 HL089856)



Segments of the lung

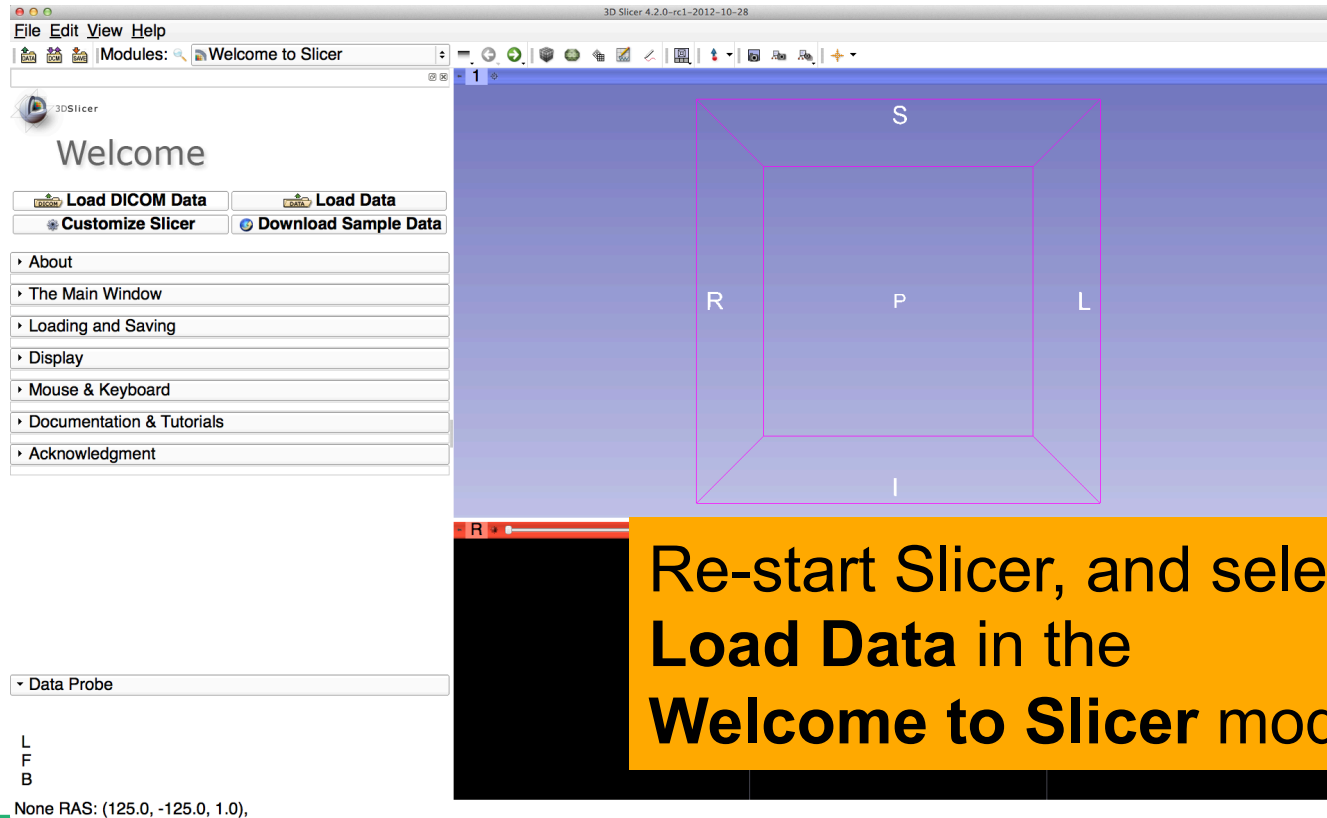


3D parcellation of arteries and veins from original model of pulmonary vessels
(Kitt Shaffer, M.D., Ph.D. - Sonia Pujol, Ph.D.)

- Right Upper Lobe (RUL)
 - RUL Pulmonary Vein
 - RUL Anterior Segment
 - RUL Apical Segment
 - RUL Posterior Segment
- Right Middle Lobe (RML)
 - RML Pulmonary Vein 1 & 2
 - RML Lateral Segment
 - RML Medial Segment
- Right 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

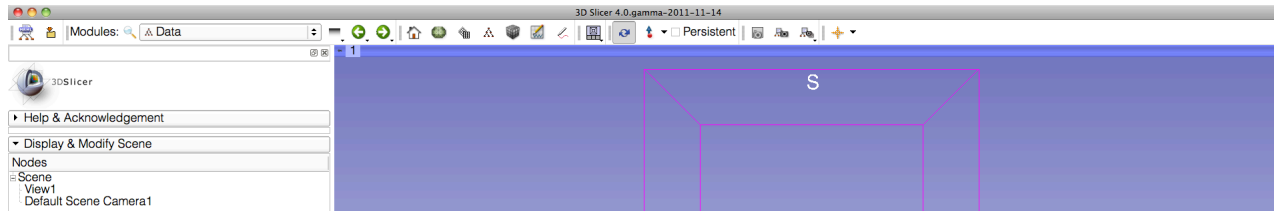


Loading the Chest Data Scene





Loading the Lung Scene



Click on Choose Files and browse to the directory

C:\Pujol2012\3DVisualization_Tuesday_Nov27_2012

Select the subdirectory dataset4_CT-Chest

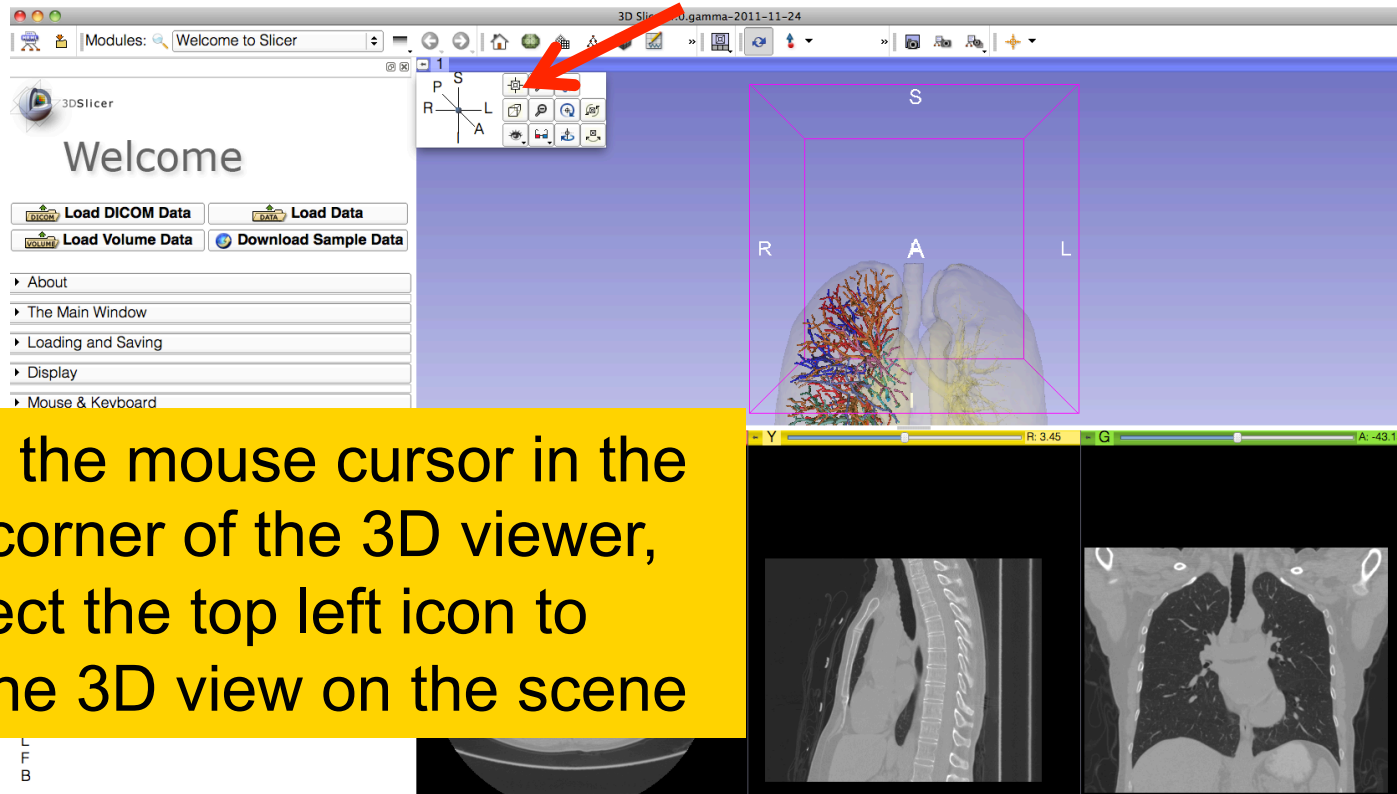
Select the file **LungSegment_Scene.mrml**

Click on Open

Click on OK to load the scene in Slicer



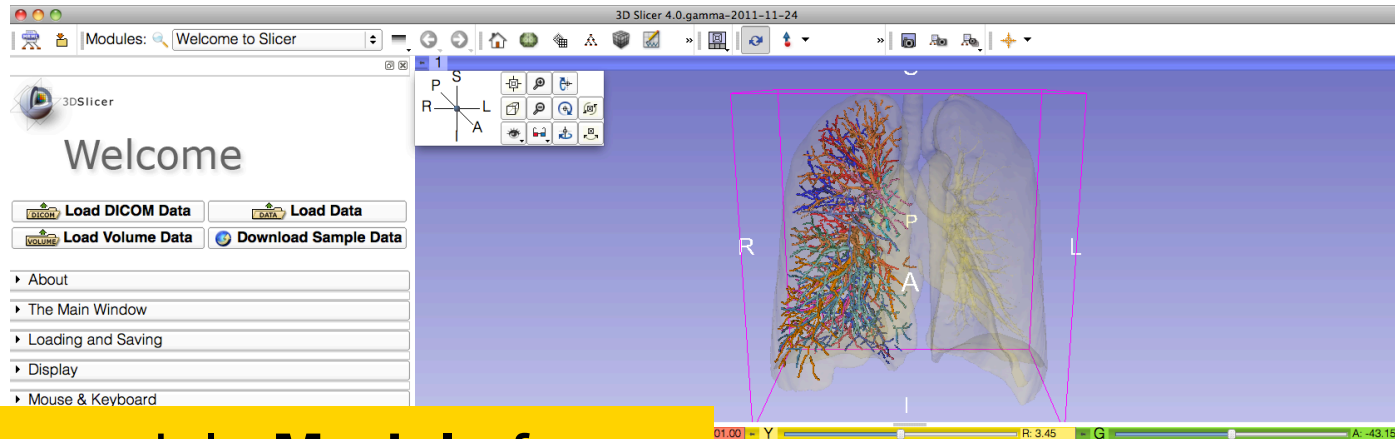
Loading the Lung Scene



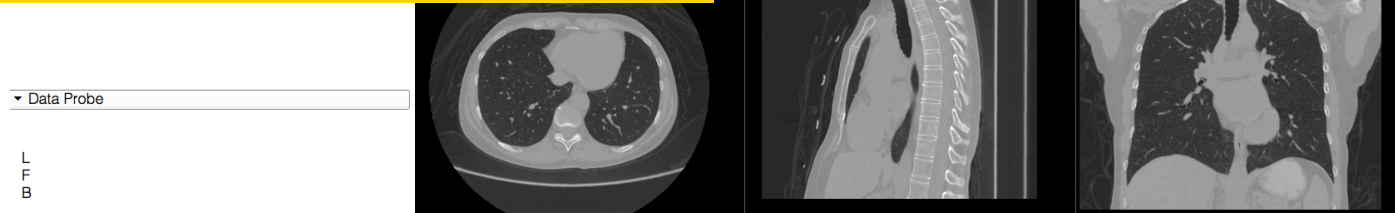
Position the mouse cursor in the top left corner of the 3D viewer, and select the top left icon to center the 3D view on the scene



Loading the Lung Scene

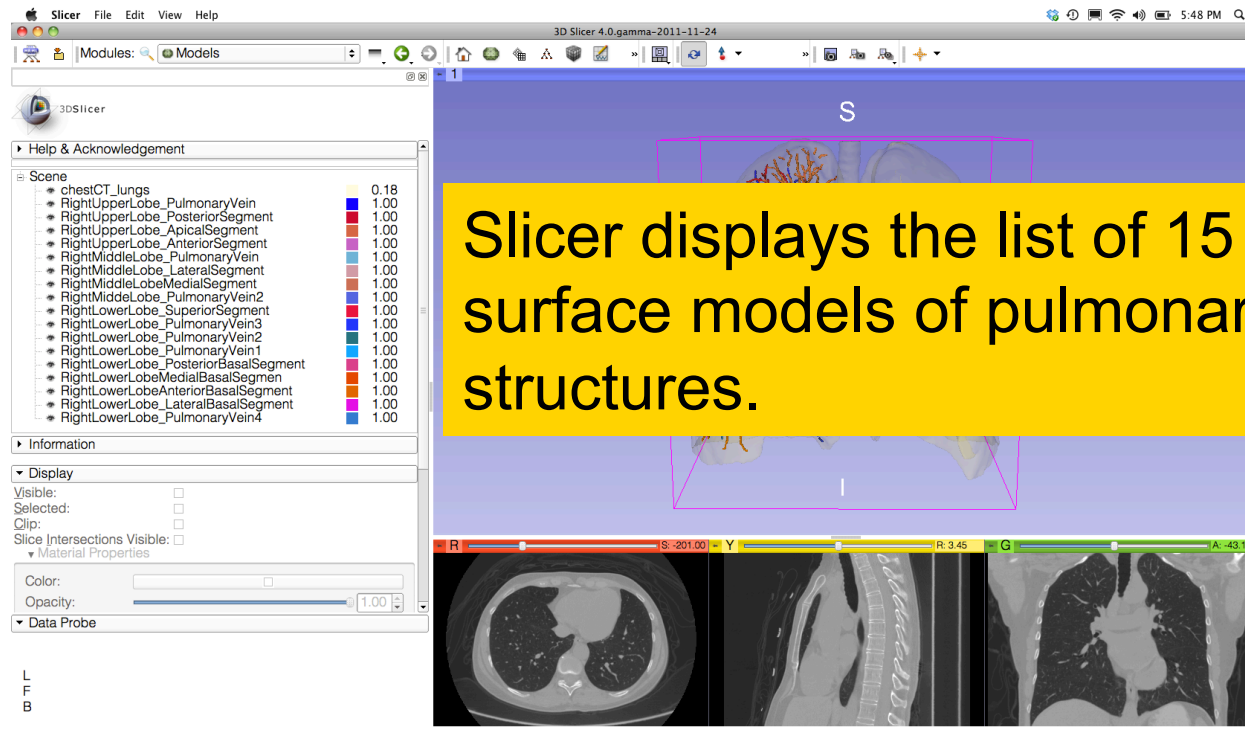


Select the module **Models** from the modules Menu.



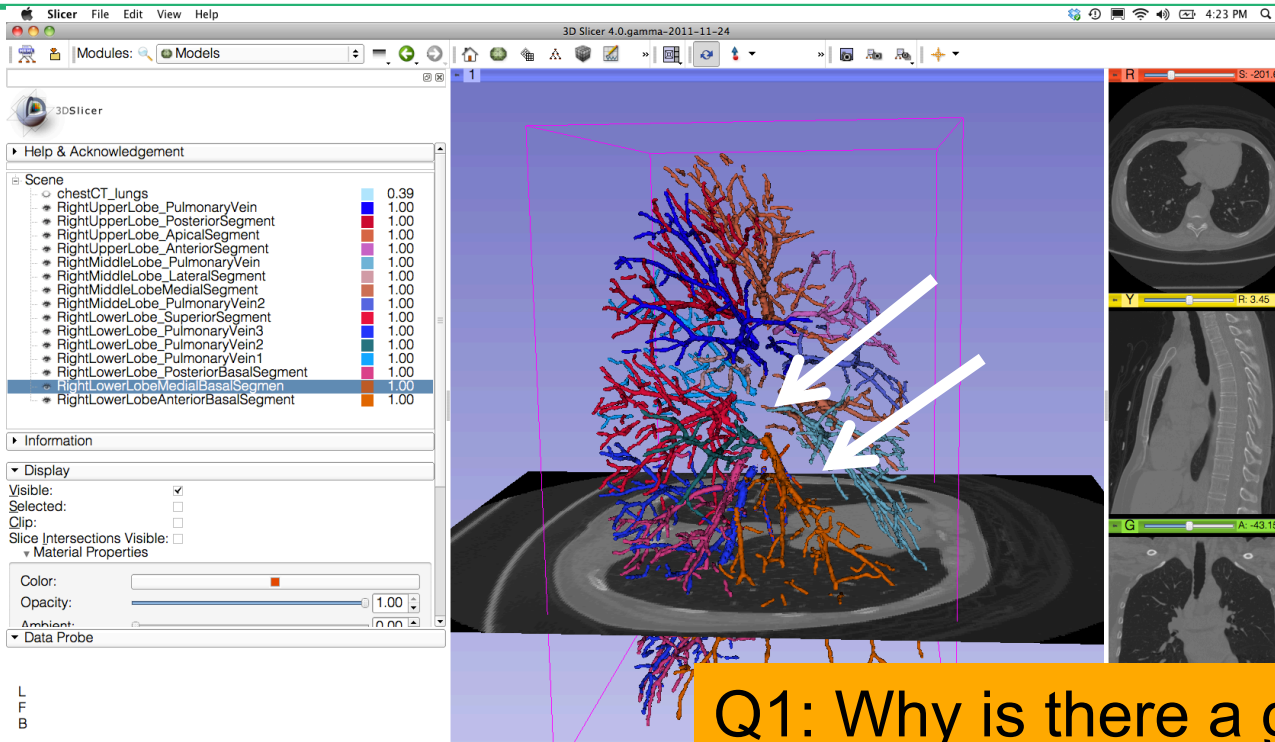


Lung Segments





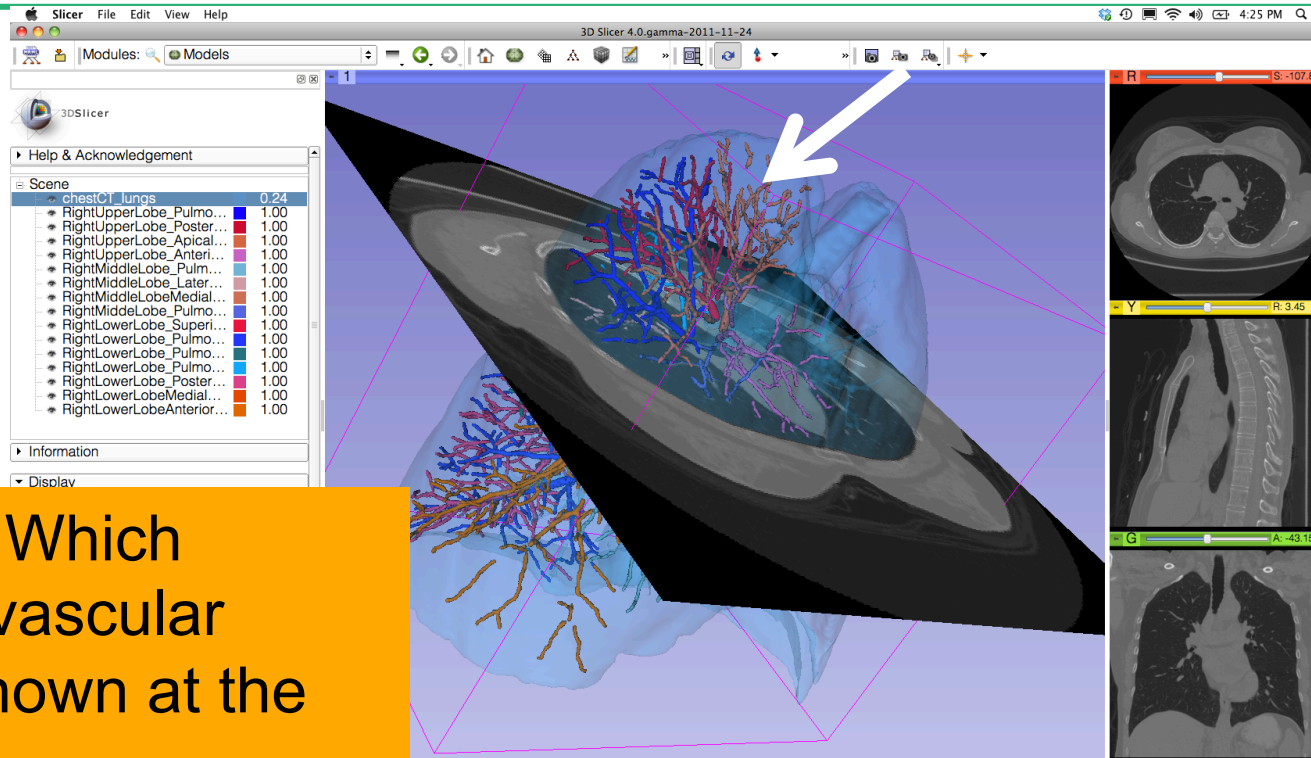
Lung Segments – Question 1



Q1: Why is there a gap in the vessels at the arrows?



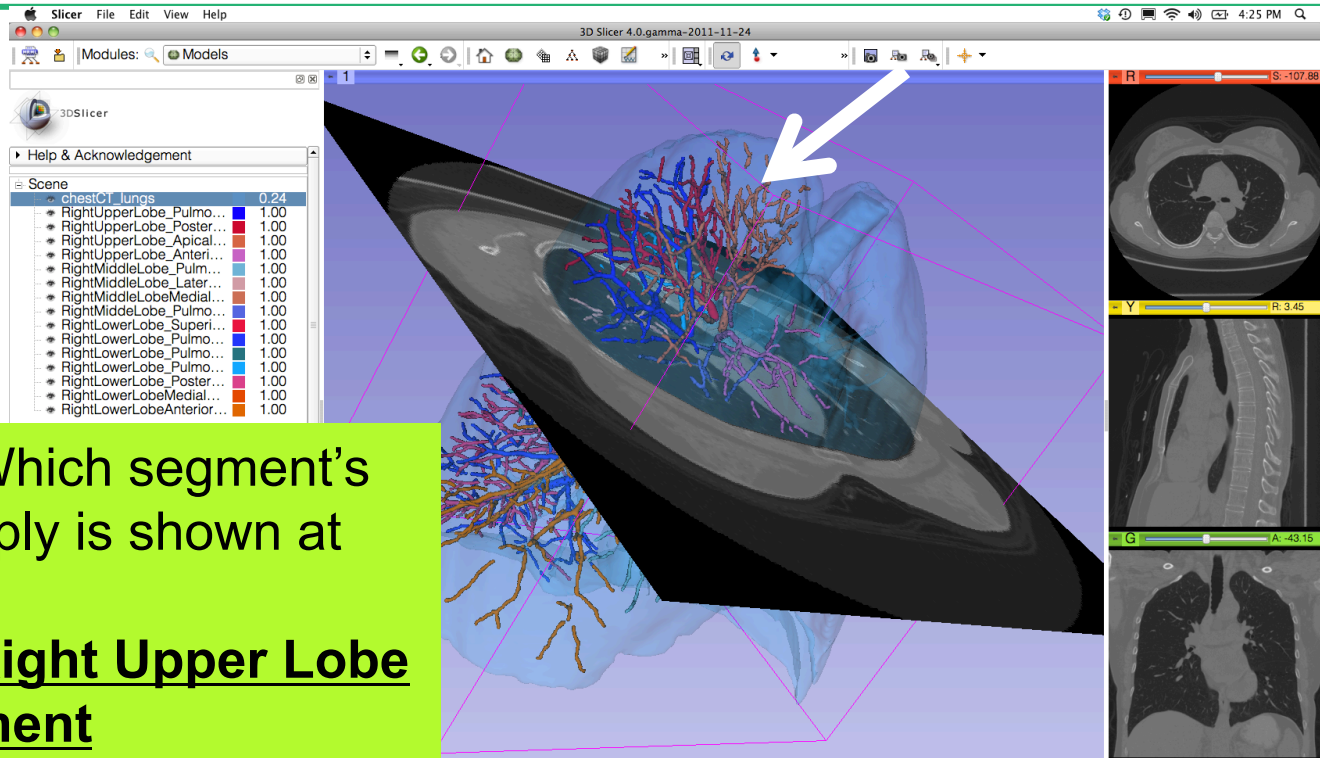
Lung Segments – Question 2



Question 2: Which segment's vascular supply is shown at the arrow?



Lung Segments – Question 2

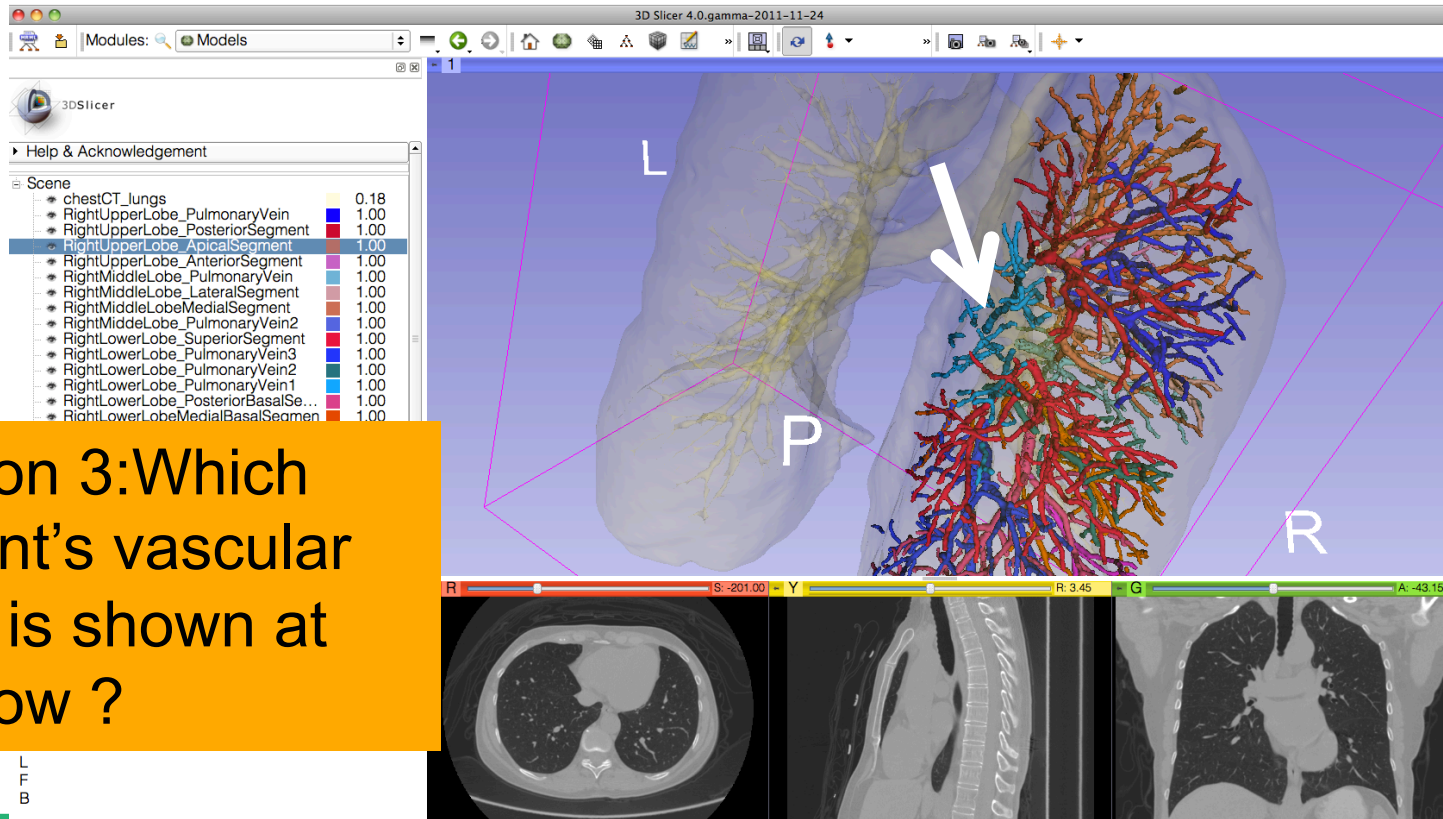


Question 2: Which segment's vascular supply is shown at the arrow?

Answer 2: Right Upper Lobe Apical Segment



Lung Segments – Question 3

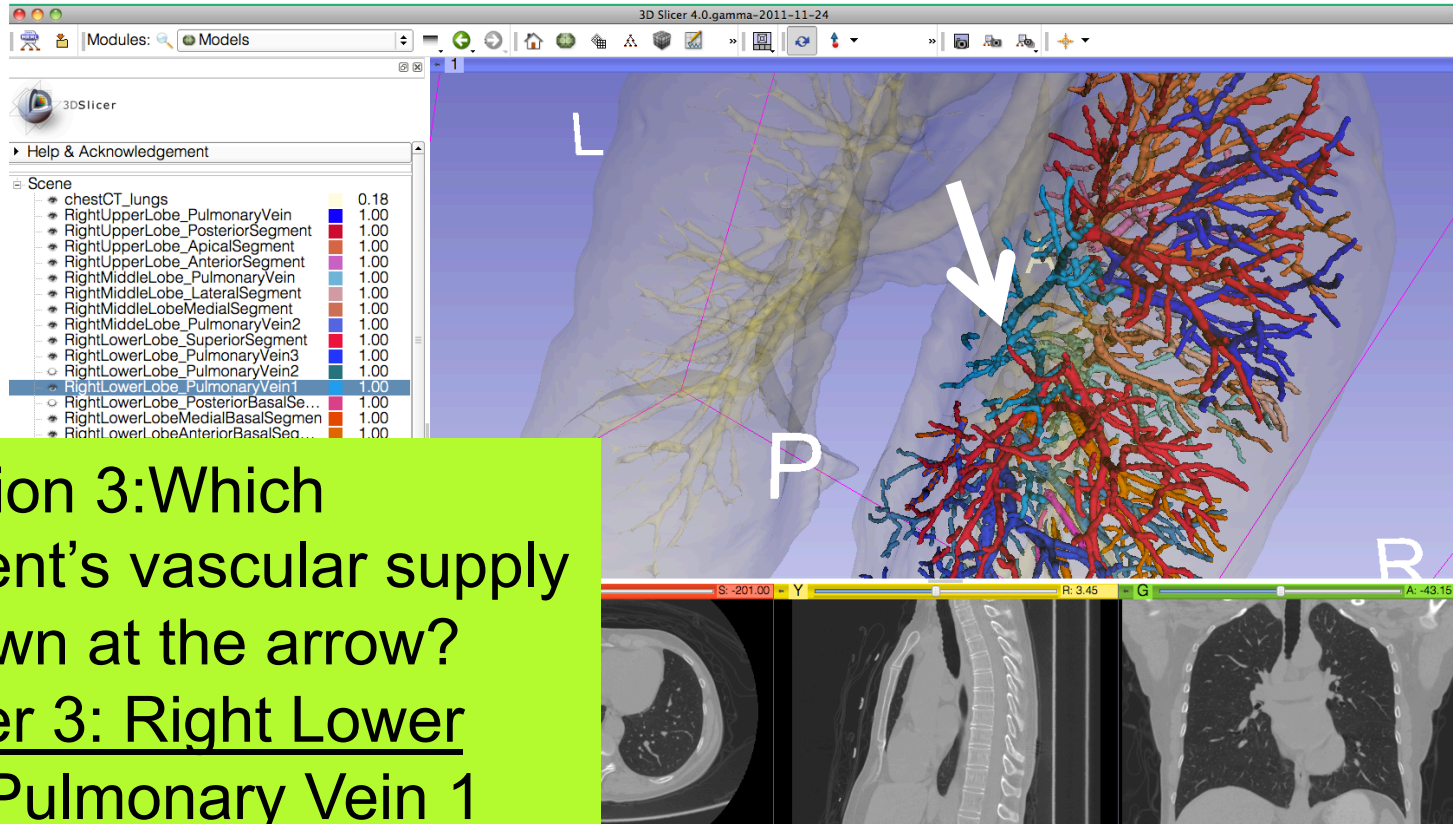


Question 3: Which segment's vascular supply is shown at the arrow?

L
F
B



Lung Segments – Question 3

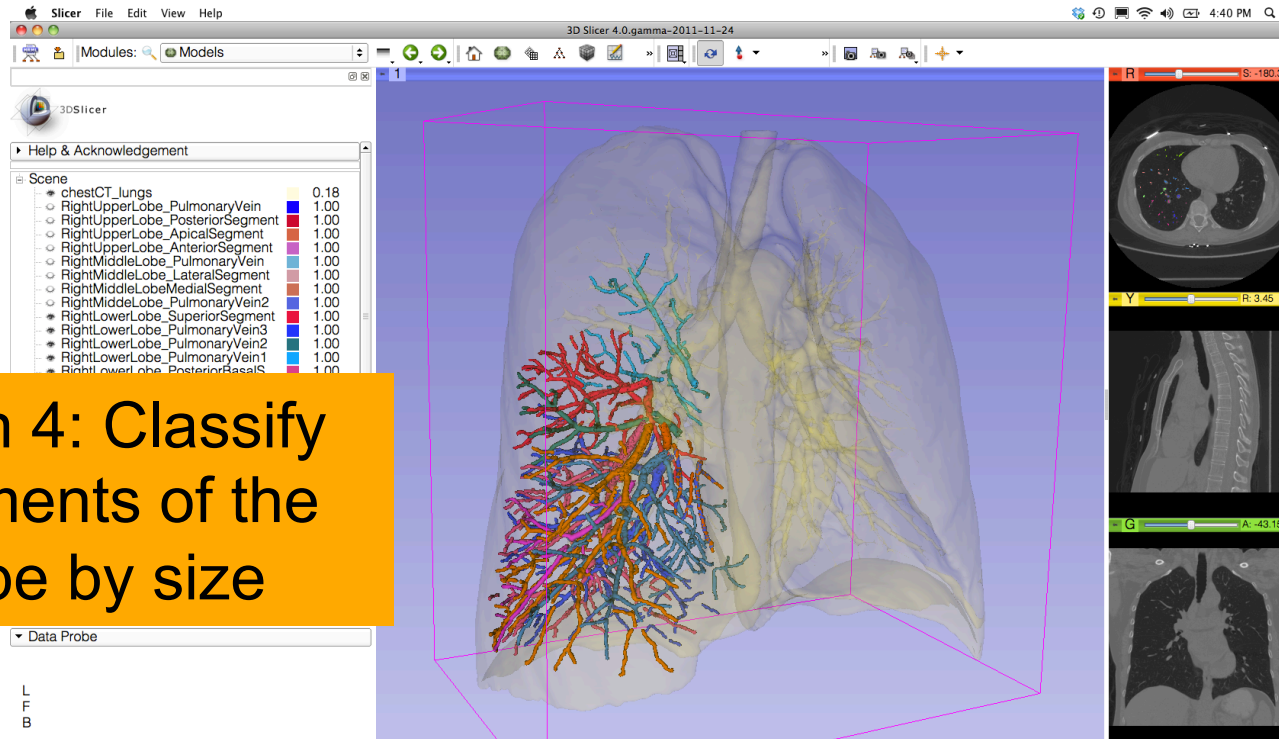


Question 3: Which segment's vascular supply is shown at the arrow?
Answer 3: Right Lower Lobe Pulmonary Vein 1



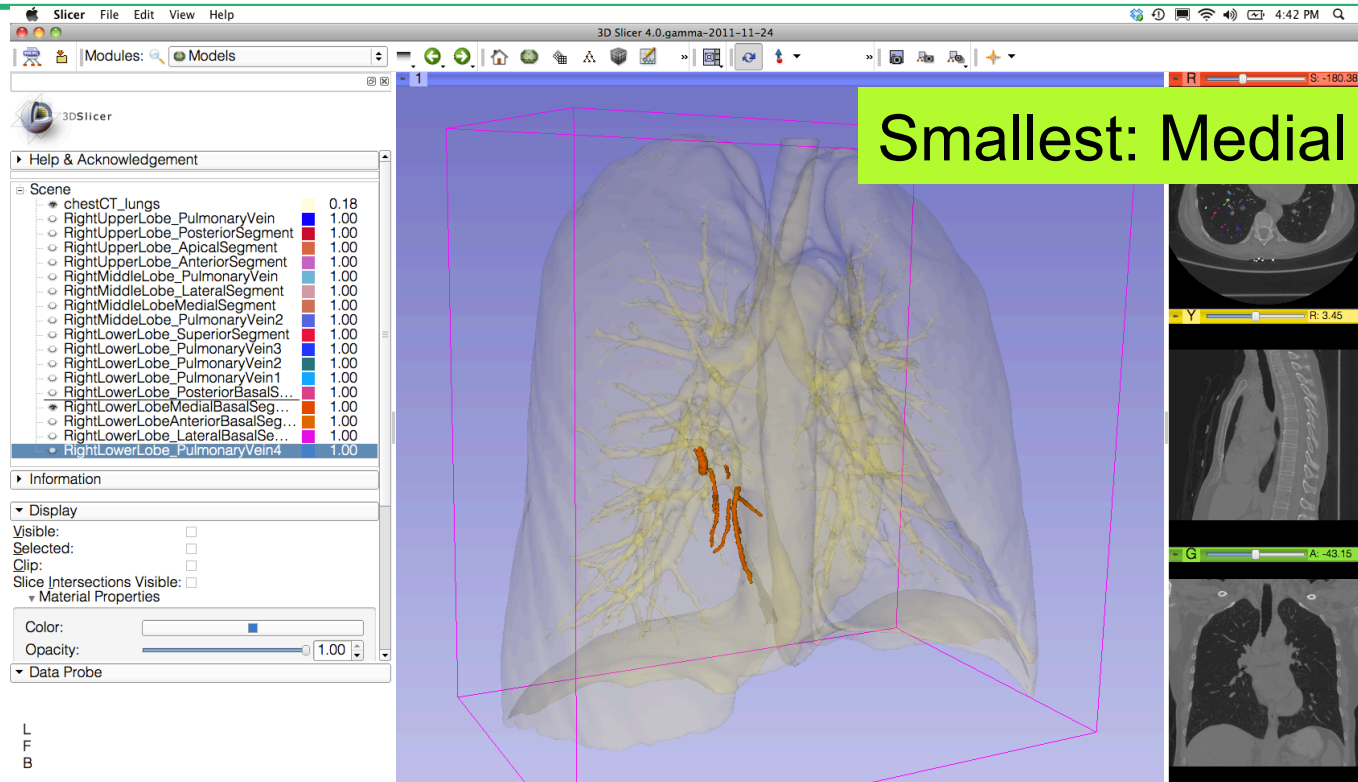
Lung Segments – Question 4

Question 4: Classify the segments of the lower lobe by size



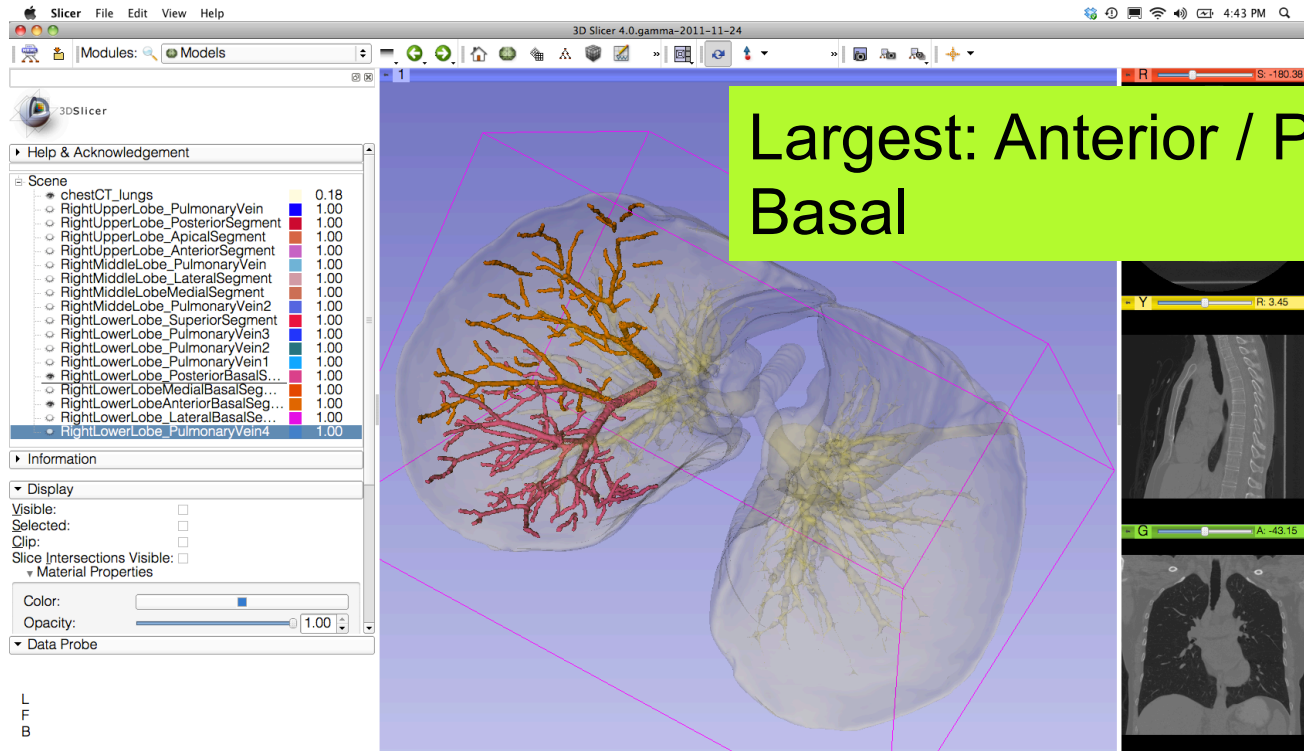


Lung Segments – Question 4



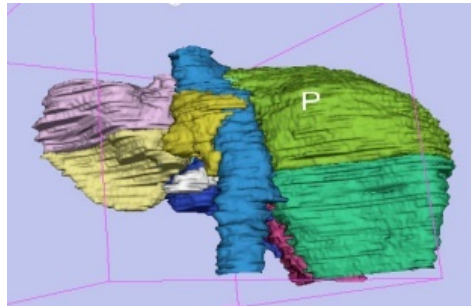
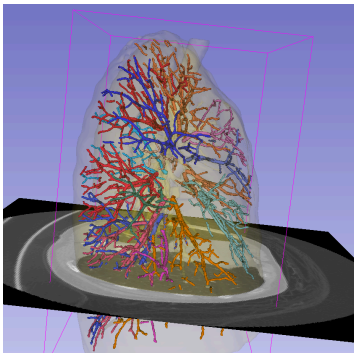
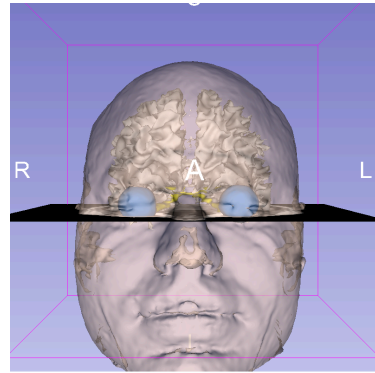
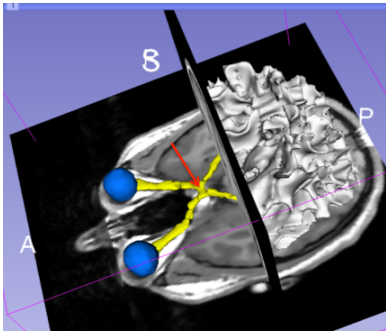


Lung Segments – Question 4





3D Visualization of DICOM images



- Interactive user-interface to load and manipulate greyscale volumes, labelmaps and 3D models.
- User-defined 3D view of the anatomy
- 3D Open-source platform for Linux, Mac and Windows



Acknowledgments



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



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

Marianna Jakab, Surgical Planning Laboratory, Brigham
and Women's Hospital



3DSlicer website

The screenshot shows the 3DSlicer website homepage. At the top left is the 3DSlicer logo, a stylized sphere with a grid. To its right is the text "3DSlicer" and a tagline: "A multi-platform, free and open source software package for visualization and medical image computing". Below the tagline are four buttons: "Download", "Tutorial", "Feedback", and "Documentation". A search bar is located in the top right corner.

On the left side, there is a "Slicer Wiki" section with a sidebar menu containing "About Slicer" (with sub-links for Introduction, Acknowledgments, and Contact Us) and "Resources" (with a "Download" button and sub-links for For Users, For Developers, Commercial Use, NCIA, Publication DB, Image Gallery, Slicer Community, Source Code, Licensing, Mailing Lists, and Web Archive).

The main content area features three columns of images illustrating the software's capabilities:

- Powerful processing.** Shows a series of medical images with a heatmap overlay.
- Streamlined interface.** Shows a 3D model of a brain with a yellow mesh overlay.
- Extensible platform.** Shows a 3D model of a hand with a purple mesh overlay.

Below these images is a large banner for "3D Slicer version 4" with the website URL "www.slicer.org".

At the bottom of the page, there is a notice: "The community of Slicer developers is proud to announce the release of Slicer 4.2. Find out more..." and a link to a "Webinar: Introduction to Slicer 4.1".

Footnote text at the very bottom: "Content of this site is Copyright 2012 BWH and 3D Slicer contributors, unless otherwise noted. Contact webmaster@bwh.harvard.edu for questions about the use of this site's content. See [here](#) for more information about the web infrastructure."