



Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

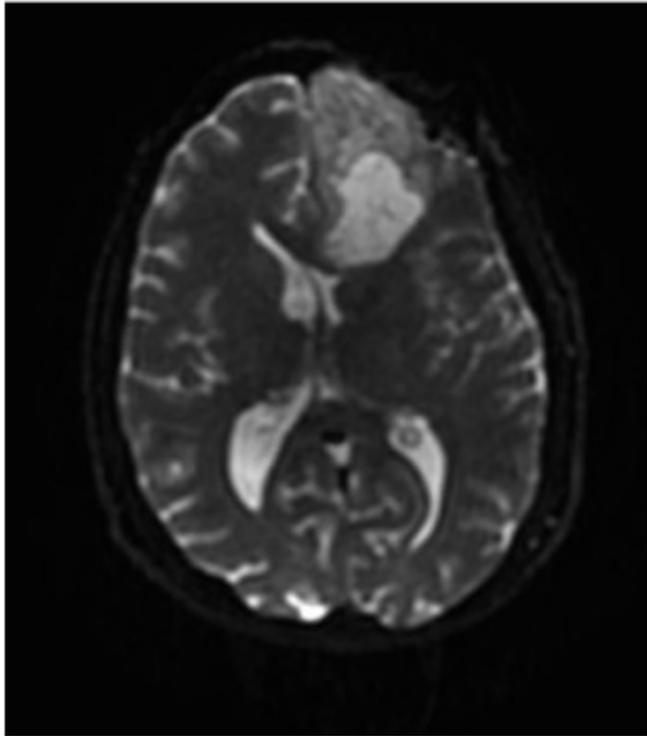
Sonia Pujol, Ph.D.

Ron Kikinis, M.D.

Surgical Planning Laboratory

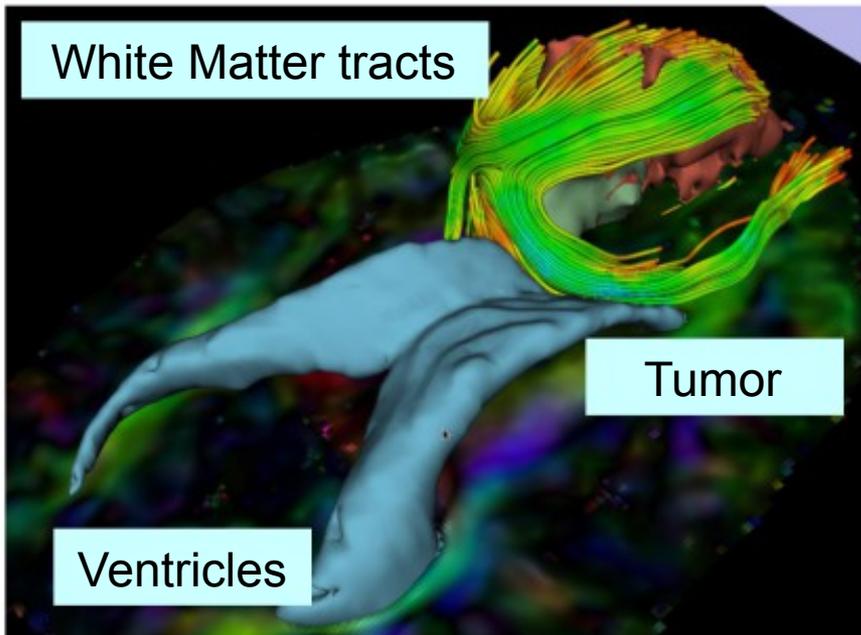
Harvard University

Clinical Case



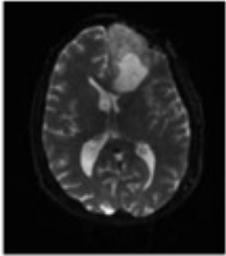
- 35 year-old male diagnosed with Glioblastoma multiform (GBM)
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal

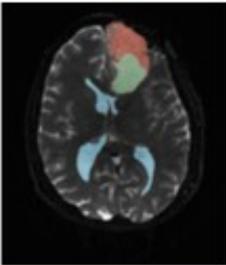


The goal of this tutorial is to explore white matter fibers surrounding a tumor using Diffusion Tensor Imaging (DTI) Tractography.

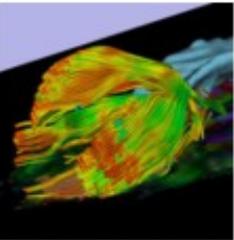
Overview of the analysis pipeline



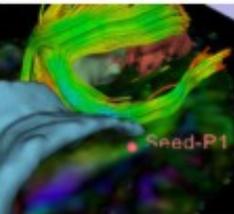
Part 1: Loading & Visualization of Diffusion Data



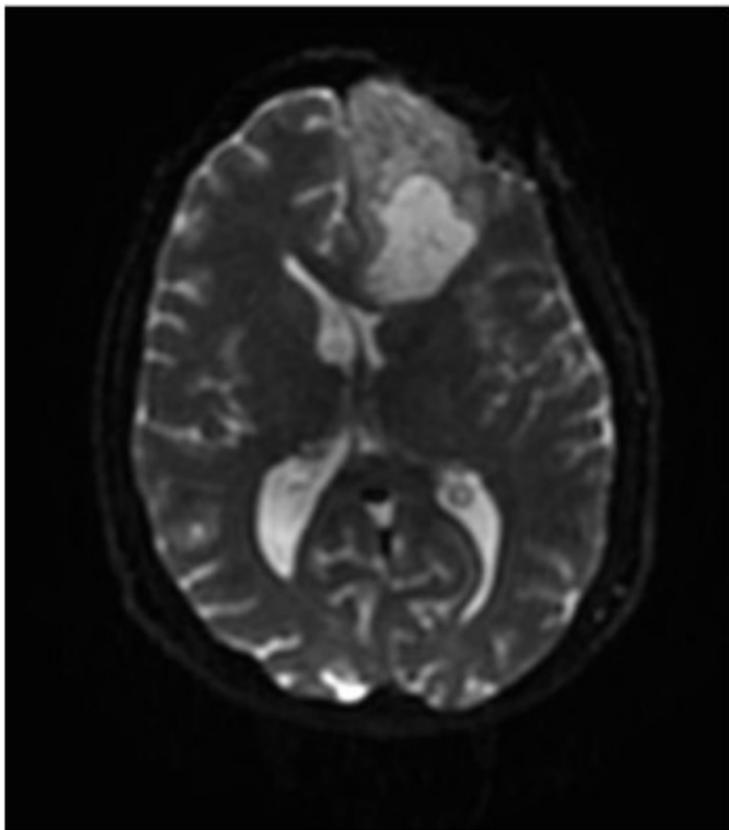
Part 2: Segmentation of lat. ventricles, and solid and cystic parts of the tumor



Part 3: Tractography reconstruction of white matter fibers in the peri-tumoral volume

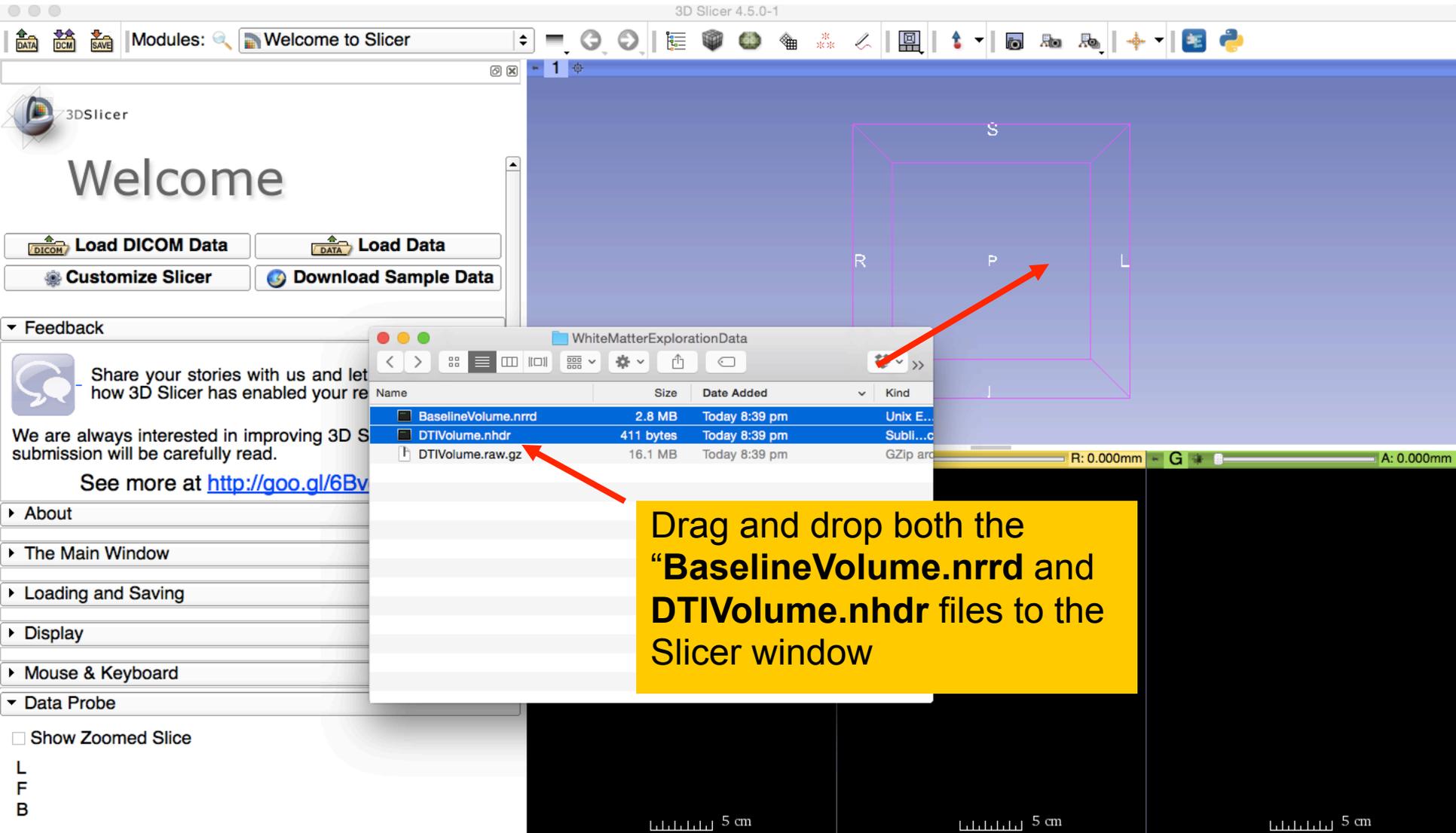


Part 4: Tractography exploration of the ipsilateral and contralateral side



Part 1: Loading and Visualization of Diffusion Data

Loading DTI and Baseline Data



Loading DTI and Baseline Data

3D Slicer 4.5.0-1

Modules: Welcome to Slicer

3DSlicer

Welcome

Load DICOM Data

Customize Slicer

Feedback

Share your stories with us and how 3D Slicer has enabled you

We are always interested in improving 3D Slicer. Your submission will be carefully read.

See more at <http://goo.gl/6>

About

The Main Window

Loading and Saving

Display

Mouse & Keyboard

Data Probe

Show Zoomed Slice

L
F
B

5 cm

5 cm

5 cm

Add data into the scene

Choose Directory to Add

Choose File(s) to Add

Show Options

File	Description
...gfan/Downloads/WhiteMatterExplorationData/BaselineVolume.nrrd	Volume
...hangfan/Downloads/WhiteMatterExplorationData/DTIVolume.nhdr	Volume

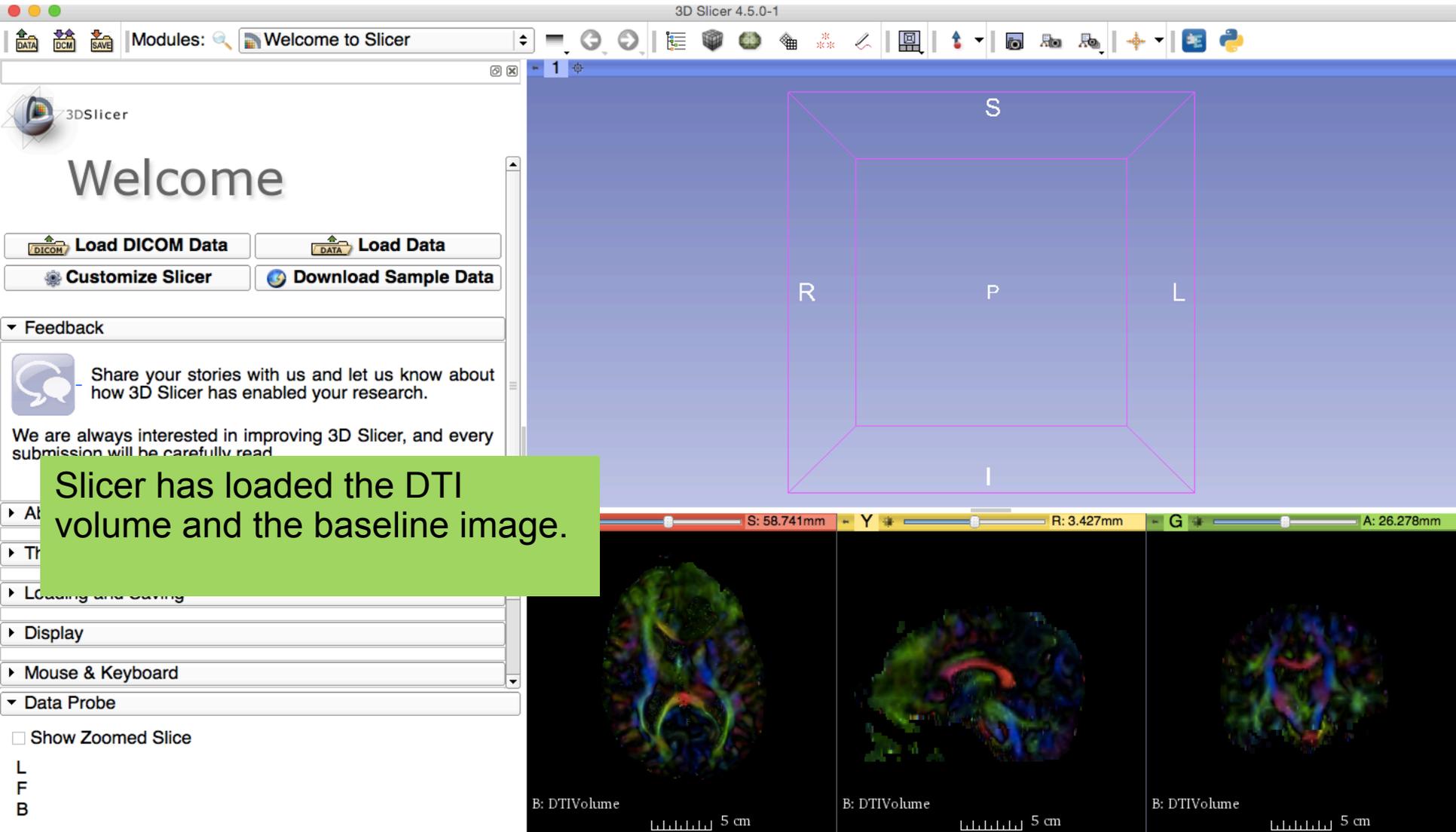
Reset

OK

Cancel

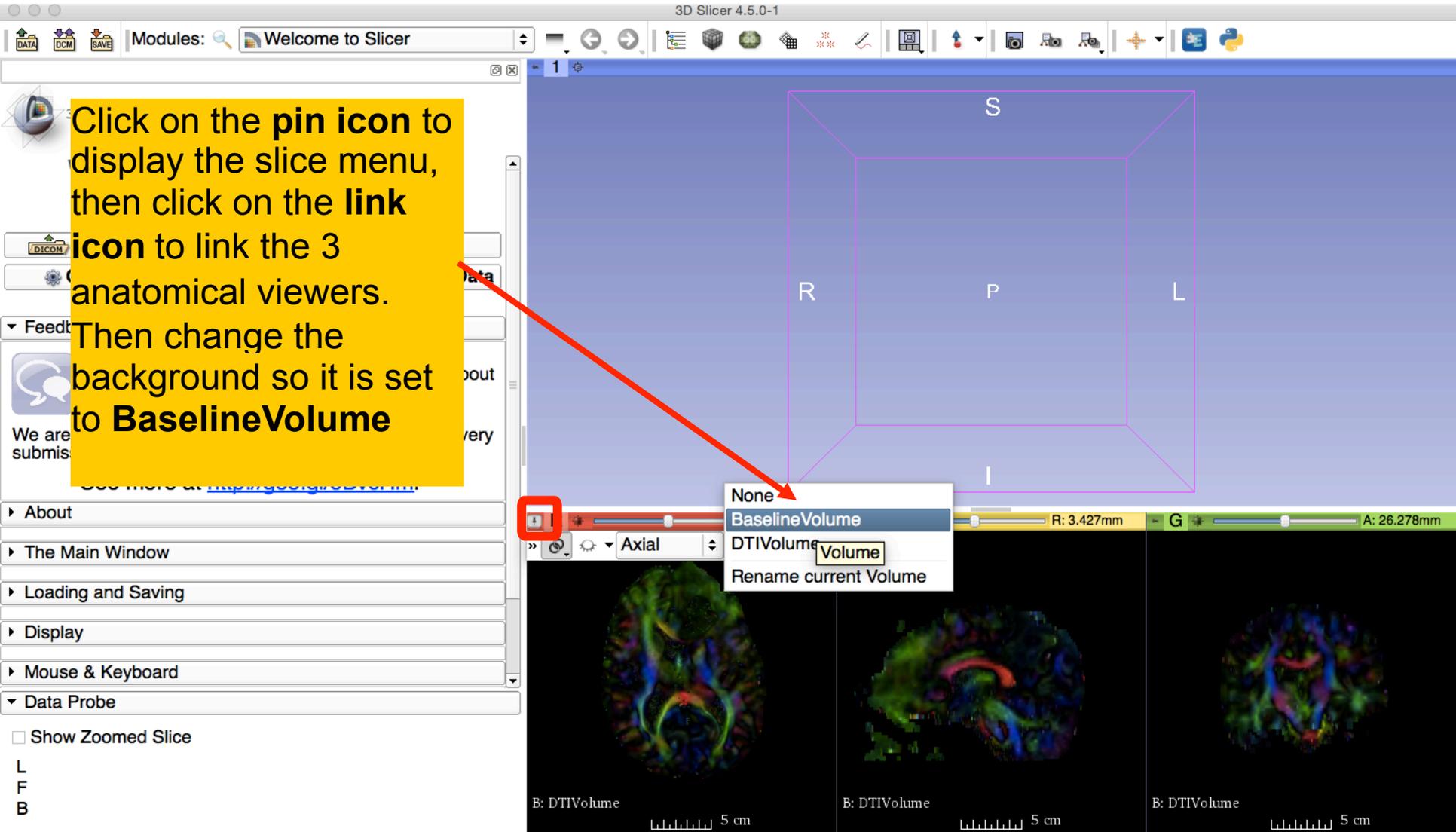
After dragging and dropping the **“.nrrd and .nhdr volume files”** into the Slicer window, click on **OK**

Loading DTI and Baseline Data

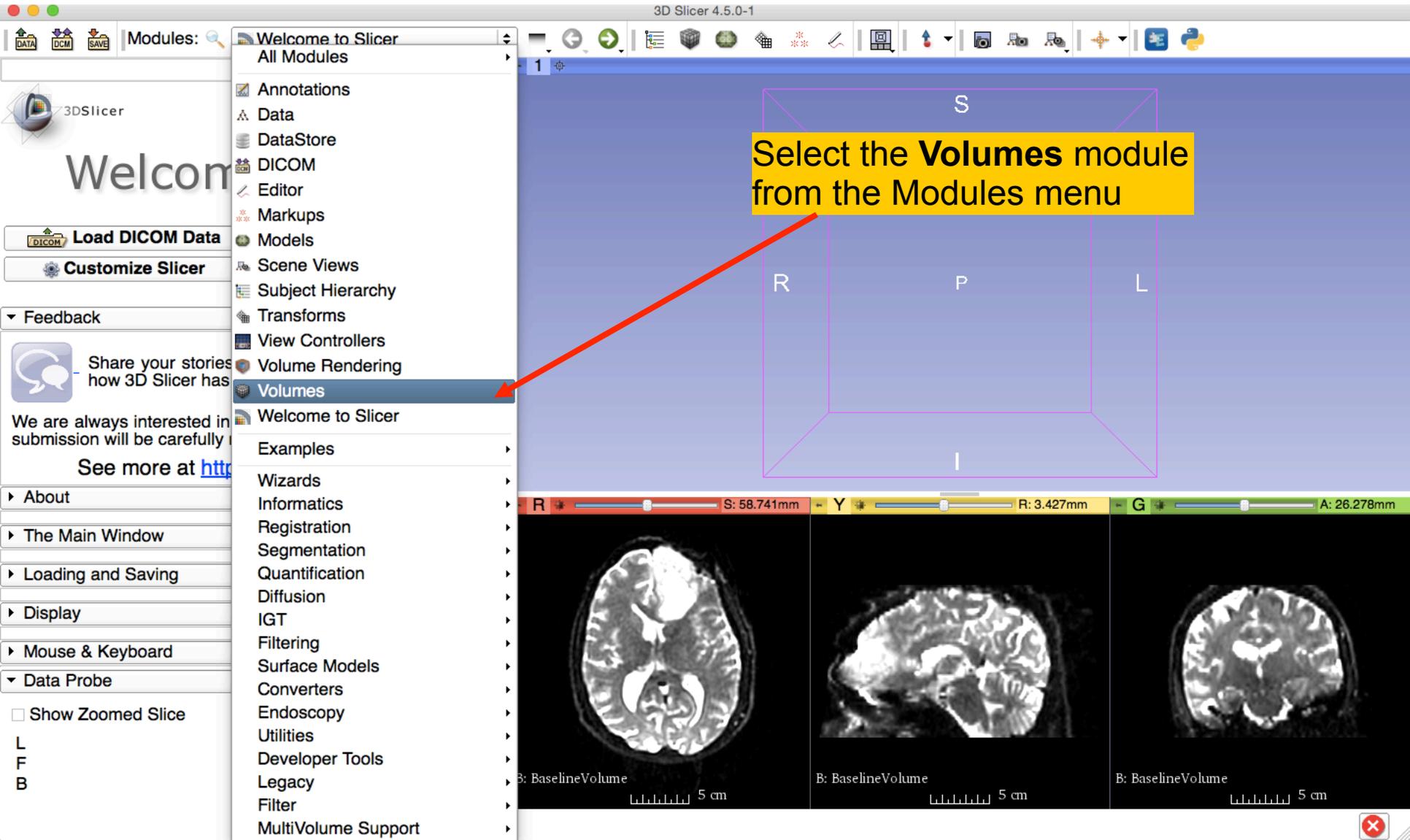


Loading DTI and Baseline Data

Click on the **pin icon** to display the slice menu, then click on the **link icon** to link the 3 anatomical viewers. Then change the background so it is set to **BaselineVolume**



Loading DTI and Baseline Data



Loading DTI and Baseline Data

The screenshot displays the 3D Slicer 4.5.0-1 interface. The top toolbar includes icons for DATA, DCM, SAVE, and various viewing tools. The 'Modules' dropdown is set to 'Volumes'. The left sidebar shows the '3DSlicer' logo and a 'Help & Acknowledgement' section. Below this, the 'Active Volume' is set to 'BaselineVolume'. The 'Volume Information' section is collapsed. The 'Display' section is expanded, showing a 'Lookup Table' set to 'Grey' and 'Interpolate' checked. Under 'Window Level editor presets', five icons are visible. A red box highlights the 'Manual W/L' section, which includes a 'W: 1599' field, a 'Manual W/L' dropdown, and an 'L: 890' field. Below this is a 'Threshold' section with a 'Manual' dropdown and a range from -721 to 18369. A 'Histogram' section is also present. The 'Data Probe' section is collapsed, with 'Show Zoomed Slice' unchecked. The bottom left corner shows 'L', 'F', and 'B' labels. The main 3D view shows a brain slice with a purple wireframe box. A green text box overlaid on the 3D view reads: 'The user can manually adjust the **Window Level editor presets** with the **Volume** module menu'. Below the 3D view are three 2D slice views: an axial slice (labeled 'R'), a sagittal slice (labeled 'S: 58.741mm'), and a coronal slice (labeled 'R: 3.427mm'). Each slice view has a 5 cm scale bar. The bottom right corner has a red 'X' icon.

Loading DTI and Baseline Data

The screenshot displays the 3D Slicer 4.5.0-1 interface. On the left, the 'Volumes' module is active, showing the 'BaselineVolume' as the active volume. The 'Display' section includes a 'Lookup Table' set to 'Grey', 'Interpolate' checked, and 'Window Level editor presets' with a 'Manual W/L' slider set to 'W: 1599' and 'L: 890'. The 'Threshold' is set to 'Manual' with a range from -721 to 18369. The 'Data Probe' section has 'Show Zoomed Slice' unchecked. The main 3D view shows a brain slice with a red 'R' label. A yellow callout box with a red arrow points to the 'Layout' menu, which is open and shows 'Red slice only' selected. The menu options include: Conventional, Conventional Widescreen, Conventional Quantitative, Four-Up, Four-Up Quantitative, Dual 3D, Triple 3D, 3D only, One-Up Quantitative, Red slice only, Yellow slice only, Green slice only, Tabbed 3D, Tabbed slice, Compare, Compare Widescreen, Compare Grid, Three over three, Three Over Three Quantitative, Four over four, Two over Two, Side by side, Four by three slice, Four by two slice, and Three by three slice. The bottom of the interface shows three viewports, each displaying a brain slice with a 5 cm scale bar and the label 'B: BaselineVolume'.

Click on the **Layout** menu and select the layout **Red slice only**

3D Slicer 4.5.0-1

Modules: Volumes

Active Volume: BaselineVolume

Volume Information

Display

Lookup Table: Grey

Interpolate:

Window Level editor presets:

W: 1599 Manual W/L L: 890

Threshold: Manual

-721 18369

Histogram

Data Probe

Show Zoomed Slice

L
F
B

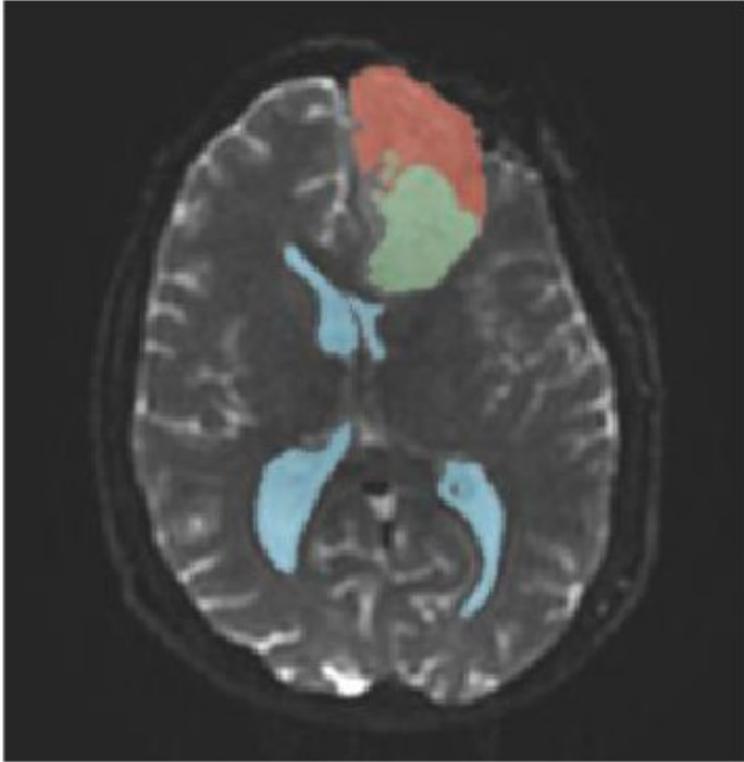
Conventional
Conventional Widescreen
Conventional Quantitative
Four-Up
Four-Up Quantitative
Dual 3D
Triple 3D
3D only
One-Up Quantitative
Red slice only
Yellow slice only
Green slice only
Tabbed 3D
Tabbed slice
Compare
Compare Widescreen
Compare Grid
Three over three
Three Over Three Quantitative
Four over four
Two over Two
Side by side
Four by three slice
Four by two slice
Three by three slice

R

B: BaselineVolume 5 cm

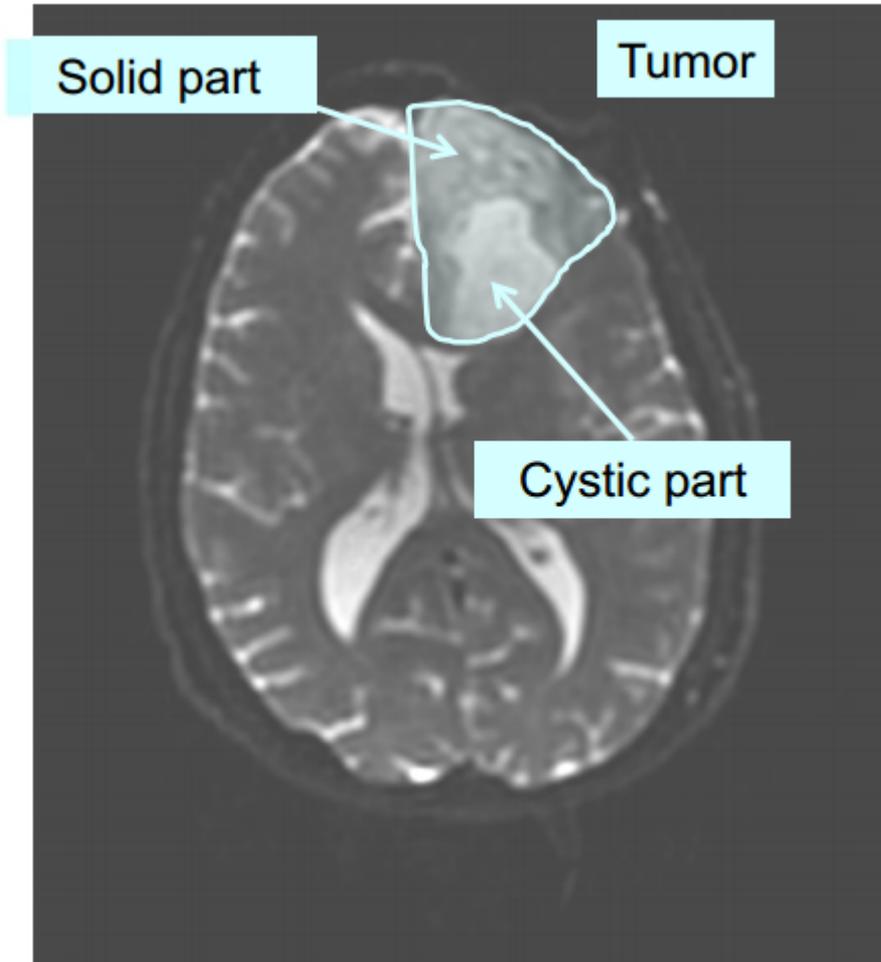
B: BaselineVolume 5 cm

B: BaselineVolume 5 cm



Part 1:
Segmenting the
tumor and ventricles

Tumor Segmentation



The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

In this section, we will segment the different parts of the tumor using a Grow Cut Segmentation algorithm.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Volumes

Active Volume: BaselineVolume

Display

Lookup Table: Grey

Interpolate:

Window Level editor presets:

W: 3001 Manual W/L L: 1390

Threshold: Manual

-168 17202

Histogram

Slicer displays only the Axial anatomical slice in the Viewer

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

B: BaselineVolume

10 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

Tumor Segmentation

The image shows the 3D Slicer 4.5.0-1 software interface. The 'Modules' menu is open, and the 'Editor' module is highlighted. A red arrow points from a yellow callout box to the 'Editor' module. The callout box contains the text: 'Click on the Modules menu and select the module **Editor**'. The main window displays an axial MRI slice of a brain with a tumor. The interface includes a top toolbar, a left sidebar with various toolbars (Data, DCM, SAVE, Help & Acknowledgement, Active Volume, Volume Information, Display, Lookup Table, Interpolate, Window Level editor presets, Threshold, Histogram, Data Probe), and a bottom status bar with text: 'White Matter Exploration for Neurosurgical Planning', 'Sonia Pujol, Ph.D. - Ron Kikinis, M.D.', and 'NA-MIC ARR 2012-2015'. A scale bar indicates 10 cm.

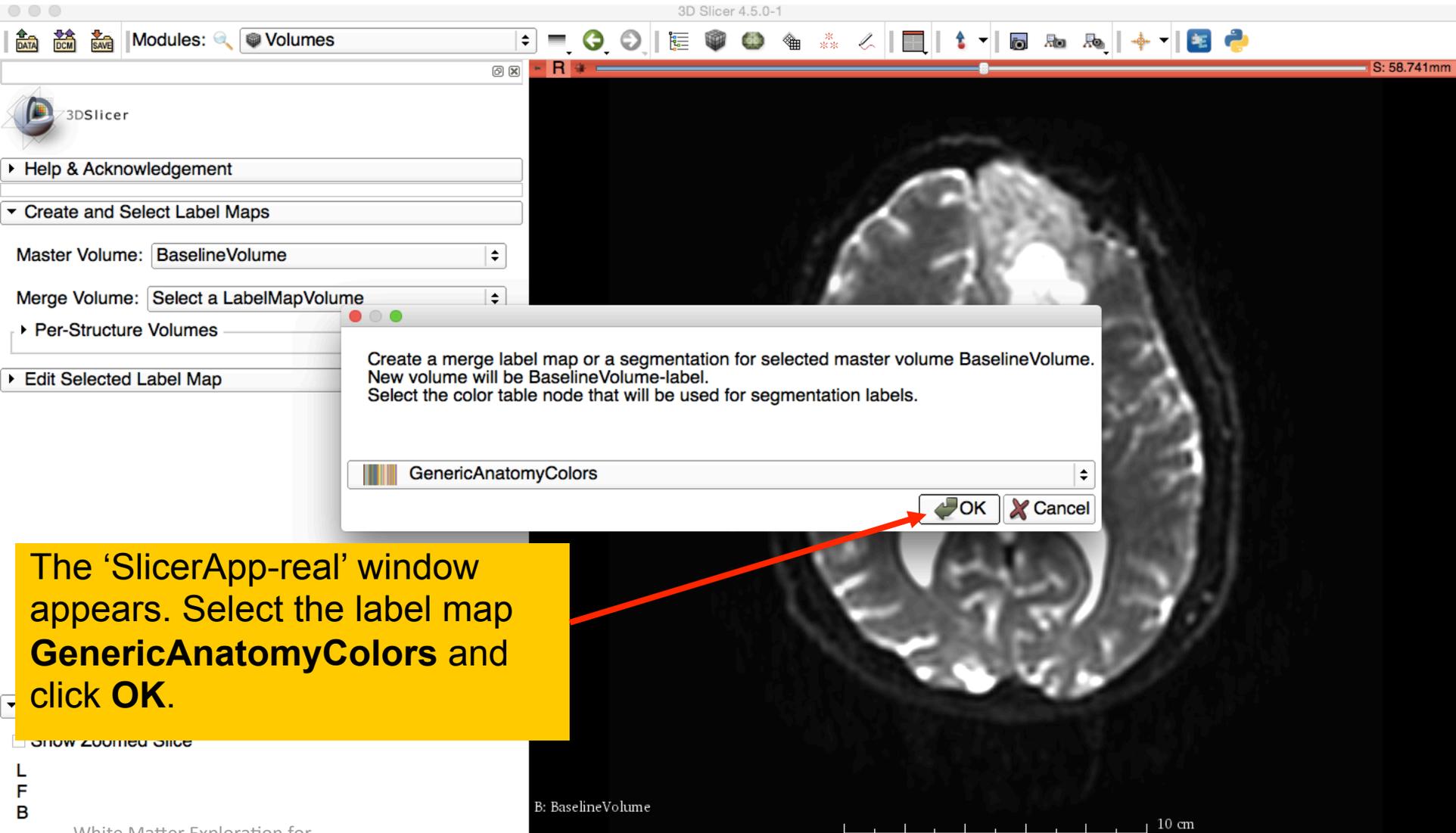
Click on the Modules menu and select the module **Editor**

White Matter Exploration for Neurosurgical Planning

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

Tumor Segmentation



The 'SlicerApp-real' window appears. Select the label map **GenericAnatomyColors** and click **OK**.



Tumor Segmentation

The image shows the 3D Slicer 4.5.0-1 software interface. The main window displays an axial MRI slice of a brain with a white tumor region. A yellow callout box with the text "Select the PaintEffect" has a red arrow pointing to the "PaintEffect" icon in the "Edit Selected Label Map" toolbar. The interface includes a top menu bar with "Modules" set to "Editor", a left sidebar with various tool panels, and a bottom status bar showing "L: BaselineVolume-label (100%)", "B: BaselineVolume", and a 10 cm scale bar.

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Edit Selected Label Map

PaintEffect

Undo/Redo: [Undo] [Redo]

Active Tool: DefaultTool

Label: tissue 1

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

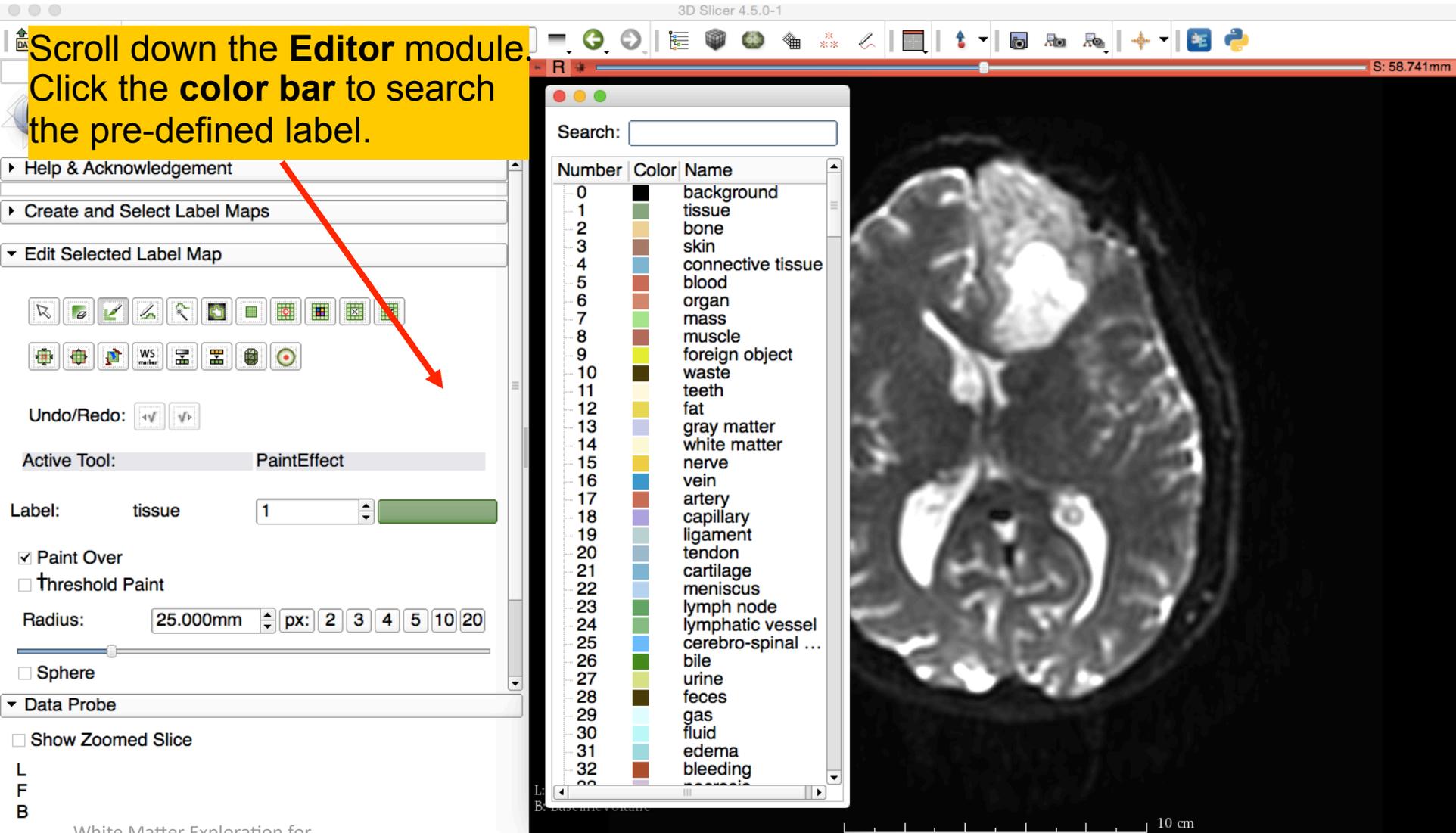
NA-MIC ARR 2012-2015

S: 58.741mm

10 cm

Tumor Segmentation

Scroll down the **Editor** module.
Click the **color bar** to search
the pre-defined label.



Tumor Segmentation

Input **cyst** and select number **309** for cystic part of the tumor.

3D Slicer 4.5.0-1

Search: cyst

Number	Color	Name
309	[Green]	cyst

Label: tissue 1 [Green]

Active Tool: PaintEffect

Radius: 25.000mm px: 2 3 4 5 10 20

White Matter Exploration for Neurosurgical Planning

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

10 cm

S: 58.741mm

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

- Help & Acknowledgement
- Create and Select Label Maps
- Edit Selected Label Map

Set Radius to 4

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: cyst 309

Paint Over
 Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

Sphere

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

L: BaselineVolume-label (100%)
B: BaselineVolume

10 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D. NA-MIC ARR 2012-2015

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: cyst 309

Paint Over

Threshold Paint

Radius: 4.000mm px: 2 3 4 5 1

Sphere

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

In a single motion, draw a circle in the **cystic part of the tumor** in 3 continuous frames.

L: BaselineVolume-label (100%)
B: BaselineVolume

10 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D. NA-MIC ARR 2012-2015

Tumor Segmentation

Input **mass** and select number **7** for solid part of the tumor.

3D Slicer 4.5.0-1

Search: mass

Number	Color	Name
309	Yellow	cyst
7	Green	mass
--		
7	Green	mass

Label: mass 7

Radius: 4.000mm px: 2 3 4 5 10 20

Active Tool: PaintEffect

Undo/Redo: [Undo] [Redo]

Paint Over

Threshold Paint

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

10 cm

S: 58.741mm

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.741mm

3DSlicer

- Help & Acknowledgement
- Create and Select Label Maps
- Edit Selected Label Map

Active Tool: PaintEffect

Label: mass 7

Paint Over

Threshold Paint

Radius: 4.000mm px: 2 3 4 5 1

Sphere

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

L: BaselineVolume-label (100%)
B: BaselineVolume

10 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D. NA-MIC ARR 2012-2015

In a single motion, draw a line in the solid part of the tumor in 3 continuous frames.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

Undo/Redo: [undo] [redo]

Active Tool: PaintEffect

Label: ventricles of brain 107

Paint Over

Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

Sphere

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

Select color #107 and draw a circle around the solid and cystic parts of the tumor.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

Select the **GrowCutEffect** tool.

Edit Selected Label Map

GrowCutEffect

Undo/Redo: [undo] [redo]

Active Tool: PaintEffect

Label: ventricles of brain 107

Paint Over
 Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

Sphere

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

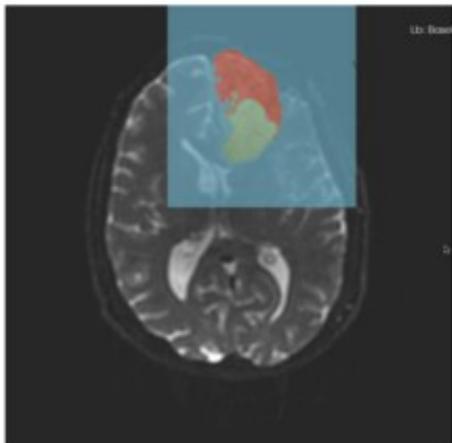
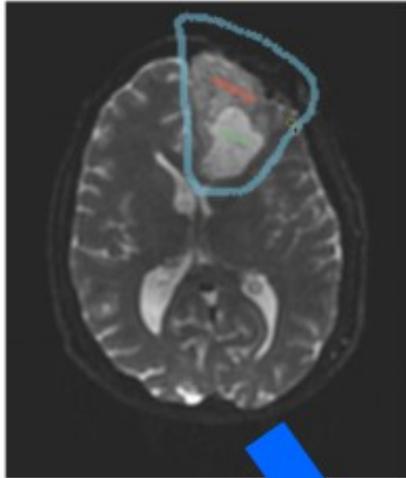
L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

Grow Cut Segmentation



- The Grow Cut Segmentation method is a competitive region growing algorithm using Cellular Automata.
- The algorithm performs multi-label image segmentation using a set of user input scribbles.
- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". Proc. Graphicon. 2005 . pp. 150-156.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

- Help & Acknowledgement
- Create and Select Label Maps
- Edit Selected Label Map

Active Tool: GrowCutEffect

Label: ventricles of brain 107

Run the GrowCut segmentation on the current label map. This will use your current segmentation as an example to fill in the rest of the volume.

Apply

Apply to run segmentation. Creates a new label volume using the current

Click **Apply** to apply the **GrowCutEffect** segmentation algorithm.

White Matter Exploration for Neurosurgical Planning

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

3DSlicer

Help & Ack

Create and

Edit Selected Label Map

Undo/Redo:

Active Tool: GrowCutEffect

Label: ventricles of brain 107

Run the GrowCut segmentation on the current label map. This will use your current segmentation as an example to fill in the rest of the volume.

Apply

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

Solid part

Cystic part

L: BaselineVolume-label (100%)
B: BaselineVolume

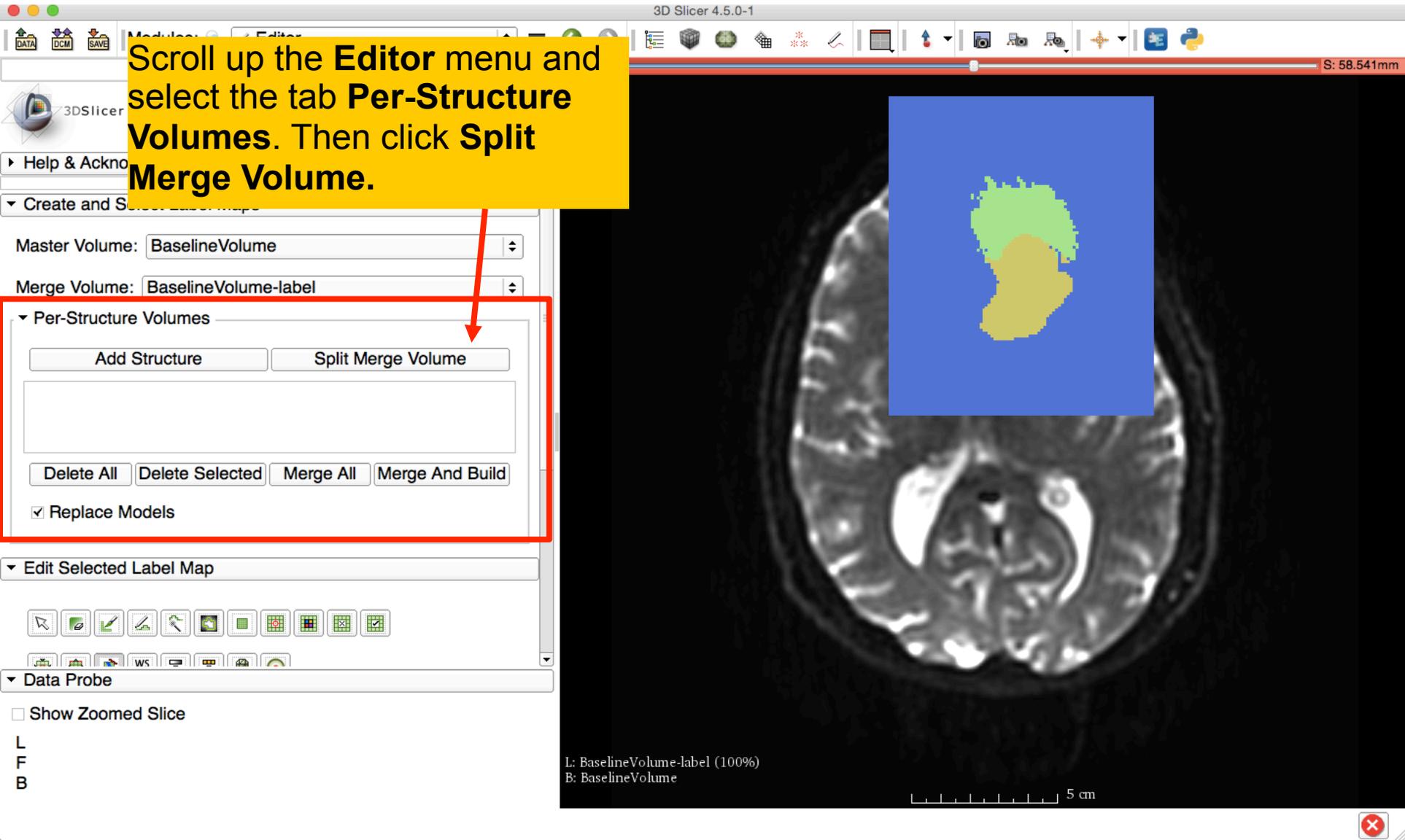
5 cm

Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

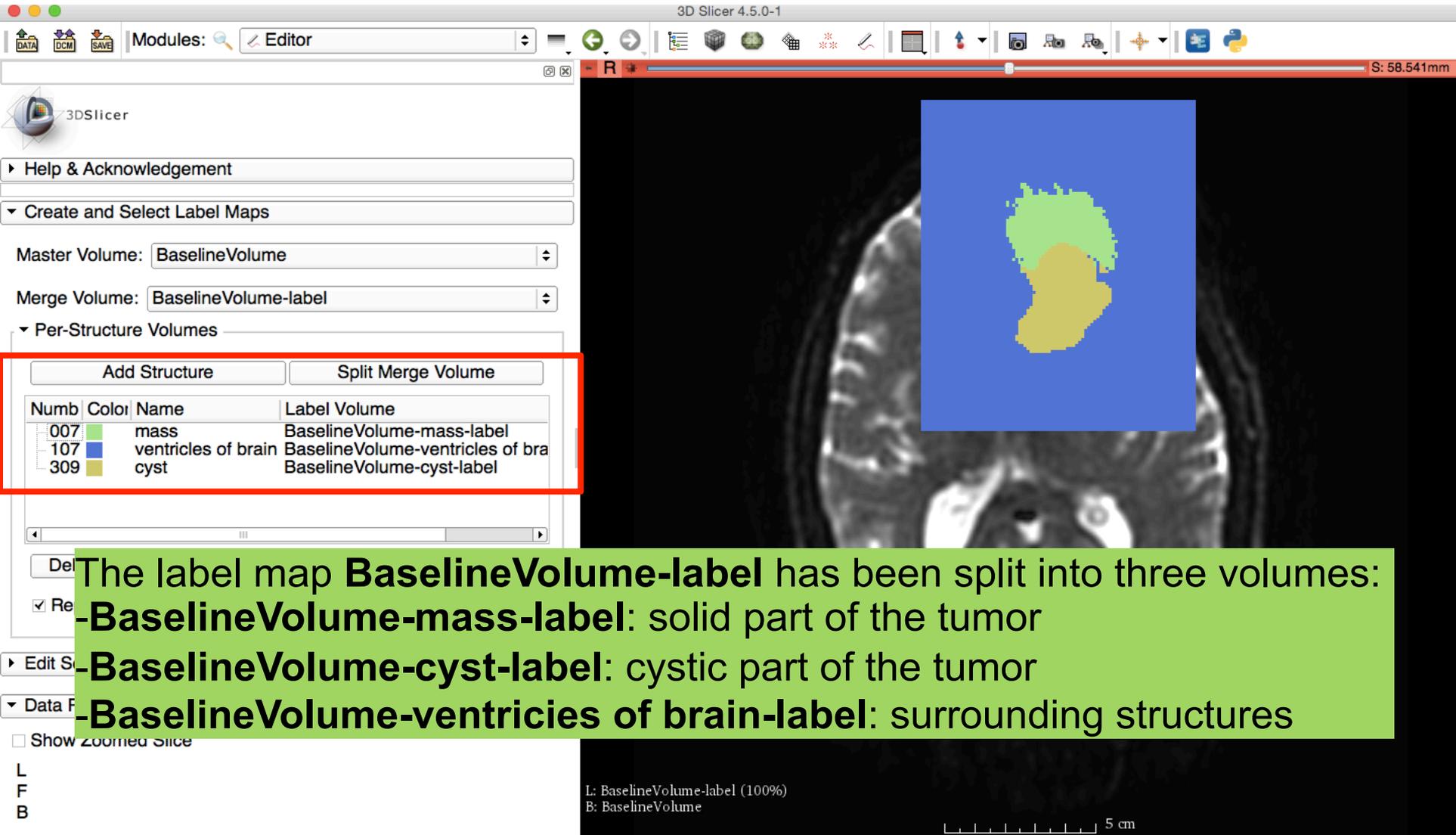
NA-MIC ARR 2012-2015

Tumor Segmentation

Scroll up the **Editor** menu and select the tab **Per-Structure Volumes**. Then click **Split Merge Volume**.



Tumor Segmentation



3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of bra
309	Yellow	cyst	BaselineVolume-cyst-label

Del

Re

Edit S

Data F

Show zoomed slice

L
F
B

L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

The label map **BaselineVolume-label** has been split into three volumes:

- BaselineVolume-mass-label**: solid part of the tumor
- BaselineVolume-cyst-label**: cystic part of the tumor
- BaselineVolume-ventricies of brain-label**: surrounding structures

Tumor Segmentation

3D Slicer 4.5.0-1

Modules:

- Editor
- All Modules
- Annotations
- Data**
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Examples
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- Filter
- MultiVolume Support

Help & Acknowledgement

Create and Select Label Map

Master Volume: BaselineVolume

Merge Volume: BaselineVolume

Per-Structure Volumes

Add Structure

Numb	Color	Name
007	Green	mass
107	Blue	ventricles of
309	Yellow	cyst

Delete All Delete Selected

Replace Models

Edit Selected Label Map

Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

Click on the Modules menu and select the Module **Data**.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Data

3DSlicer

Help & Acknowledgement

Display & Modify Scene

Nodes

- Scene
 - View1
 - Red
 - Yellow
 - Green
 - Default Scene Camera
 - BaselineVolume
 - DTIVolume**
 - BaselineVolume-label
 - BaselineVolume-mass-label
 - BaselineVolume-ventricles of brain-label
 - BaselineVolume-cyst-label

Scene Model: Transform

Display MRML ID's

The different label maps have been generated.

Data Probe

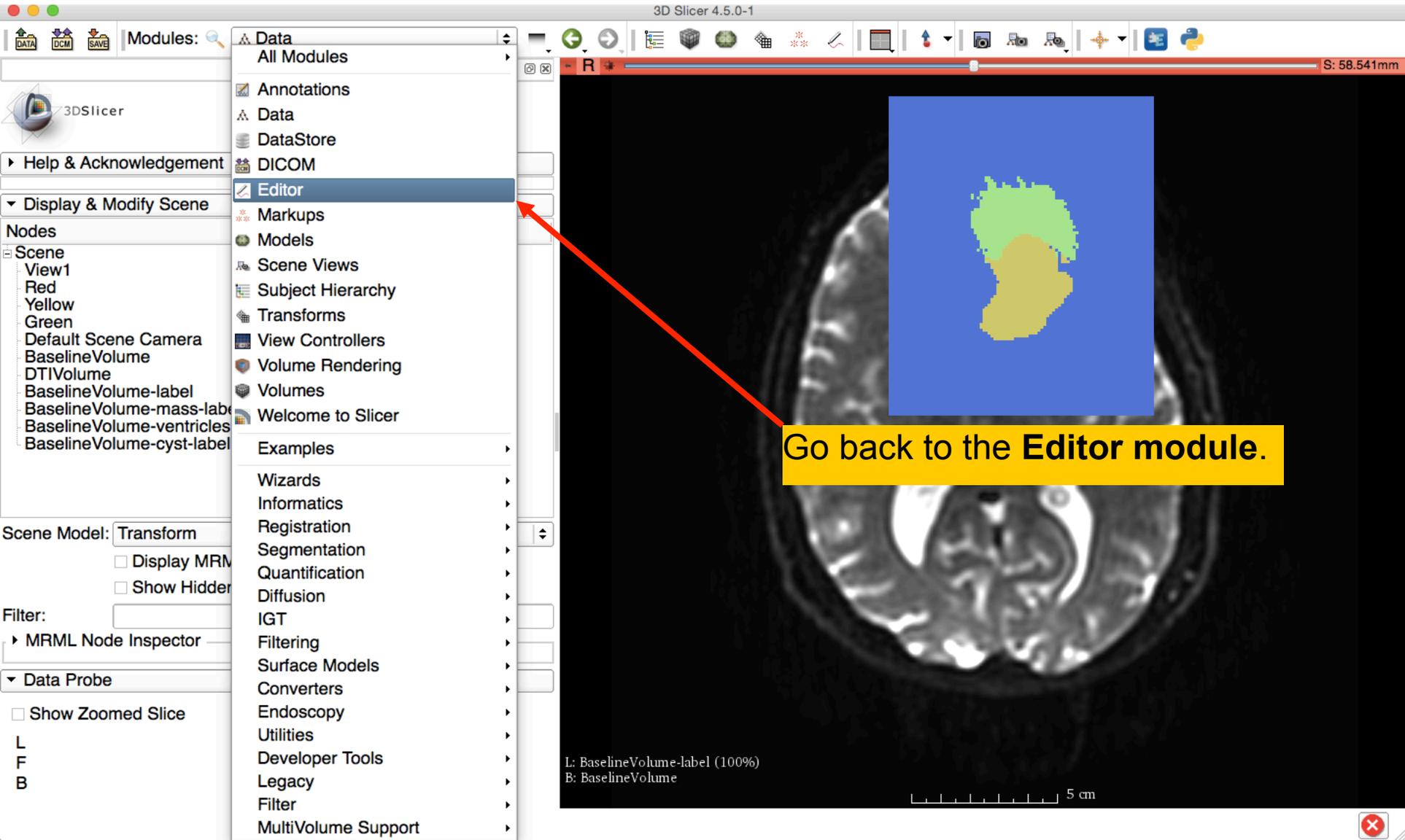
Show Zoomed Slice

L
F
B

L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

Ventricles Segmentation



Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	green	mass	BaselineVolume-mass-label
107	blue	ventricles of brain	BaselineVolume-ventricles of brain-label
200	orange	cyst	BaselineVolume-cyst-label

Delete All Delete Selected Merge All Merge And Build

Replace Models

Edit Selected Label Map

Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

S: 58.541mm

Select the volume BaselineVolume-ventricles of brain-label.

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

Per-Structure Volumes

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of

Delete All Delete Selected Merge All Merge And Build

Replace Models

Edit Selected Label Map

Select the **ThresholdEffect** tool.

ThresholdEffect

Active Tool: DefaultTool

Label: ventricles of brain 107

Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

Replace Models

Edit Selected Label Map

Active Tool: ThresholdEffect

Label: ventricles of brain 107

Threshold Range: 1700.00 18197.00

Use For Paint

Apply

Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

S: 58.541mm

Scroll down the **Editor** module, set the lower **Threshold Range** to **1700** and click **Apply**

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of br

Delete All Delete Selected Merge All Merge And Build

Replace Models

▼ Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: DefaultTool

Label: ventricles of brain 107

▼ Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

Slicer displays the result of the threshold

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of br

Delete All Delete Selected Merge All Merge And Build

Replace Models

▼ Edit Selected Label Map

SavelslandEffect

Undo/Redo: [Undo] [Redo]

Active Tool: DefaultTool

Label: ventricles of brain 107

▼ Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

S: 58.541mm

Select the SavelslandEffect in the Editor module.

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of brain-label

Delete All Delete Selected Merge All Merge And Build

Replace Models

▼ Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Label: **Click in the occipital horn of the ventricle .**

▼ Data Probe

Red RAS: (26.9, 2.3, 58.5) Axial Sp: 2.6

L BaselineVolume-mass-label (103, 151, 25) ventricles of brain (107)

F None

B BaselineVolume (103, 151, 25) 3507

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

Ventricles Segmentation

The screenshot displays the 3D Slicer 4.5.0-1 interface. The main window shows an axial MRI slice of a brain with the lateral ventricles segmented in blue. The left sidebar contains the 'Editor' module, which includes a table of segmented volumes and various editing tools.

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of br

Buttons: Add Structure, Split Merge Volume, Delete All, Delete Selected, Merge All, Merge And Build. Replace Model.

Active Tool: SaveIslandEffect

Label: ventricles of brain 107

Data Probe:

- Red RAS: (27.6, 5.3, 58.5) Axial Sp: 2.6
- L BaselineVolu...ain-label (103, 148, 25) ventricles of brain (107)
- F None
- B BaselineVolume (103, 148, 25) 3242

Bottom right: L: BaselineVolume-ventricles of brain-label (100%) B: BaselineVolume. Scale bar: 5 cm.

Slicer displays the results of the segmentation of the lateral ventricle.

Ventricles Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of br

Buttons: Add Structure, Split Merge Volume, Delete All, Delete Selected, Merge All, Merge And Build

Replace Models

▼ Edit Selected Label Map

Undo/Redo

Active Tool

Label:

▼ Data Process

Show Zoomed Slice

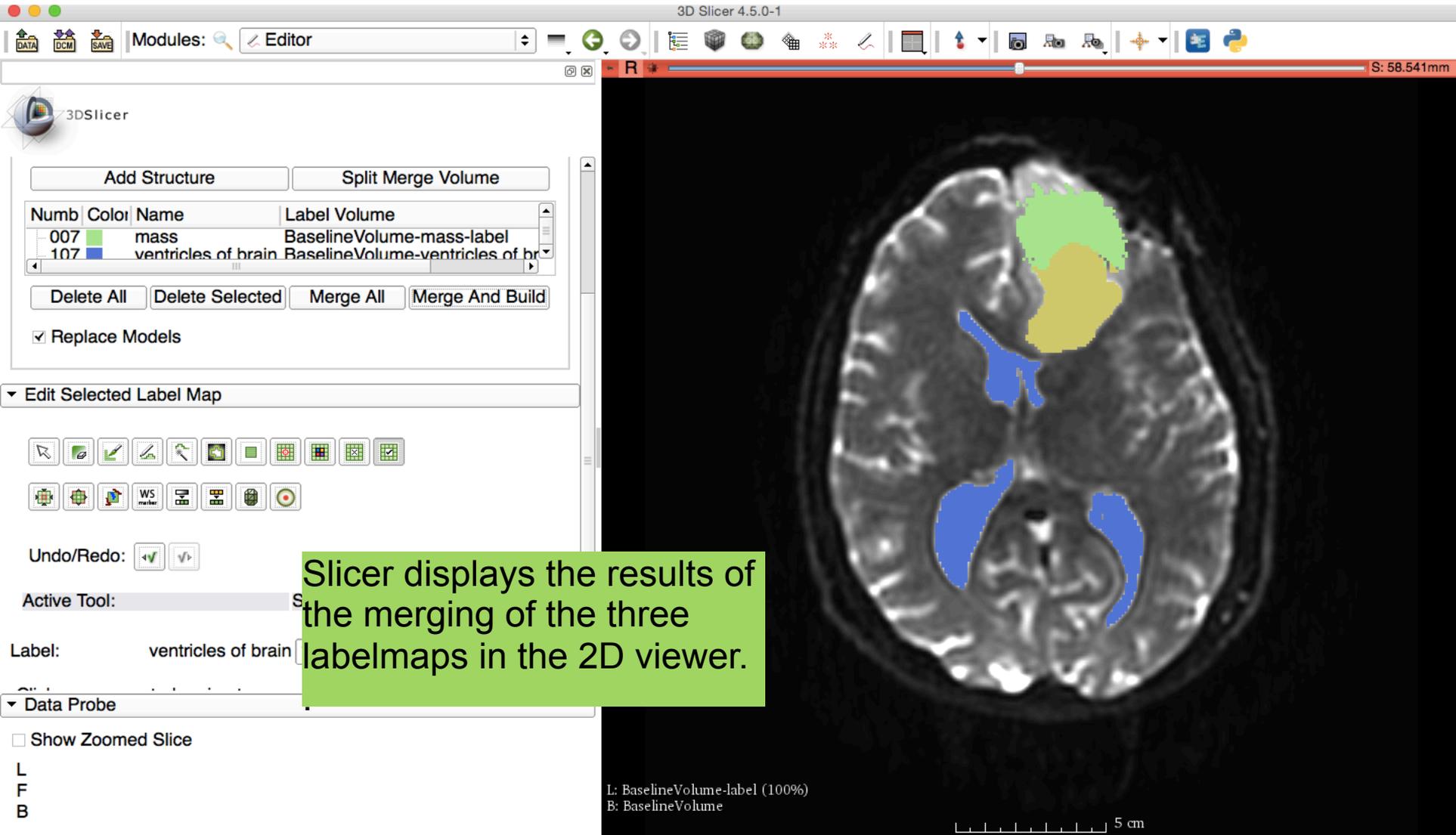
L
F
B

L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

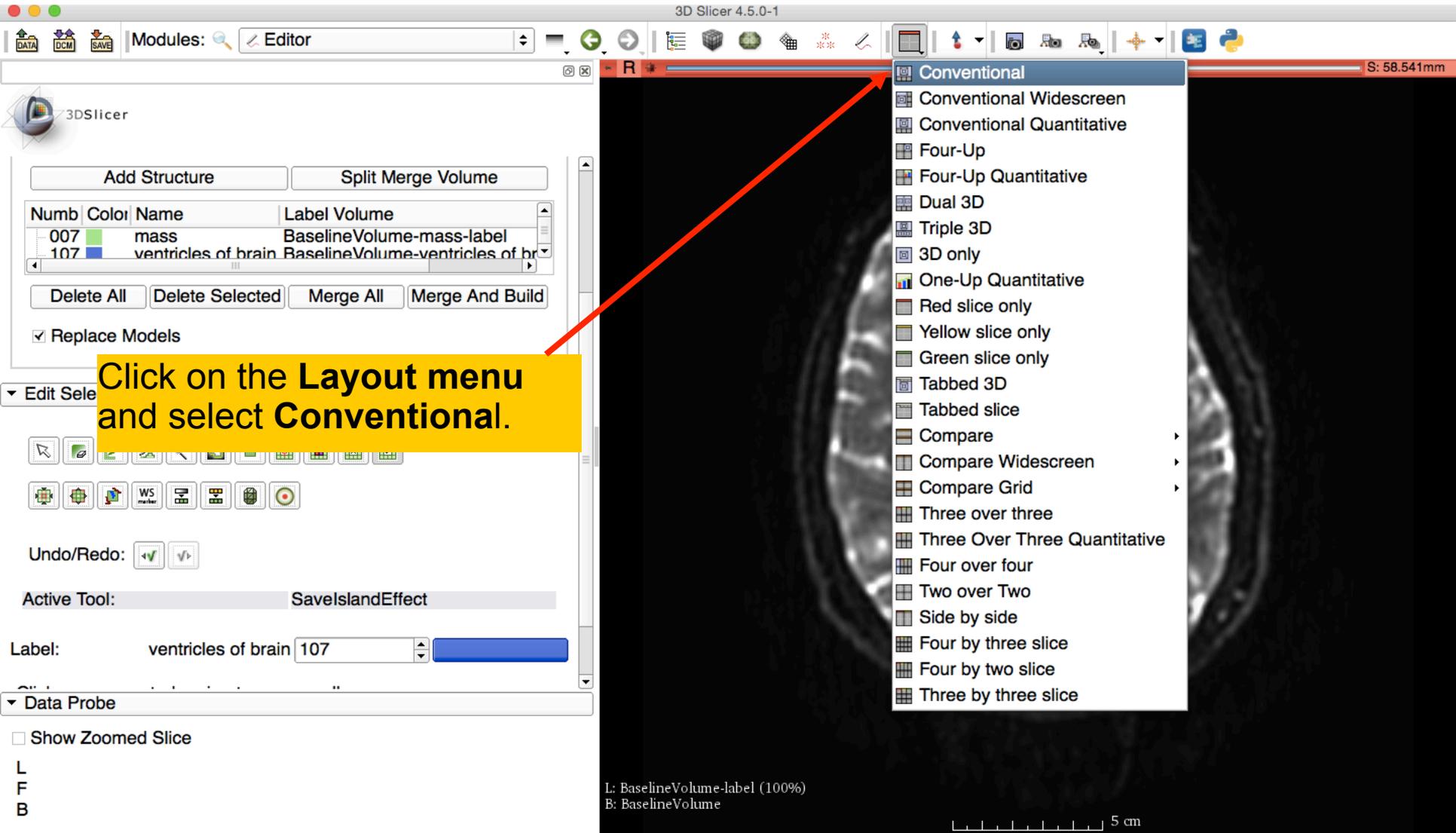
5 cm

Scroll back up and click on **Merge and Build** to merge the three label maps, and generate 3D models of the tumor and ventricles using a Marching Cubes algorithm.

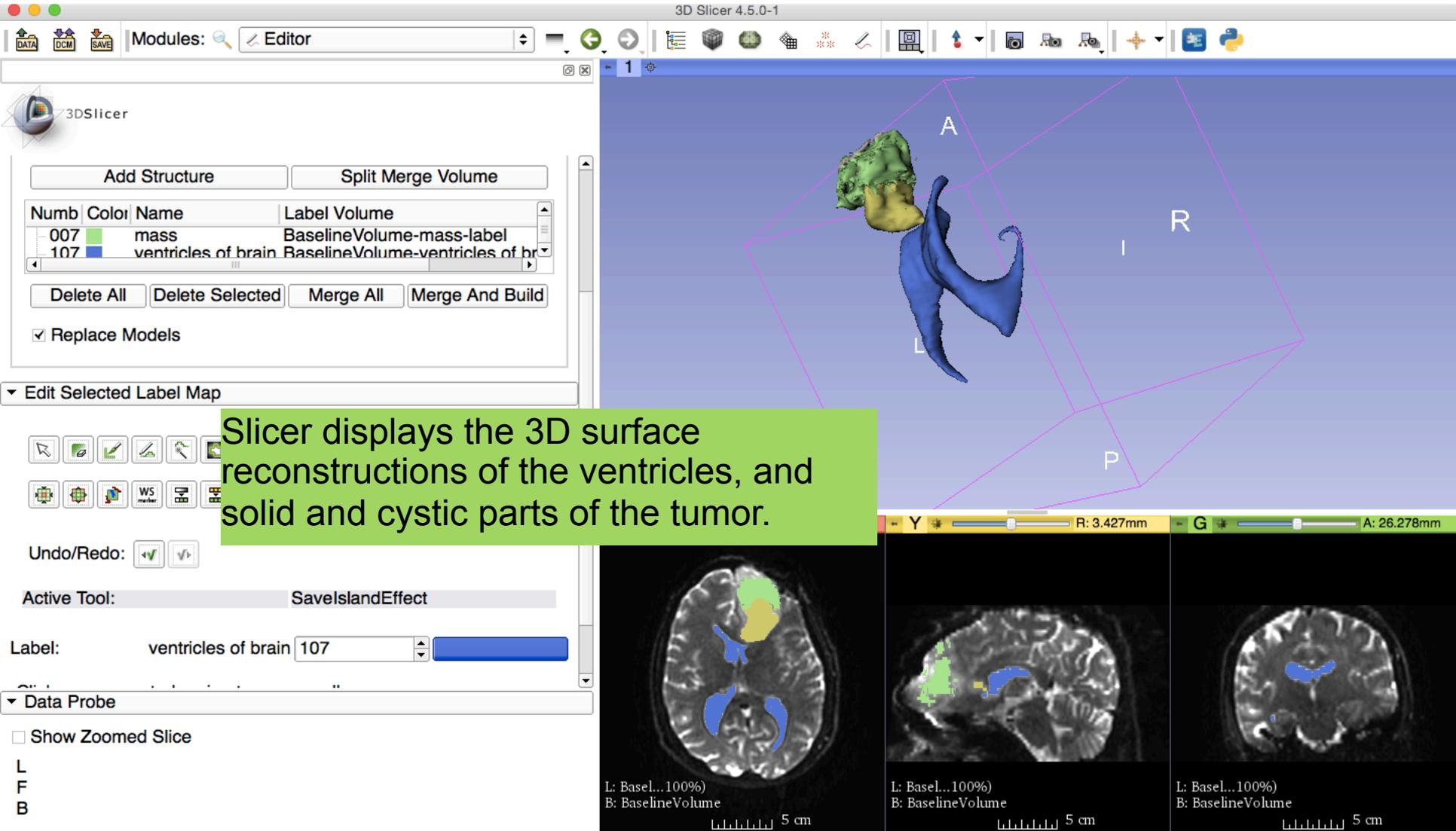
Final Result of Segmentation



Final Result of Segmentation



Final Result of Segmentation



Definition of peri-tumoral volume

The image shows the 3D Slicer 4.5.0-1 software interface. The main 3D viewer displays an axial MRI slice of a brain with segmented structures: a green and yellow mass, and blue ventricular structures. A yellow callout box with black text is overlaid on the left side of the 3D viewer, containing instructions on how to view a single axial slice. A red arrow points from the callout box to the 'eye' icon in the bottom toolbar. Below the 3D viewer, there are three smaller 2D slice views (axial, sagittal, and coronal) showing the same data. A yellow callout box points to the 'eye' icon in the toolbar, with the text 'Toggle slice visibility in 3D view'. The interface includes a top toolbar with various icons, a left sidebar with 'Add Structure' and 'Split Merge Volume' buttons, and a bottom toolbar with 'Undo/Redo' and 'Active Tool' (SavelslandEffect) options. The bottom status bar shows coordinates: S: 58.541mm, R: 3.427mm, A: 26.278mm. The bottom right corner has a red 'X' icon.

3D Slicer 4.5.0-1

Modules: Editor

Add Structure Split Merge Volume

Position the mouse over the **pin icon**, deselect the **link icon**, and select the **eye icon** to view just the axial slice in the 3D viewer.

Edit Selected Label Map

Undo/Redo: [undo] [redo]

Active Tool: SavelslandEffect

Label: ventricles of brain 107

Data Probe

Show Zoomed Slice

L F B

Toggle slice visibility in 3D view

S: 58.541mm R: 3.427mm A: 26.278mm

Toggle slice visibility in 3D view

L: BaselineVolume 5 cm

L: BaselineVolume 5 cm

L: BaselineVolume 5 cm

Definition of peri-tumoral volume

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
309		cyst	BaselineVolume-cyst-label

Delete All Delete Selected Merge All Merge And Build

Replace Models

▼ Edit Selected Label Map

DilateEffect

Undo/Redo: [undo] [redo]

Active Tool: SaveIslandEffect

Label: cyst 309

▼ Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume 5 cm
B: BaselineVolume

L: BaselineVolume 5 cm
B: BaselineVolume

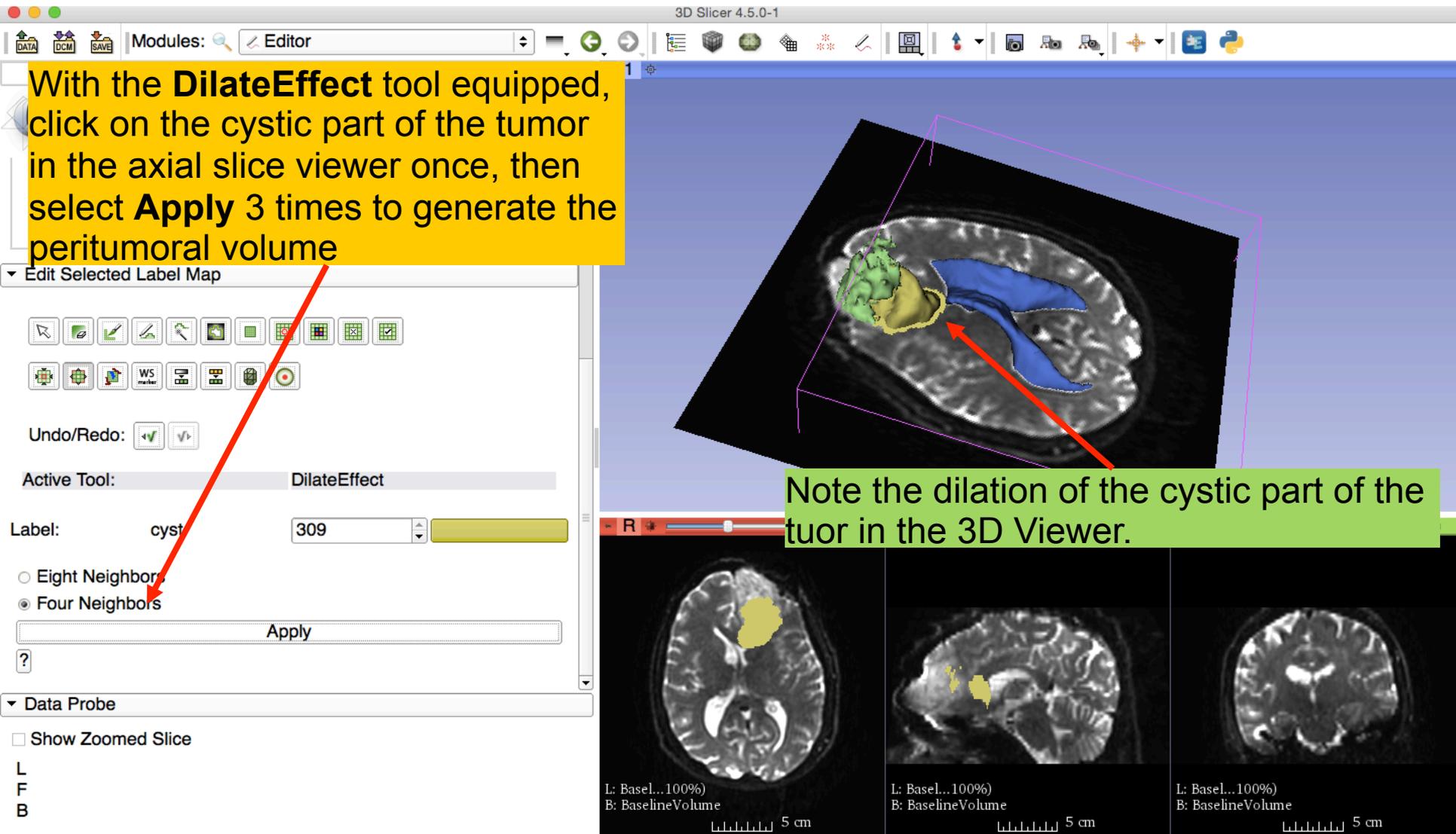
L: BaselineVolume 5 cm
B: BaselineVolume

S: 58.541mm R: 3.427mm A: 26.278mm

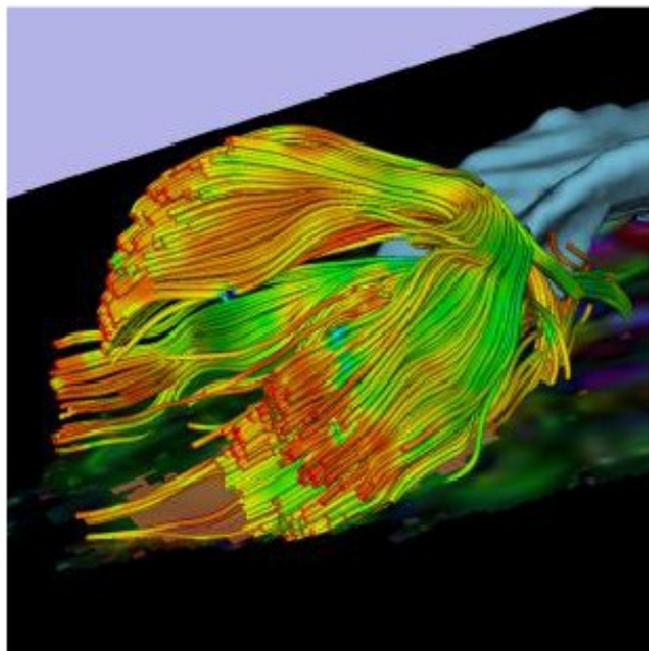
Select the label map **BaselineVolume-cyst-label** (yellow) and select the **DilateEffect** tool.

Definition of peri-tumoral volume

With the **DilateEffect** tool equipped, click on the cystic part of the tumor in the axial slice viewer once, then select **Apply** 3 times to generate the peritumoral volume

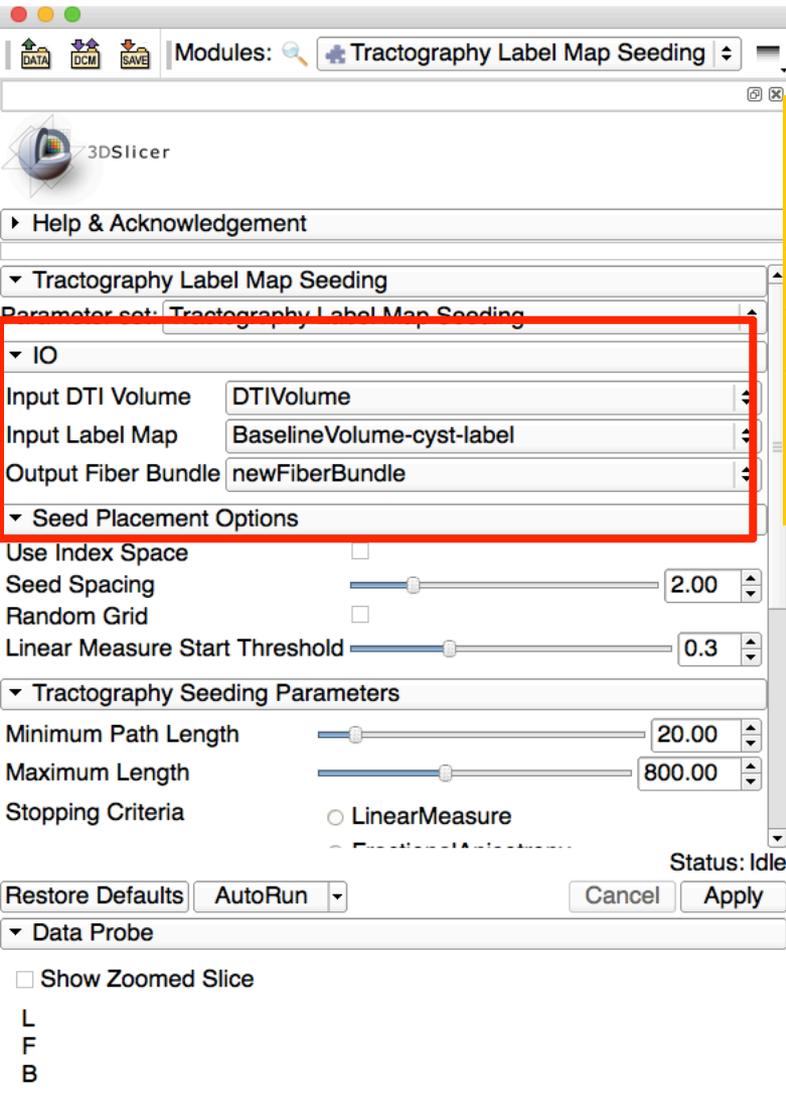


Note the dilation of the cystic part of the tuor in the 3D Viewer.



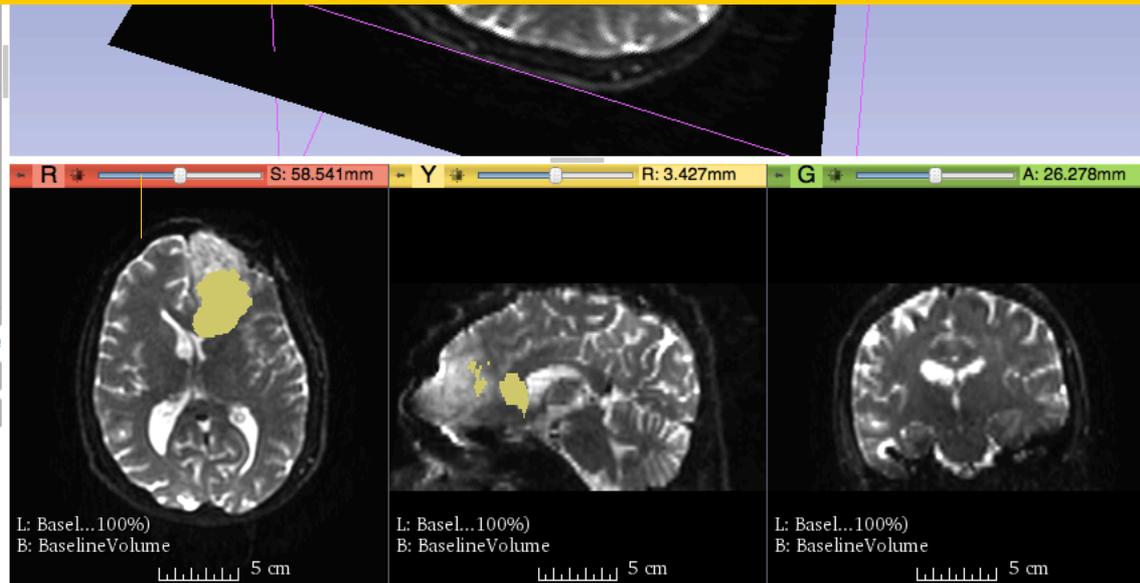
Part 2: Tractography
exploration of peri-
tumoral white matter
fibers

Tractography LabelMap Seeding



Go to **I/O** and set the following values:

- **Input DTI Volume:** DTIVolume
- **Input Label Map:** BaselineVolume-cyst-label
- **Output Fiber Bundle:** Create and rename newFiberBundle



Tractography LabelMap Seeding

3D Slicer 4.5.0-1

Modules: Tractography Label Map Seeding

3DSlicer

Help & Acknowledgement

Tractography Label Map Seeding

Parameter set: Tractography Label Map Seeding

IO

Input DTI Volume: DTIVolume

Input Label Map: BaselineVolume-cyst-label

Output Fiber Bundle: newFiberBundle

Seed Placement Options

Use Index Space

Seed Spacing: 2.00

Random Grid:

Linear Measure Start Threshold: 0.3

Tractography Seeding Parameters

Minimum Path Length: 20.00

Maximum Length: 800.00

Stopping Criteria: LinearMeasure

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

5 cm

5 cm

5 cm

L: Baseline...100%
B: BaselineVolume

L: Baseline...100%
B: BaselineVolume

L: Baseline...100%
B: BaselineVolume

S: 58.541mm Y R: 3.427mm G A: 26.278mm

Scroll down to **Seed Placement Options** and set the following values:

- Check **Use Index Space**

Tractography LabelMap Seeding

3D Slicer 4.5.0-1

Modules: Tractography Label Map Seeding

3DSlicer

Help & Acknowledgement

Tractography Seeding Parameters

Minimum Path Length 20.00

Maximum Length 800.00

Stopping Criteria

LinearMeasure

FractionalAnisotropy

Stopping Value 0.15

Stopping Track Curvature 0.7

Integration Step Length(mm) 0.5

Label definition

Seeding label 309

Multiple File Output

Write Fibers To Disk

Output Directory /Applications

File Prefix Name line

Status: Idle

Restore Defaults AutoRun

Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

L: BaselineVolume 5 cm

L: BaselineVolume 5 cm

L: BaselineVolume 5 cm

Scroll down to **Tractography Seeding Parameters** and set the following values:

- Set **Stopping Criteria** to **FractionalAnisotropy**
- Set **Stopping Value** to **0.15**

Scroll down to **Label Definition** and set the following values:

- Set **Seeding Label** to **309 (cyst)**

Click on **Apply**

Tractography LabelMap Seeding

3D Slicer 4.5.0-1

Modules: Tractography Label Map Seeding

Help & Acknowledgments

Tractography Seeding Parameters

- Minimum Path Length: 20.00
- Maximum Length: 800.00
- Stopping Criteria:
 - LinearMeasure
 - FractionalAnisotropy
- Stopping Value: 0.15
- Stopping Track: 10
- Integration Step: 1

Label definition

Seeding label: 3

Multiple File Output

Write Fibers To Disk:

Output Directory: /Applications

Status: Completed

100%

Restore Defaults | AutoRun | Cancel | Apply

Data Probe

Show Zoomed Slice

L
F
B

S: 58.741mm | Y: | R: 3.427mm | G: | A: 26.278mm

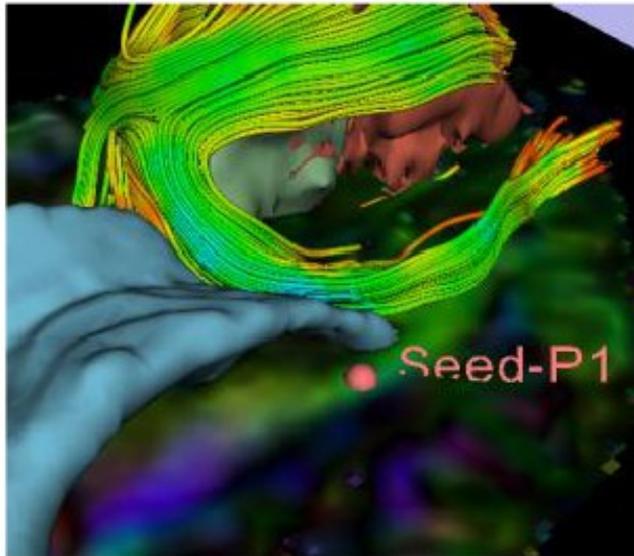
L: BaselineVolume (100%) | B: BaselineVolume | 5 cm

L: BaselineVolume (100%) | B: BaselineVolume | 5 cm

L: BaselineVolume (100%) | B: BaselineVolume | 5 cm

Slicer displays the white matter fibers surrounding the tumor

The fibers are colored according to fractional anisotropy values (red = low FA; blue, green = high FA)



Part 4: Tractography
exploration of the
ipsilateral and
contralateral side

Tractography on-the-fly

The image shows the 3D Slicer 4.5.0-1 software interface. On the left, the 'Modules' menu is open, listing various modules. The 'Diffusion' category is expanded, and 'Tractography Interactive Seeding' is highlighted. An orange callout box with white text says: 'Click on the **Modules** menu and select the module **Tractography Interactive Seeding**'. A red arrow points from this text to the 'Tractography Interactive Seeding' menu item. The main window displays a brain MRI slice with a green and yellow tractography volume. Below the main window, there are three smaller slices showing different views of the brain. The bottom right corner of the interface shows the text 'NA-MIC ARR 2012-2015' and a red 'X' icon.

3D Slicer 4.5.0-1

Modules: Tractography Label Map Seeding

All Modules

- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer

Examples

- Wizards
- Informatics
- Registration
- Segmentation
- Quantification

Diffusion

- DWI to Full Brain Tractography
- Tractography Display
- Diffusion Data Conversion
- Diffusion Tensor Images
- Diffusion Weighted Images
- Tractography

Diffusion Tensor Scalar Measurements

Resample DTI Volume

Tractography Interactive Seeding

Tractography Label Map Seeding

Click on the **Modules** menu and select the module **Tractography Interactive Seeding**

NA-MIC ARR 2012-2015

Tractography on-the-fly

3D Slicer 4.5.0-1

Modules: Tractography Interactive Seeding

3DSlicer

Help & Acknowledgement

IO

Parameters: FiducialSeedingParameters

Presets: Slicer4 Interactive Seeding Defaults

IO

Input DTI Volume: DTIVolume

Input Fiducials, Model or Label Map: Select a MarkupsFiducial

Output Fiber Bundle: Select a FiberBundle

Enable Seeding Tracts:

Seed Placement Options

Fiducial Region Size: 2.50mm

Fiducial Seeding Step Size: 1.00mm

Seed Selected Fiducials:

Max Number of Seeds: 100

Data Probe

Show Zoomed Slice

L
F
B

Position the mouse over the **pin icon** in the axial slice viewer and change the volume to **DTIVolume**

None
BaselineVolume
DTIVolume
Baseli|DiffusionTensorVolume
BaselineVolume-mass-label
BaselineVolume-ventricles of brain-label
BaselineVolume-cyst-label
Rename current Volume

R
Axial
G
A: 26.278mm

L: BaselineVolume
B: BaselineVolume
5 cm

L: BaselineVolume
B: BaselineVolume
5 cm

L: BaselineVolume
B: BaselineVolume
5 cm

Tractography on-the-fly

3D Slicer 4.5.0-1

Modules: Tractography Interactive Seeding

3DSlicer

Help & A
IO
Parameters
Presets
IO

Input DTI Volume: DTIVolume

Input Fiducials, Model or Label Map: Select a MarkupsFiducial

Output Fiber Bundle: Select a FiberBundle

Enable Seeding Tracts:

Seed Placement Options

Fiducial Region Size: 2.50mm

Fiducial Seeding Step Size: 1.00mm

Seed Selected Fiducials:

Max Number of Seeds: 100

Data Probe

Show Zoomed Slice

L
F
B

S: 58.741mm Y: R: 3.427mm G: A: 26.278mm

L: Basel...100%)
B: DTIVolume

L: Basel...100%)
B: BaselineVolume

L: Basel...100%)
B: BaselineVolume

5 cm

5 cm

5 cm

Tractography on-the-fly

3D Slicer 4.5.0-1

Modules: Tractography Interactive Seeding

3DSlicer

Help & Acknowledgement

IO

Parameters: FiducialSeedingParameters

Presets: Slicer4 Interactive Seeding Defaults

IO

Input DTI Volume: DTIVolume

Input Fiducials, Model or Label Map: F

Output Fiber Bundle: FiberBundle_F

Enable Seeding Tracts:

Seed Placement Options

Fiducial Region Size: 2.50mm

Fiducial Seeding Step Size: 1.00mm

Seed Selected Fiducials:

Max Number of Seeds: 100

Data Probe

Show Zoomed Slice

L
F
B

L: Basel...100%)
B: DTIVolume

L: Basel...100%)
B: BaselineVolume

L: Basel...100%)
B: BaselineVolume

5 cm

5 cm

5 cm

S: 58.741mm Y R: 3.427mm G A: 26.278mm

Set Input DTI Volume to **DTIVolume**
Set Fiducial List or Model to **F**
Set Output Fiber Bundle to **Create new Fiber Bundle**

Tractography on-the-fly

3D Slicer 4.5.0-1

Modules: Tractography Interactive Seeding

3DSlicer

▼ Seed Placement Options

Fiducial Region Size 2.50mm

Fiducial Seeding Step Size 1.00mm

Seed Selected Fiducials

Max Number of Seeds 100

▼ Tractography Seeding Parameters

Minimum Path Length 10.000mm

Maximum Path Length 800.000mm

Stopping Criteria Fractional Anisotropy

Stopping Value 0.15

Stopping Track Curvature 0.70

Integration Step Length 0.500mm

▼ Enabling Options

Create Tracts Initially As Tubes

▼ Data Probe

Show Zoomed Slice

L
F
B

3D View: A 3D rendering of a brain with a green and yellow tract. A purple box highlights the tract. A label 'F-1' is visible near the tract.

2D Views: Three 2D slices (L, F, B) showing the tract in different planes. Each slice has a 5 cm scale bar. The L slice is labeled 'L: Basel...100%) B: DTIVolume'. The F slice is labeled 'L: Basel...100%) B: BaselineVolume'. The B slice is labeled 'L: Basel...100%) B: BaselineVolume'.

Callout Box: Scroll down the module and set the **Minimum Path Length** to 10.0 mm and the **FA Stopping Value** at 0.15

Tractography on-the-fly

3D Slicer 4.5.0-1

Modules: Tractography Interactive Seeding

3DSlicer

Seed Placement Options

- Fiducial Region Size: 2.50mm
- Fiducial Seeding Step Size: 1.00mm
- Seed Selected Fiducials:
- Max Number of Seeds: 100

Tractography Seeding Parameters

- Minimum Path Length: [Slider]
- Maximum Path Length: [Slider]
- Stopping Criteria: Fractional Anisotropy
- Stopping Value: 0.15
- Stopping Track Curvature: 0.70
- Integration Step Length: 0.500mm

Enabling Options

- Create Tracts Initially As: Tubes

Data Probe

- Show Zoomed Slice

L
F
B

Position the fiducial in the cingulum on the contralateral side opposite to the tumor

L: BaselineVolume (100%)
B: DTIVolume

L: BaselineVolume (100%)
B: BaselineVolume

L: BaselineVolume (100%)
B: BaselineVolume

5 cm

5 cm

5 cm

Tractography on-the-fly

The screenshot displays the 3D Slicer 4.5.0-1 interface. The top toolbar includes icons for DATA, DCM, SAVE, and various navigation tools. The 'Modules' dropdown is set to 'Tractography Interactive Seeding'. The left sidebar contains the following sections:

- Seed Placement Options**
 - Fiducial Region Size: 2.50mm
 - Fiducial Seeding Step Size: 1.00mm
 - Seed Selected Fiducials:
 - Max Number of Seeds: 100
- Tractography Seeding Parameters**
 - Minimum Path Length: 10.000mm
 - Maximum Path Length: 800.000mm
 - Stopping Criteria: Fractional Anisotropy
 - Stopping Value: 0.15
 - Stopping Track Curvature: 0.70
 - Integration Step Length: 0.500mm
- Enabling Options**
 - Create Tracts Initially As: Tubes
- Data Probe**
 - Show Zoomed Slice

The main 3D view shows a brain model with fiber-like structures. A red arrow points to a specific region labeled 'F-1'. Below the 3D view are three zoomed slices: a coronal slice (S: 58.741mm), a sagittal slice (R: 3.427mm), and an axial slice (A: 26.278mm). A yellow text box is overlaid on the bottom right of the 3D view.

Explore the aspect of the cingulum in the contralateral and ipsilateral sides

At the bottom, there are three panels showing zoomed slices with labels: 'L: BaselineVolume', 'B: DTIVolume', and '5 cm' scale bars.

Conclusion

- Fully integrated pipeline for semi-automated tumor segmentation and white matter tract reconstruction
- 3D interactive exploration of the white matter tracts surrounding a tumor (peritumoral tracts) for neurosurgical planning

Acknowledgments

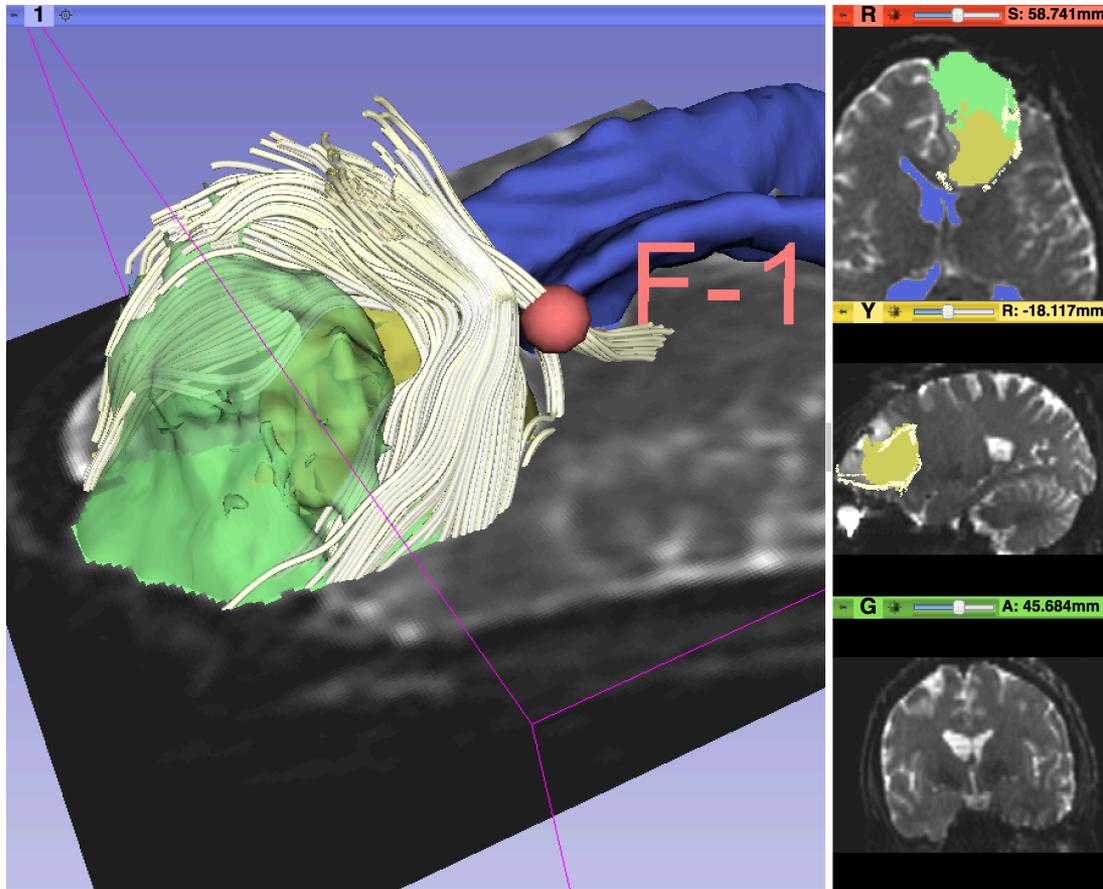


- National Alliance for Medical Image Computing (NA-MIC)
NIH U54EB005149



- Neuroimage Analysis Center (NAC)
NIH P41RR013218
- Fan Zhang, University of Sydney

Questions/Comments



Contact: spujol@bwh.harvard.edu