Exploration and Study of MultiVolume Image Data using 3D Slicer

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INTRODUCTION

- This tutorial uses 3D Slicer which is a free, open-source software for image analysis and visualization [1].

- It is assumed that the reader of this tutorial is familiar with the basics of Slicer4, while an introduction to 3D Slicer is accessible on this link [2].

- The pre-compiled version of Slicer4 is freely downloadable for different operation systems. See the next page for more info.

INTRODUCTION

According to your operation system and whether you use a 32-bit or 64-bit CPU, one of the Slicer versions below would suit you:

- MacOSX: Slicer_nightly-build_2013-03-28 MacOSX
http://download.slicer.org/bitstream/40004

- Linux 64: Slicer_nightly-build_2013-03-28 Linux64
http://download.slicer.org/bitstream/40003

- Windows 7 64: Slicer_nightly-build_2013-03-28 Win64
http://slicer.kitware.com/midas3/download?items=19141

- Windows 7 32: Slicer_nightly-build_2013-03-28 Win32
http://slicer.kitware.com/midas3/download?items=19153

INTRODUCTION

- This tutorial provides step-by-step instructions of how to use the ***MultiVolumeExplorer*** module in Slicer4.

- This module is useful for visualization of DICOM datasets with multiple frames (e.g. DCE-MRI), where all frames are strictly in the same coordinate frame.

- Documentation of this module is available in this [page](#) [3]. The source code of the module is also accessible on [Github](#) for developers.

DATASET PREPARATION

- The input of the MultiVolumeExplorer module is a MultiVolume node.

- If the entire dataset is stored as DICOM files, then the DICOM module can convert them to a MultiVolume node, to be utilizable in the MultiVolumeExplorer module.

- An anonymized DCE MRI DICOM dataset of prostate is used in this tutorial and is available to download:
  - Windows users: here

    http://wiki.slicer.org/slicerWiki/images/c/c2/DCE_series.zip
  - Unix-like users: here

    http://wiki.slicer.org/slicerWiki/images/5/56/Case1_DCE.tgz

DCE-MRI definition

- DCE-MRI, or *Dynamic Contrast Enhanced* MRI, is a series of MR-images, scanned while the contrast agent is being delivered.

- DCE-MRI captures the behavior of a flowing contrast agent in a living tissue, and can facilitate analysis of the tissue character.

- The idea is: *distribution and concentration of contrast agent* in blood in DCE-MRI is relevant to *physiological information* of the tissue, and hence DCE-MRI has the potential to be used as a diagnostic tool.

Load dataset
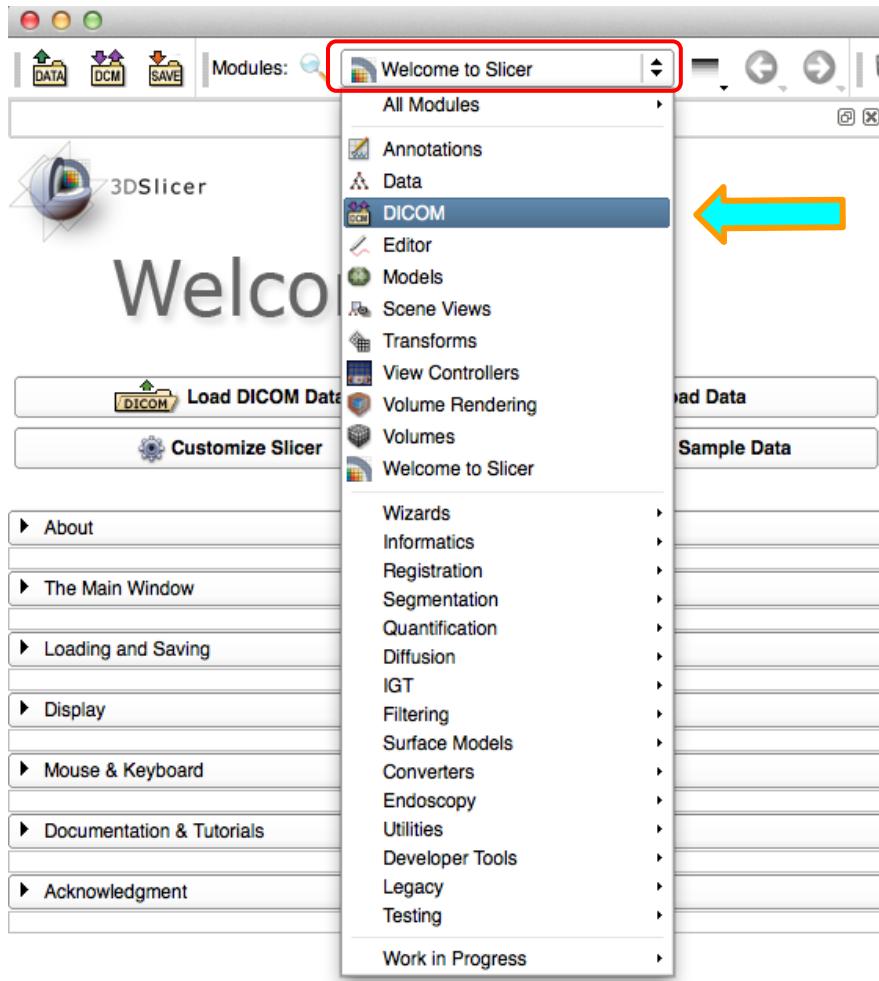
- Open Slicer4 which leads you to the Welcome module.

- Open the list of module (shown by red rectangle), and find the DICOM module.

- The DICOM module will be used to read the dataset.

Load dataset
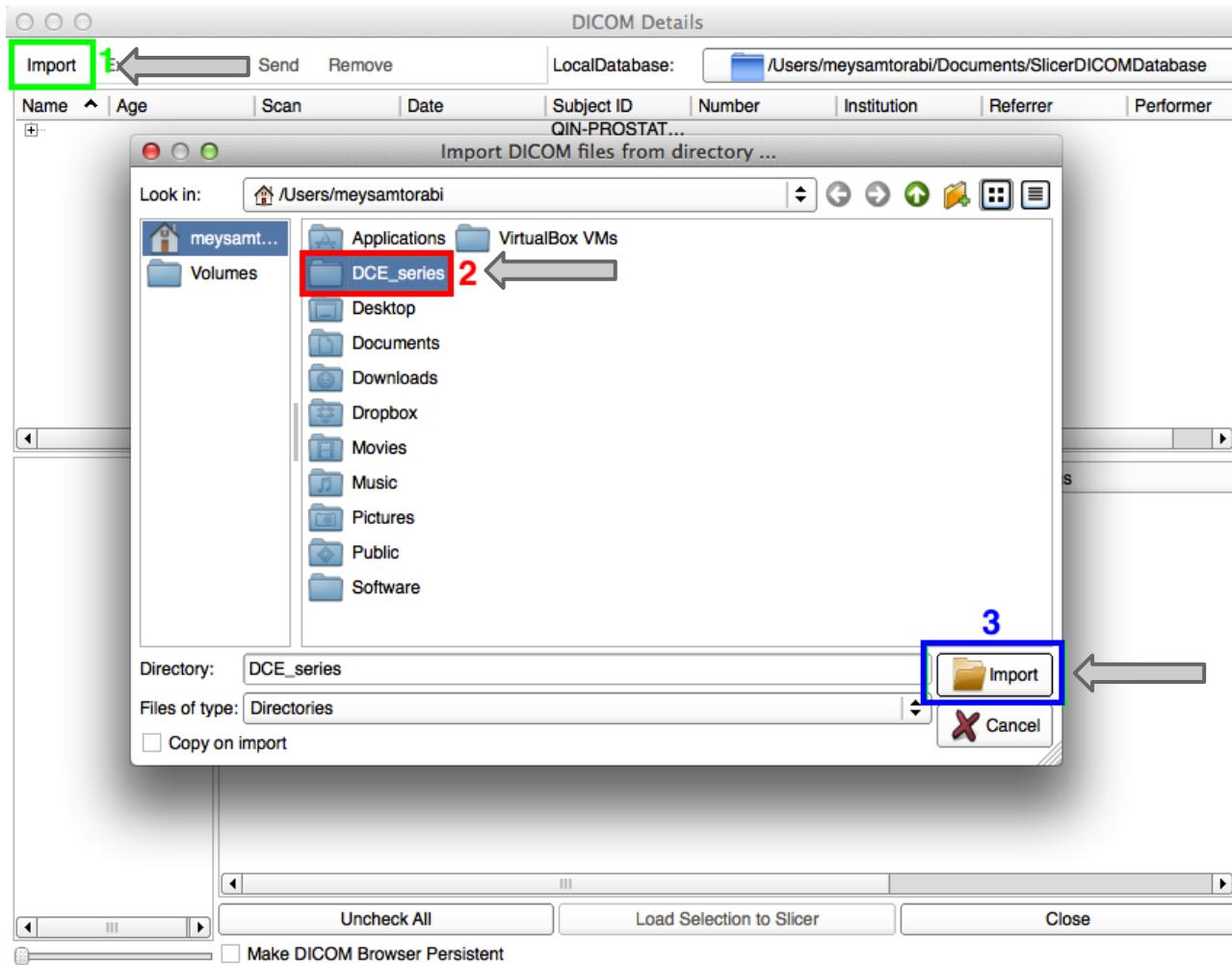
1. Press *"Import"*.

2. Navigate towards the dataset directory.

3. Press *"Import"*, and wait till the data is fully loaded.

Load dataset
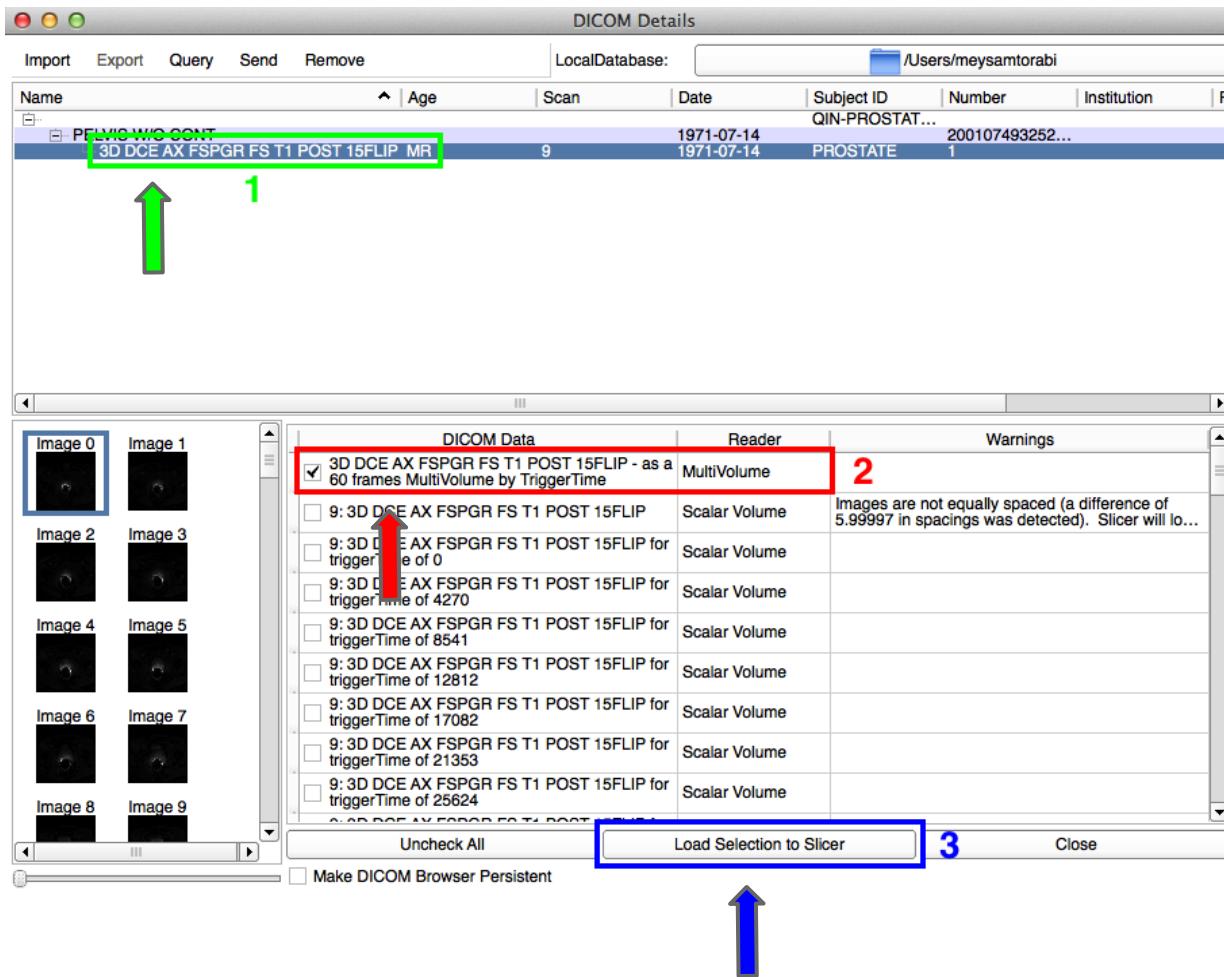
1. Click on "+" and find the dataset.

2. The DICOM module detects the MultiVolume data.

3. Press *"Load Selection to Slicer"*, and wait till the MultiVolume data is loaded.

Run MultiVolumeExplorer module
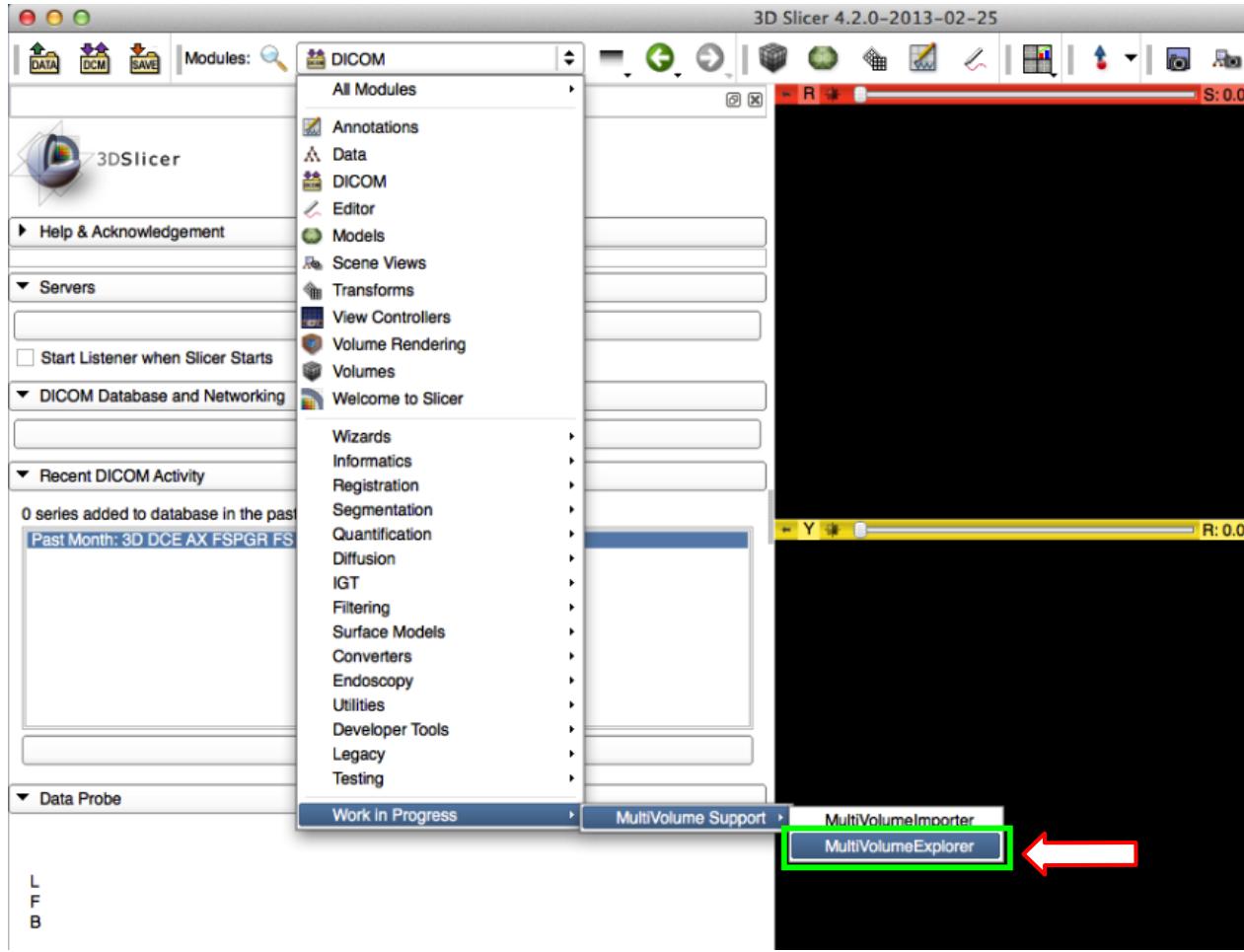
- Now the data is loaded into 3D Slicer.

- From the list of modules open the "MultiVolume Explorer" module to visualize the loaded images.

Select MultiVolume node
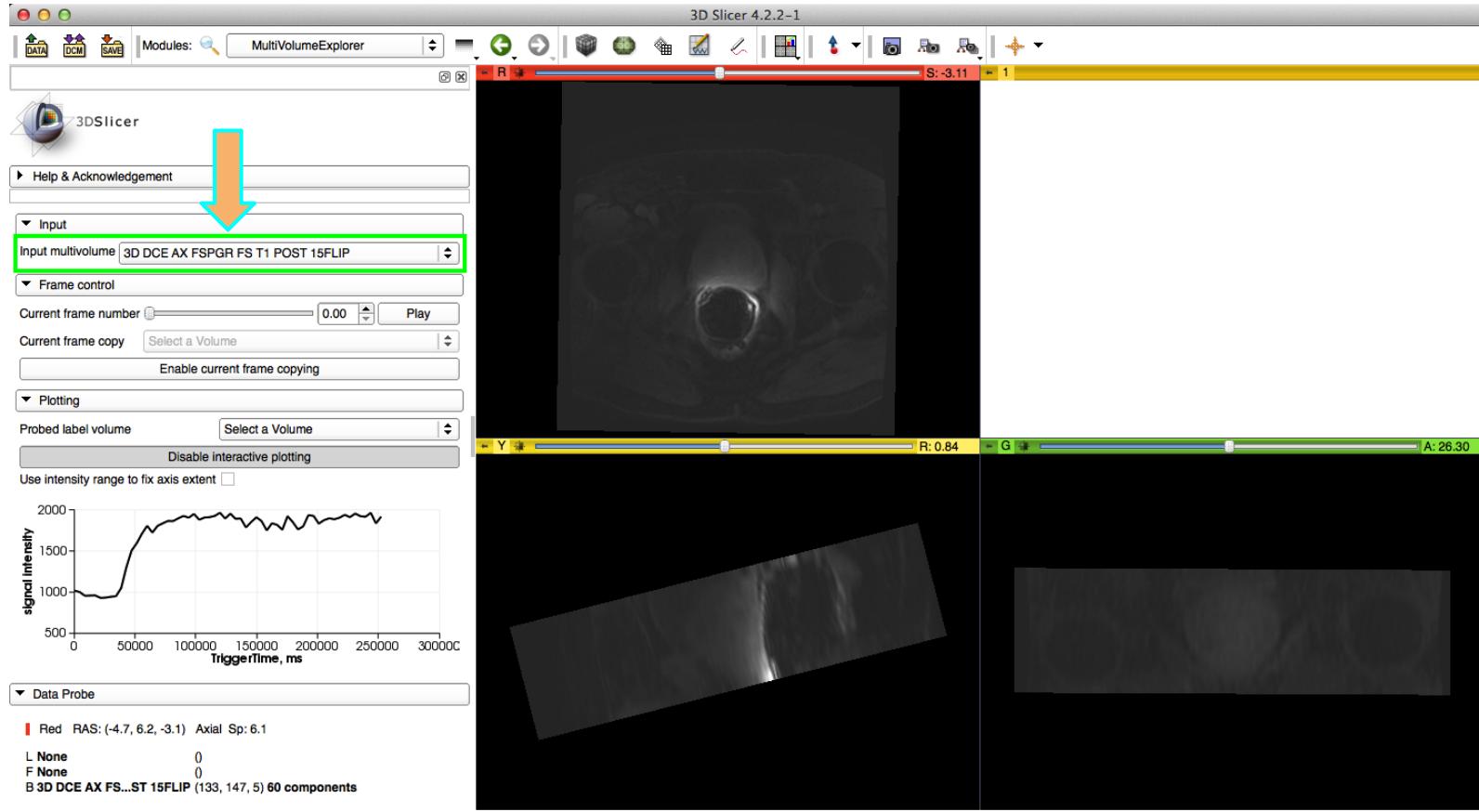
The loaded dataset is now shown as a MultiVolume node.

Adjust volume contrast
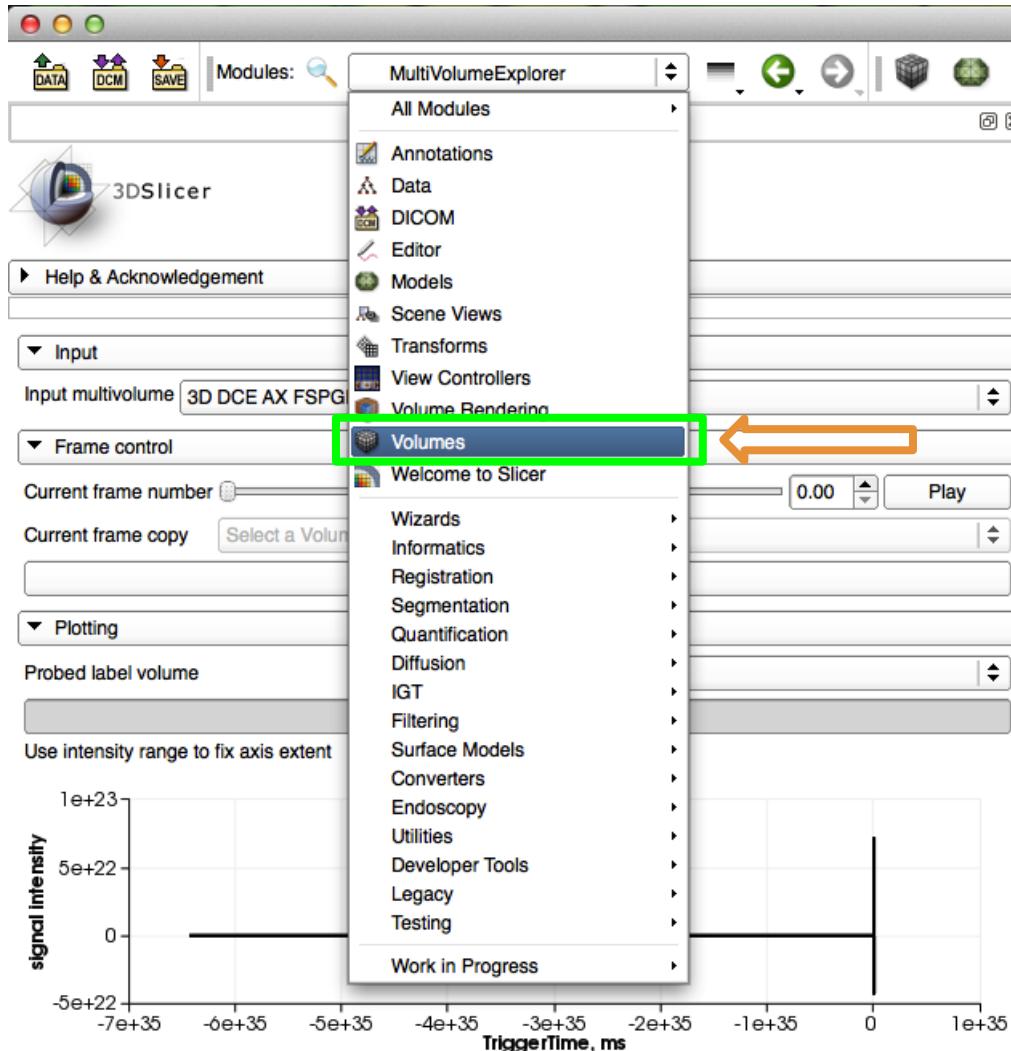
- You may barely see the loaded image due to low contrast. You can adjust the contrast in the Volumes module.

- Open the list of module and find the Volume module.

Image contrast adjustment
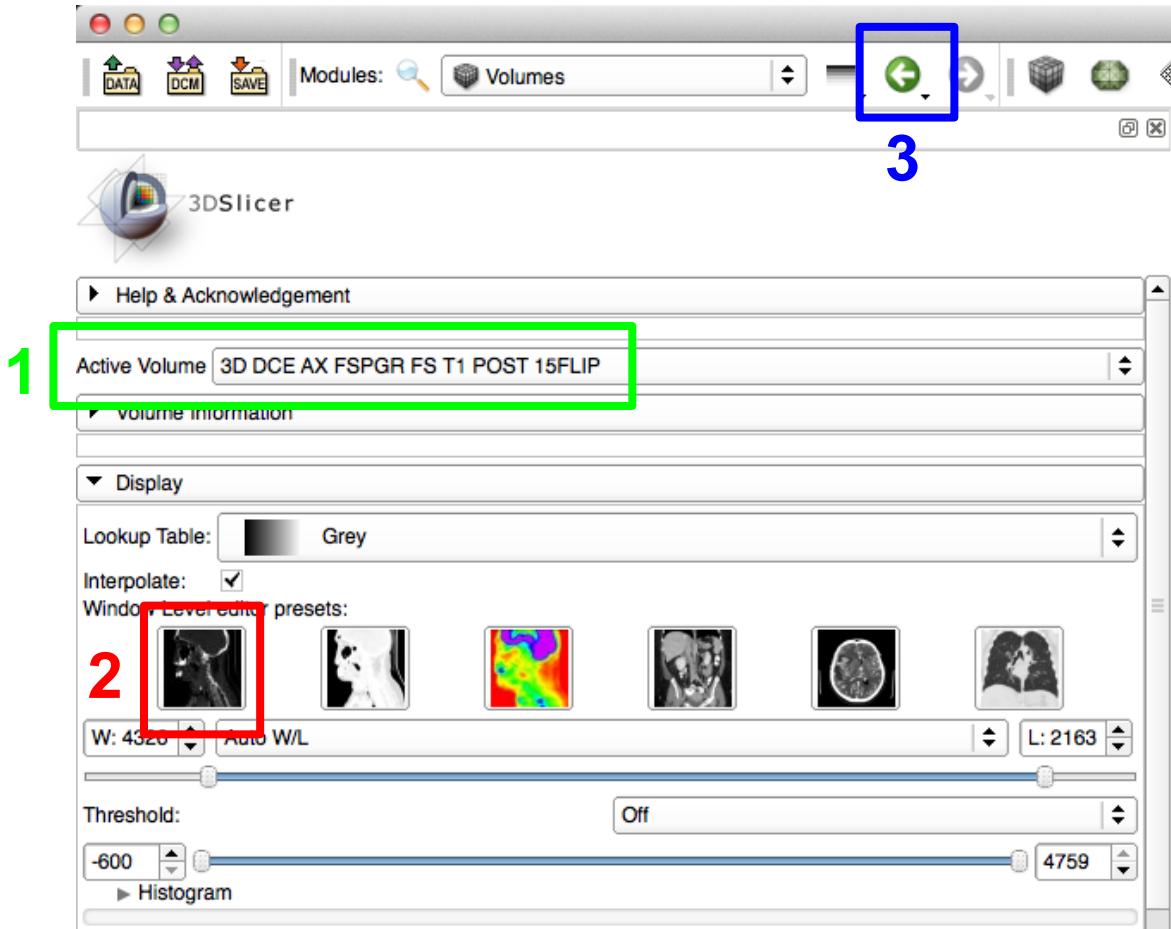
1. Make sure the active volume is correctly selected.

2. Select the preset contrast option that is shown in the figure.

3. Switch back to the module.

Run MultiVolumeExplorer module
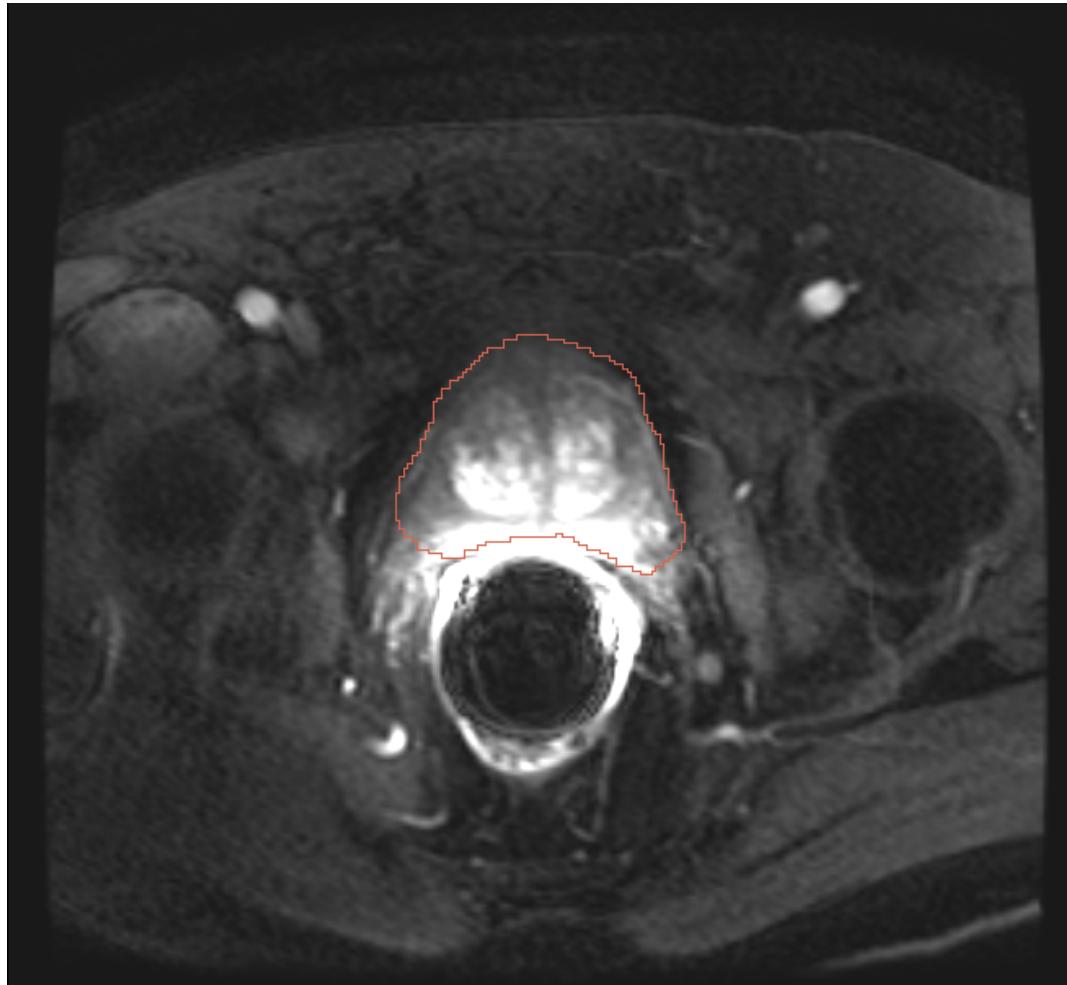
- Now you can clearly see the image.

- In particular, we are interested in observing the Time-Intensity signal of prostate area which is shown by the red boundary in the image.

Run MultiVolumeExplorer module
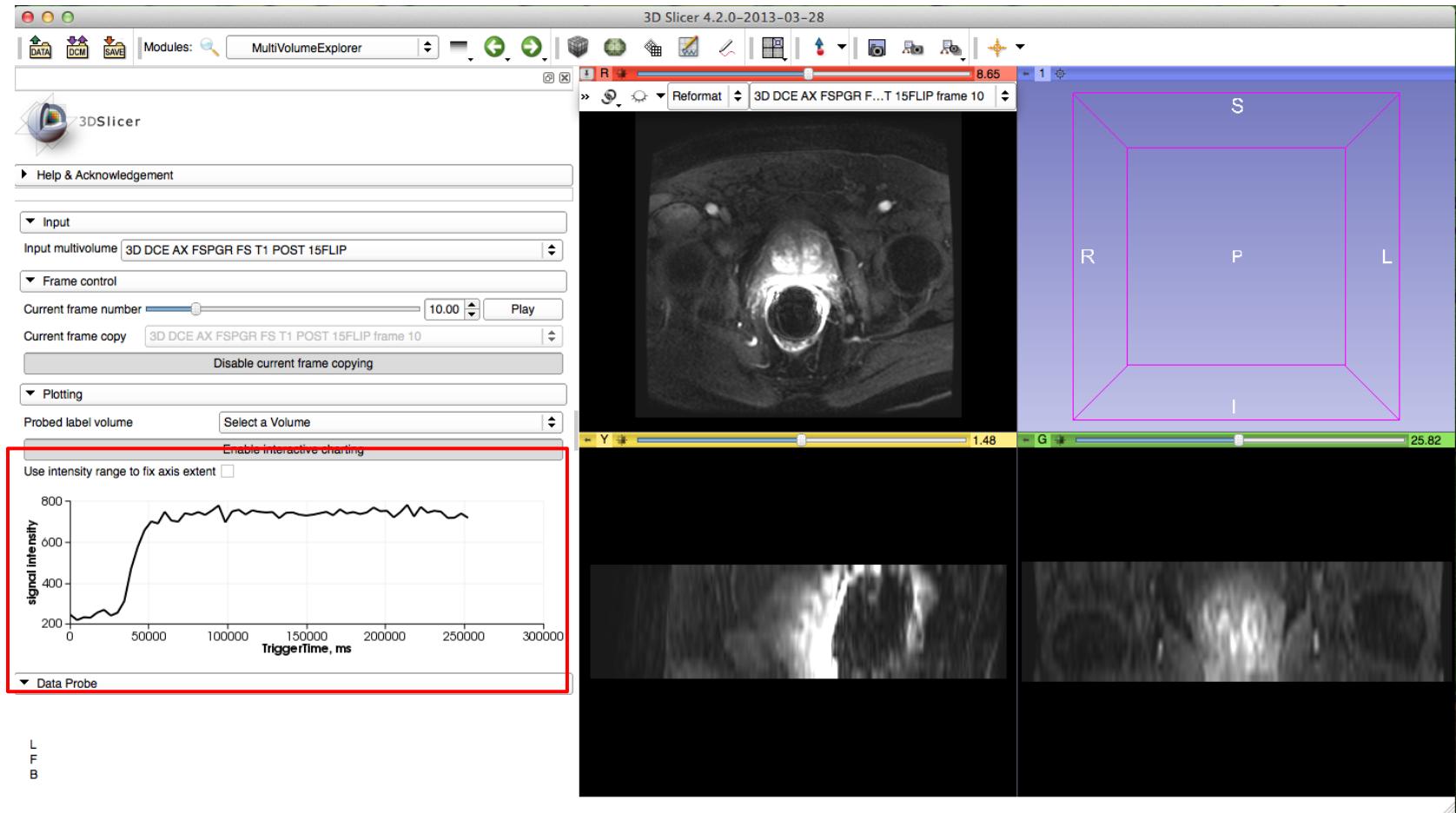
- Hover the mouse over the prostate to see different curves.

(This feature can be disabled by the "Disable Interactive Charting" pushbutton.)

Run MultiVolumeExplorer module
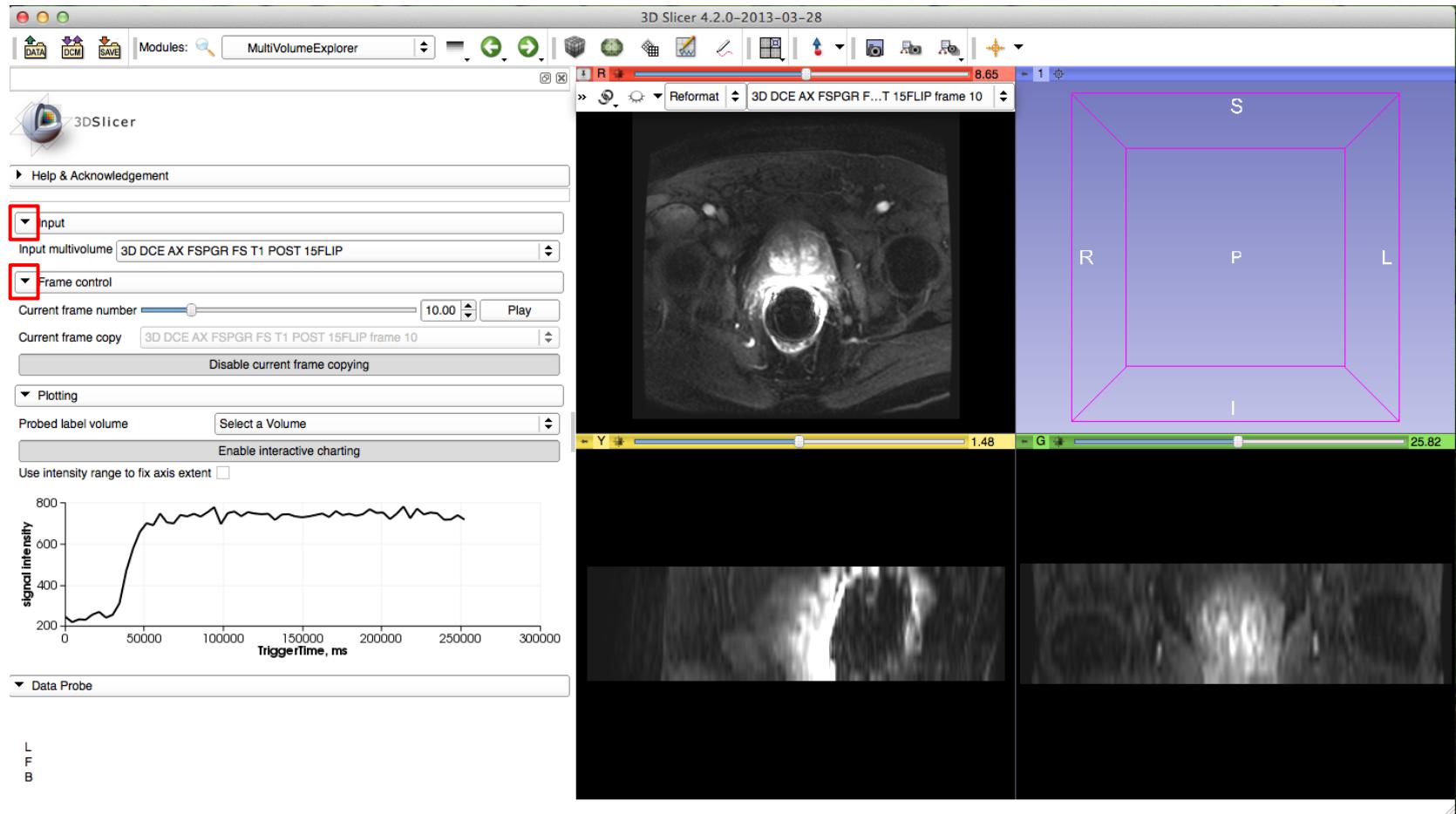
- If the size of graph is too small, you may close the two top frames as shown in the figure.

Run MultiVolumeExplorer module
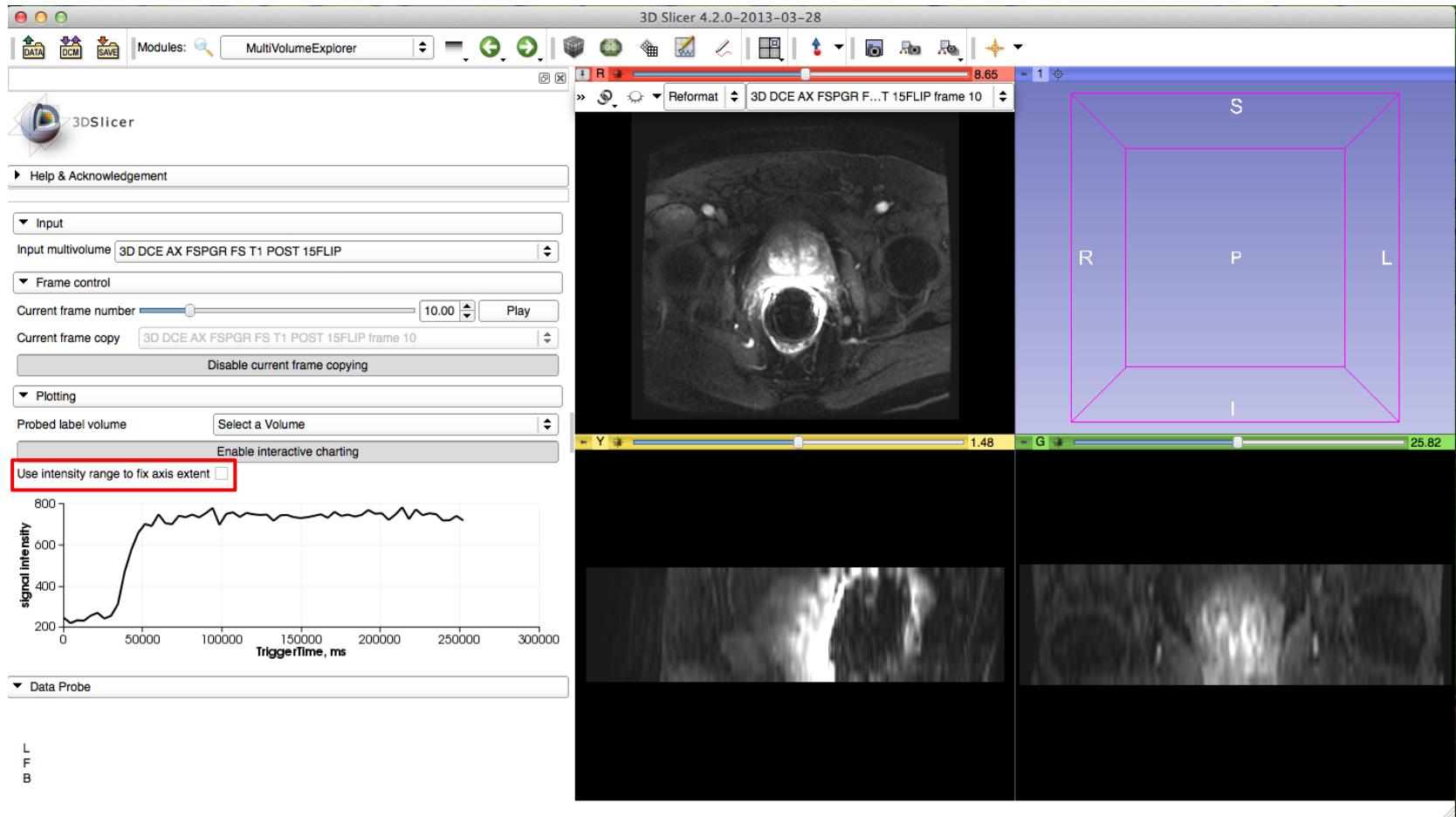
- In order to compare the curves, check the "Use intensity range to fix axis extent" option.

Run MultiVolumeExplorer module
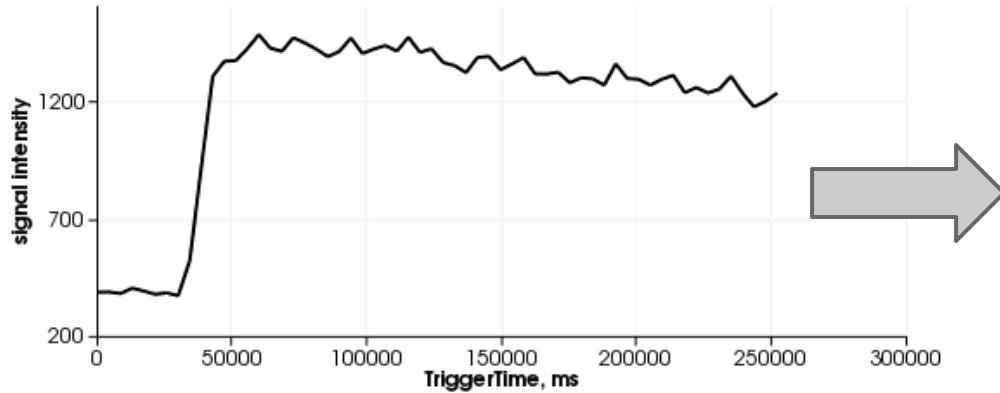
Tissues with rapid *Uptake* curve are very likely to have the cancer.
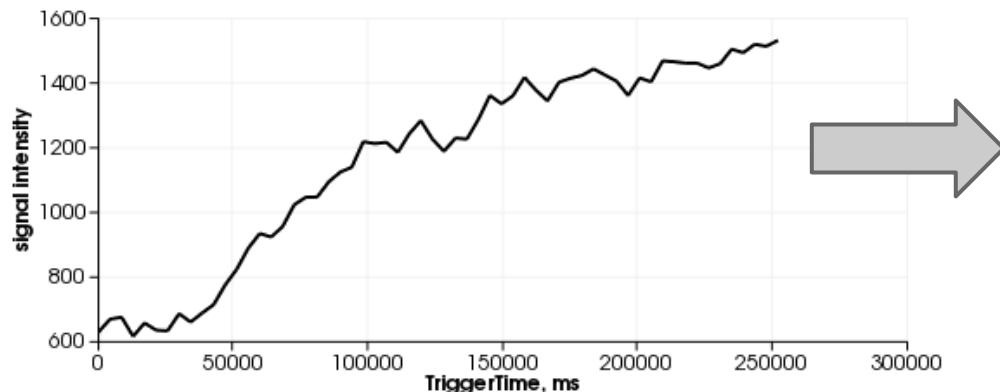
Healthy tissues do not show an uptake.

Visualize multiple frames
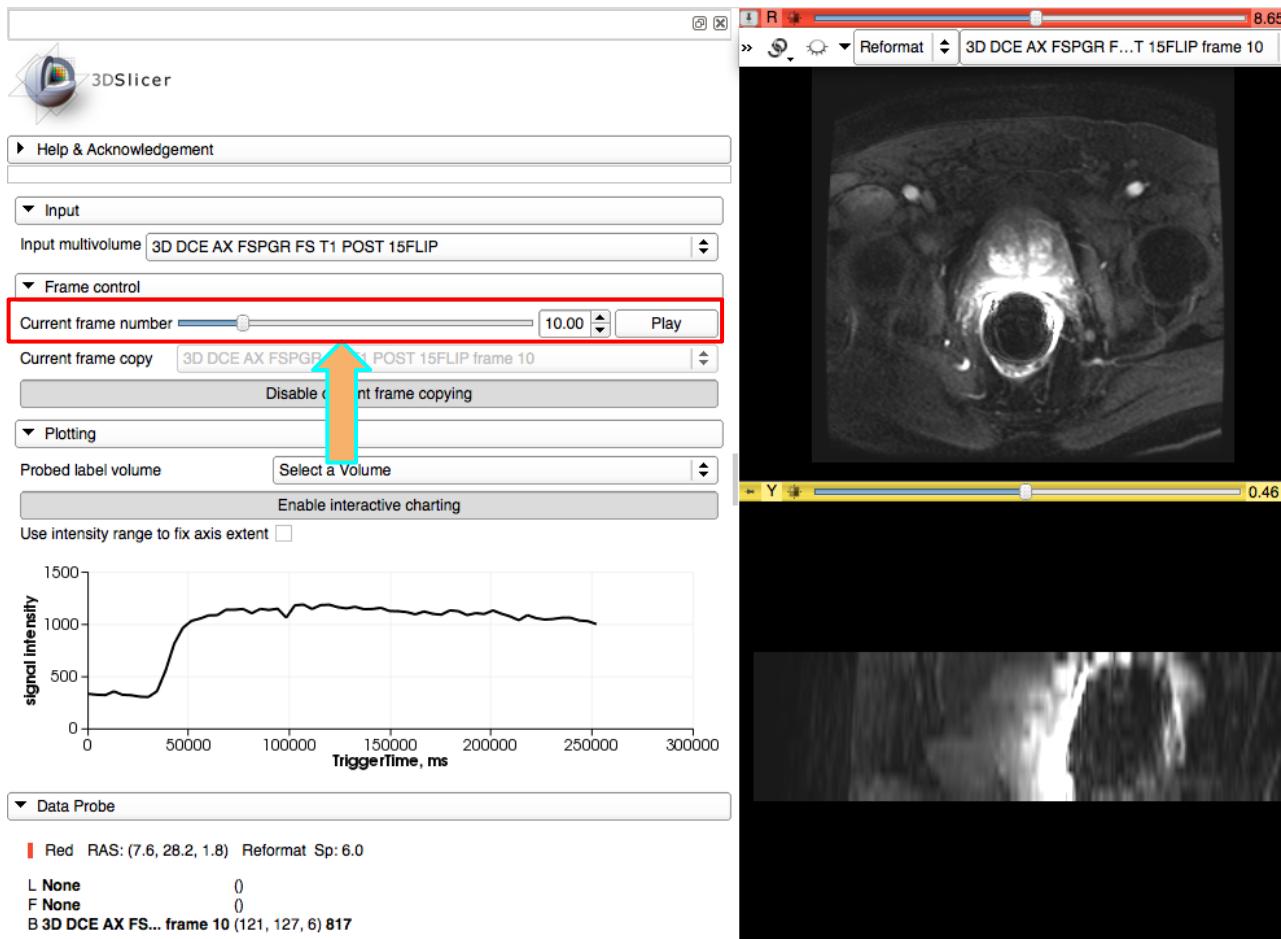
- By moving the Slider-bar, the desired frame in the dataset can be selected. You may also press the *"Play"* pushbutton to see an animation of all frames over time.

Visualize multiple frames
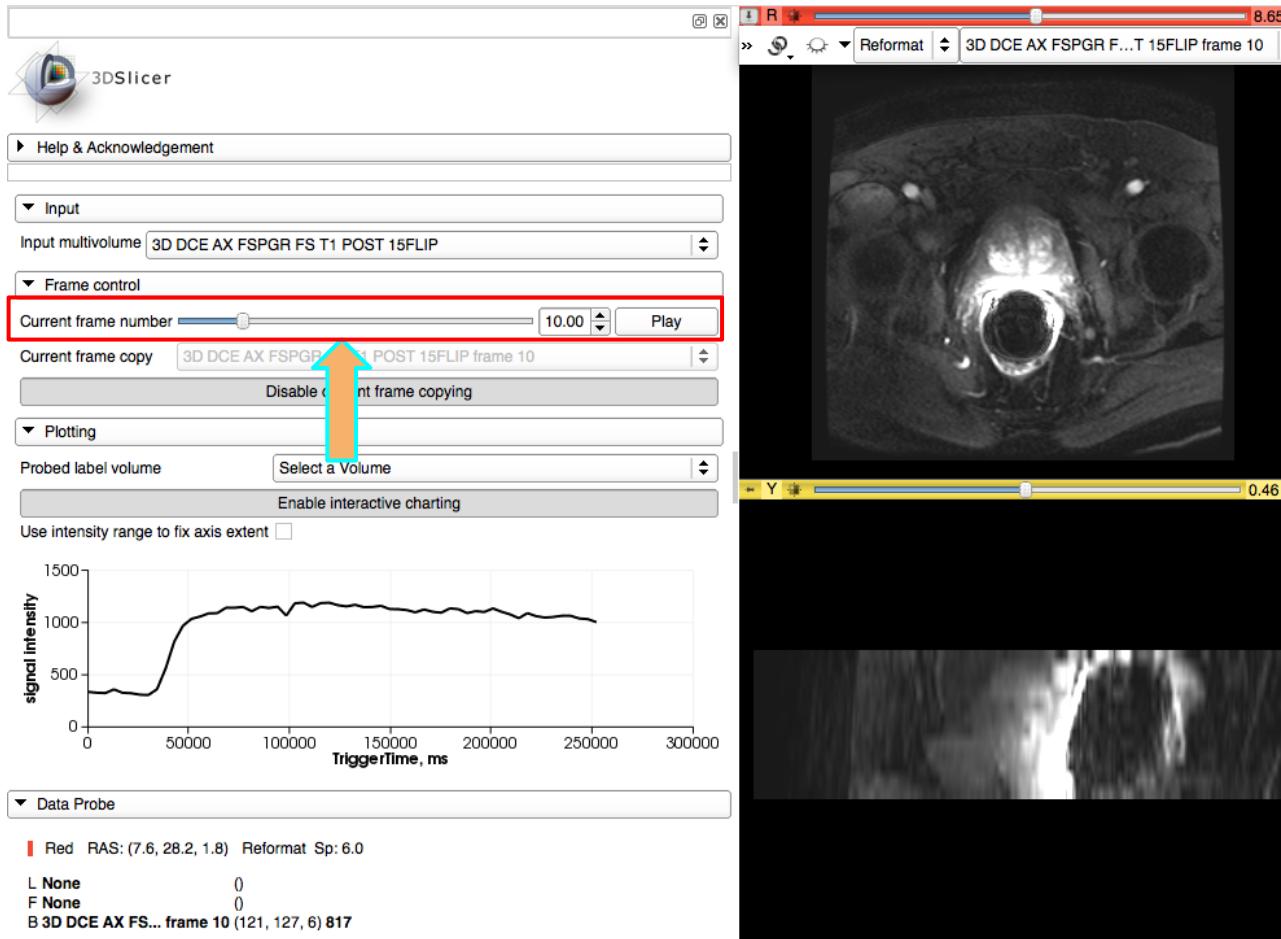
- As the "*Play*" pushbutton is pressed, tissue movement is also observable.

- Too much tissue movement makes the analysis hard.

Lesion-based signal intensity plotting

- So far, point-based signal intensity of DCE-MRI was demonstrated by the module.

- In order to plot the lesion-based signal intensity, the *Editor* module should be utilized.

- We will briefly explain how to use the *Editor* module. For more info about the *Editor* module, please refer to this link.

- In order to use the *Editor* module, the first step is to select one of the frames of the MultiVolume node.

Select and save a frame
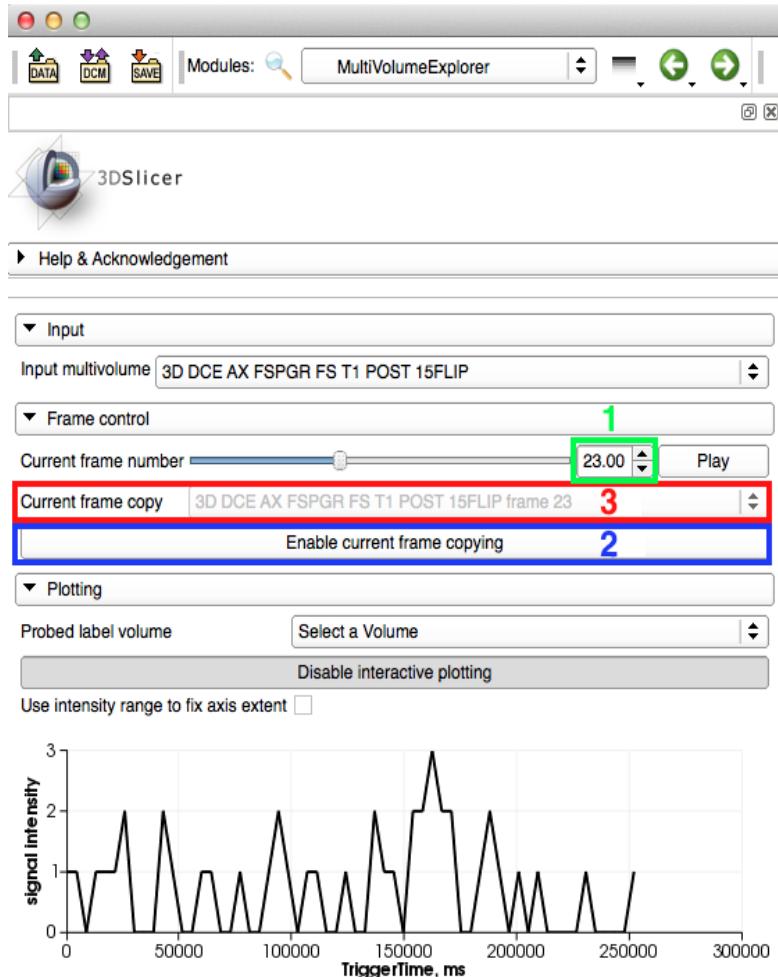
1. Type different frame numbers, and use the sliderbar to observe the diffusion of agent in tissue.

2. Then, press the "*Enable current frame copying*" pushbutton to save the selected frame*.*

3. After the desired frame is saved, its name and frame number are shown*.*

Select and save a frame

1. Now stop the slider-bar, and select a frame.

2. Here we have selected frame number 10.

3. Thus, the selected frame is saved as a volume named: "3D DCE AX FSPGR FS T1 POST 15 FLIP frame 10".

Use Editor module
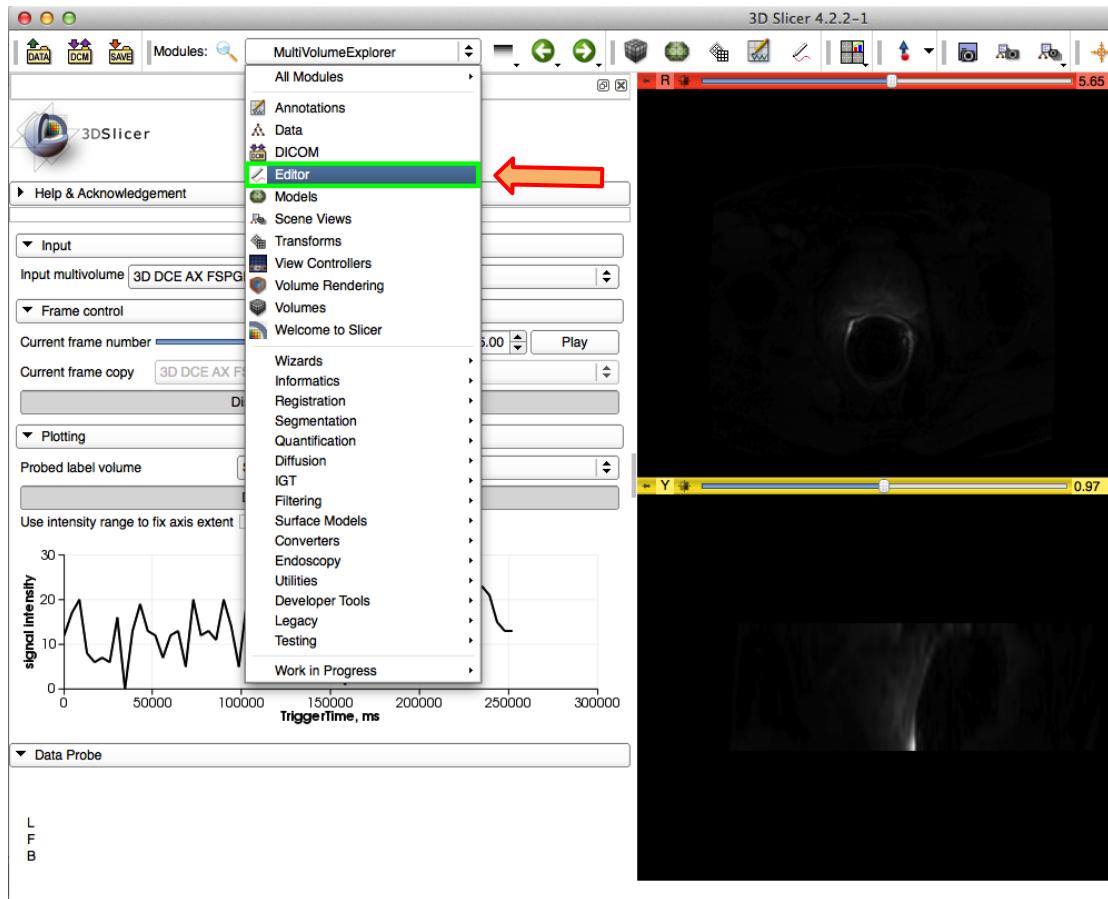
- From the list of modules, select and open the *Editor* Module.

- Editor module is used to create a label volume which contains the Region Of Interests (ROI's).

Use Editor module
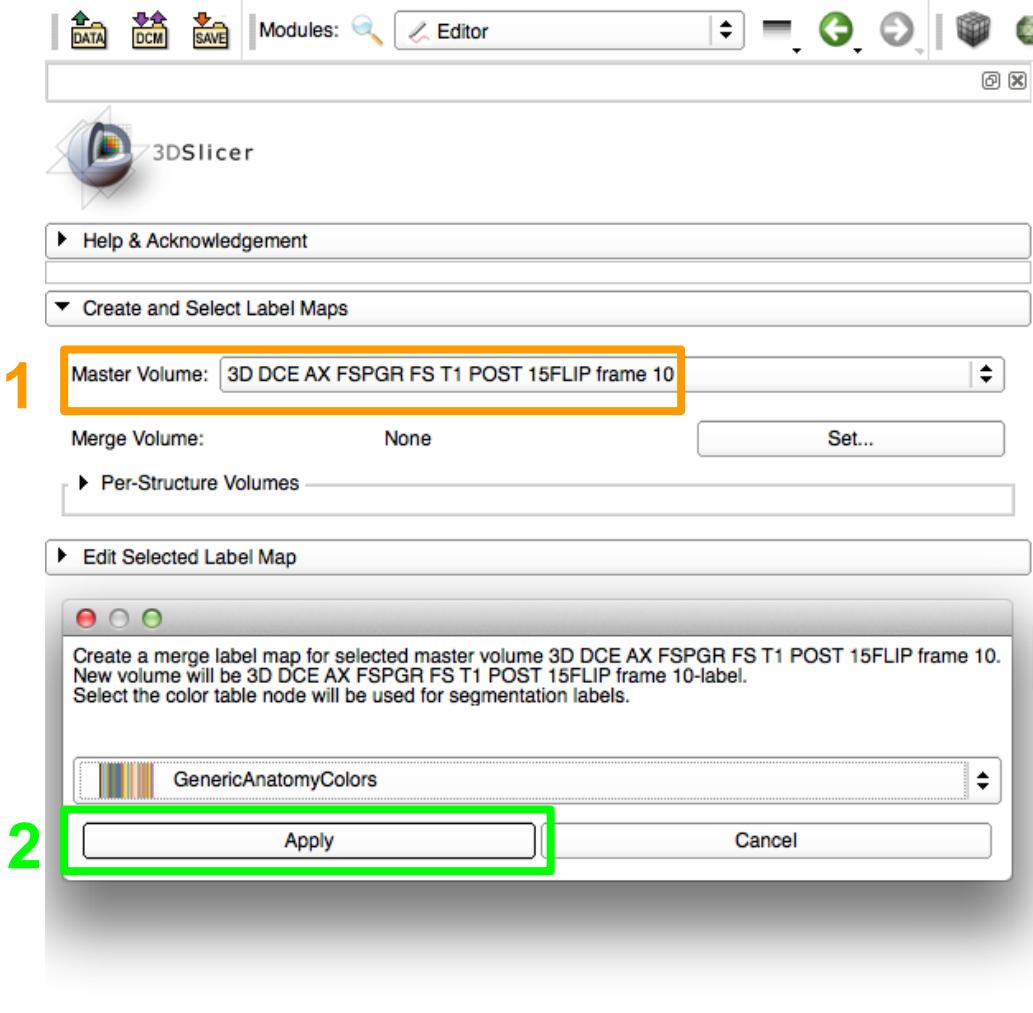
1. Select the Master Volume to be the frame volume that you just selected.

2. A window will show up. Press "Apply" to create a label for the selected frame volume.

Adjust volume contrast
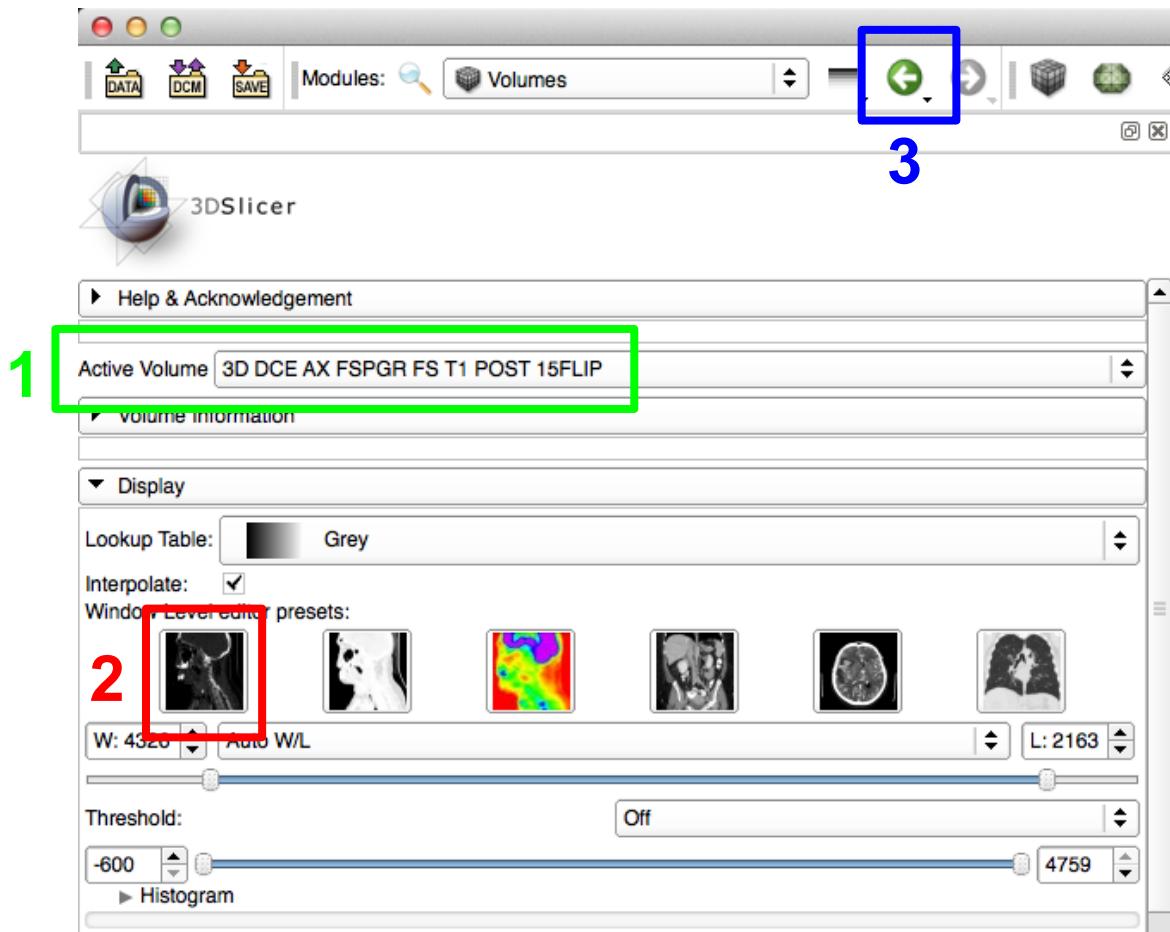
Go to the Volumes module:

1. Select "3D DCE AX FSPGR FS T1 POST 15 FLIP frame 10".

2. Select the preset contrast option that is shown in the figure.

3. Switch back to the *Editor* module.

Create label for frame
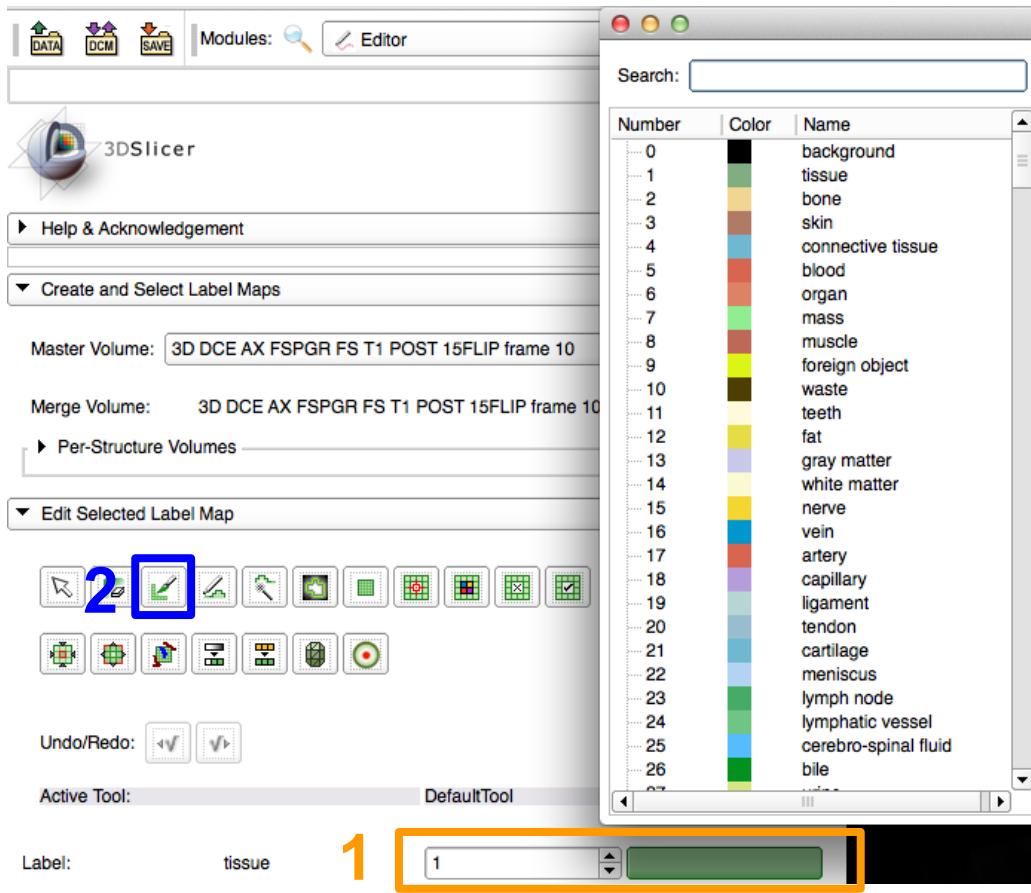
1. For the saved frame volume, select a label number/color from the list.

2. Select one of the drawing tools such as PaintEffect, as shown in the figure.

Note: You can always erase your drawing, if you select label '0' or black color.

Create regions in label volume

- Hold the left mouse click and start drawing the region of interest. When done with drawing, press "return" key. Then switch back to the MultiVolumeExplorer module.
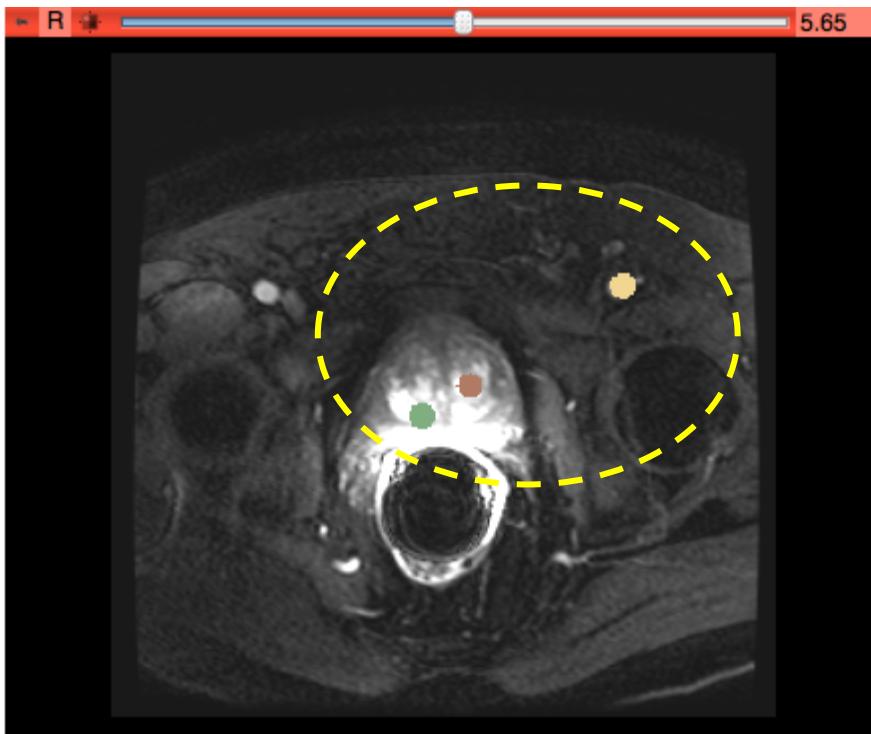
- As shown in the figure, one may create multiple regions with different label values and their own unique colors.

Static plotting
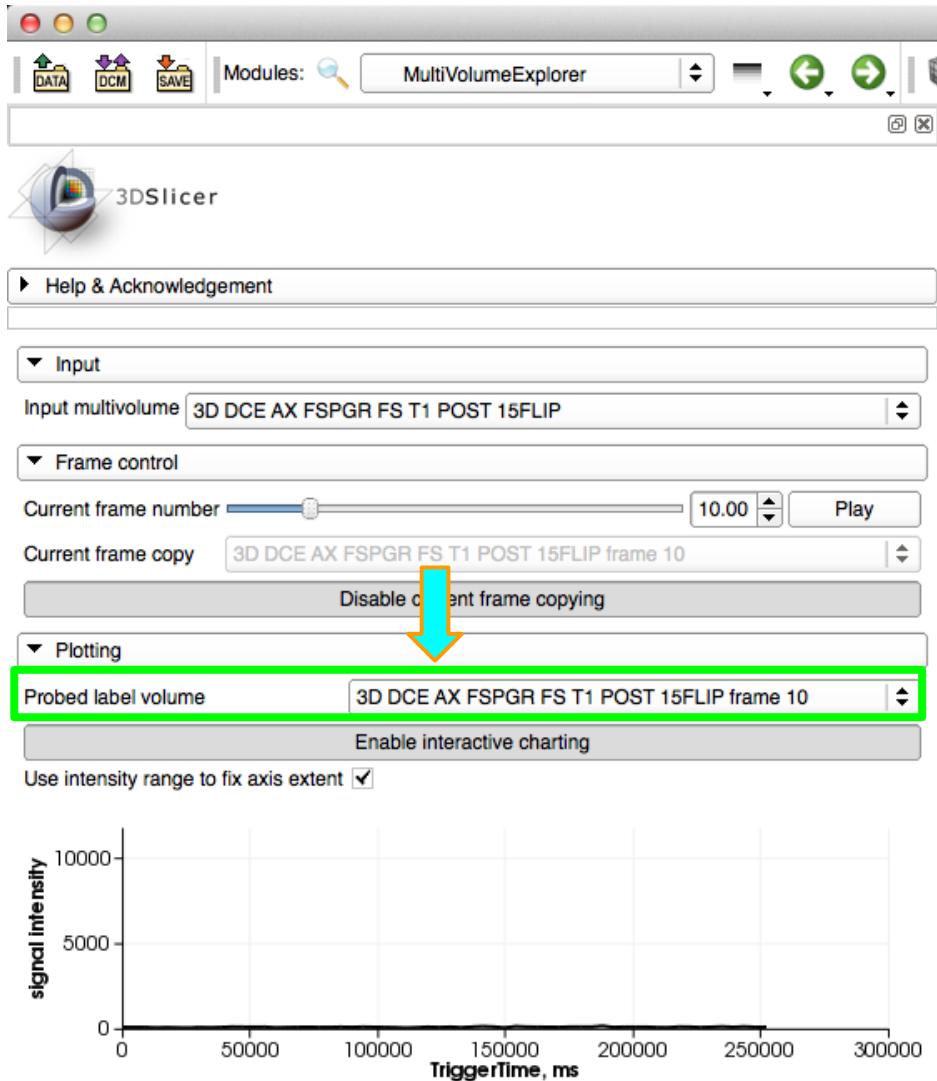
- In the "*Probed labeled volume*" drop-down menu, select the label volume that was created in the *Editor* module.

- Then, the static plot of the labeled regions will immediately show-up (See the next page).

Static plotting

The plots for the three ROI's are graphed with selected colors.
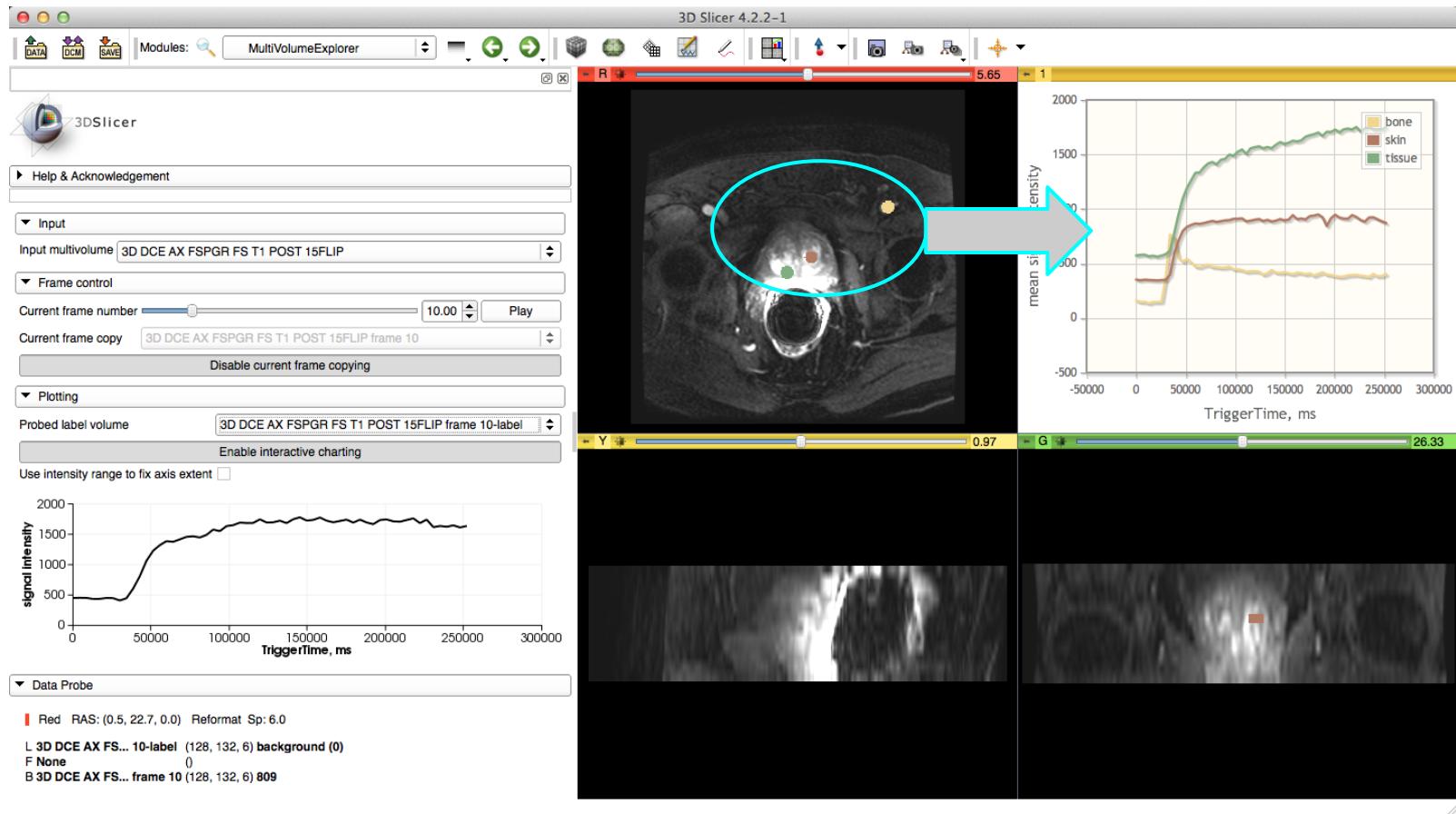
Static plotting

- The static plot shows the average intensity of a labeled ROI.

- The color of each graph corresponds to the color of the labeled ROI.
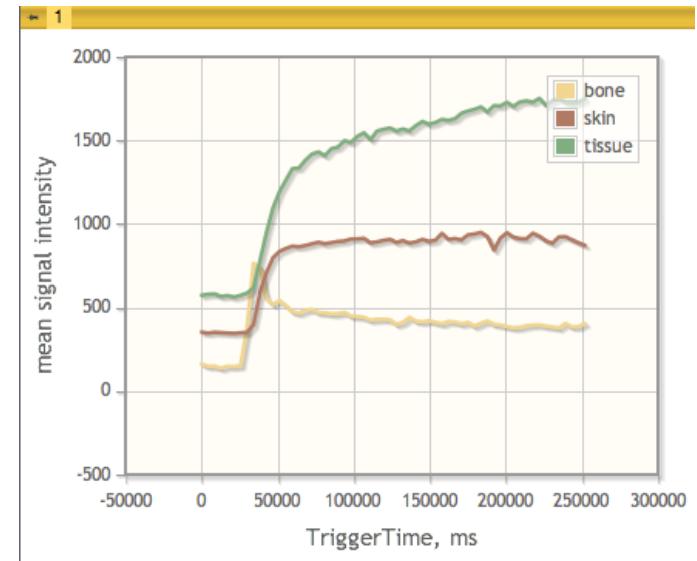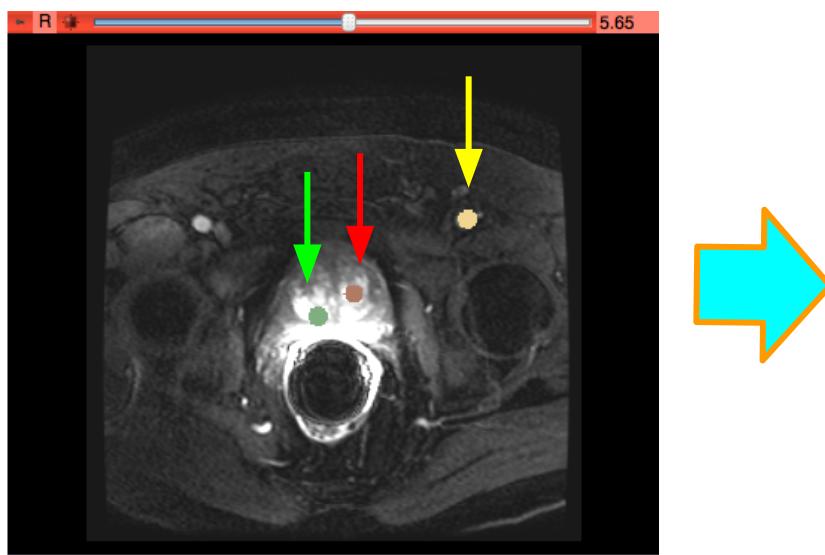
Static plotting

- Tissues which exhibit rapid uptake curves are more likely cancerous (green plot), while healthy tissues show slow increase (red plot).

Clinical significance (tissue classification)

- DCE-MRI has shown potential for the study of prostate cancer.

- The idea is that tumor vessels are leaky which leads to fast blood exchange between the tissue and capillaries [4]. The faster blood exchange, clearly, causes higher intensity in DCE-MRI.

- Consequently, in malignant tumors, *Time-Signal Intensity* curves of DCE-MRI show early rapid high enhancement after injection followed by a relatively rapid decline compared with a slower and continuously increasing signal intensity for normal tissues [5]. This behaviour would qualitatively assess and classify the tissue.

Clinical significance (tissue classification)

- In particular, cancerous tissues in prostate are reported to show early enhancement and rapid washout of contrast material in the Time-Signal Intensity curve [6].

- In semi-quantitative approaches, time-to-peak and peak intensity, and maximum slope would take into account and be analyzed.

- Pharmacokinetics (PK) is a purely quantitative approach which attempts to fit the Intensity-time curve to PK model.

Clinical significance (tissue classification)

- Right figure [5]: The red plot is for cancerous prostate tissue which shows stronger enhancement and faster washout than the blue plot which is for healthy tissue.
- Left figure is generated by our dataset which exhibits the two curve templates introduced in the right figure.
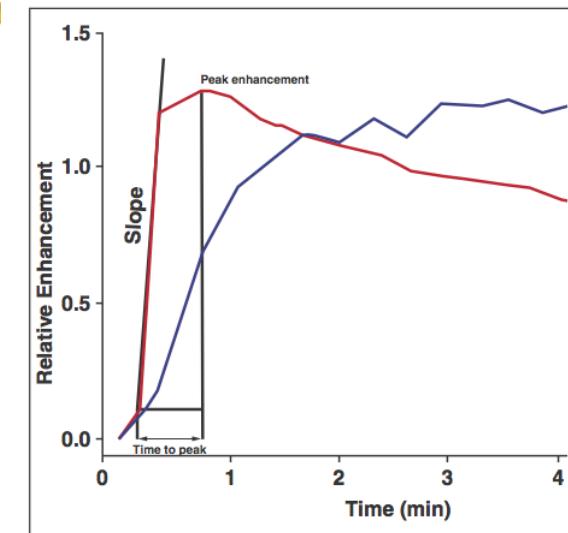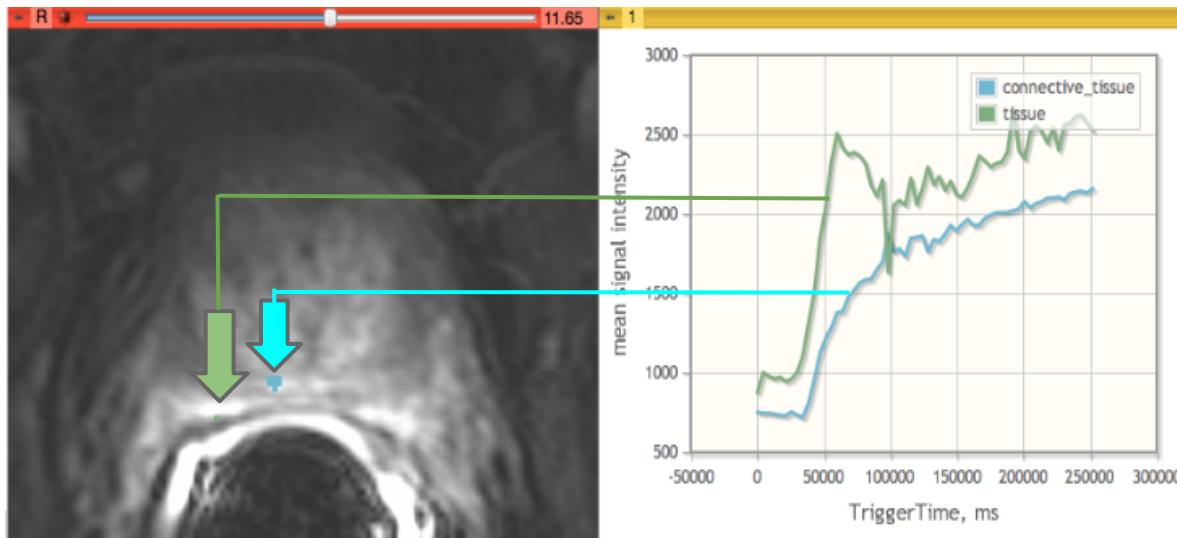
Acknowledgment

Conclusions

- This tutorial trains how to use the MultiVolumeExplorer module of 3D Slicer to visualize DCE-MRI data.

- The module generates dynamic and static plots of intensity-signal over time for point-based and lesion-based studies respectively.

- Potential clinical applications were briefly introduced, and one example from prostate dataset was presented.

- This module demonstrates the possibility of using DEC-MRI analysis in order to classify the tissues to healthy and cancerous tissues..

References

[1] Pieper S., Halle M., Kikinis R. 3D SLICER. Proceedings of the 1st IEEE International Symposium on Biomedical Imaging: From Nano to Macro 2004; 1:632–635.

[2] Pujol S., Slicer Welcome, NA-MIC, April 2011-2012.

[3] Fedorov A., Fillion Robin J.C., Finet J., Pieper S., and Kikinis R. "http://www.slicer.org/slicerWiki/index.php/Documentation/Nightly/Modules/MultiVolumeExplorer.

[4] Erbersdobler A, Isbarn H, Dix K, et al. Prognostic value of microvessel density in prostate cancer: a tissue microarray study. World J Urol 2010; 28:687–692

[5] Verma S, Turkbey B, Muradyan N, Rajesh A, Cornud F, Haider MA, Choyke PL, Harisinghani M. Overview of dynamic contrast-enhanced MRI in prostate cancer diagnosis and management. AJR. American journal of roentgenology. 2012 June 1;198(6):1277–88.

[6] Bloch BN, Furman-Haran E, Helbich TH, et al. Pros- tate cancer: accurate determination of extracapsular extension with high-spatial-resolution dynamic con- trast-enhanced and T2-weighted MR imaging— initial results. Radiology 2007; 245:176–185