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# **Slicer3 Tutorial**

## **Registration Library Case 27:**

**DTI MRI pre-op planning: align DTI with FLAIR and T1,  
extensive pathol.**

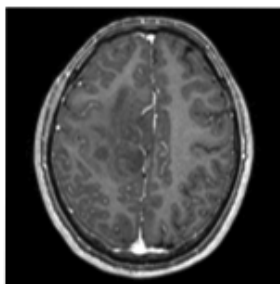
Dominik Meier, Ron Kikinis  
Sept. 2010

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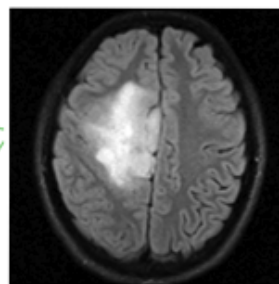
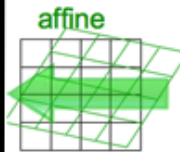


# Introduction

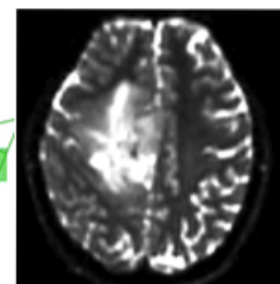
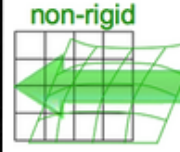
- This is an example dataset of an MRI exam obtained for pre-operative planning. We seek to align the DTI with the structural reference T1 scan to transfer information about critical fiber pathways.
- There is extensive pathology in the right hemisphere and acquisition-related distortion in the DTI data
- The FLAIR provides T2-weighted contrast more similar to the DTI baseline than the T1, which makes it a good target for registration. However it has low axial resolution (4mm thick slices) that make it suboptimal as final space in which to resample the DTI.
- We therefore follow a 2-step approach: 1) we register the FLAIR to the T1 and resample to the same isotropic resolution as present in the T1; 2) we then register the DTI to the resampled FLAIR.



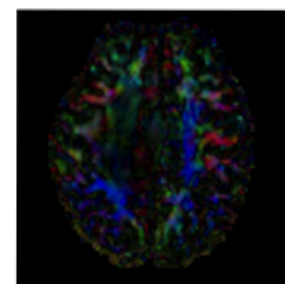
fixed image/target  
T1



fixed image/target  
FLAIR



moving image 2a  
DTI baseline

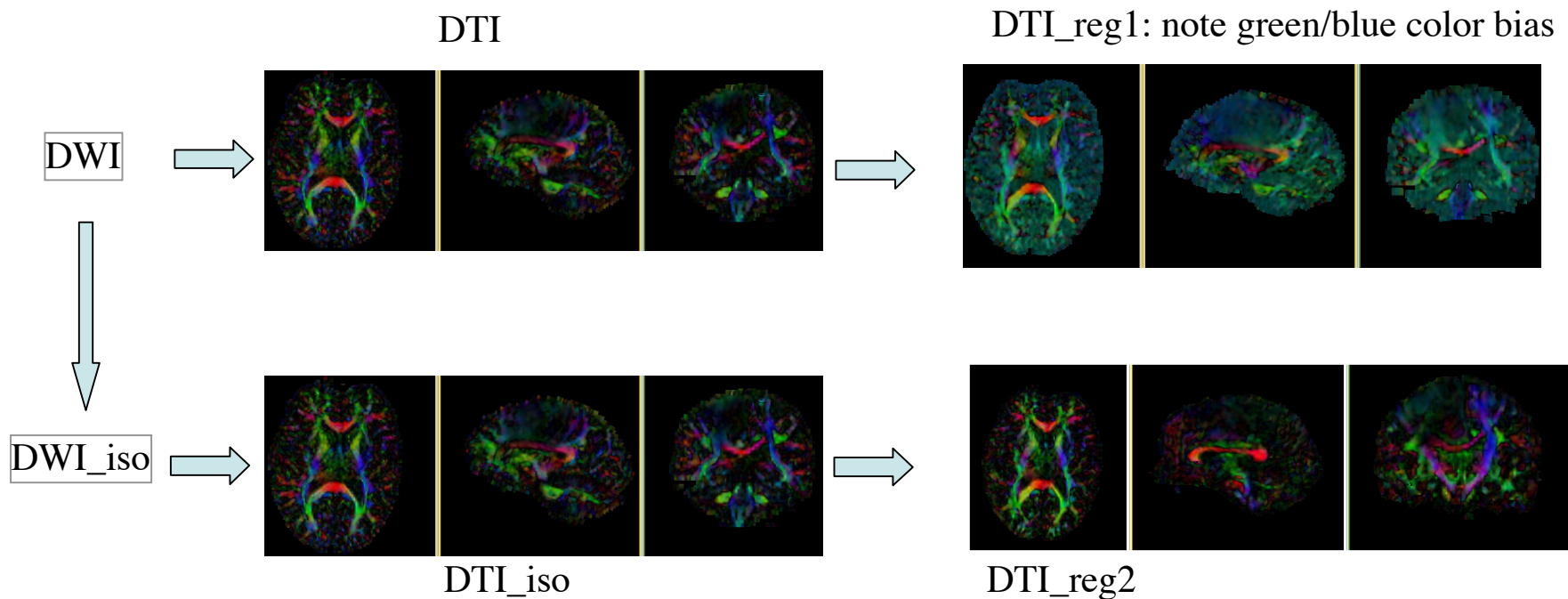


moving image 2b  
DTI tensor



# Resolution & Anisotropy Issues

- The original DWI image has a voxel size of  $1.96 \times 1.96 \times 3$  mm. The DTI estimation and subsequent rotation of the tensor data can lead to strong interpolation artifacts: in this case directionality in the z-direction (inferior-superior) will “blur” across slices and lead to a systematic bias/offset in the final resample DTI image (DTI\_reg1).
- It is therefore recommended to first resample the DWI to an isotropic resolution similar to the target space, and then perform DTI estimation and registration (DTI\_reg2).





# Modules Used

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- To accomplish this task we will use the following modules:

– Volumes Module



– Diffusion Tensor Estimation Module

Modules:

– BRAINSFit Registration Module

Modules:

– Data Module



– Resample Scalar/Vector/DWI Volume

Modules:

– Resample DTI Module

Modules:



# Prerequisites

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- Slicer version 3.6.1 or later
- **Example Dataset:** download and extract the dataset for this tutorial: RegLib\_C27\_DATA.zip, which should contain this tutorial, all original and some intermediate solution data files.
- **Tutorials to complete first (optional):**
  - Slicer3Minute Tutorial
  - Loading and Viewing Data
  - DTI tutorial

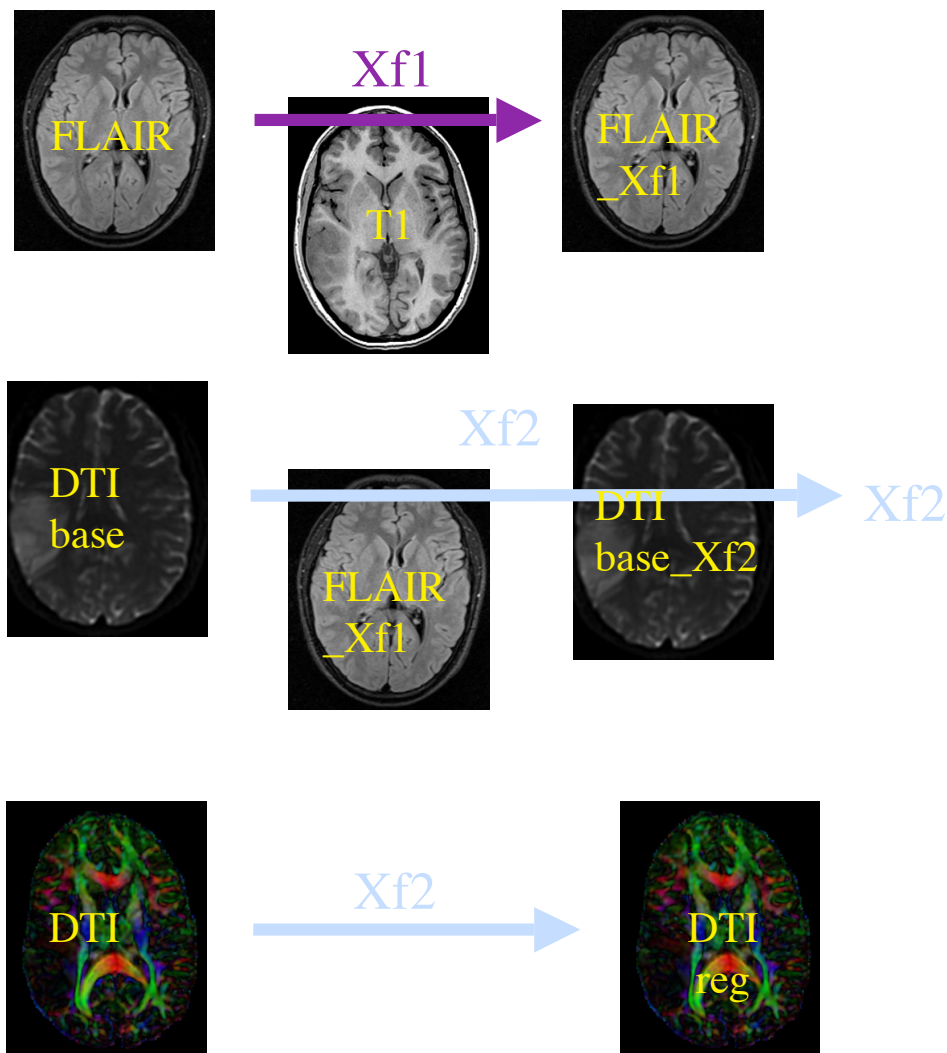


# Registration Strategy

1. Register the FLAIR scan to the T1 (affine)
2. Register the DTI\_baseline to the above registered FLAIR
3. Apply the second transform to the DTI volume.

The reason for these 2 steps is that best registration quality and robustness is achieved when image contrast and/or resolution are similar. A registration of the DTI\_baseline to the T1 is a large step in both image contrast and resolution / FOV and likely to fail

We register to the T2 after it is aligned with the T1. Registering to the original T2 and then moving to the T1 would require concatenating transforms in a form not currently supported, or alternatively would require additional resampling which would reduce DTI image quality.





# Register T2 (FLAIR) -> T1

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1. Go to the “BrainsFit” module
2. Input:  
Fixed Image: T1  
Moving Image: T2
3. Output:  
“Slicer Linear Transform”: create new, rename to “Xf1\_FLAIR-T1\_Affine”  
Output Volume: create new, rename to “FLAIR\_Xf1”  
Check boxes for: “rigid”, “affine”

Registration Parameters all defaults except Number of Samples 200,000

Registration Parameters	
Transform Type	
Number Of Iterations	1500
Number Of Samples	200000
Minimum Step Size	0.005
Transform Scale	1000



# Resample DWI to isotropic

1. Go to the “Resample Scalar/Vector/DWI” module

2. Input:

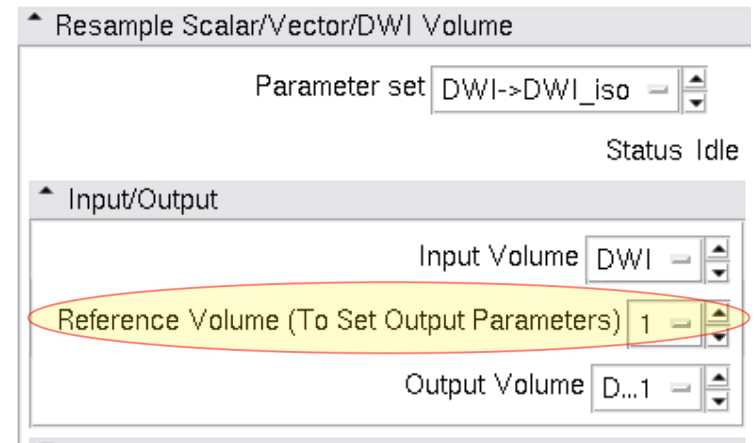
Input Volume: DWI

Reference Volume: T1

Output Volume: “Create New DWI Volume”, rename to “DWI\_iso”

We choose the new resolution via the reference volume, i.e. the DWI will be resampled into the close to isotropic voxel size of the T1 image.

3. Click: “Apply”





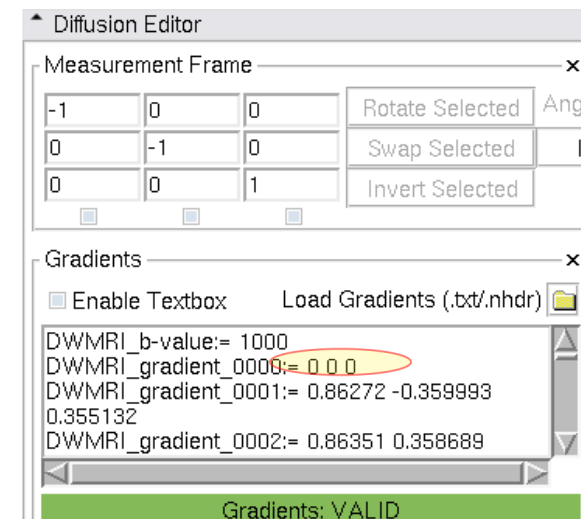
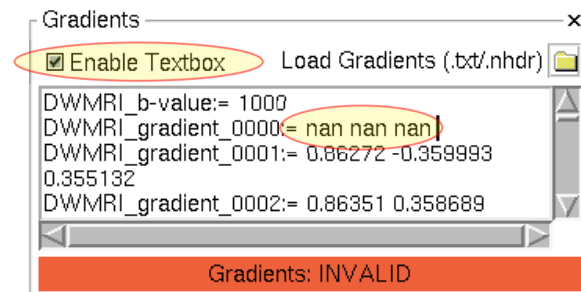


# DWI gradient fix:

It can happen that upon resampling the zero-gradient numbers become “NaN” entries in the gradient description, which can cause the subsequent DTI estimator to fail. If necessary we therefore first check & ev. edit the gradient description:

1. Go to the Volumes module
2. As Active Volume, select the “DWI\_iso”
3. Select the Diffusion Editor tab. You should see the list of gradients as shown on the right. At the bottom of the box you get an evaluation that says “Gradients: VALID” or “Gradients: INVALID”. If you have the latter, see if the first and possibly other gradient directions are set to NaN. If that’s the case, open the gradient info of the original DWI image (procedure as above) and look up the correct values for those particular gradient entries. Then return to this volume to edit the table:
4. Check the “Enable Textbox” box. You should now be able to type and edit the gradient file.
5. Replace the gradient NaN numbers with the correct entries, in this case it is likely that the zero gradients were affected, i.e. change NaN NaN Nan back to 0 0 0
6. Continue editing until the “Gradients: VALID” note appears.
7. Save the DWI\_iso image back to disk to maintain this fix.

Active Volume:

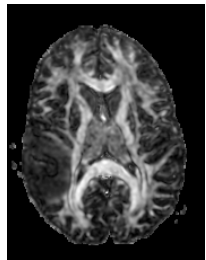




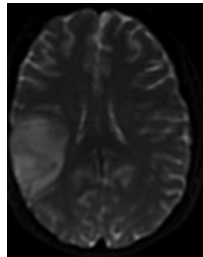
# DWI -> DTI conversion

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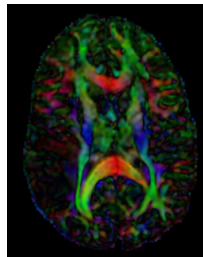
We're now ready to convert the new isotropic DWI into a DTI. This conversion will produce 3 new volumes:



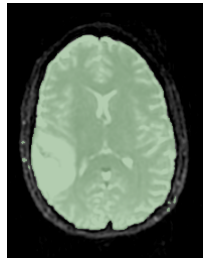
DWI



**DTI\_base:** used as moving image to compute the registration with a T2 reference



**DTI:** final registration transform will be applied to the tensor to resample it in the new reference space (T2).

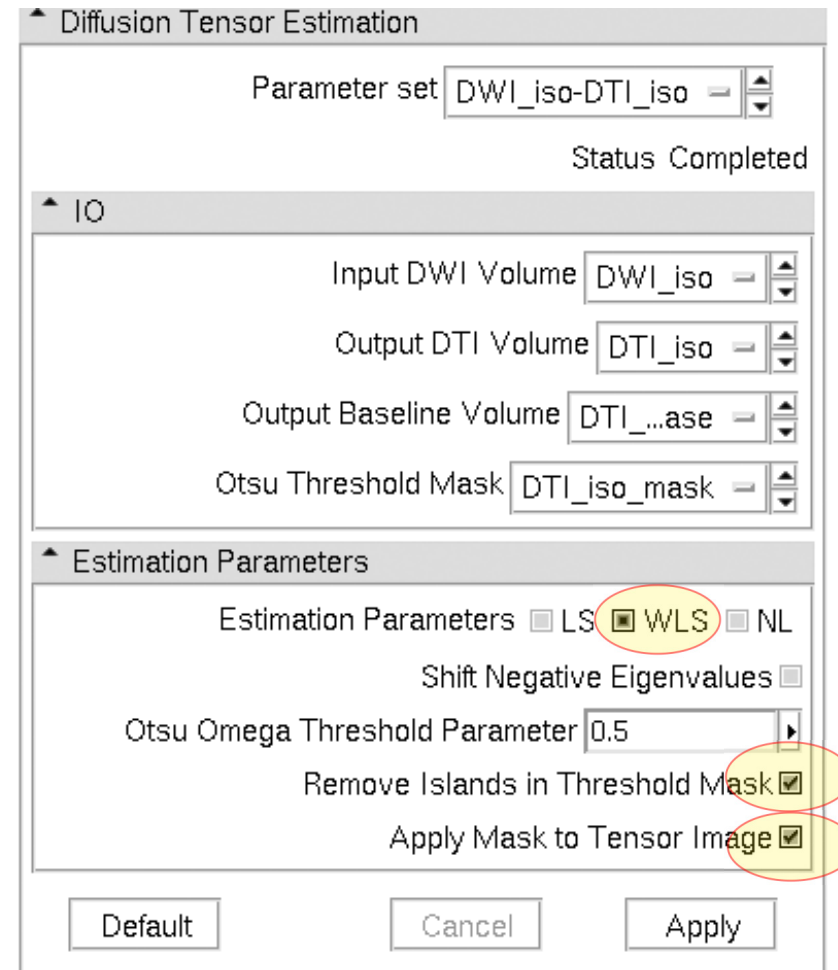


**DTI\_mask:** the mask will be used to guide the automated intensity-based registration of the DTI\_baseline. Particularly the nonrigid aspects of the registration to correct for the DTI distortions benefit from the ROI provided by the mask.



# Convert DWI -> DTI

1. We next convert the DWI volume into a DTI tensor image that can be used for fiber tracking and other forms of quantifying diffusion.
2. The DTI Estimation module in the Diffusion / Utilities section will perform this task in a single automated step:
  1. Select the DWI image
  2. Create new DTI output image
  3. Create new output baseline volume
  4. Create new Otsu mask volume
  5. Leave Estimation Parameters at defaults
  6. Click Apply
  - The DTI\_baseline output will serve as moving image for the registration
  - The Otsu mask image may be useful as mask to focus registration





# Register DTI baseline to FLAIR

1. Go to the “BrainsFit” module

2. Input:

Fixed Image: FLAIR\_Xf1

Moving Image: DTI\_base

Output:

“Slicer Bspline Transform”: create new, rename to “Xf2\_DTI-FLAIR\_unmasked”

Check boxes for: “rigid”, “affine” + “Bspline” registration

Registration Parameters as shown below: Changes to defaults highlighted

Registration Parameters	
Transform Type	
Number Of Iterations	1500
Number Of Samples	200000
Minimum Step Size	0.005
Transform Scale	1000
Reproportion Scale	1
Skew Scale	1
Number Of Grid Subdivisions	5,5,3
Maximum B-Spline Displacement	0

Modules: BRAINSFit

3DSlicer

Help & Acknowledgement

BRAINSFit

Parameter set: BRAINSFit

Status: Idle

Input Parameters

Fixed Image Volume: T2

Moving Image Volume: DT...e

Registration Phases To Use

Initialize with previously generated transform: e

Initialize with MomentsAlign registration phase:

Initialize with GeometryCenterAlign registration phase:

Initialize with CenterOfHeadAlign registration phase:

Include Rigid registration phase:

Include ScaleVersor3D registration phase:

Include ScaleSkewVersor3D registration phase:

Include Affine registration phase:

Include BSpline registration phase:

Output Settings (At Least One Output Must Be Specified)

Slicer BSpline Transform: X...m

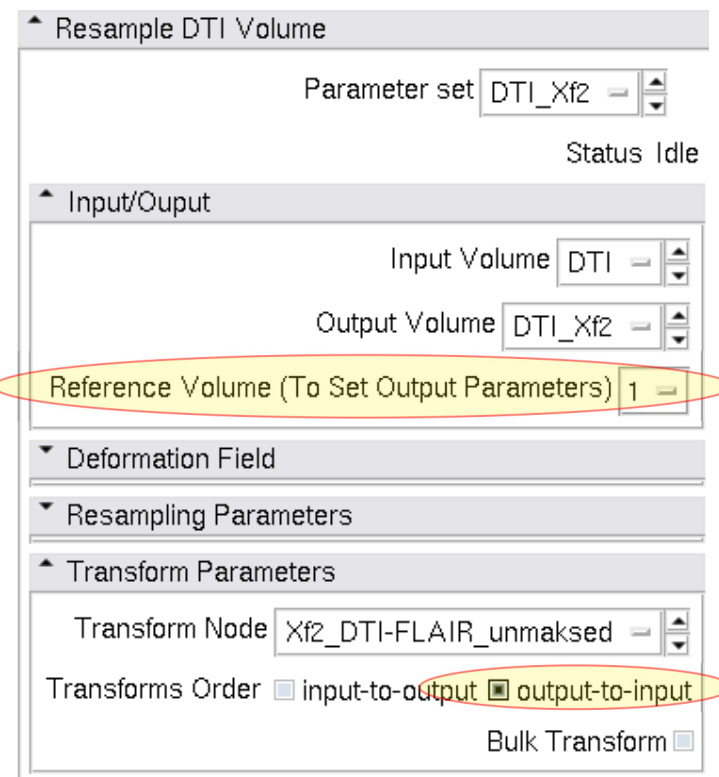


# Resample DTI

Last step is to resample the DTI with the new transform (Xf3).

This is done with the *Resample DTI Volume* Module, found in the *Diffusion / Utilities Set*

1. Input image = DTI  
Output Volume = New DTI Volume  
Reference Volume = T1
2. Transform Parameters:  
Transform Node = Xf3\_DTI-T1\_masked  
Select/check the *output-to-input* box
3. Apply





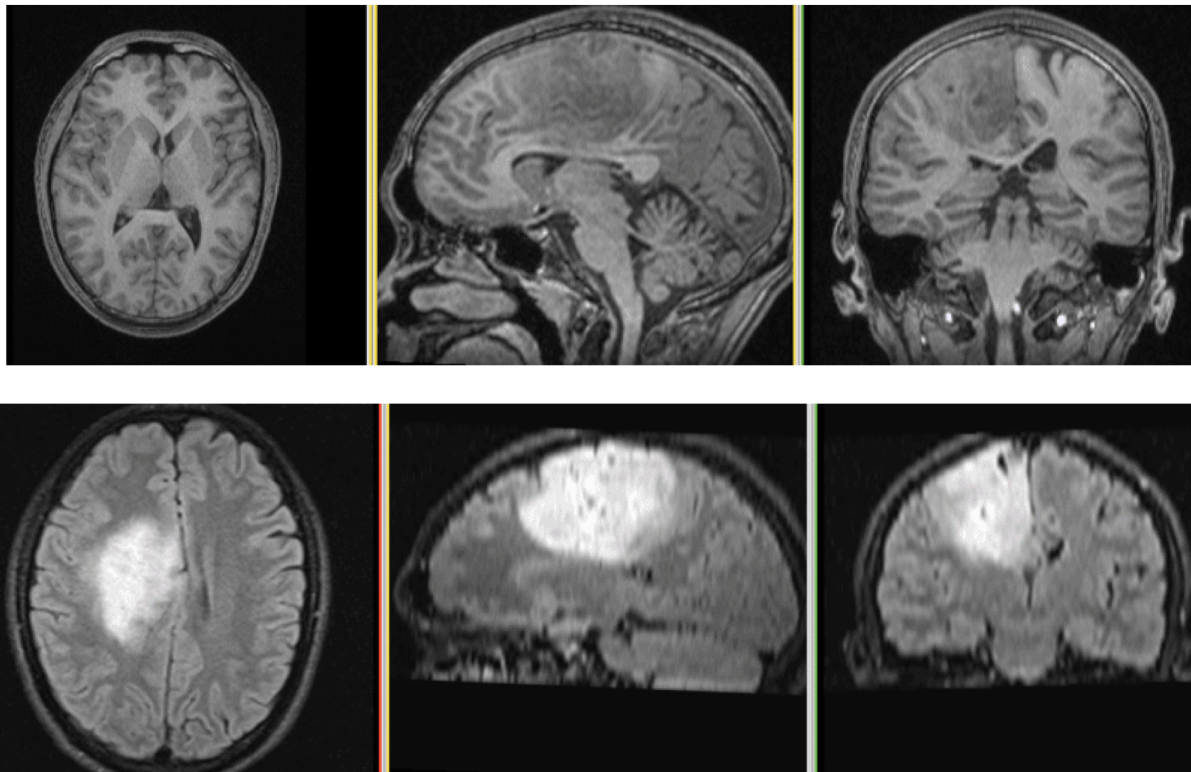
# Results

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We have now the DTI in the same orientation and resolution as the T1 reference scan.

For verification: for the resampled DTI\_Xf2 select “Color Orientation” from the Display tab in the Volumes module, then set fore- and background to the T1 and DTI\_Xf2 respectively and drag the fade slider to a halfway position.

[animated gifs, view in presentation mode](#)





# Acknowledgements

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National Alliance for Medical Image Computing  
NIH U54EB005149



Neuroimage Analysis Center  
NIH P41RR013218 -12S1 (ARRA Suppl)