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Manual for General Cortical Ribbon Editing using 3D Slicer

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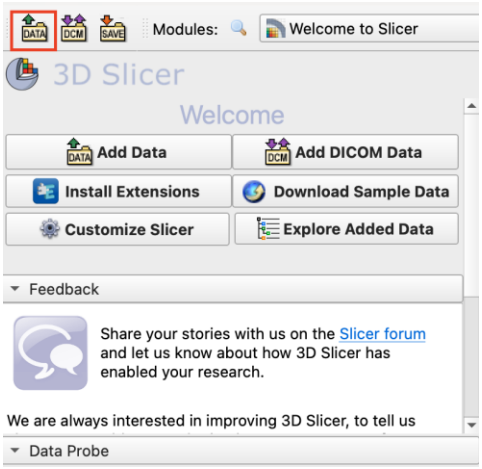
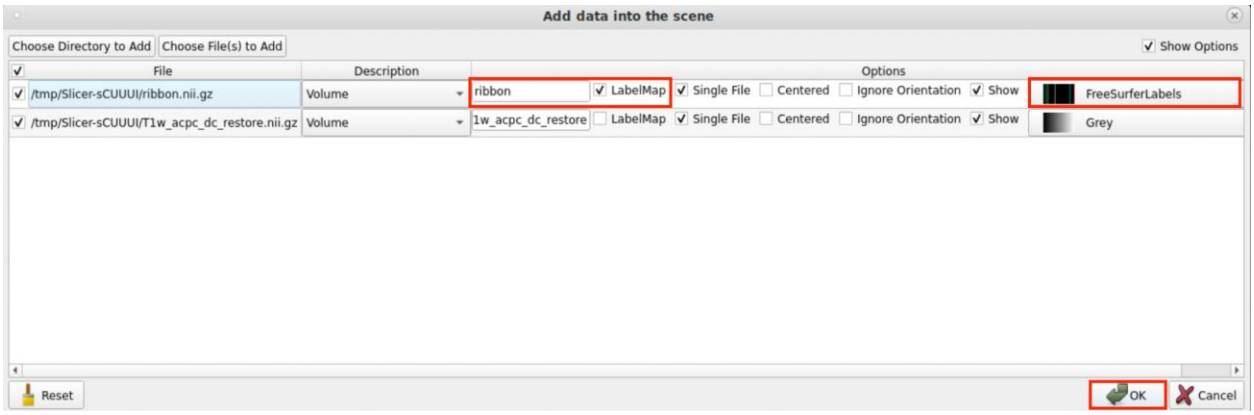
Introduction:

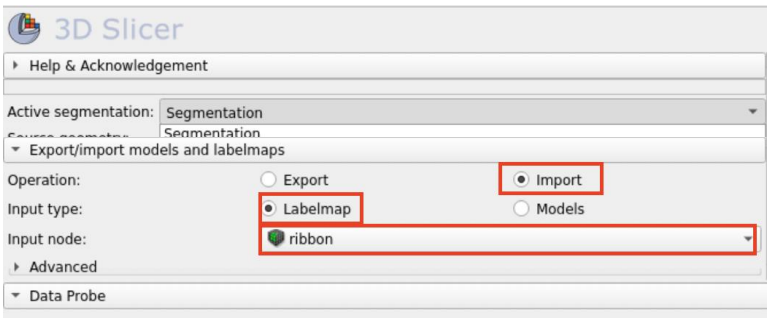
The purpose of this manual is to present procedures for editing the cortical ribbon generated by automated algorithms. These procedures use the segmentation module of the 3D slicer software program to produce a corrected volumetric ribbon.

Part 1: Loading Files Overview

After opening 3D Slicer, click on Data, and a window will open. At the top of the window, click on the **Choose File to Add** button, and in the subsequent window, select the T1-weighted MRI and Ribbon files, then click on **Show Options** in the top left corner. Select Label Map for the Ribbon file, change the colors to Free Surfer Labels, and click **OK** at the lower right corner.



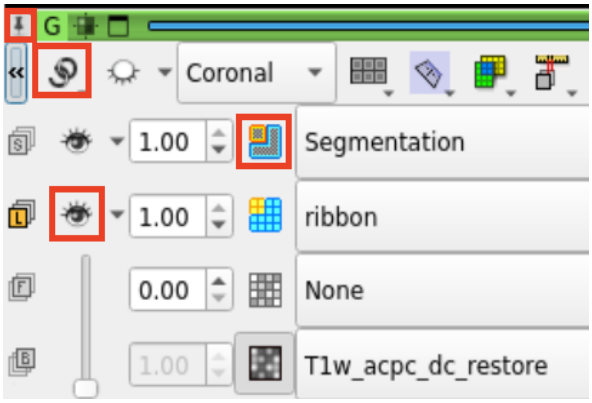


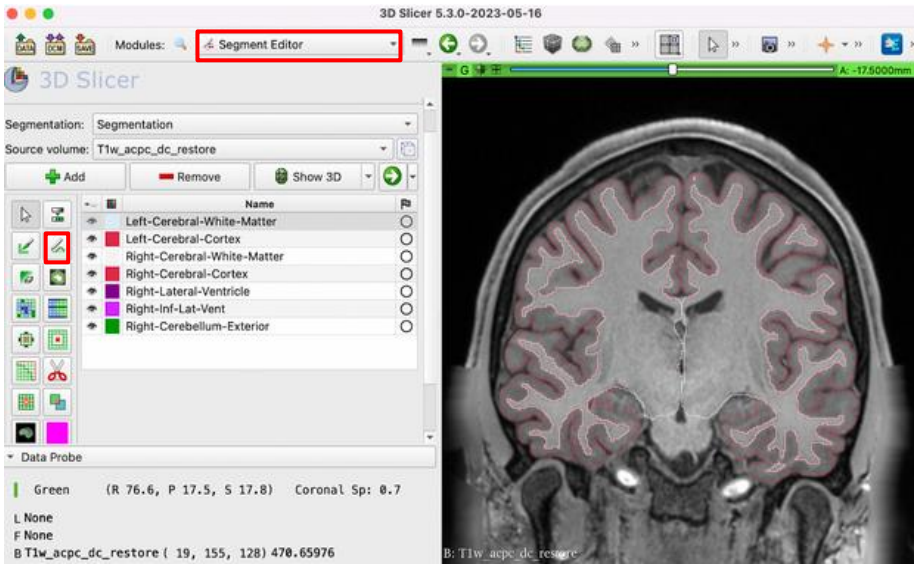


After loading the T1 and ribbon files, open the **segmentations module** and **create a new segmentation**. Scroll down to **Export and Import Models and**

Labelmaps, and **Import Ribbon Label map**.

Once you have imported the Label map, click on the pin at the top left side of any view to link them together. Then, turn off the ribbon by clicking on the eyeball and turn off the slice fill for the segmentation.

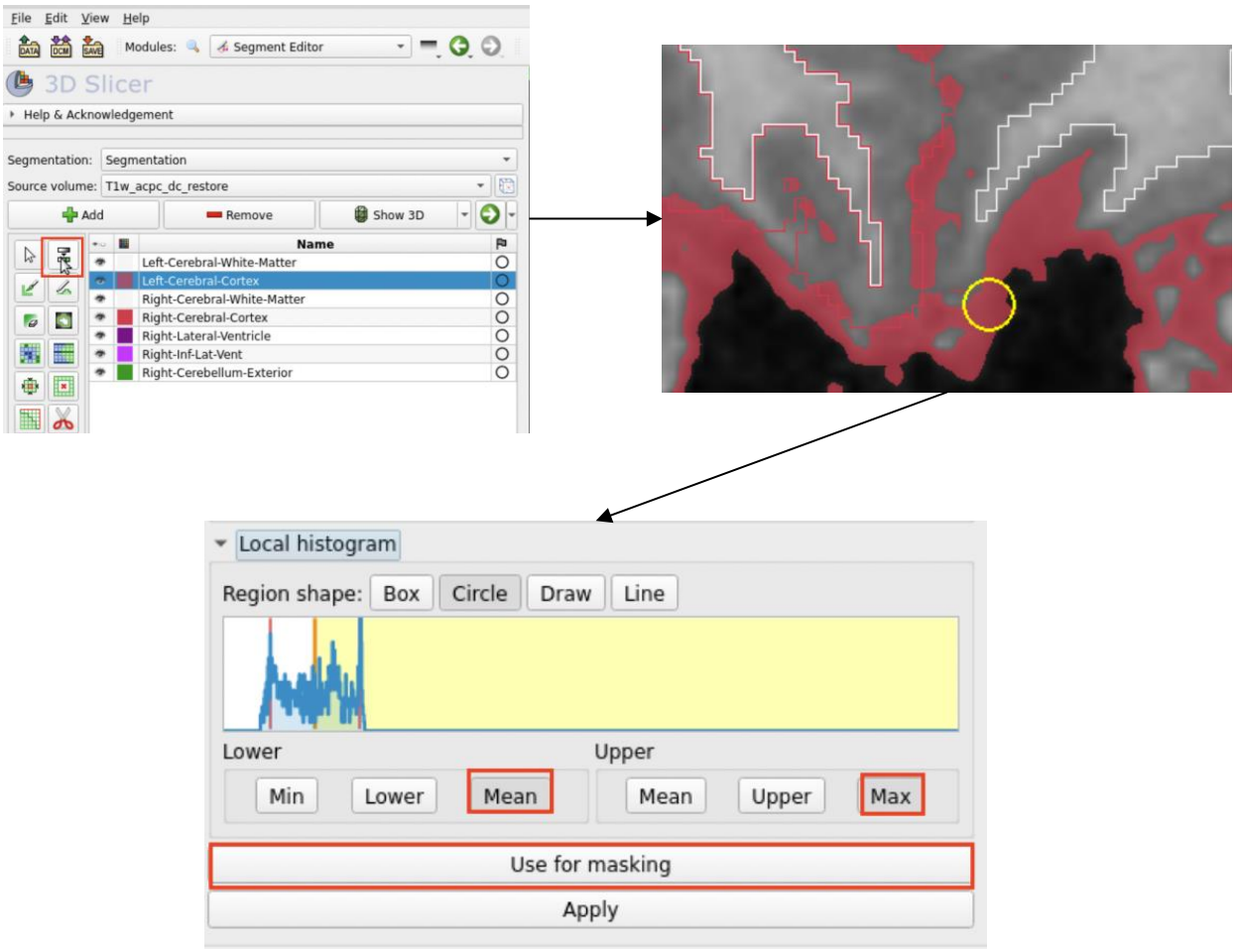




To edit the cortical segmentation, open the **segment editor** module and double-click on the coronal view. Then, select the segment that requires editing and click on the **drawing tool.**

Note: Using the Threshold Tool

When correcting the cortical segmentation, the threshold tool can be helpful in accurately delineating borders. Click on the segment you want to edit, then click the threshold icon, and a flickering image will appear. Click on the arrowhead to the left of ***local histogram*** and, using a coronal slice, click on the border of interest. Drag the mouse until you can see two distinct peaks on the histogram, then click on one and drag the mouse until you reach the other. Change the Lower bound button under the window to ***mean*** and the Upper bound to ***max***, then click on ***use for masking***. The threshold range is now applied to the segmentation tools.


File Edit View Help
Modules: Segment Editor
3D Slicer
Help & Acknowledgement
Segmentation: Segmentation
Source volume: T1w_acpc_dc_restore
Add
Remove
Show 3D
Name
Left-Cerebral-White-Matter
Left-Cerebral-Cortex
Right-Cerebral-White-Matter
Right-Cerebral-Cortex
Right-Lateral-Ventricle
Right-Inf-Lat-Vent
Right-Cerebellum-Exterior
Local histogram
Region shape: Box Circle Draw Line
Lower
Upper
Min Lower Mean Mean Upper Max
Use for masking
Apply

Section 2: General Procedure

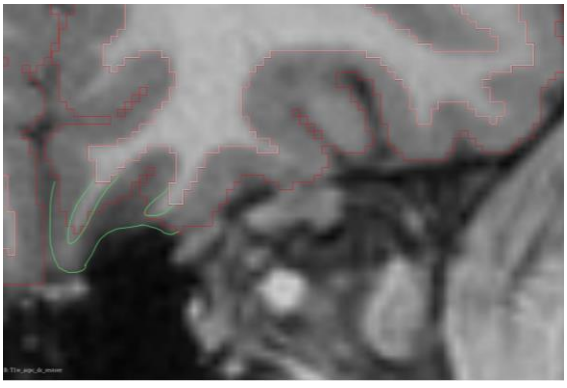
To ensure thorough and accurate correction of cortical ribbons, it is essential to follow a systematic and organized procedure. This approach minimizes the risk of overlooking crucial edits. Begin by selecting one hemisphere and hide the other to streamline your focus. Start editing from the most anterior slide and move towards the posterior end, concurrently addressing white and grey matter errors. Initially, focus on the common regions requiring correction, then conduct a secondary review to identify any remaining errors. Once you have completed the edits to your satisfaction, utilize the 3D view feature to inspect the model from various angles, paying particular attention to any instances of white matter protrusion. Repeat these steps for the opposite hemisphere.

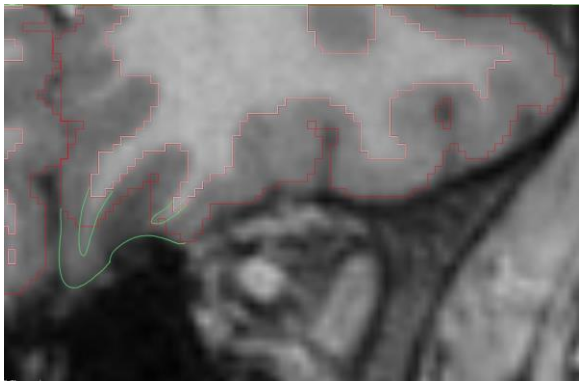
Section 3: Common issues

The section below details common regions that require correction. These are not the only issues; every brain should be carefully evaluated. Many errors arise from the MRI signal strength being reduced in specific places, thereby omitting a gray matter area or ascribing gray matter of the cerebral cortex to a subcortical area or meninges. The threshold tool allows for local adjustments and should be used to correct to the extent possible. In the below figures, the green line represents the intended correction.

1. The Gyrus Rectus and the Medial Orbital Gyri

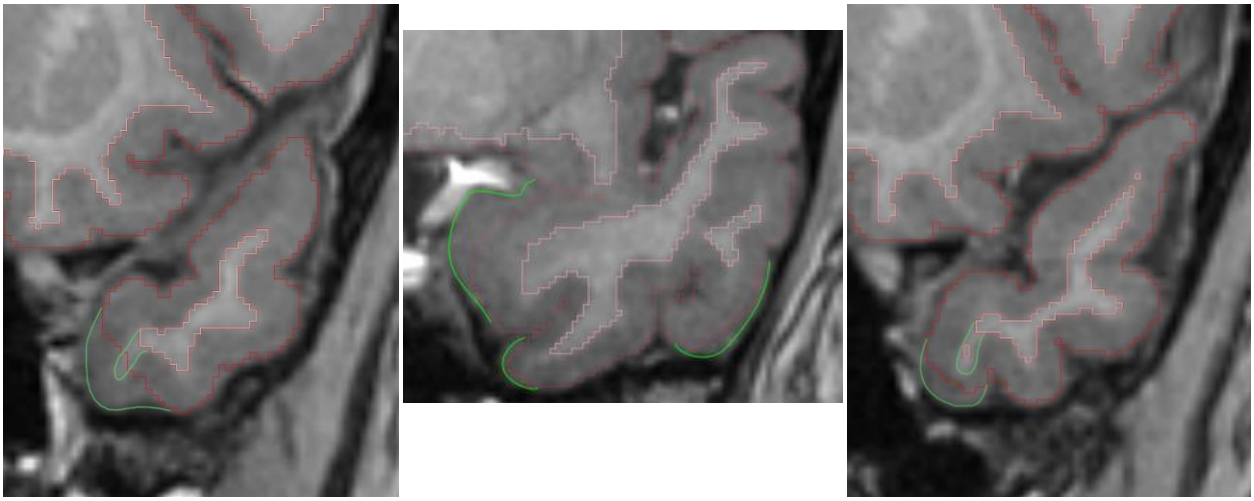
The gyrus rectus is located at the medial-most margin of the inferior surface of the frontal lobe. This gyrus and the most medial orbital gyri commonly contain missing gray and white matter due to a signal drop.





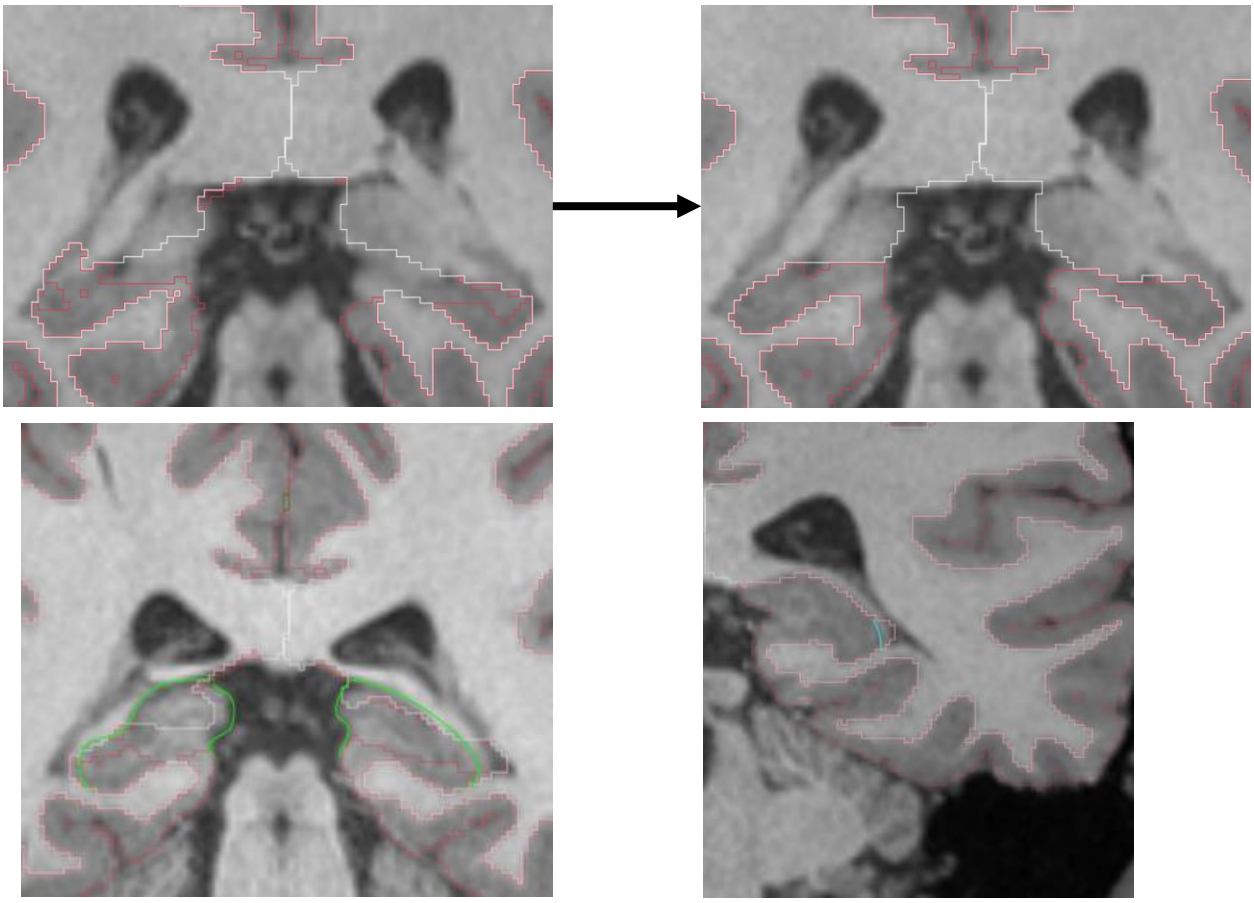
2. Temporal Pole

The temporal pole refers to the most anterior end of the temporal lobe. This region frequently contains errors in which the gray and white matter are not labeled.



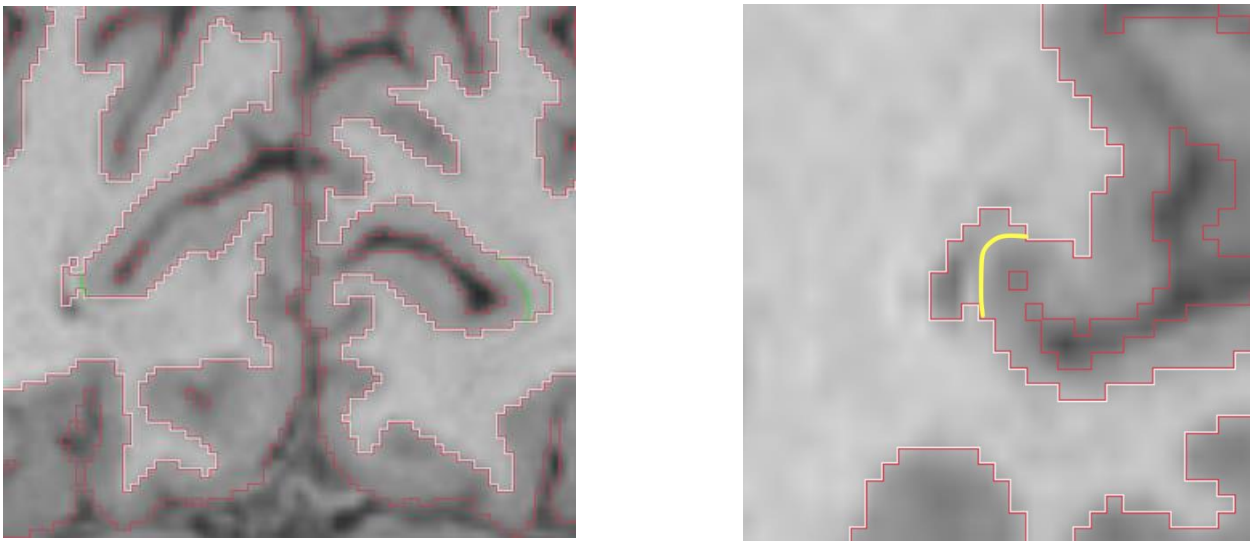
3. Hippocampus

The hippocampus is located medially in the temporal lobe. This region is partially excluded by the FreeSurfer algorithm, thus requiring further editing. Extend the gray matter to encompass the hippocampus and exclude any gray matter extending into the lateral ventricles.



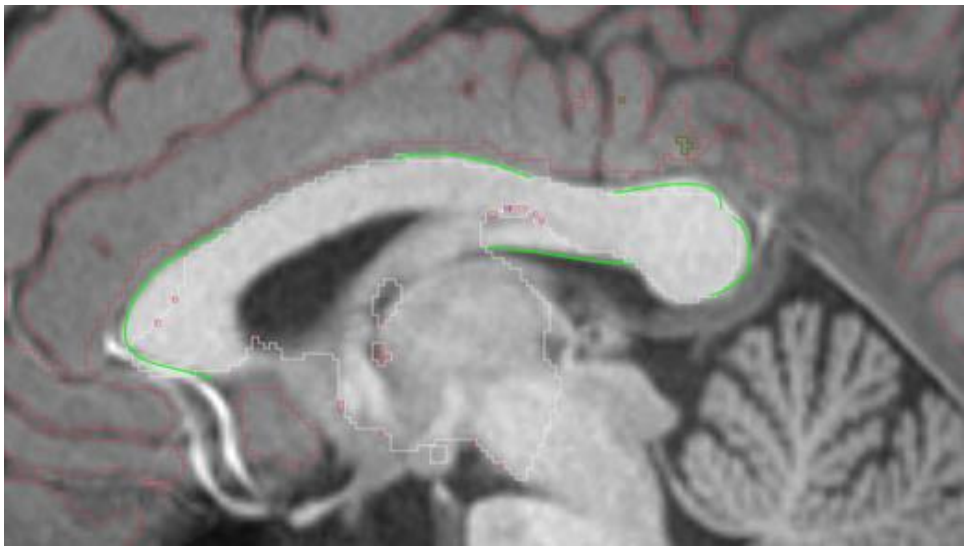
4. Posterior Horn of the Lateral Ventricles

The lateral ventricles change shape from anterior to posterior. The posterior portion of the lateral ventricle, also called the occipital horn, extends into the occipital lobe. Here, the gray matter ribbon of the calcarine fissure often extends through the thin intervening white matter into the posterior horn.



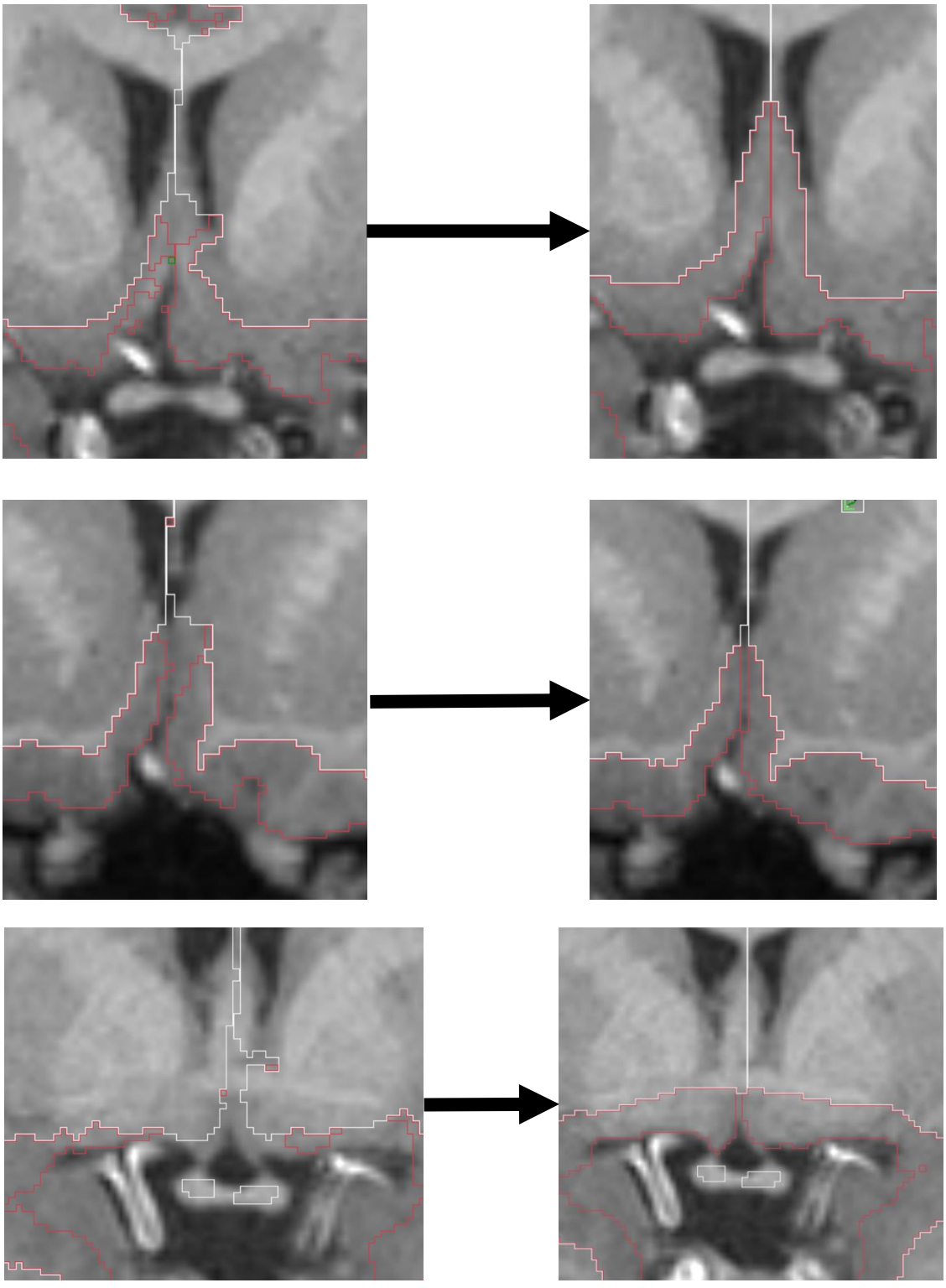
5. Corpus Callosum

The corpus callosum is a large C-shaped nerve fiber bundle beneath the cerebral cortex. It is best appreciated in the sagittal view and commonly requires extension of white matter.



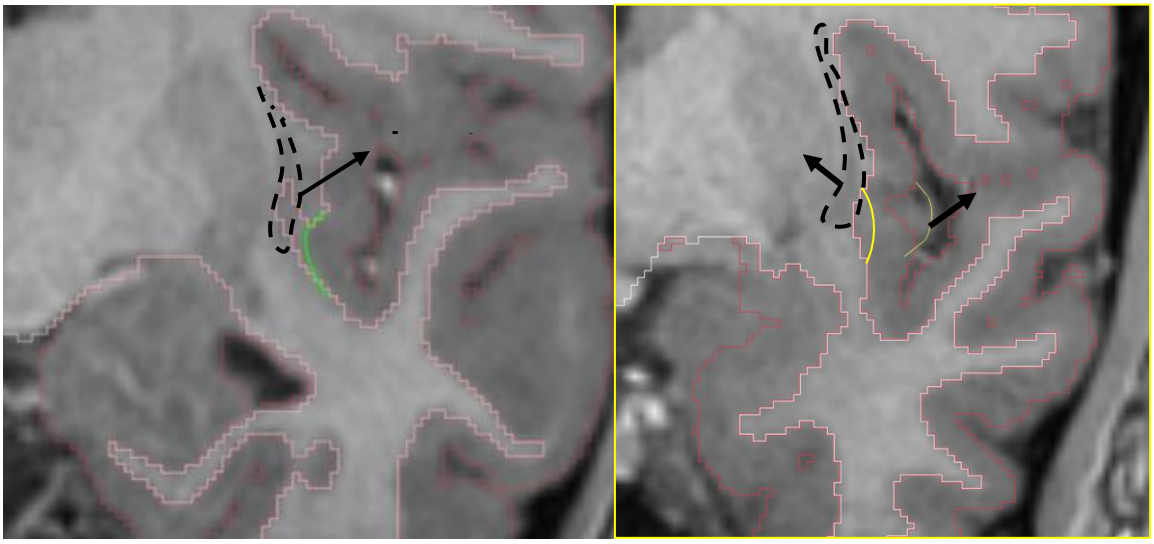
6. Septal Area

The septal area is located on the lower posterior part of the medial surface of the frontal lobe. Extend the white matter superiorly to include the thin strip, and make sure the border is with the dark lateral ventricle. Do not extend where there is no gray matter. Only do so in coronal sections anterior to the anterior commissure. Once the anterior commissure is visible, extend the grey matter to fully encompass the region below it, as shown in the third panel.



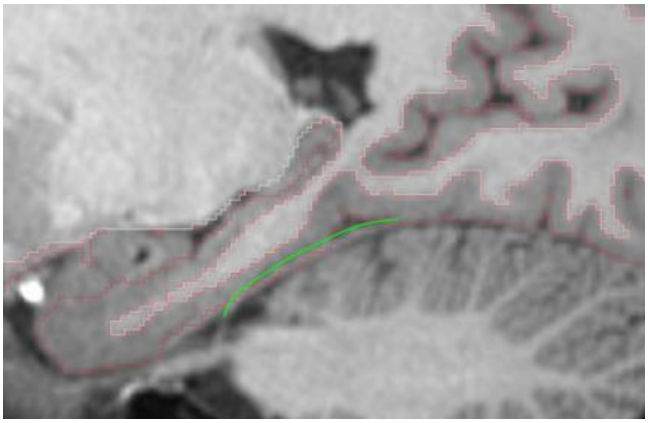
7. Claustrum/Insula

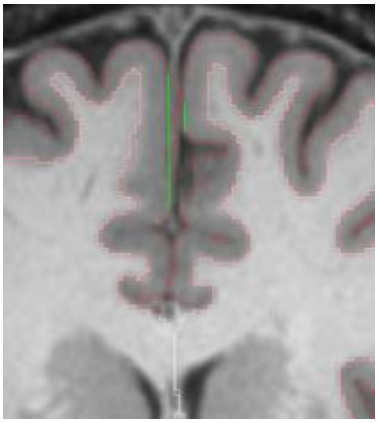
The claustrum is a thin sheet of gray matter between the insula and the external capsule. Given its thin composition, this region tends to be delineated as a cerebral cortex gray matter. The white matter subjacent to the insula may also be included as gray matter, requiring corrections.



8. Dura

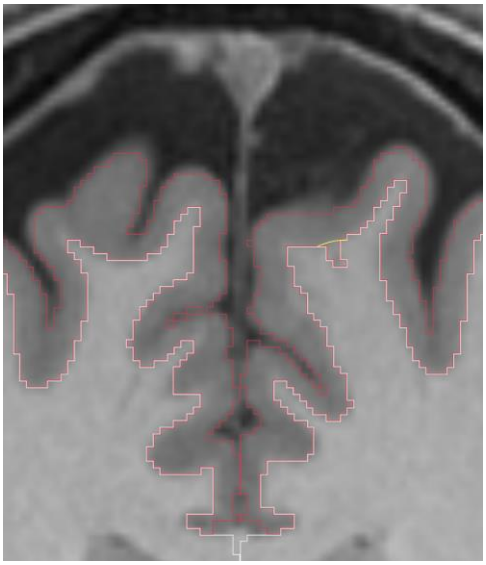
The dura mater is the outermost membrane enveloping the brain and spinal cord. Occasionally, the cerebral ribbon includes the dura, requiring corrections.

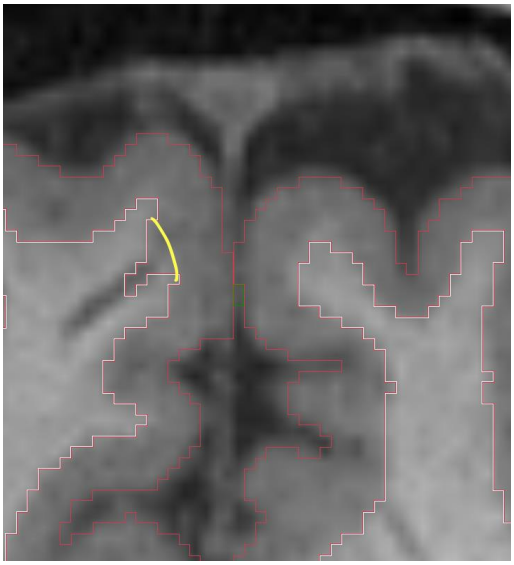




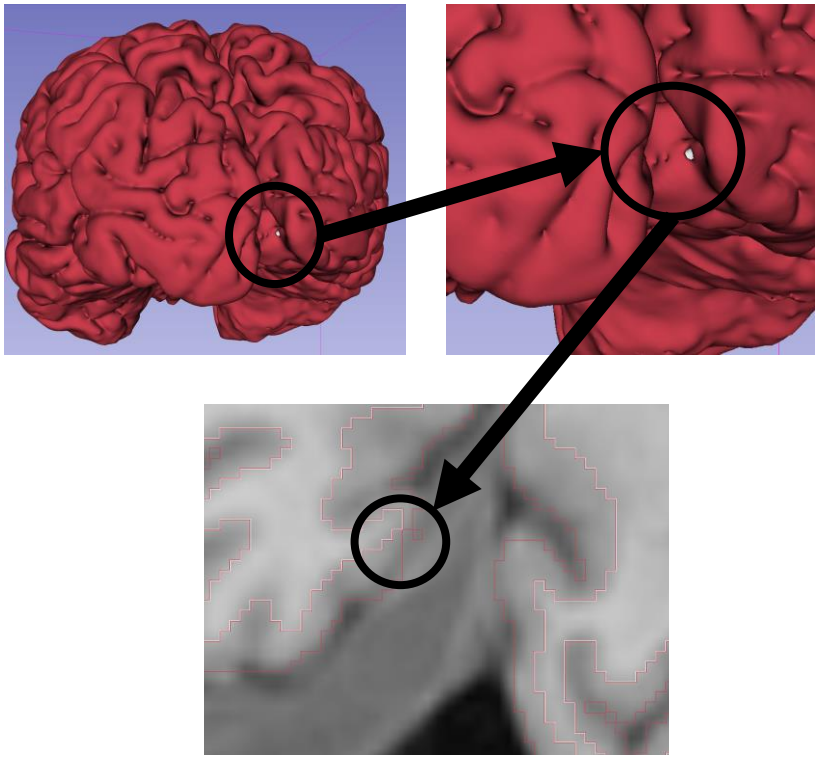
9. Vessels

The brain contains a rich vessel network; occasionally, the blood vessels display a strong signal decrease and are incorporated into the ribbon because the algorithm misidentifies the blood vessel lumen as a sulcus.





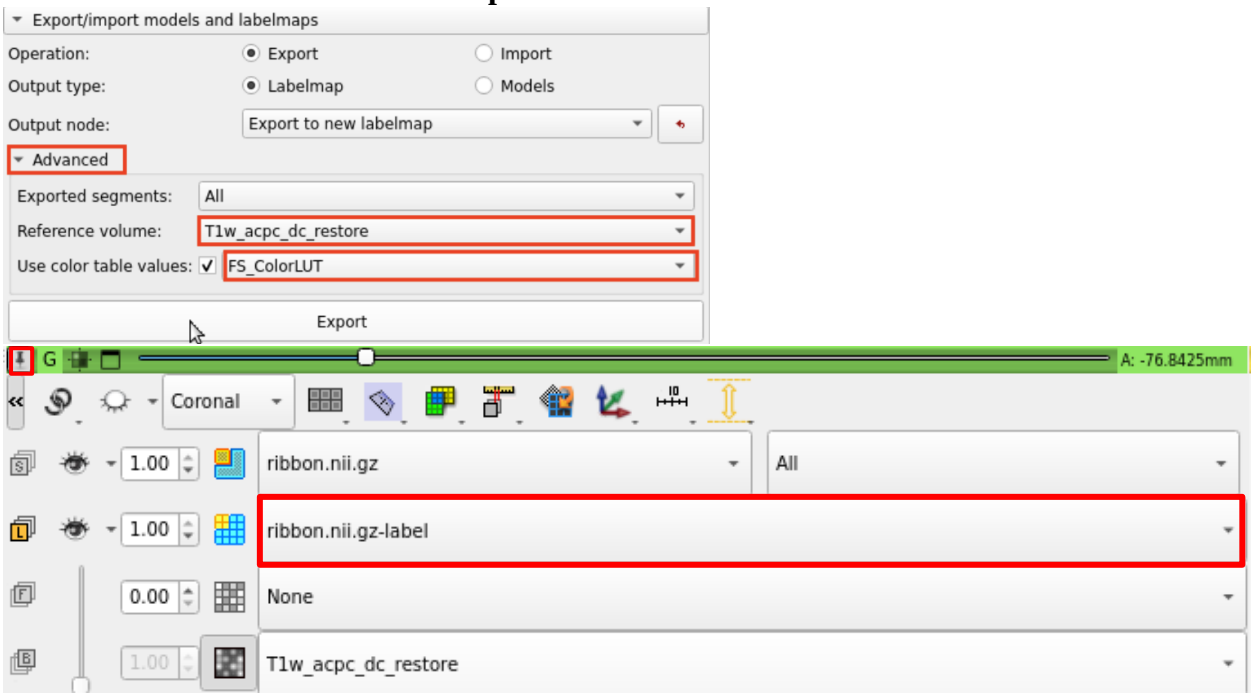
10. White Matter extensions through the cerebral exterior segmentation



The white matter should not reach the medial surface. Look through the 3D model by clicking on **show 3D** under the segment editor, click on the **crosshair tool,** press shift, and hover over the areas where the white matter is poking through to make corrections on the coronal view. Be sure to examine the medial aspect of each hemisphere by hiding and rotating the opposite hemispheric structures. There should be no regions where the white matter is visible through the gray matter.

Section 3: Exporting Segmentation as a Label Map

Once the ribbon editing is complete, click on the **segmentations** module and scroll down to **export/import models and label maps.** Click on export as a new label map, and under the advanced settings, select the T1 as the reference volume and freesurfer for the color table values. Once you export, double-check that the label map has the correct labels, which should be 2,3,41 and 42. To do so, click on the pin on the top left corner of any of the views, then click on the L box and select **segment-label** from the drop-down options. Then, hover over the cortex and check the information under the **data probe.**



Click the save menu and select the exported label map. Change the name to XXXXX_ribbon-Edit.nii.gz, where XXXXX is the case name.