

# **Manual Segmentation of Sinus CT-Scans using Slicer 3D**

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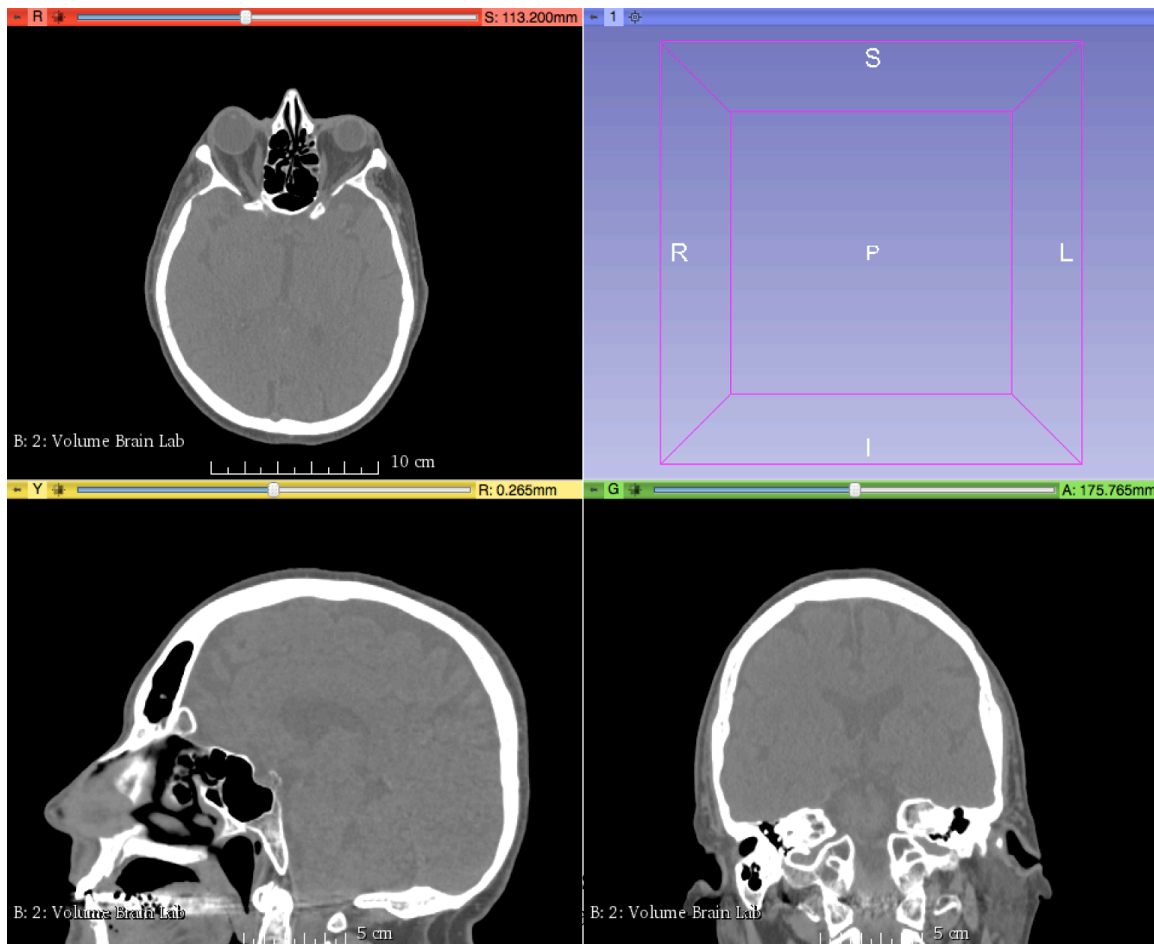
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## Introduction

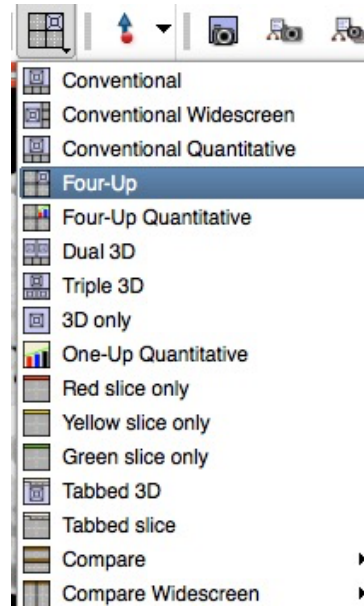
This tutorial describes the process of manually segmenting the skull and sinus cavities of a CT-DICOM scan in the open-source software Slicer 3D. Through a manual segmentation of a scan, Slicer 3D is then able to render a 3-D representation of the “map” you have created and can also calculate the volume of the specific structures. You can then utilize this information to compare the size of sinus cavities of various scans or calculate specific opacification percentages.

## Segmenting the Skull

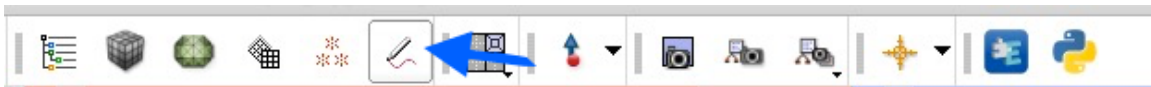
1. After you have imported the patient you would like, you should see three different views (axial, sagittal, coronal) of the CT scan. You can adjust the contrast by clicking and dragging to the right and left. Brightness can be adjusted by clicking and dragging up and down.



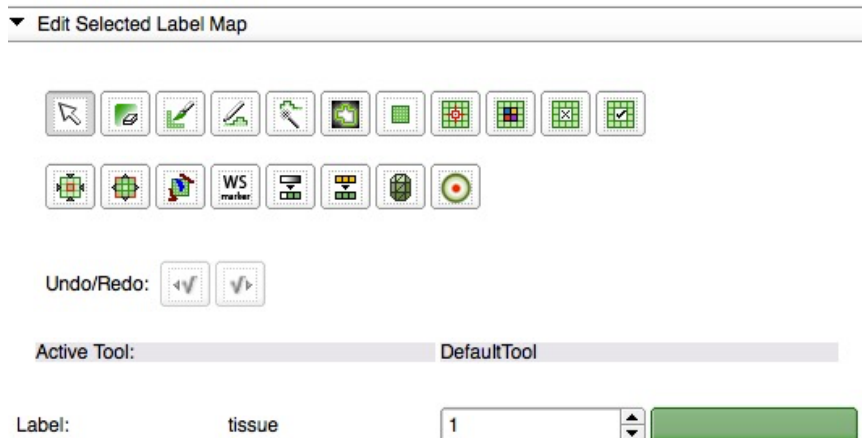
- The “Four-Up” view is the easiest to visualize all three views of the scan and the view can be changed through the toolbar on the top, as seen in the picture below:



- To begin segmenting the skull, click on the editor in the toolbar



- You will then be prompted to select a set of colors for the label map you are creating. Select “Generic Anatomy Colors” and click apply.
- You should then see a series of tools as seen below:




6. Click on the Label colors and change it the yellow color denoted, “bone”

Number	Color	Name
0	Black	background
1	Green	tissue
2	Yellow	bone
3	Brown	skin
4	Blue	connective tissue
5	Red	blood
6	Orange	organ
7	Light Green	mass
8	Dark Brown	muscle
9	Bright Yellow	foreign object
10	Dark Brown	waste
11	Light Yellow	teeth
12	Yellow	fat
13	Light Purple	gray matter
14	Light Yellow	white matter

7. To segment the skull, we will use what is called the threshold tool, and it is located as seen below:

▼ Edit Selected Label Map

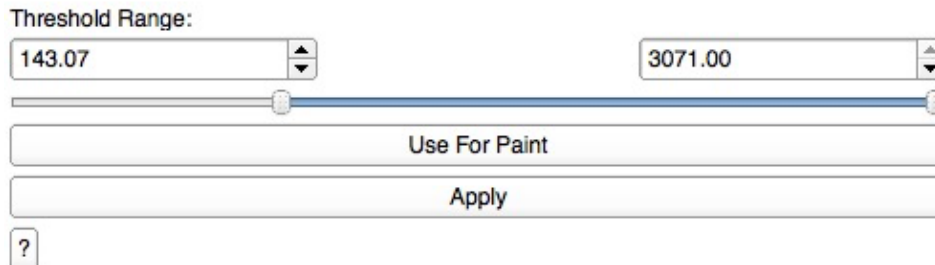


Undo/Redo: [Undo] [Redo]

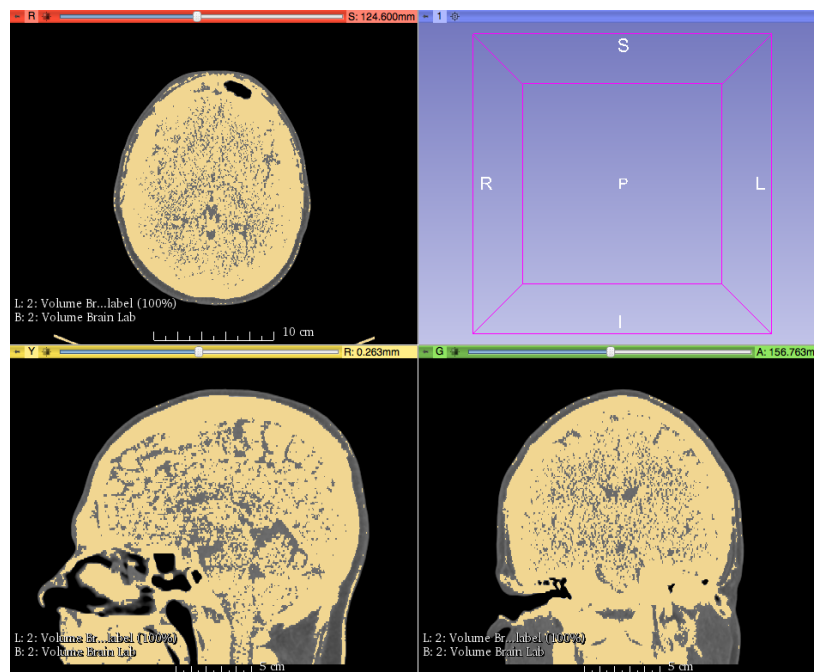
Active Tool: [Threshold] DefaultTool

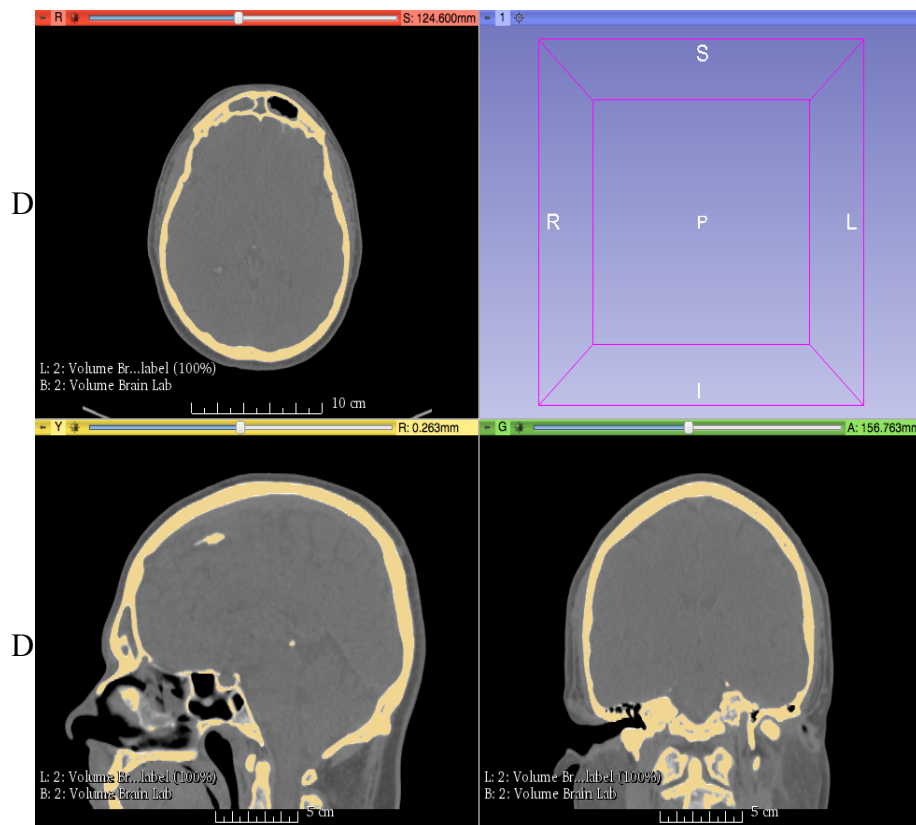
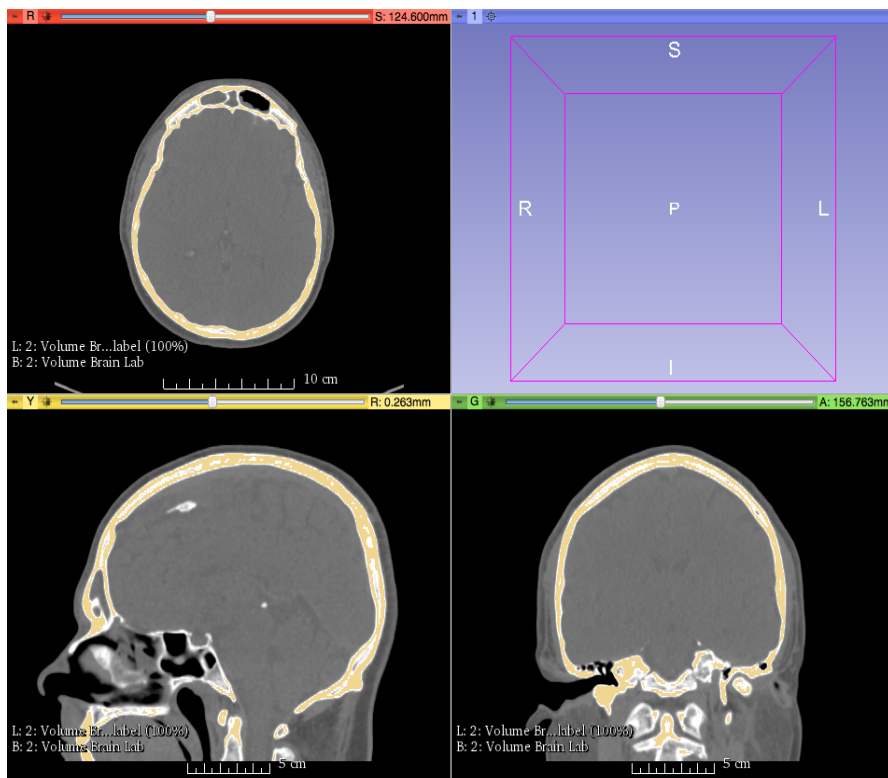
Label: tissue [1] [Color swatch]

- Once you click on this, you will begin to see flashing yellow appear in the 3 different CT views. Adjust the threshold range bar to apply different densities to of color to the scans. Once you feel that you have covered most of the skull, click apply.

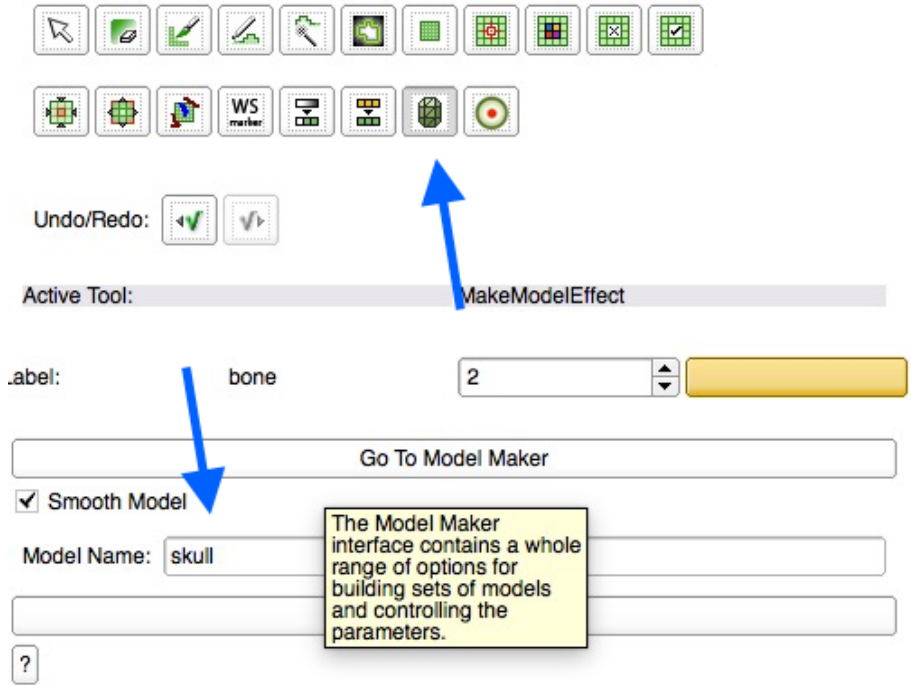


- Below are three different examples of different densities. The first one has too much as it begins to include soft tissue, the second one is too little as it does not include all of the bone, and third one is just right.

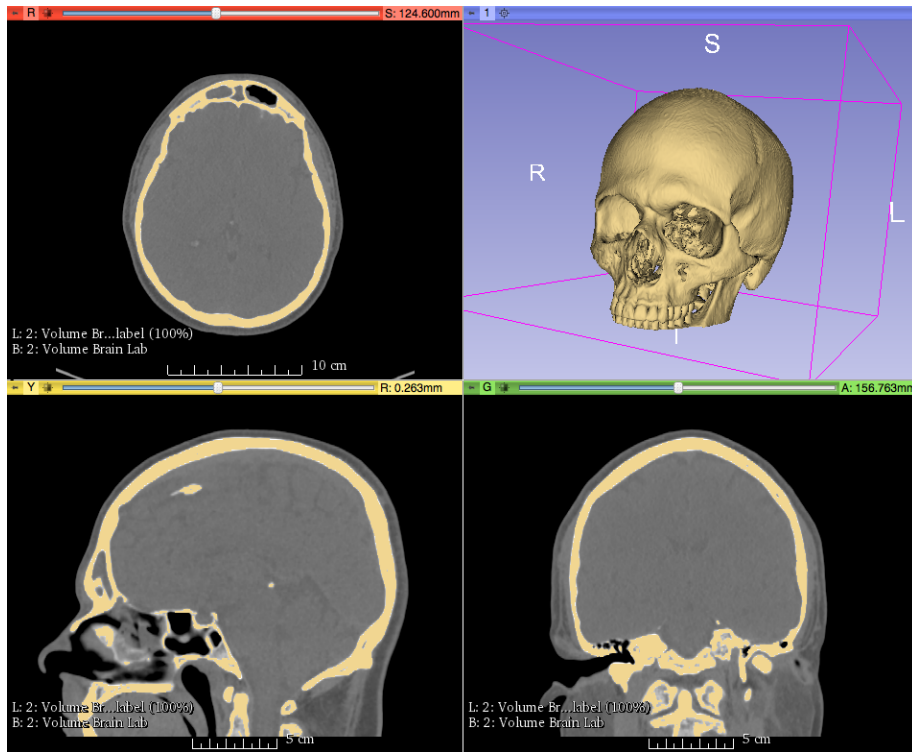




10. After you have completed the threshold, select the model tool as seen below and change the label name from “bone” to “skull”. Then select apply



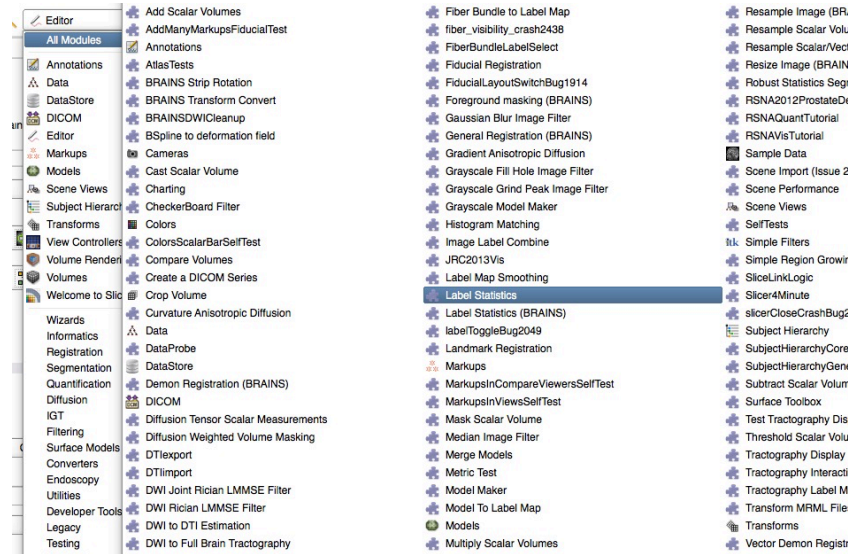
11. A model of the skull should soon appear in the fourth window at the upper right. This may take a few moments and you may have to click the “center” button.





## Calculating the Skull Volume

1. Once the skull is segmented, finding the volume can be done very easily. Click the modules tab on the home toolbar, then select all modules and find label statistics.



2. Change the grayscale volume to the name of the CT scan and change the label map to the same name with “label” added at the end. Then click apply. You will then see calculations as below.

Grayscale Volume: 2: Brain Lab Sinus Sinus Vol

Label Map: 2: Brain Lab Sinus Sinus Vol-label

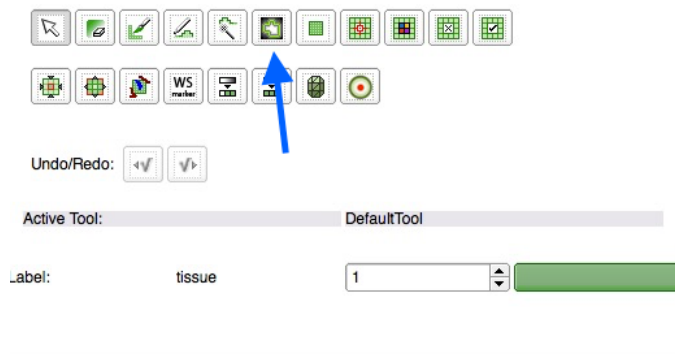
Apply

	Index	Count	Volume mm <sup>3</sup>	Volume cc	Min
■	0	4.49931e...	1.19623e+07	11962.3	-1024
■	2	2.45492e...	652687	652.687	81

3. The program has calculated the volume of the skull based on the yellow label map that was originally made of the skull. In this case, the volume of the skull is 652.687 cc or mm<sup>3</sup>. Copy the data into an excel workbook.

## Segmenting the Sinus Cavities

1. There are four different pairs of sinuses that we will be segmenting, the frontal, ethmoid, maxillary, and sphenoid.
2. Segmenting the sinuses is similar to segmenting the skull, however we will be using the segment tool rather than the threshold tool. This tool creates an outline for an area that you would like to fill in. Return to the editor to find this tool. You may still see the label map of the skull or you may not. The segment tool is pictured below.



3. Depending on the scan you are segmenting, there may be disease within the sinuses, which will appear as a gray space within the sinuses. If you are interested in finding the % opacification, or the precise amount of disease, it will be discussed after this section. The first step however, is to segment all of the sinus cavities.

### Frontal Sinus

1. The frontal sinuses are on the forehead and are typically found at the beginning of the CT scans. If you look at the coronal slices and begin as pictured below:



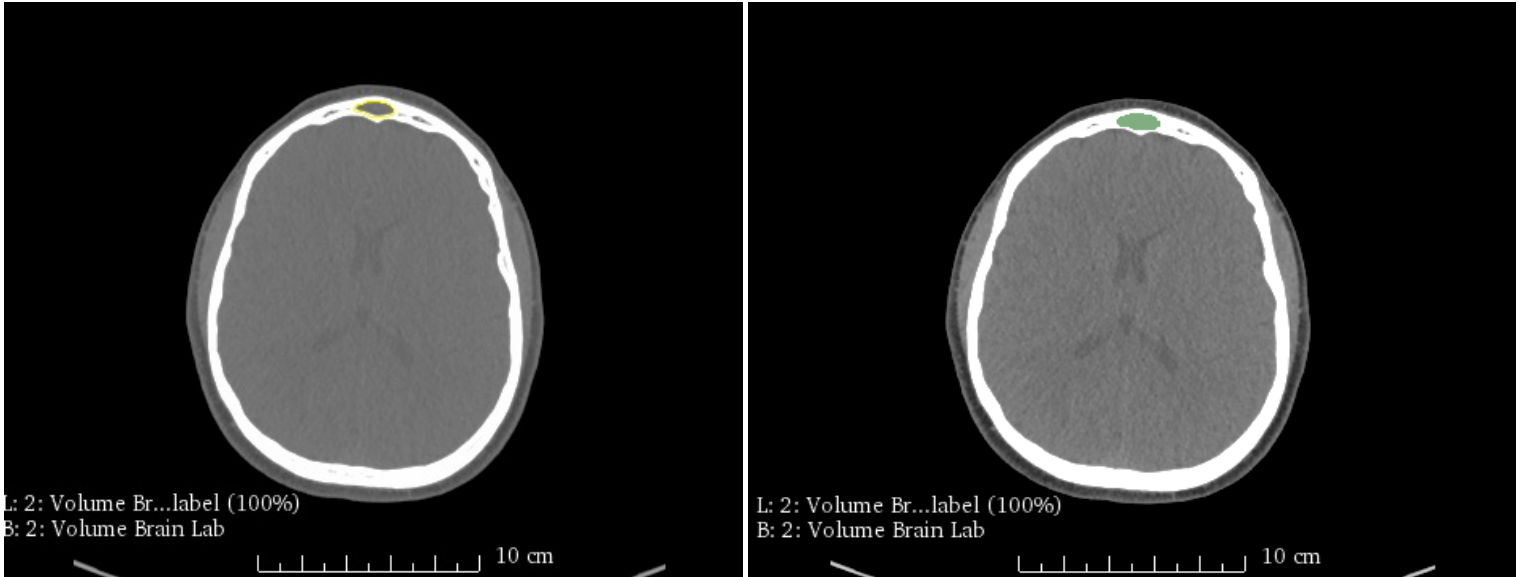
2. As you begin to scroll left, with your arrow key, you will come across a small opening. This is the beginning of the frontal sinus. It may either be black or gray depending on if there is disease or not.



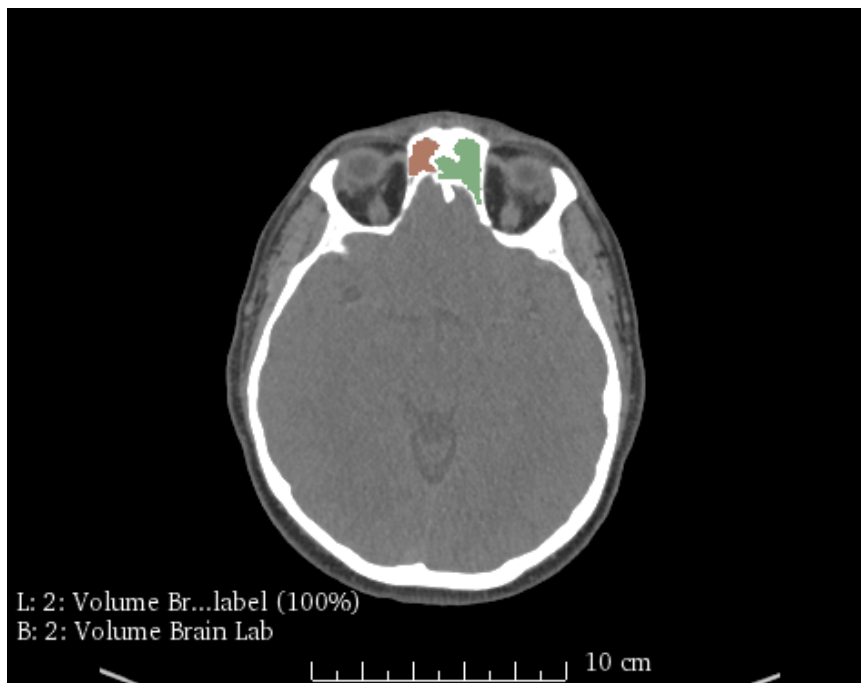
3. As you continue to scroll, the frontal sinus becomes larger and ends when they begin to reach the midline of the eye.



- To begin segmenting the frontal sinus, choose whichever color you would like and select the segmentation tool. Return to where the frontal sinus begins, and outline the area with tool and click on it. The area should have filled with the color you have chosen.



- Continue to segment until you reach the end of the frontal sinus. If you would like to delineate between the right and left frontal sinus then you can use two different colors as shown below.



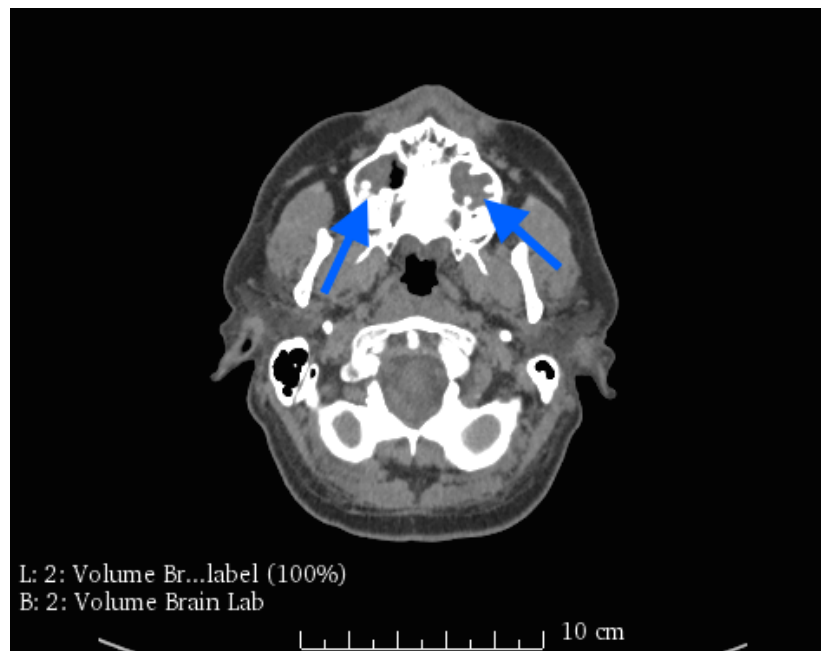
6. There may be times when the segmentation tool is unable to cover the entire area that you would like. If this occurs, you can use the pain tool for finer touch up of the area as shown below.



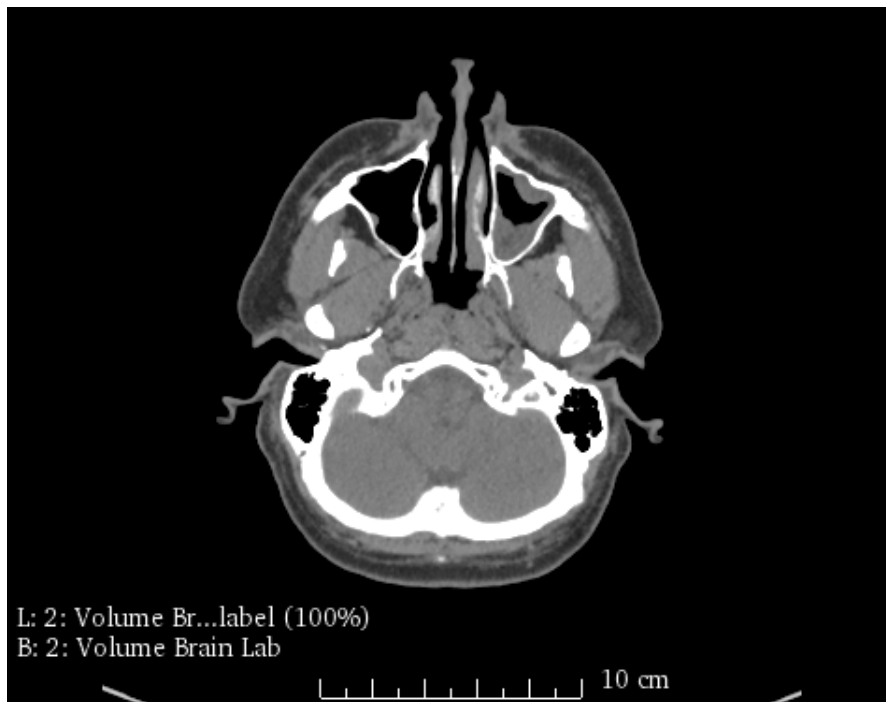
7. You can then create a 3D model of the frontal sinus; similar to the way this was done with the skull.

## Maxillary Sinus

1. The maxillary sinuses are the cheek sinuses and are generally the easiest to notice. They begin on the opposite spectrum of the frontal sinus, near the teeth. You will first notice them as holes appearing within the teeth as seen below.



2. As you continue to scroll to the right, you will see them enlarge.



3. They typically end near the junction of the ethmoid and sphenoid sinuses.



4. Begin segmenting the maxillary sinus similar to the way the frontal sinus was segmented, however use a different label color. Make sure to segment the entire sinus cavity including any disease present. Once again, if you would like to

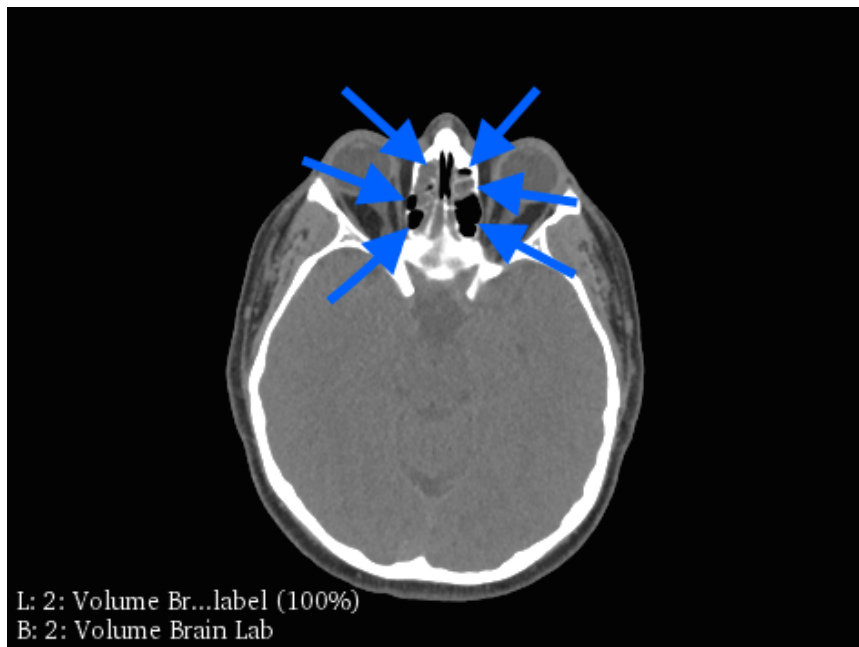
delineate between the right and left maxillary sinuses, you will need to use two different label colors.



5. You can then also create a 3-D model of the maxillary sinuses.

### Ethmoid Sinus

1. The ethmoid sinuses are between the eyes. They typically begin, where the frontal sinus ends. The ethmoid is delineated by multiple cells or cavities within the sinus itself as shown below.



2. As you continue to scroll to the left, the cells increase number. The two large cavities at the bottom are the sphenoid sinuses so ensure that you do not segment those cavities along with the ethmoid sinus.

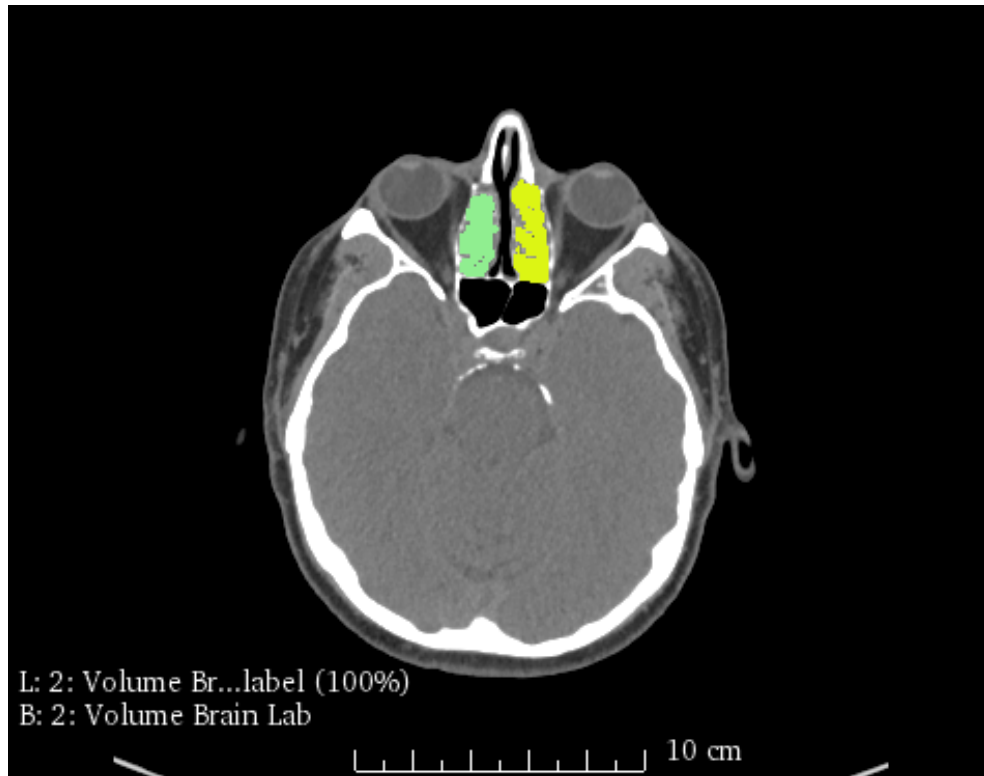


3. The ethmoid sinus ends as you continue to scroll to the left and the cells begin to decrease in size and number and the maxillary sinus begins to reappear.





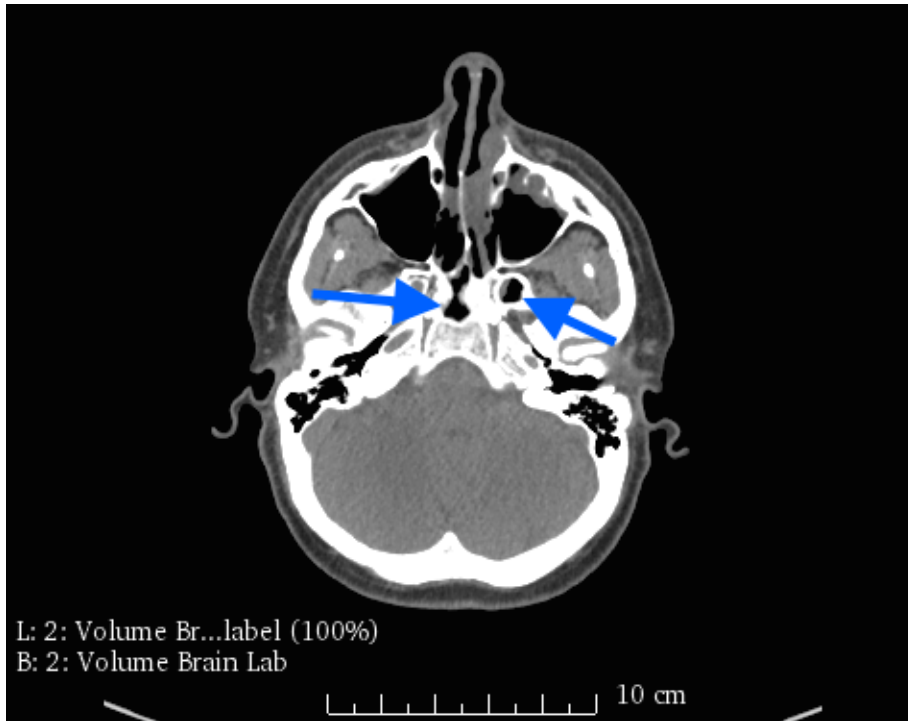
4. Begin segmenting the ethmoid sinus using the segmentation tool, similar to the previous sinuses, however use a different label color. Make sure to segment the entire sinus, including any disease that is present. Once again, if you would like to delineate between the right and left sides, you will need to use two different label colors.



5. Due to the number of cells within the ethmoid sinus, it is the most difficult to segment. You will likely often have to switch between the segmentation tool and the paint tool.
6. You can then create a 3-D model of the ethmoid sinus.

## Sphenoid Sinus

1. The sphenoid sinuses are located posterior to the rest of the sinuses. It is easiest to visualize them appearing under the large maxillary sinuses.



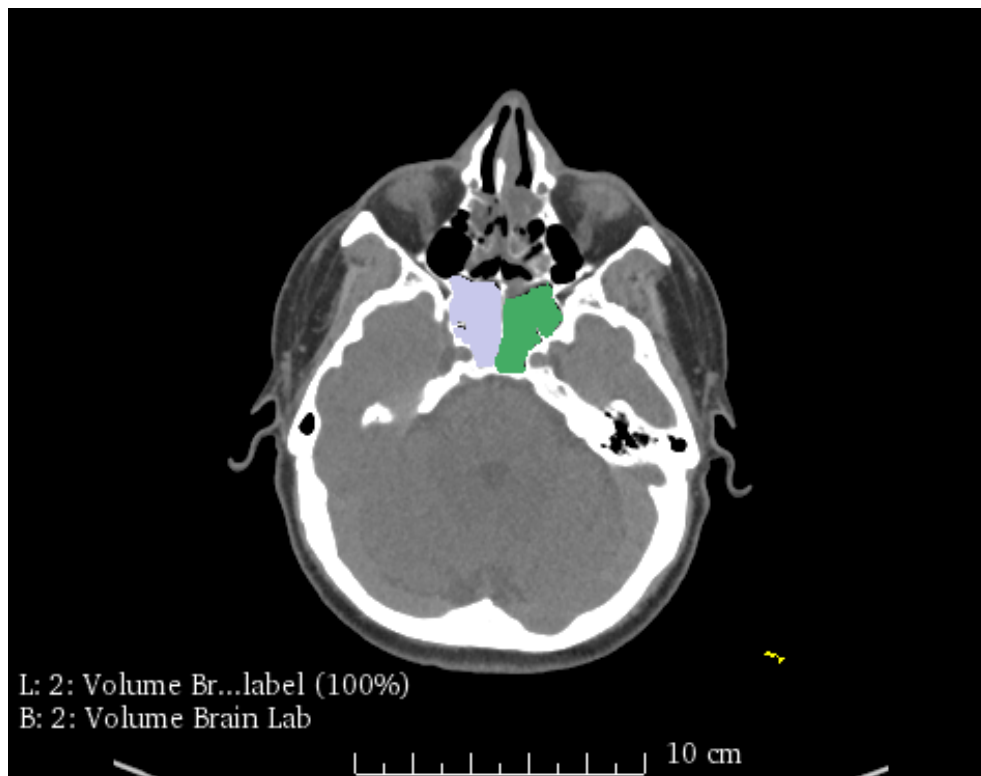
2. They continue to enlarge as you scroll right.



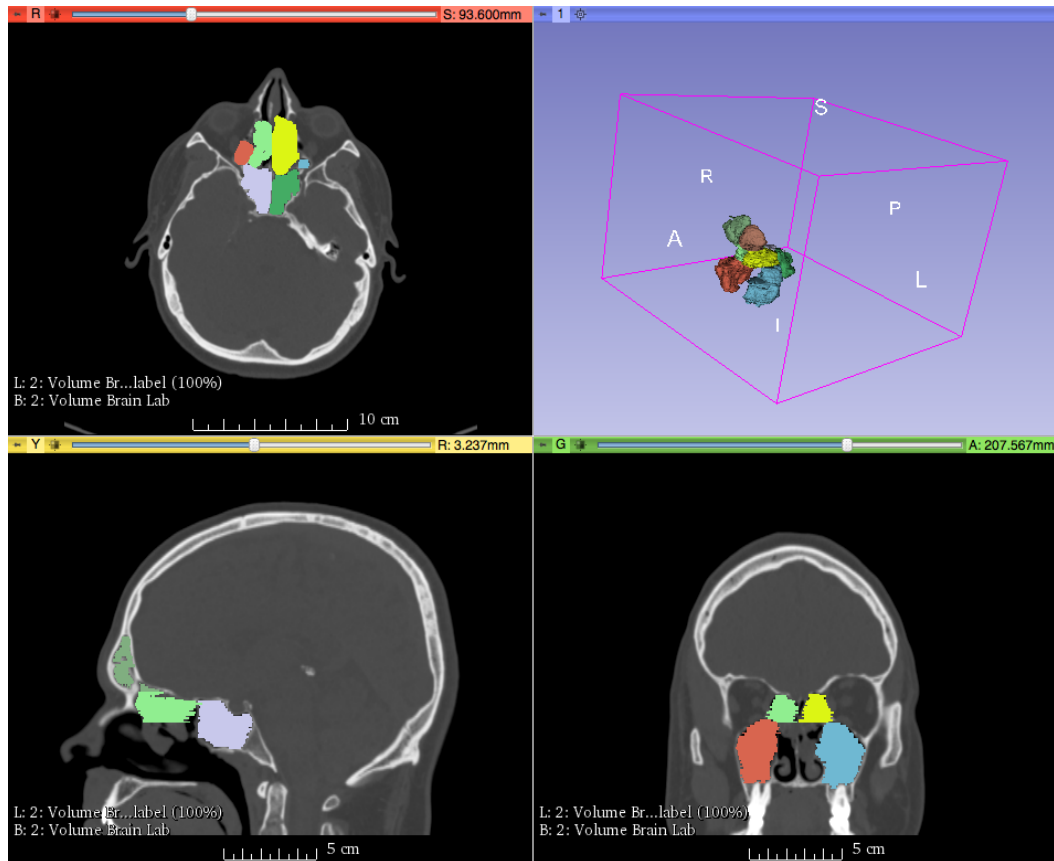
3. The sphenoid sinus typically ends in the middle of the ethmoid sinus as you continue to scroll right.



4. Use the segmentation tool to segment the sphenoid sinus, however use a different label color from the previous sinuses. Make sure to segment the entire sinus cavity, including any disease that is present. Once again, if you would like to delineate between the right and left sides, use two different label colors.

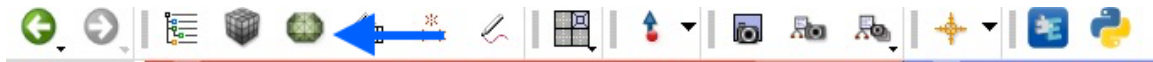


5. You can then also create a 3-D model of the sphenoid sinus
6. Once you have completed labeling all of the sinuses, you will end up with a label map as shown below. It is also important to note that three views are depicting the same slice. It may be easier to segment a certain sinus on either the sagittal or axial view, depending on your preference.



## Calculating Sinus Volume

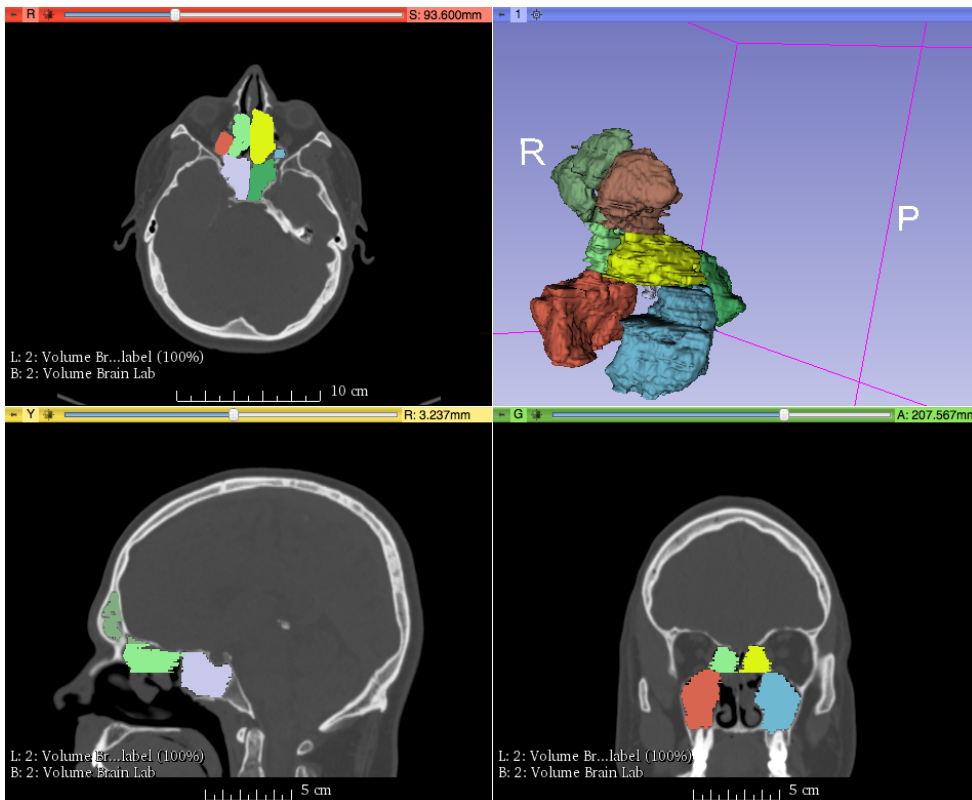
1. After you have finished labeling all of the sinuses, the 3-D model of all of the sinuses can be visualized. In the main toolbar, click on the model icon.



2. You will then see a list of all of the models that have been created with shaded eyes next to them. Click the eye next to skull to make it invisible and you should be left with a model of the sinuses.



- You will then be able to see all of the 3-D models that have been previous created based on the label maps.



- Go to label statistics as demonstrated previously with the skull and calculate the volume of all of the sinus cavities.

Grayscale Volume: 6: Vol FC30

Label Map: 6: Vol FC30-label

Apply

	Index	Count	Volume mm <sup>3</sup>	Volume cc	Min	
■	0	5.19217e...	1.13721e+07	11372.1	-32760	3
■	1	16460	3605.14	3.60514	-1831	2
■	4	157667	34532.9	34.5329	-1809	2
■	13	41523	9094.53	9.09453	-2375	3
■	32	29326	6423.1	6.4231	-2035	2

Chart Count  Ignore Zero

Save

5. Copy the data into an excel workbook

## Calculating Percent Opacification of the Sinuses

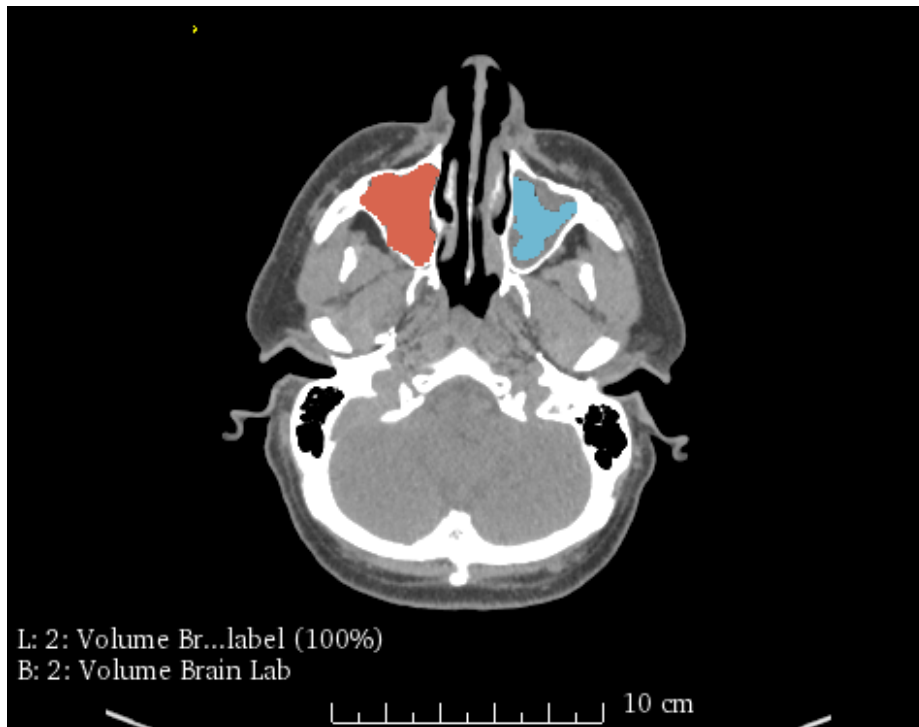
1. Some sinus cavities will be diseased, as shown below in the maxillary sinus. There is large different between the left and right maxillary sinuses. The right side is pneumatized, or air filled, while the left side is filled with “grey” or disease. We are interested in finding out by what percentage this sinus is opacified.



2. The first step is to segment the sinuses normally as shown previously. For the left maxillary sinus in the above picture, we would fill in the grey portions as if it were black. This is shown below in two different colors.



3. From here, we can calculate the volume of this label map using the label statistics module. In this case the left maxillary sinus was  $17.15 \text{ mm}^3$ .
4. The next step is to segment the sinuses again, however for the left side this time, we only segment the black or air filled portions. The grey portions will not be filled in. This is shown below.



5. We can then find the volume of only the air filled space of the left maxillary sinus by using the label statistics module again. In this case the air filled portion of the left maxillary sinus was  $8.73 \text{ mm}^3$ .

To calculate percentage opacification, the following calculation is done,  
$$\frac{17.15 - 8.73}{17.15} = 49\% \text{ opacification}$$

## Saving Your Work

1. If you would like to continue segmentation at a later time, Slicer 3D allows you to save your work.

2. Click “Save” in the toolbar and a pop-up window appears describing all of the items you have started.
3. Make sure all of the boxes are checked and select “Change Directory for Selected Files” and choose where you would like your files saved.
4. When reopening the files, click “DATA” in the toolbar and then find the folder in which you have saved your work. In order to continue segmenting, click on the file that says the date, followed by “Scene”.