

# WHOLE HEART SEGMENTATION

Using Analyze





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# Introduction

There are many applications of whole heart segmentation. They include:

- Volume measurement
- Diagnosis
- Visualization of pathology
- Treatment and intervention planning
- Educational tools
- Surface map generation for use in CAD software or 3D printing

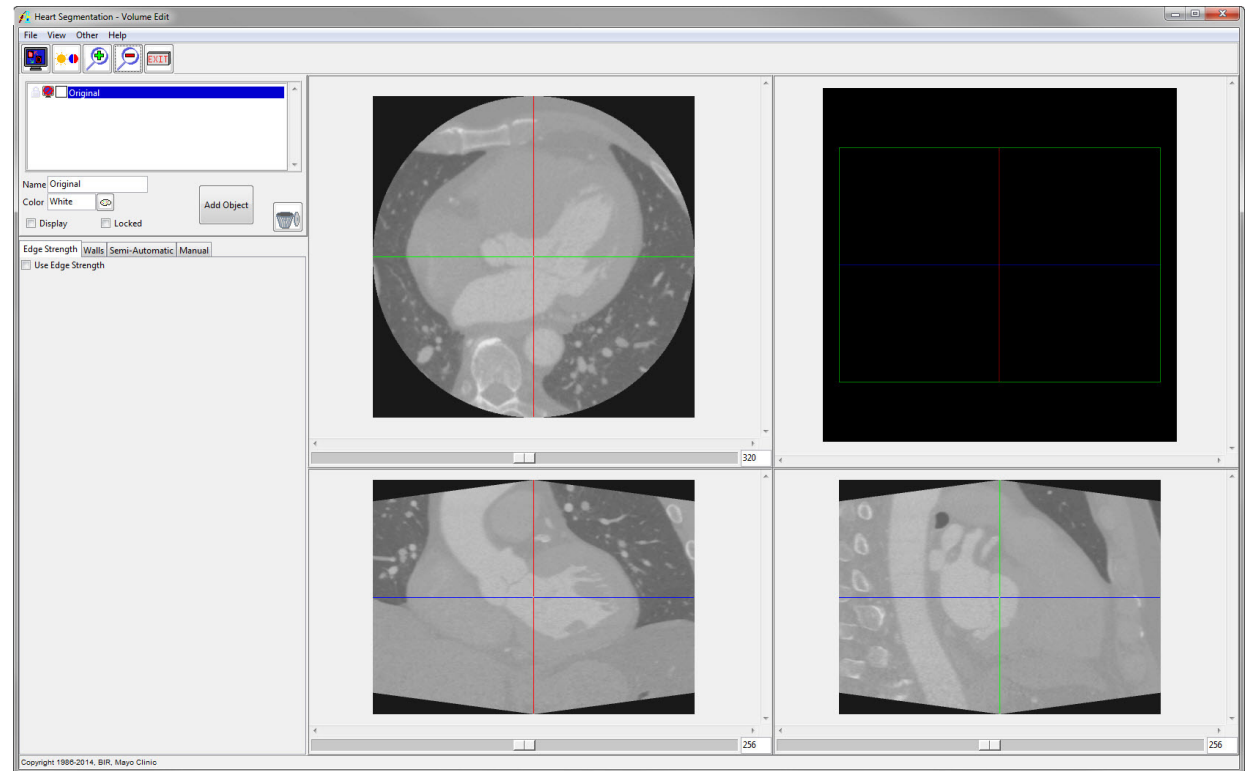
The segmentation demonstrated in this e-book uses a combination of semi-automatic and manual techniques. Automatic cardiac segmentation techniques are an active area of research<sup>1</sup>, but manual segmentation remains the gold standard. The example in this guide shows whole heart segmentation at one time point in the cardiac cycle; however, changes through the cardiac cycle can be determined by performing segmentation at multiple time points (often end-systole and end-diastole). For more information on segmentation and measurement at different time points, see the [Left Ventricle Segmentation and Measurement](#) guide. This approach may be modified for a specific application or structure of interest.



# Segmentation Instructions

Load data into Analyze. Select the dataset in the Analyze workspace, and open the Volume Edit module.

**Segment > Volume Edit.**





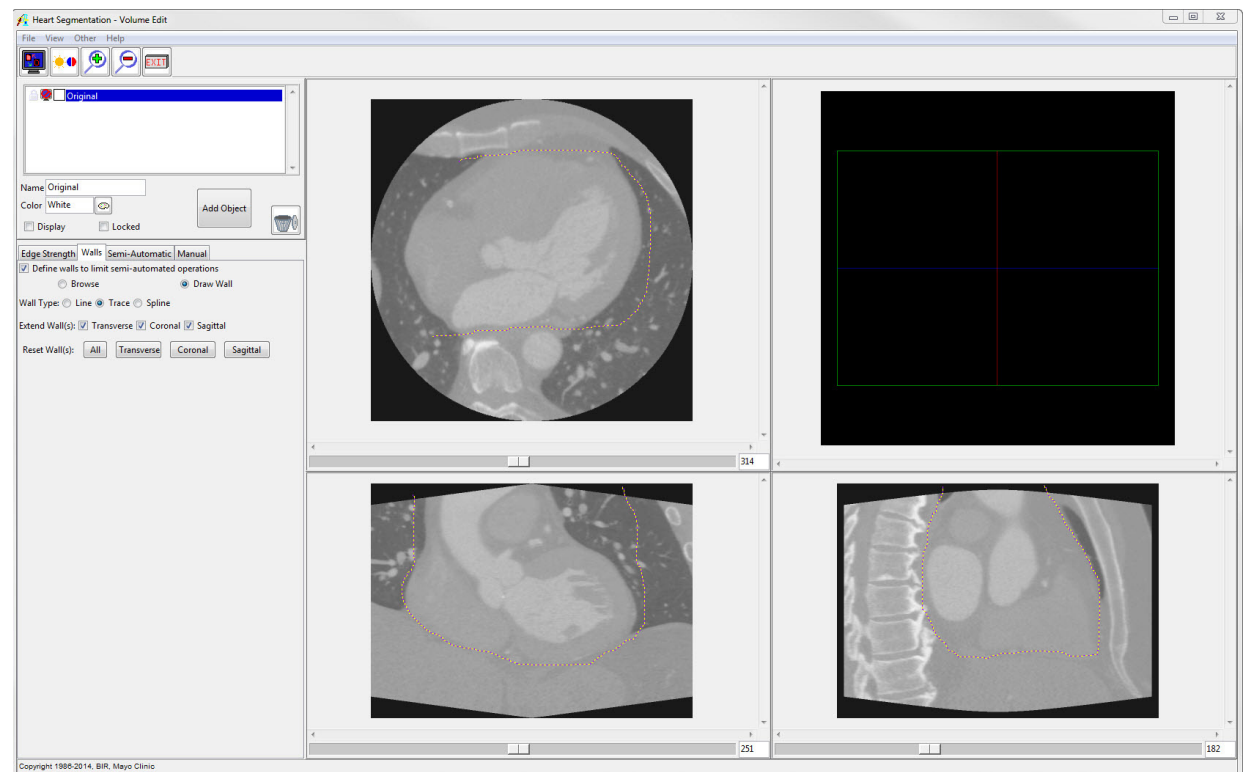
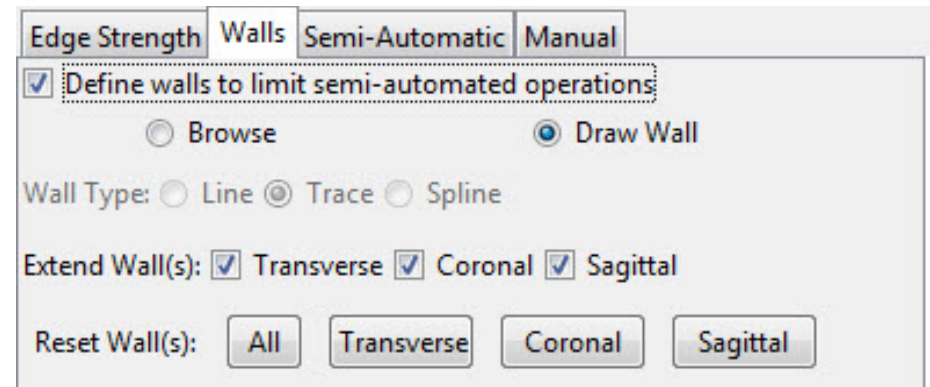
## Drawing Walls

Select the **Walls** tab and choose the **Draw Wall** radio button.

Walls drawn on the orthogonal views of the image data will set 3D limits for the segmentation algorithm. For this segmentation, the main concern is separating the heart from the ribs and spinal cord. These walls will need to be curved, so select either the Trace or Spline option, then draw walls around the heart on each orthogonal orientation. The walls will be propagated through all slices.

Move through the slices using the slider below each image, and when the wall no longer coincides with the position of the heart, redraw a new wall in that slice. The wall will be interpolated between the slices where it was specified.

*Tip: Draw walls that are not completed closed shapes. If the walls are closed, sometimes the interpolation will not stay around the shape of the heart. Instead, draw an open U or C shape, letting natural intensity boundaries in the image define the open part of the wall. See screen shot for examples of walls.*

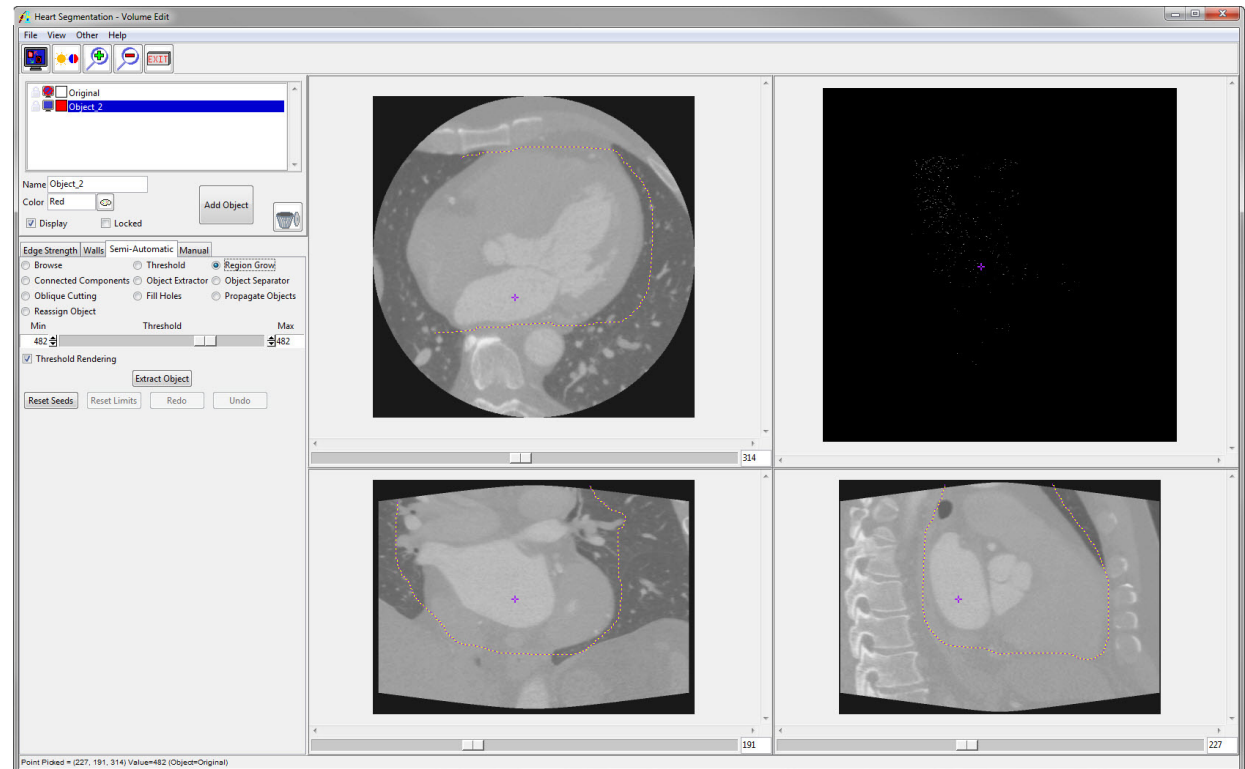




## Extracting the Blood Pool

Select the **Semi-Automatic** tab, and the **Region Grow** radio button.

Click in the blood pool in an orthogonal image to set a seed point.



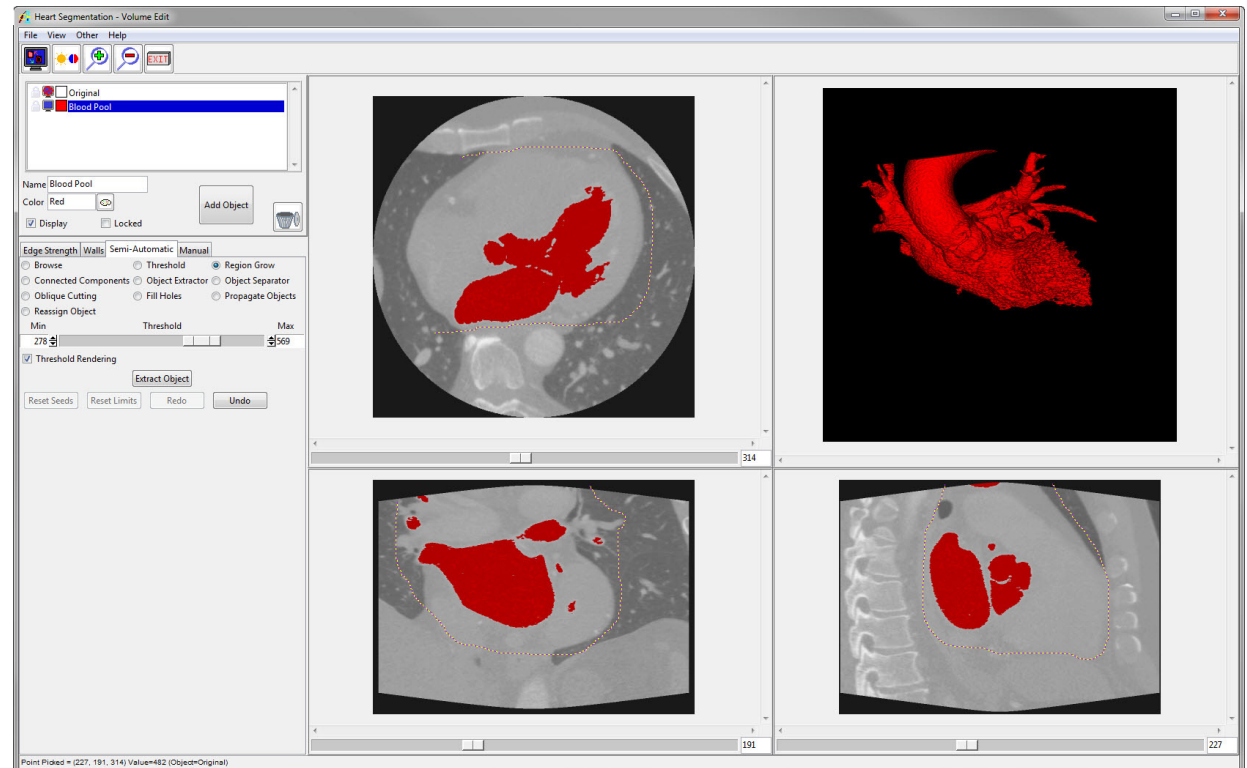


The grayscale value of the selected point will be set on the Threshold range.

Move the upper and lower limits of the threshold range to values that describe the blood pool.

Click **Extract Object**. The blood pool will be extracted.

Change the name of the object to **Blood Pool**. The regions initially extracted in this data set are the aorta, left ventricular blood pool and left atrium.



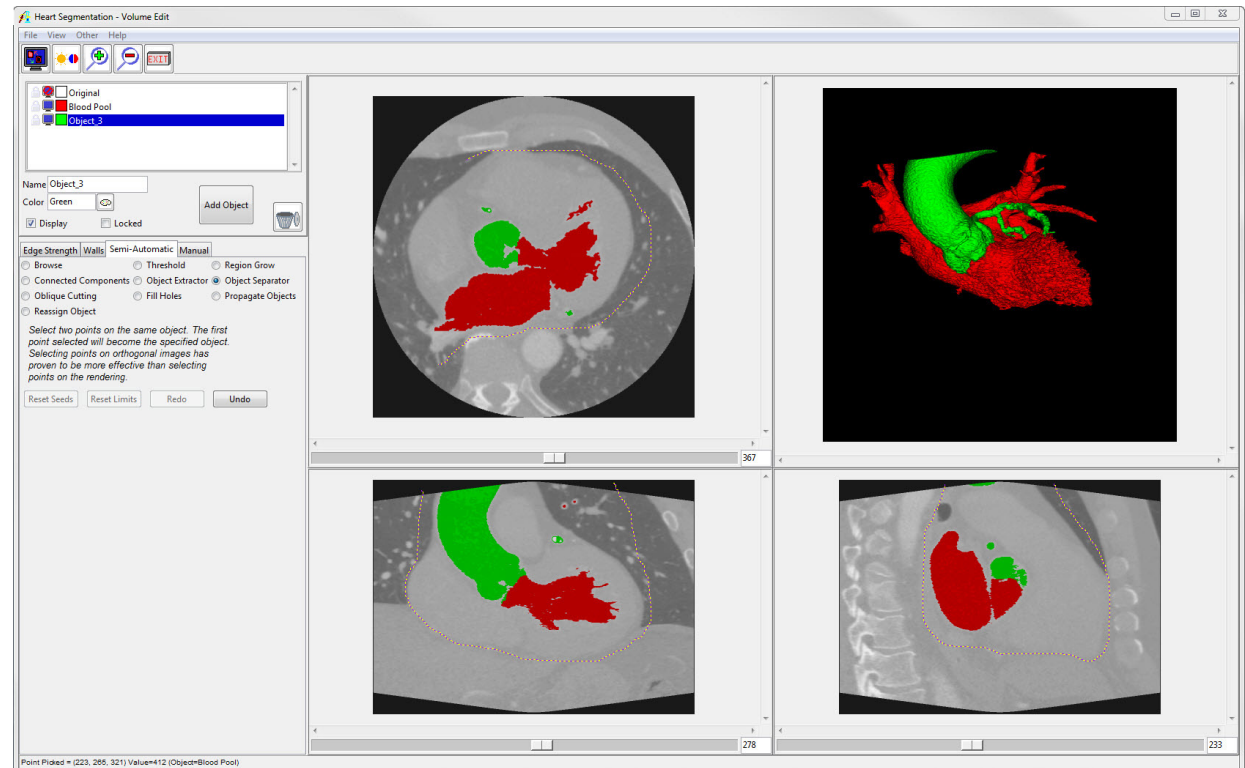


## Segmenting Regions from the Blood Pool

First we will segment the initial blood pool object into its constituent parts.

Under the **Semi-Automatic** tab, choose **Object Separator**. Add a new object, and then select two seed points. The first seed point will become part of the selected object (the new object), and the second seed point will remain part of the old object.

In this example, the aorta was separated from the blood pool object. Parts of the coronary arteries were also automatically included in the aorta object. Whether these appear in the segmentation depends on the data and the wall settings.

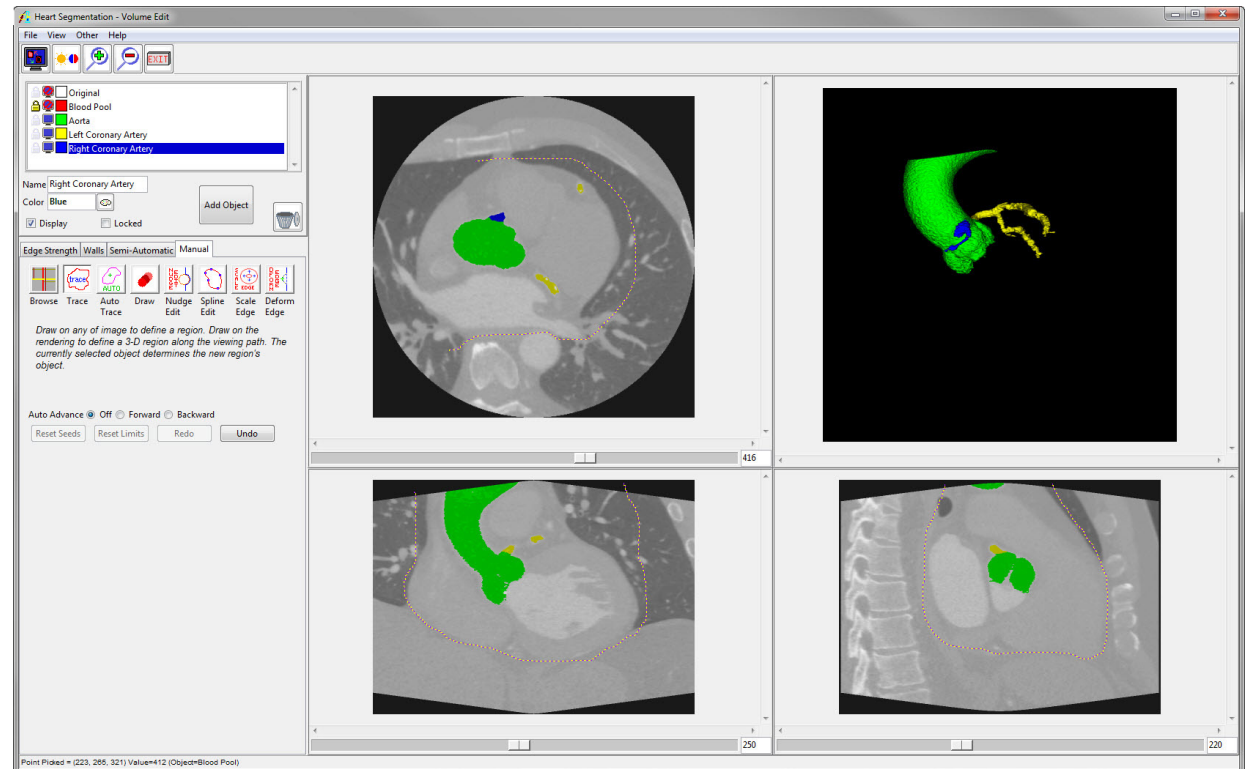






Lock and turn off the display of the blood pool object. In the **Manual** tab, select the **Trace** option.

Create two new objects for the left and right coronary arteries. In the 3D rendering, trace around each coronary artery with its respective object selected.

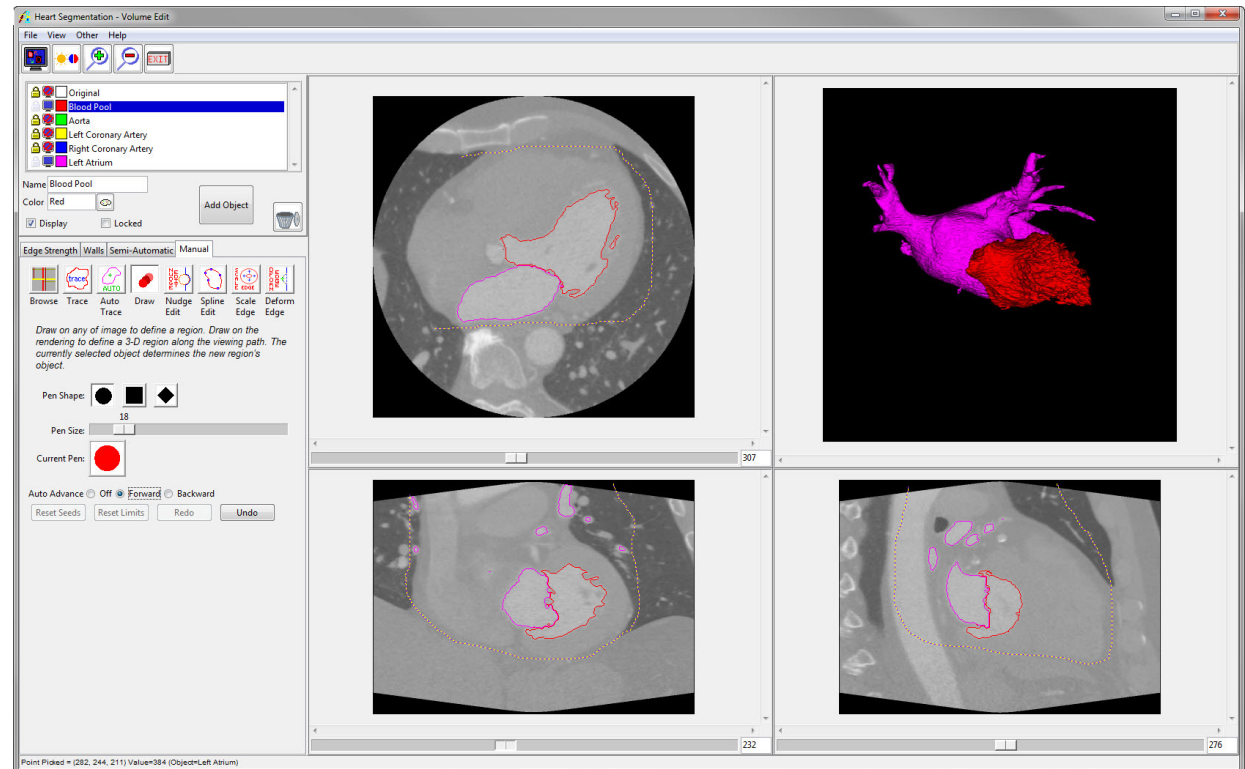




Turn the blood pool object back on and unlock it, then lock and turn off the other objects. Use **Object Separator** to separate the left atrium from the left ventricular blood pool. If the separation is not correct, try clicking Undo and selecting different seed points.

The separation can also be manually adjusted. In order to perform manual adjustments, click the **Manual tab** and choose a manual tool such as Draw. Be sure to lock the Original object when making manual edits.

*Tip: It is easiest to identify the boundary between the left atrium and ventricle in the transverse view. It may help to toggle the region display.*



Try defining the object on every 3, 5, or 7 slices, depending on the spacing of the slices in your data. Move through the slices by pressing the + and - buttons on the keyboard. If using a spline, press the "a" key to apply the spline to that slice. Then, use **Propagate Objects** under the **Semi-Automatic** tab.

Select the object to propagate, select **Current Object**, and select the orthogonal orientation in which the changes were made. Choose smoothing if needed, then click **Propagate**. This will smoothly interpolate the modifications between slices.

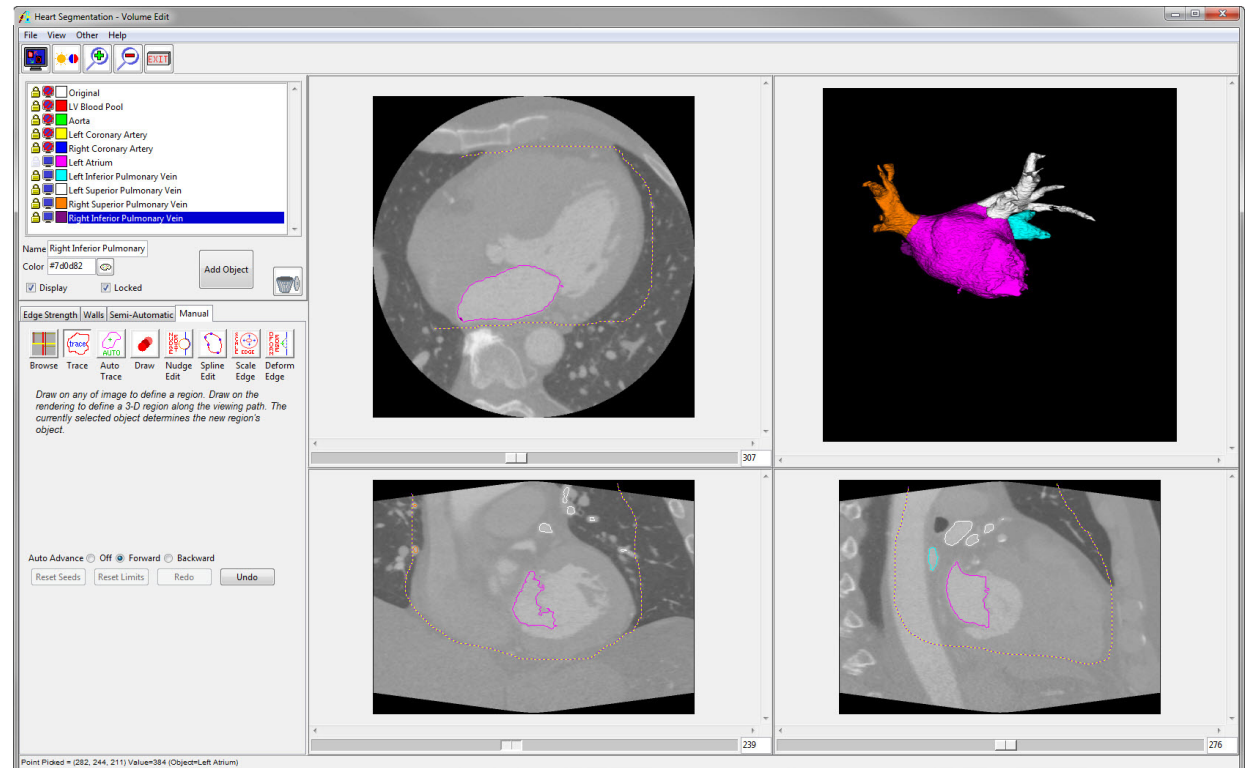
Check the results in all orientations, and if necessary repeat the edits and propagation in another orientation.



Rename the blood pool object to **LV Blood Pool**, then **lock and turn off** that object. The remaining displayed objects are the left atrium and pulmonary veins.

Create four new objects for the pulmonary veins: **Left Superior Pulmonary Vein**, **Left Inferior Pulmonary Vein**, **Right Superior Pulmonary Vein**, and **Right Inferior Pulmonary Vein**.

Use the **Trace tool** under the Manual tab to trace around each pulmonary vein on the rendering with the correct object selected.

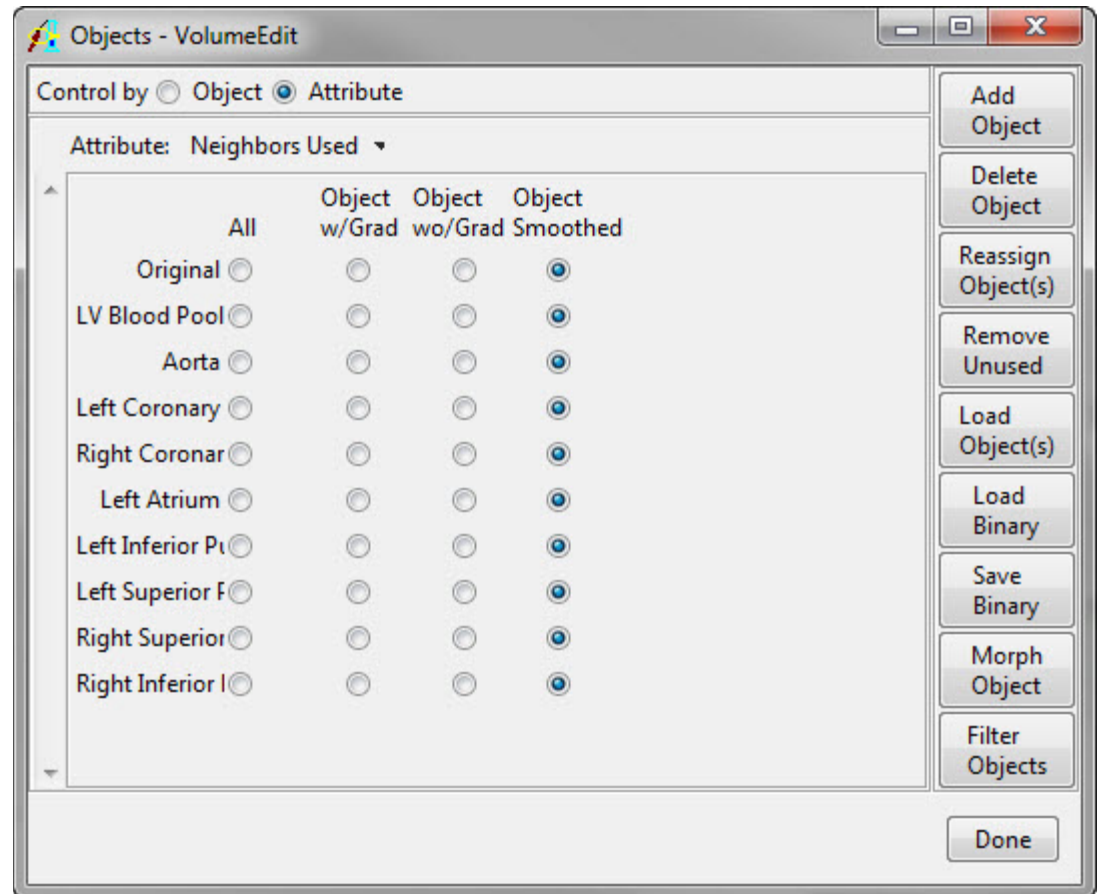
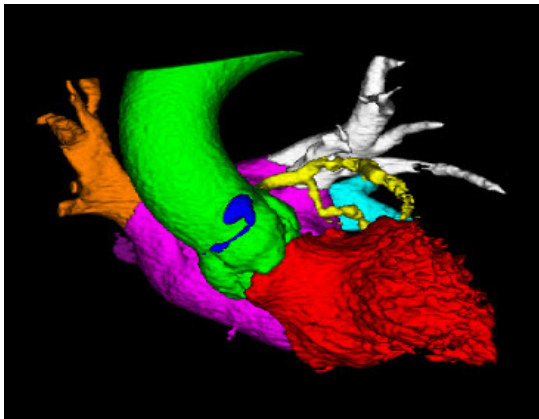




In order to clean up the objects segmented so far and improve the rendering smoothness, we will change some display settings.

From the **View** menu, select **Objects**. In the Objects window, select the **Attribute** radio button and change the Attribute to **Neighbors Used**.

Change each object to **Object Smoothed**. This will smooth the 3D rendering.



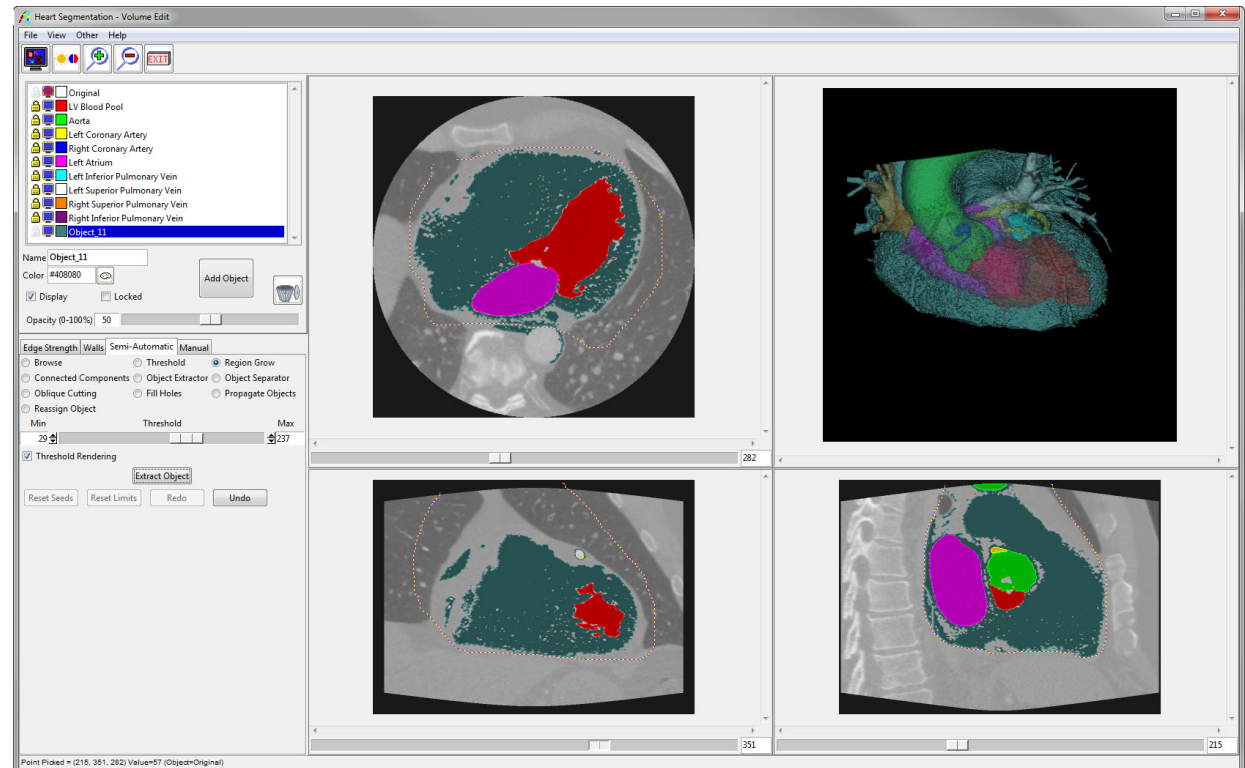


## Segmenting Regions Outside the Blood Pool

Now we need to add the remaining chambers of the heart to our segmentation. The left ventricular myocardium, and the right atrium and ventricle are currently missing.

In this data set, those regions have a lower intensity so were not included in the initial region grow step.

Create a **new object** and **lock** all objects but the new object and the Original object. Under the **Semi-Automatic** tab, select the **Region Grow** option.



Select a seed point and adjust the threshold range. For this step, a conservative threshold range is best to keep the region grow from adding regions that are not part of the regions of interest.

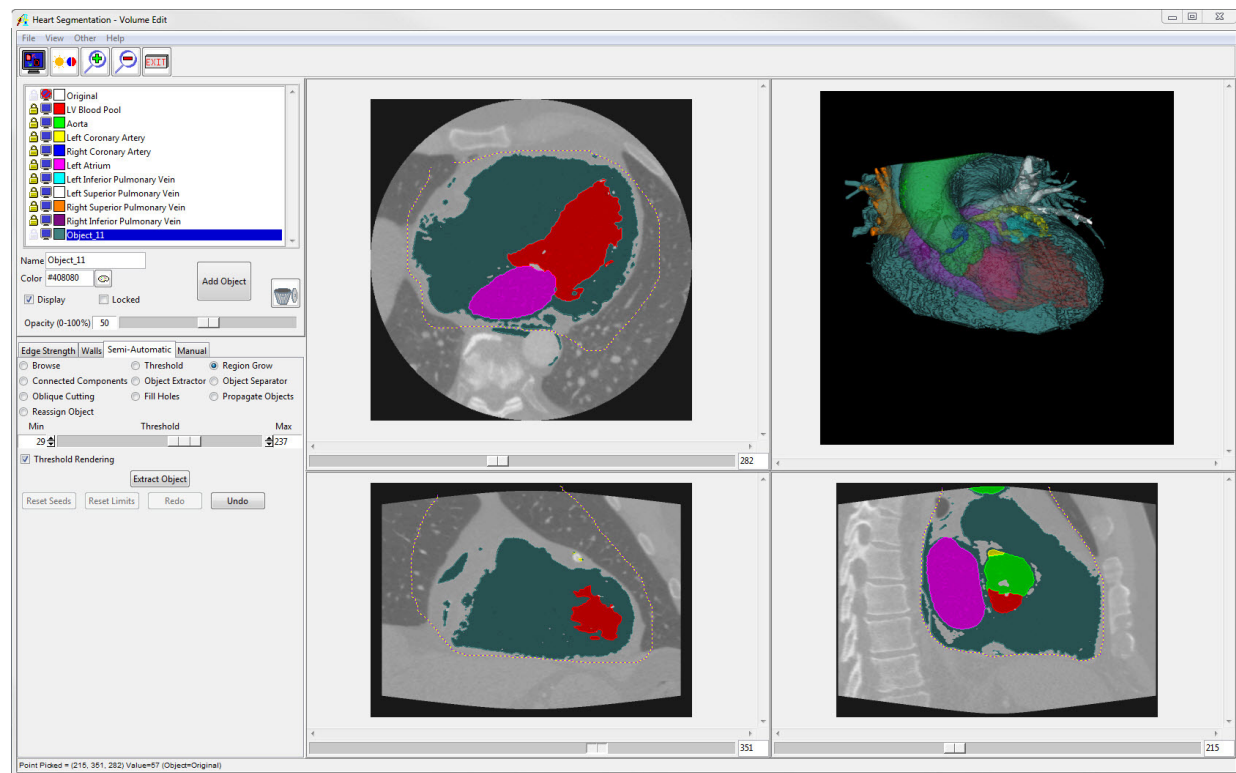
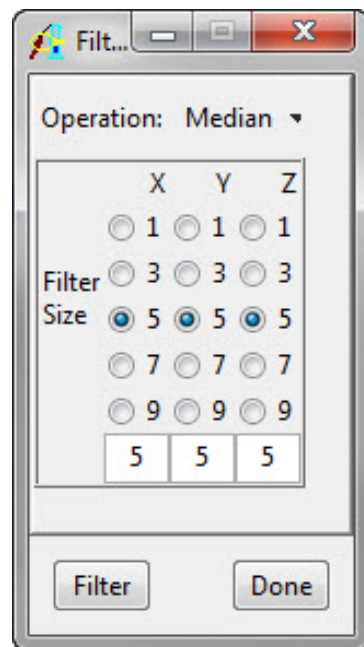
After choosing a threshold range, click **Extract Object**. The remaining heart objects will be taken from this new object, then any extra noise remaining will be deleted.



In the new object, there will be several small holes. In order to clean up this object, we will apply a median filter.

Go to **View > Objects**, then click the **Filter Objects** button on the bottom right. In the Filter Objects window, choose a **5 x 5 x 5** median filter, then click **Filter**.

The new object will be smoother and have most of the holes filled.



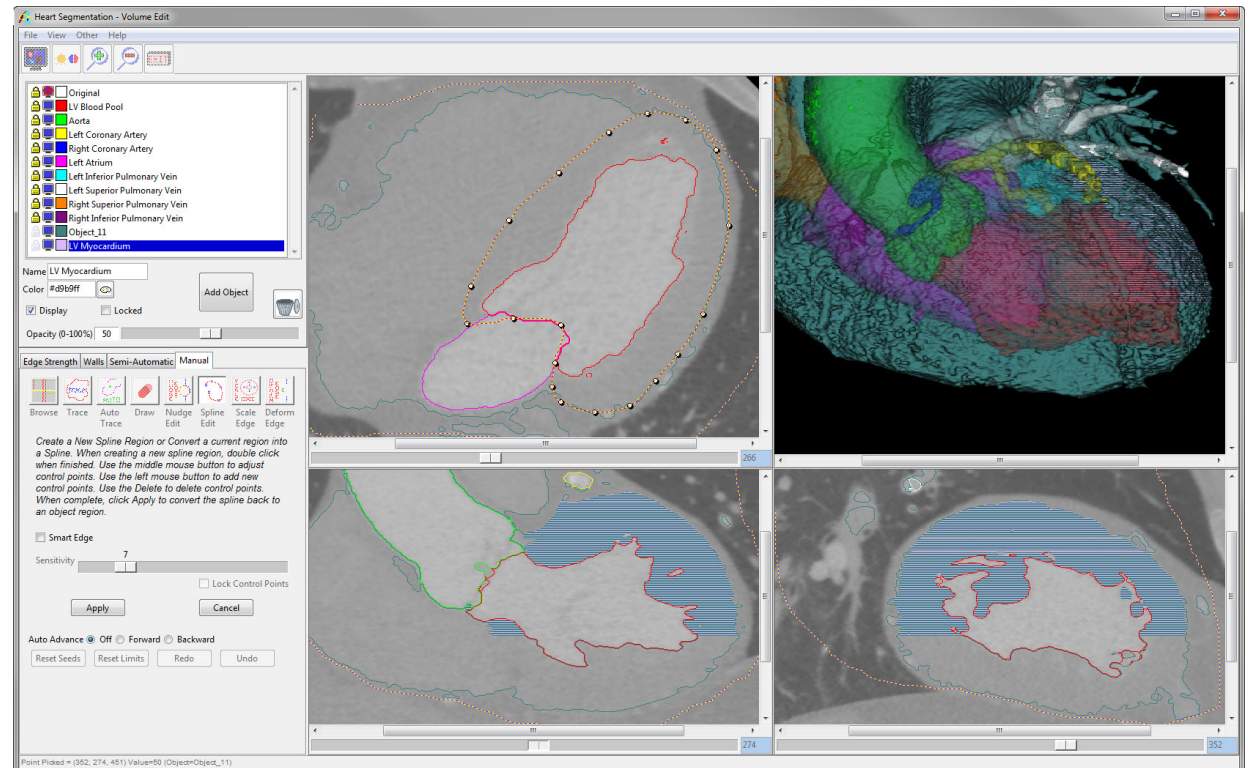




Add a new object and call it **LV Myocardium**. Lock the Original object.

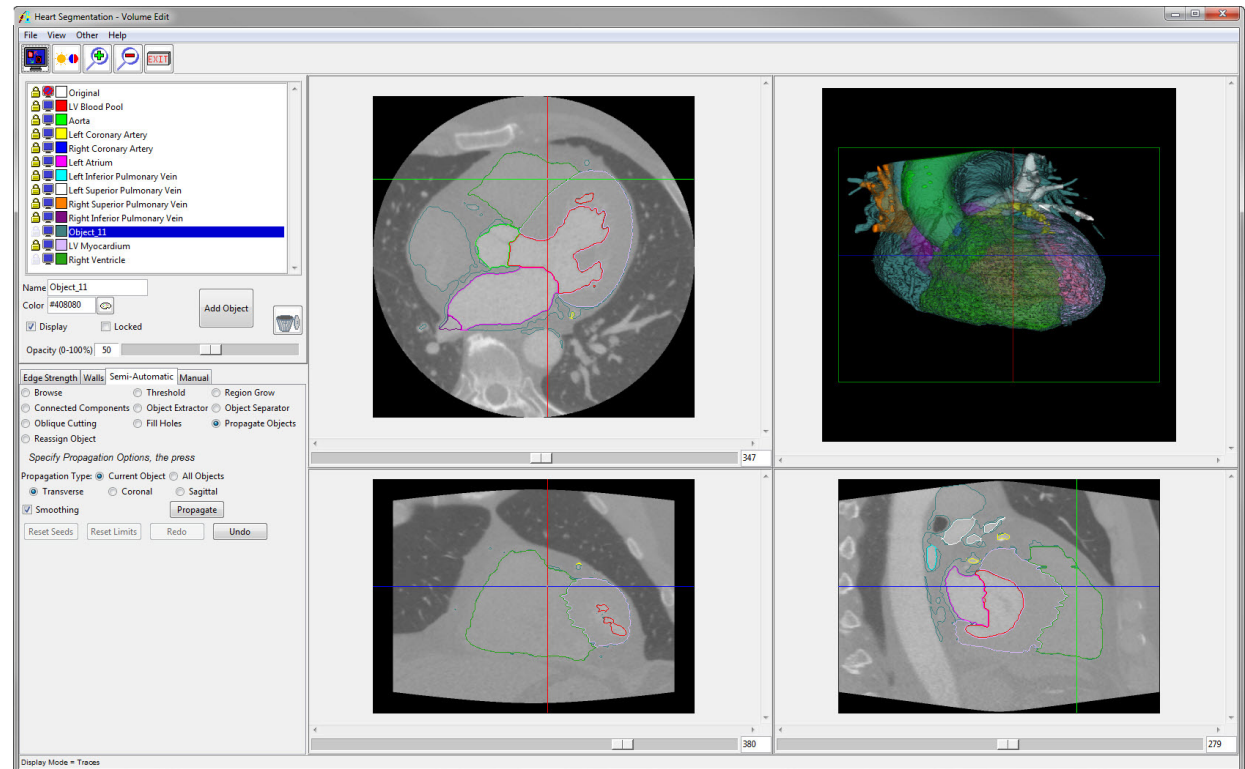
With the LV myocardium selected, use a manual tool of your choice to define the LV myocardium on every few slices, then propagate the object as described before. The spline tool works well for this.

The propagated region can be somewhat jagged if not many slices were skipped between defining the object. Try defining the object on every 5 or 7 slices (depending on the data). Applying an object filter can be used to smooth the boundary, but the filter will be applied to all objects so it may be best to wait until the end of the segmentation to apply an object filter.





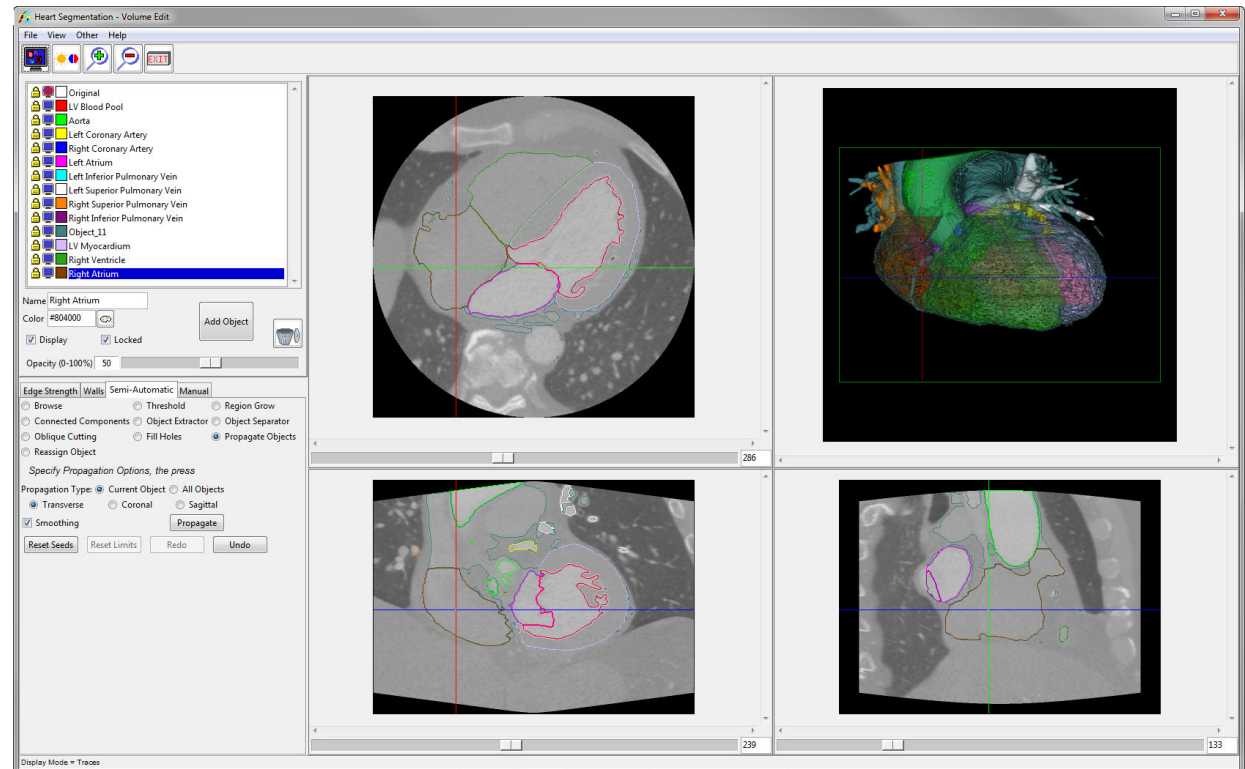
Next, we will define the right ventricle.  
Create a new object and call it **Right Ventricle**. Then follow a similar procedure to that used to define the LV myocardium.







The last remaining chamber of the heart is the right atrium. We will segment it the same way as the other chambers.

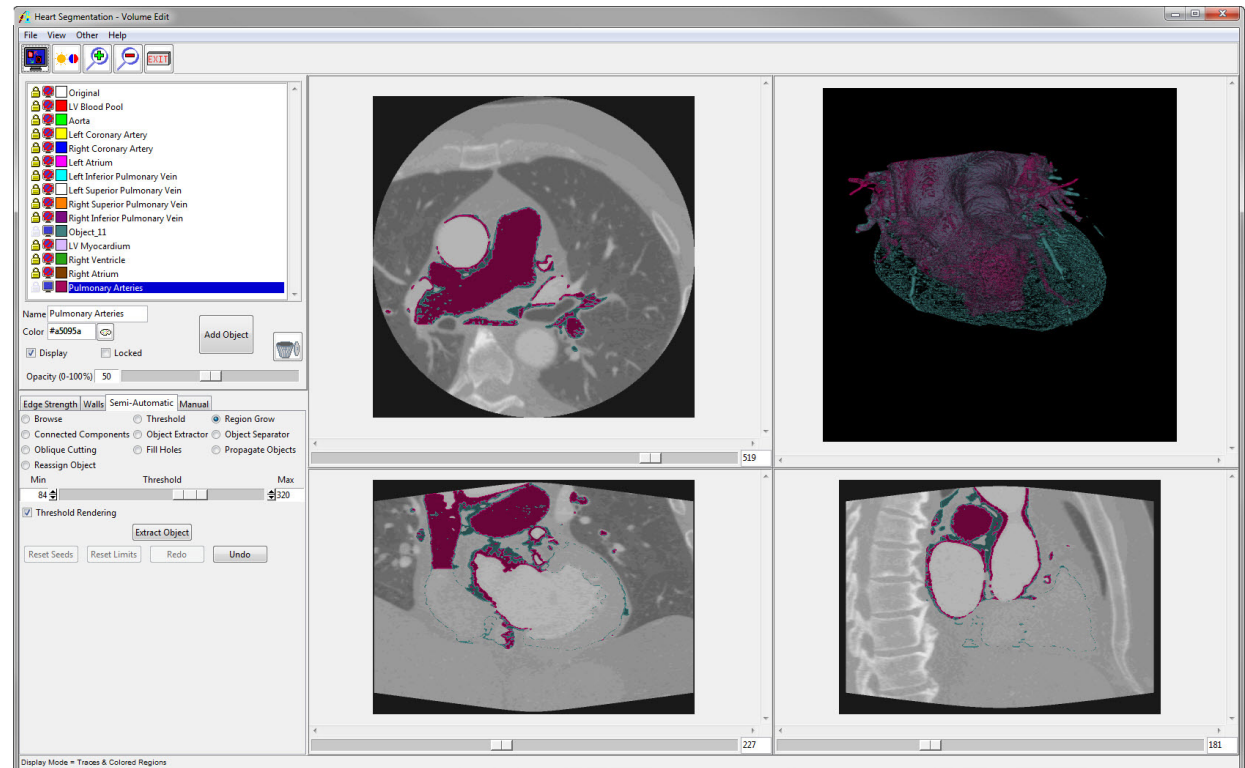




Now, all that is remaining in Object\_11 is the pulmonary arteries and vena cava along with some extra noise from the initial region grow.

Create a **new object** and call it **Pulmonary Arteries**. Lock all objects but Object\_11 and the pulmonary arteries. Under the **Semi-Automatic tab**, select the **Region Grow** option.

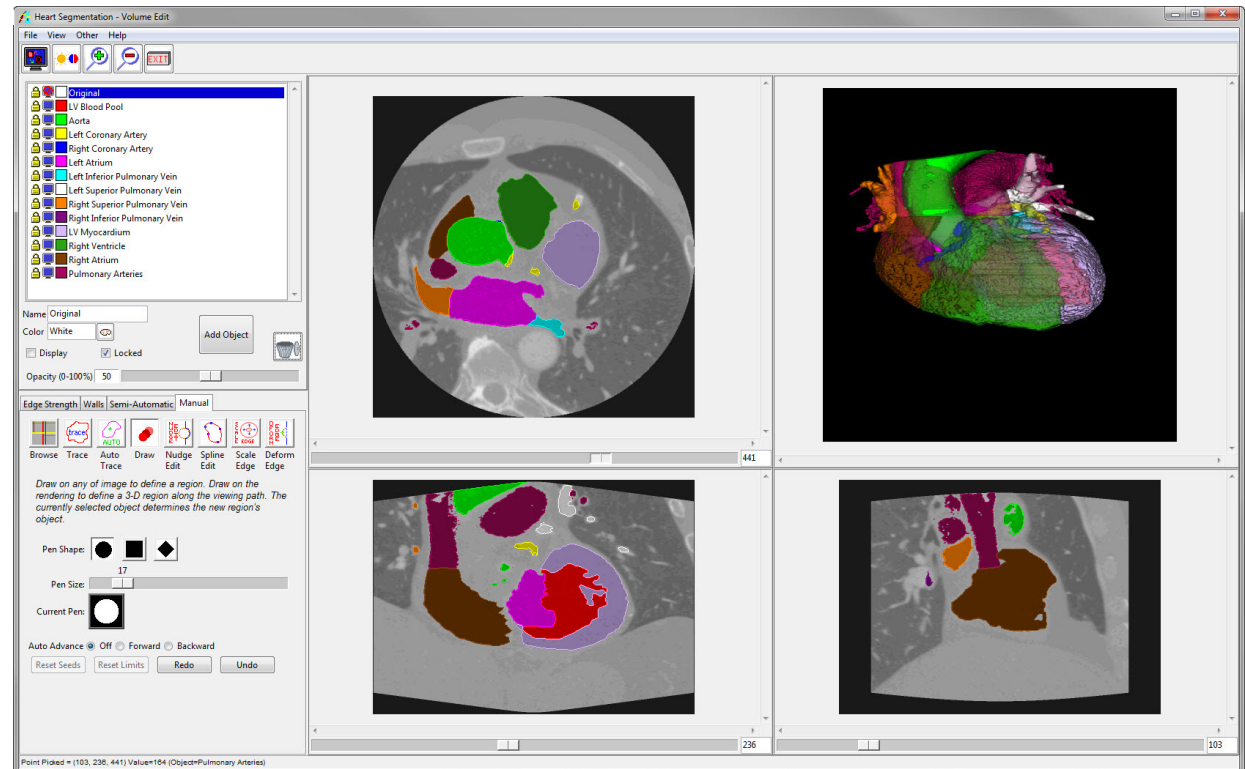
Select the **pulmonary arteries object**, then define a seed point in the main pulmonary artery. Choose an appropriate threshold range, then click **Extract Object**.





Delete **Object\_11**. There are still some parts of the pulmonary arteries object that are not part of the pulmonary arteries and need to be removed.

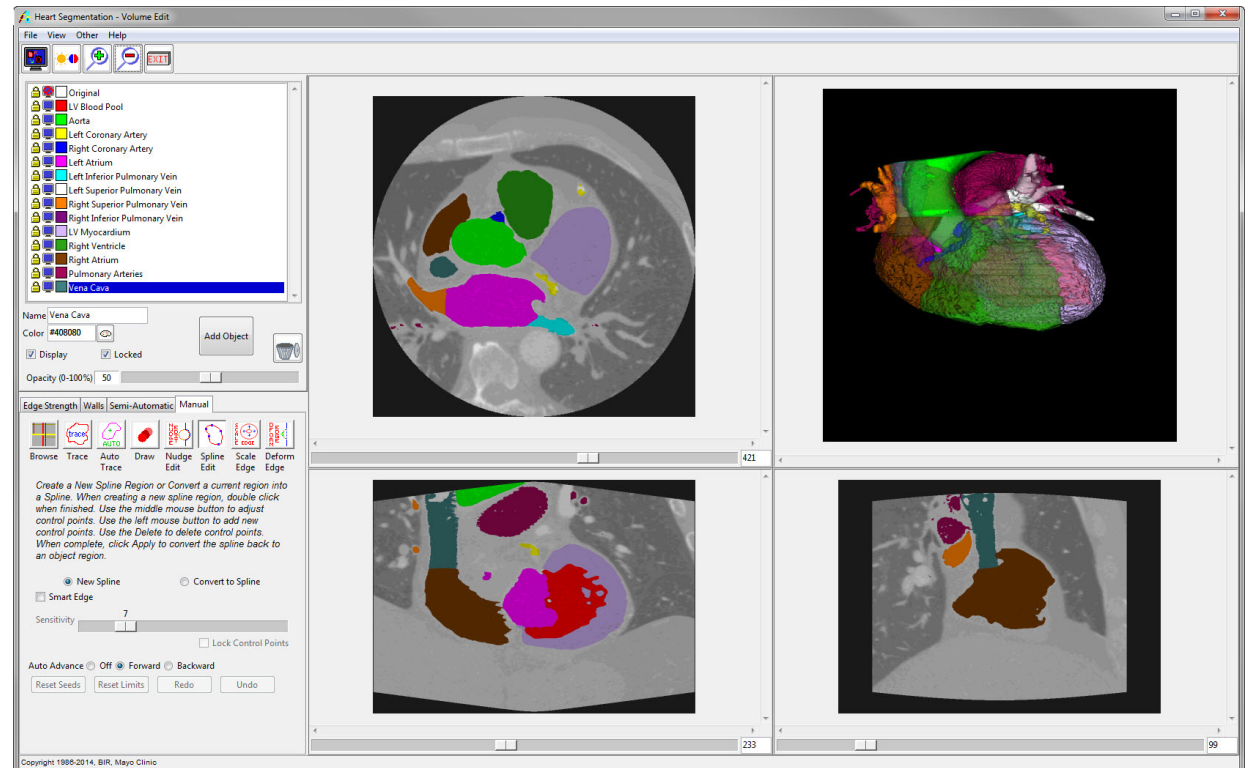
Use a manual method to reassign these areas to a new object. Use the propagate regions technique described earlier by changing every few slices, then propagating the new object.





Now we will separate the vena cava from the pulmonary arteries.

Drawing a spline around the vena cava and setting **Auto Advance** to **Forward** (or Backward if starting at the high end) works well for this.

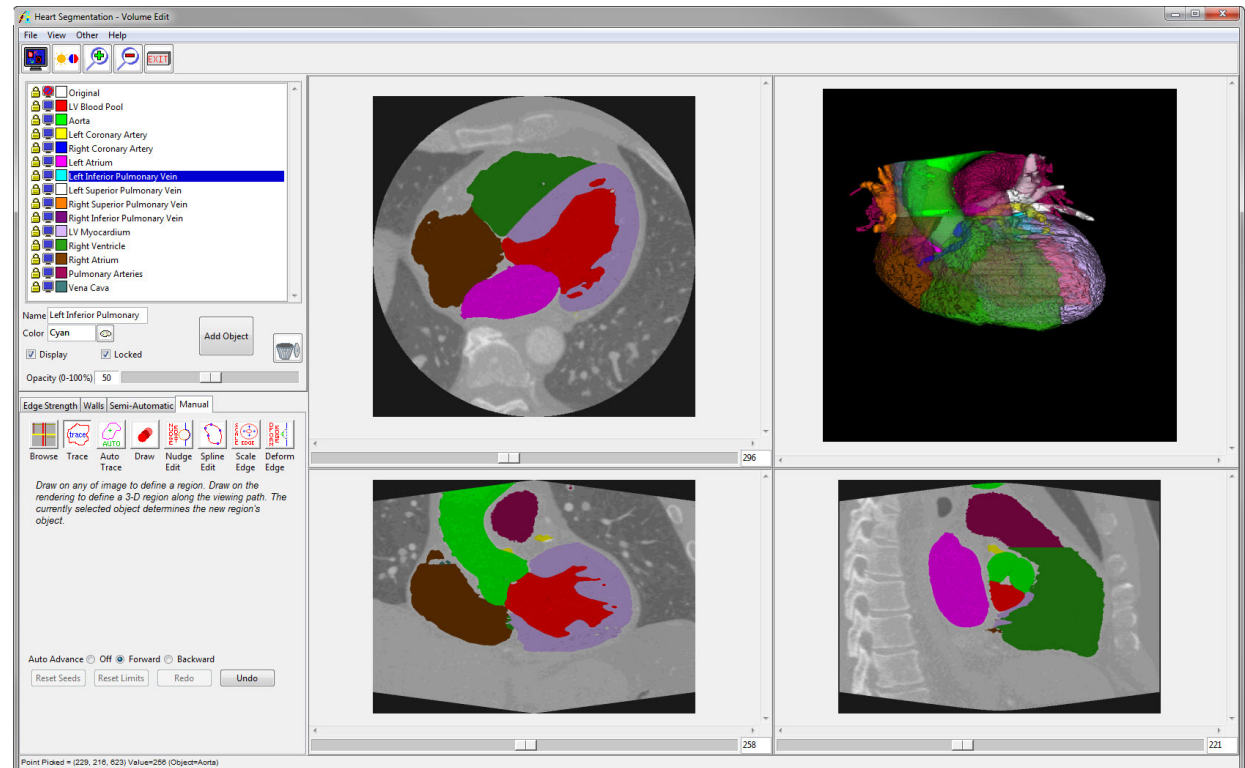




Lastly, there are a few holes in the pulmonary arteries and vena cava. Go to **View > Objects** and click the **Morph Object** button in the bottom right of the Objects window.

Change Object to **Vena Cava**, Operation to **Fill Holes**, and Defined Object to **Vena Cava**. The default setting should work fine. Click **Morph** to perform the Fill Holes operation. Repeat this process with the Pulmonary Arteries object.

Save the object map by going to **File > Save Object Map** and choosing a directory.



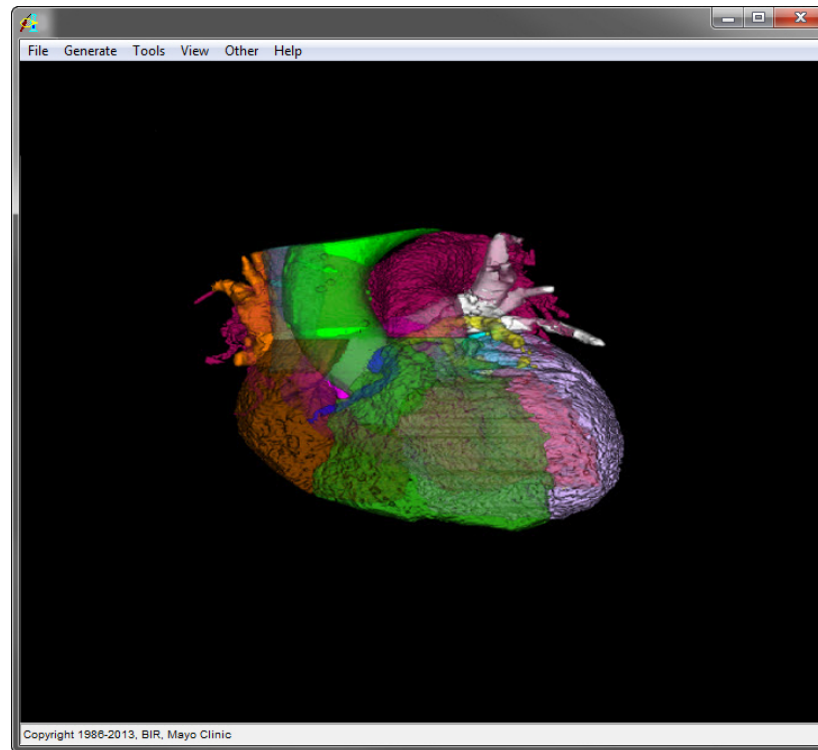


## References

1. Kang, D. et al. Heart chambers and whole heart segmentation techniques: review. *J. Electron. Imaging* 21, (2012).

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