# 

# PlaqueQuant – Blood Vessel Stenosis Quantification Software User Manual Version 2.1 FOR BETA VERSION ONLY

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## Introduction

### Purpose

PlaqueQuant is a software with various algorithms, which facilitates user to perform accurate segmentation of blood vessels. Quantitative analysis is performed to help user to quantify blood vessel stenosis

### Highlighted Features

The PlaqueQuant highlights the following features:

1. All-in-one pipeline system architecture.
2. Easy-to-use and intuitive interface.
3. DICOM image data well compatible.
4. Smart automatic segmentation algorithm.
5. 2D and 3D numerical analysis.
6. Automatic clinical report generator.

## Installation

Follow the instruction to install the software:

1. Unpack the zip/rar file.
2. Double click the installer file “Setup”.
3. Press “Install” when prompted with installation of Microsoft Visual C++ redistributable. Finish the rest of the installation as instructed.
4. Press “Run” when prompted with system security message.
5. Click “Finish” to finish installation.

## Usage

### Workflow pipeline

The PlaqueQuant adopt a pipeline fashion for each case as shown below.

Figure 1 Workflow Diagram

### Overall

The following figure is the overall of the software. The software basically contains 5 parts: Menu Bar, Tool Bar, Widget Window, Measurement Window, Viewers.

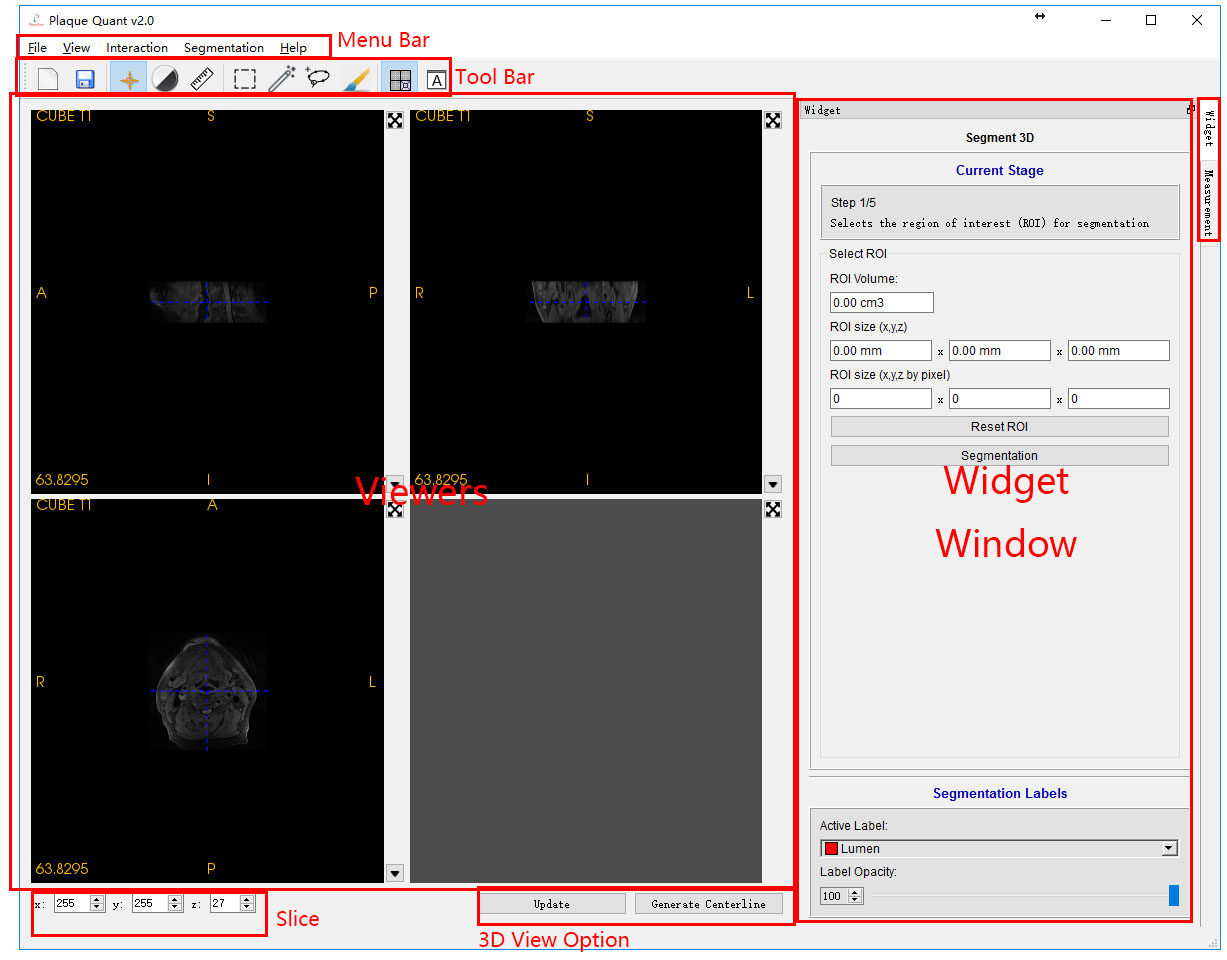


Figure 2 Main Window

#### Viewers:

There are 4 viewers in total. The lower right one is the 3D viewer; others are 2D viewers.



Figure 3 Image viewers

Every 2D viewer has a capital letter to represent its directions, (S: superior, I: interior, A: anterior, P: posterior, R: right, L: left) and a few interaction ways (be introduced in tool bar).

Upper left is the modality name.

Lower left is the voxel intensity of the cursor.

Upper right is a button which can maximize the current viewer. (This button will change to return normal size when the viewer is maximized)

Lower right is a button “▼” for changing modality.

3D viewer is a passive viewer for the performance consideration which means this viewer cannot render without clicking the “update” button during doing the segmentation. If the user wants to check their segmentation result, click the “update” button. And it only has one interaction way.

|  |  |
| --- | --- |
| Holding left click | * Rotation |
| Moving wheel and holding right click | * Zoom-in and zoom-out |
| Holding middle button | * Translating |
| Keyboard “r” | * Resetting position |

#### Tool bar:

In the tool bar, the software consists of 3 examining modes, 4 editing modes, 2 view models and the 2 basic functions (open and save) for 2D viewers.

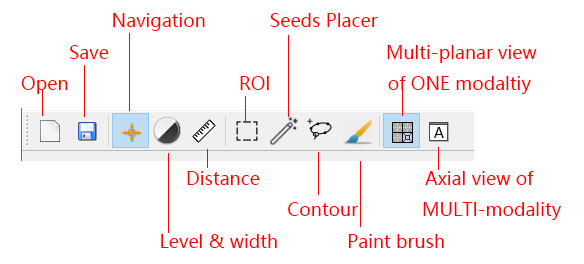


Figure 4 Toolbar tooltips

|  |  |  |
| --- | --- | --- |
| **Functions** | | **Operations** |
| Open | * Open the registration wizard for loading images | |
| Save | * Open the saving wizard for saving the segmentation image | |
| **Views** | **Operations** | |
| Multi-planar view of one modality | * Display 3 different views (axial view, sagittal view, coronal view) in 3 viewers which are from the same MRI modality image. | |
| Axial view of multi-modality | * Display 3 views in 3 viewers of 3 different MRI modalities images all in axial view | |

|  |  |
| --- | --- |
| **Modes** | **Operations** |
| All | * Move middle wheel to change slice |
| Navigation | * Left click to select slices location * Hold right click to zoom * Hold middle click to move camera |
| Level & width | * Hold left click to control the window level and widow width of images. |
| Distance | * Left click to place a point and measure the distance between 2 points |
| ROI | * Left click to the border and drag it, 3 ROI frames will move synchronously |
| Seeds Placer | * Left click to place a seed point * Hold left click to drag a seed point |
| Contour | * Left click to place a contour point * Hold left click to keep placing contour points * Right click to extract lumen wall (when auto lumen segmentation enabled) * Double left clicks to draw the contour with specified label |
| Paint brush | * Hold left click to draw with specified label. * Hold right click to erase label as an eraser |

#### Menu bar:

The operation of menu bar is almost the same as the tool bar. Provide quick access to the software functions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| File  Open Image  Recent Image  Exit | View  Display  Upper Left  Upper Right  Lower Left  Lower Right  Four Views  View Mode  All Axial View  Multi-Planar View | Interaction  Navigation  Window Level  Ruler  ROI  Seeds Placer  Contour  Paint Brush | Segmentation  Save Segmentation  Open Segmentation  Save Contour | Help  About  Help |

#### Widget Window:

On the upper part of the widget window can be change on different mode. They are using for the configurations of different modes (Ruler, ROI, Seeds Placer, Contour, Paint Brush).

On the lower part, it is the setting of label’s opacity.

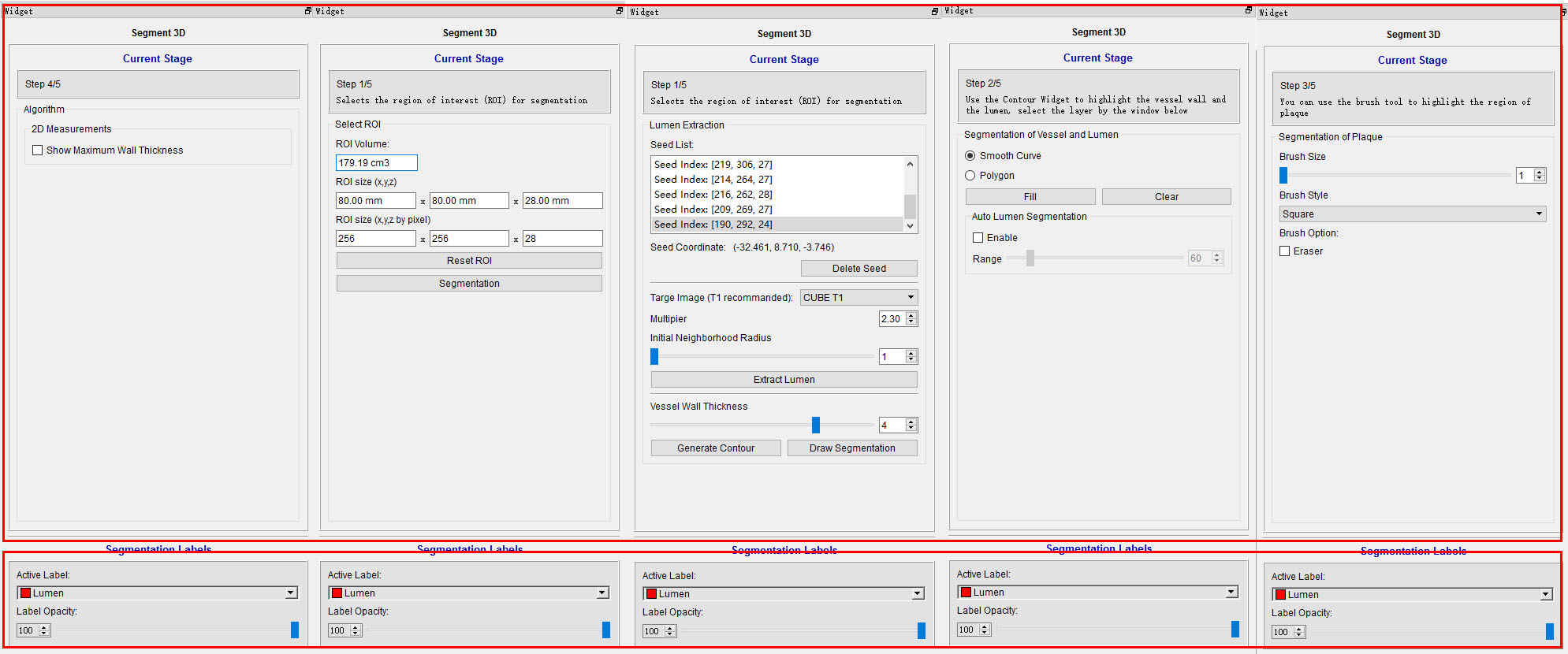


Figure 5 Widget Window

#### Measurement Window:

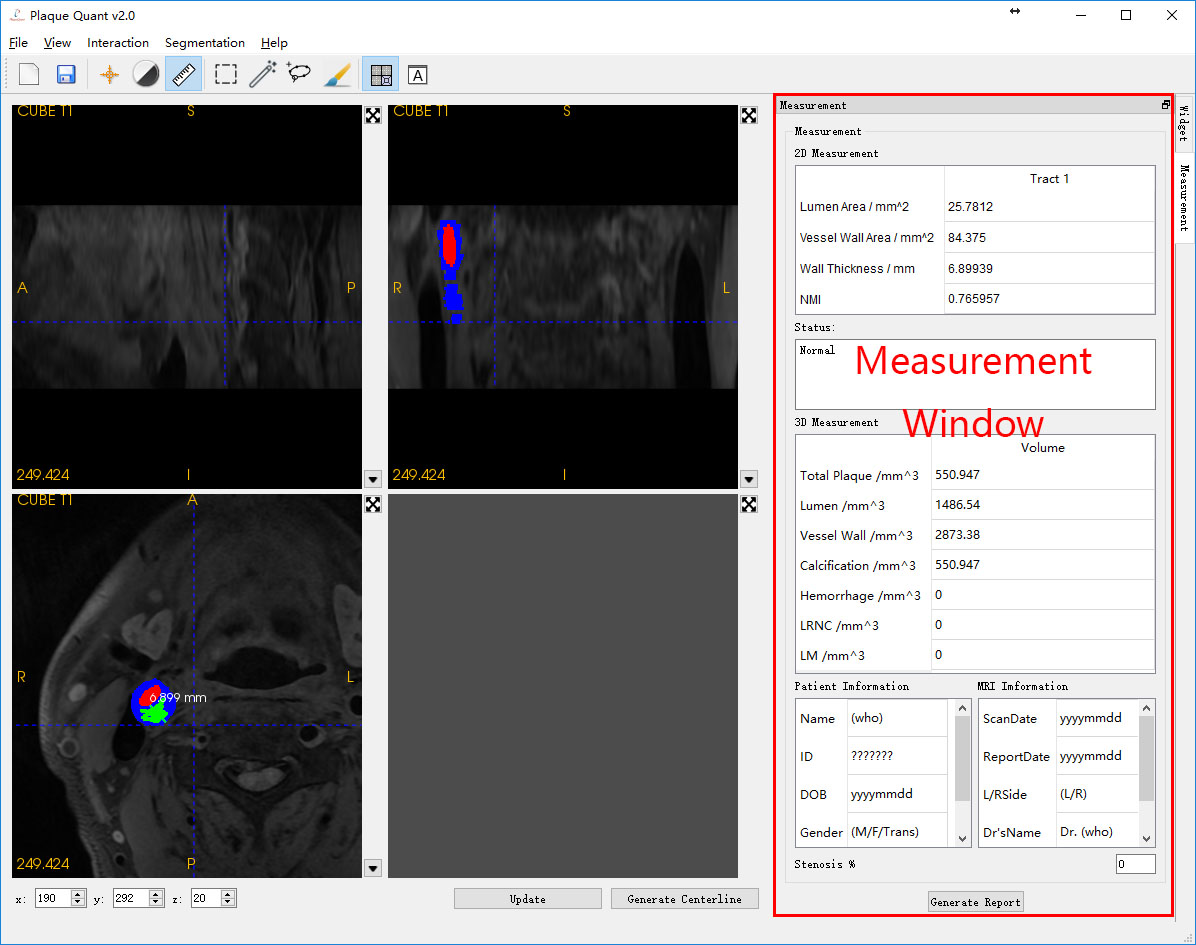


Figure 7 Measurement Window

The Measurement Window are using for 2D and 3D numerical measurement and automatic report generating. The 2D and 3D numerical measurements will be updated in real time by modifying the segmentation.

### Image Loading and Registration

Medical image loading can be performed by clicking “File” -> “Open Image” OR “Recent Image” in menu bar. Then the “File loader” will pop up. The software is able to load multi-modality MRI image in DICOM or NIFTI format. Other formats are still not yet supported. By clicking “Open Image”, user is supposed to select accurate folder which contains images to be loaded. By clicking “Recent Image”, user can select the recent folder in history.

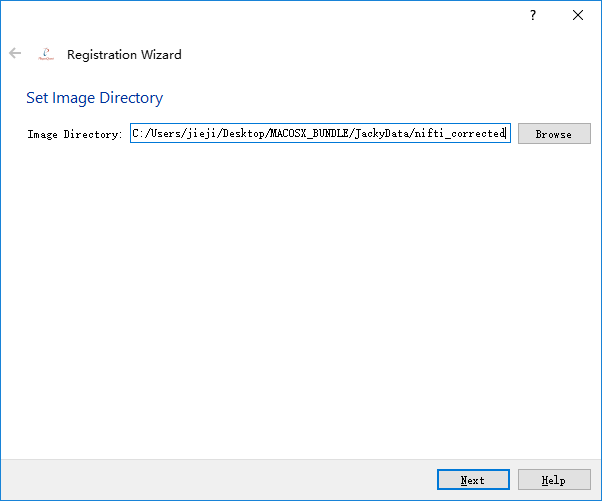


Figure 6 File loader

In the next, all supported image data are loaded into the upper table, user should follow hints of the wizard and select relevant images. By clicking “<<” the highlighted image will insert to the corresponding slot. While clicking “X”, the image in the corresponding slot will be removed. The software is capable to load 5 different modalities MRI image (CUBE T1 image，CUBE T2 image，CUBE T1 + Contrast, 2D Double Inversion Recovery(DIR)/Quadruple inversion recovery(QIR), MPRAGE).

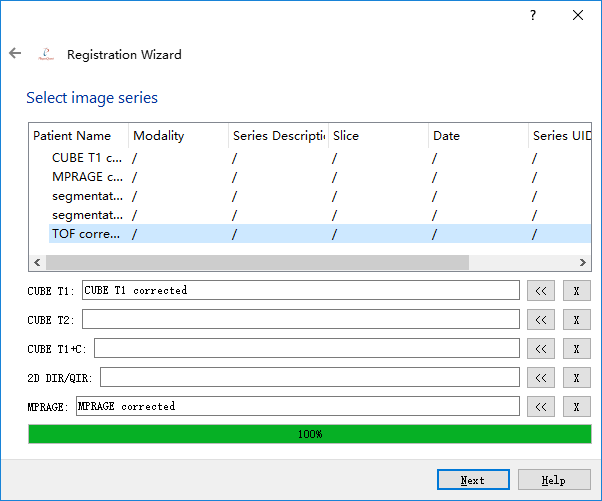


Figure 7 Image selection

In the next, properties of the selected images are displayed and user can do the final confirm whether they are the correct image to be loaded (Only for DICOM, NIFTI do not have these properties). If not, user is capable to click the “<-” in the upper left to return previous wizards. If nothing goes wrong, user can click the “finish” and the software begins to load image and do the registration, which should be taken a few seconds. Please don’t be panic if the software is not responding.

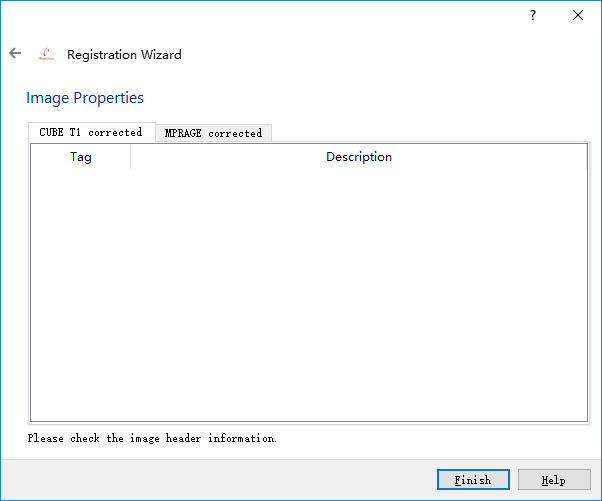


Figure 8 Function tab options - Image Preprocessing

### Image View

As it has already been written in 3.1, Multi-planar view of one modality and Axial view of multi-modality are 2 views for user to browse their images.

#### Multi-planar view of one modality C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\LayoutMultiPlanar.png

Pressing the icon, C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\LayoutMultiPlanar.png, switch the view mode to multi-planar view mode.

On upper right, it is a sagittal view. On upper left, it is a coronal view. On lower left, it is an axial view. All three 2D viewers are displaying the same modality image.

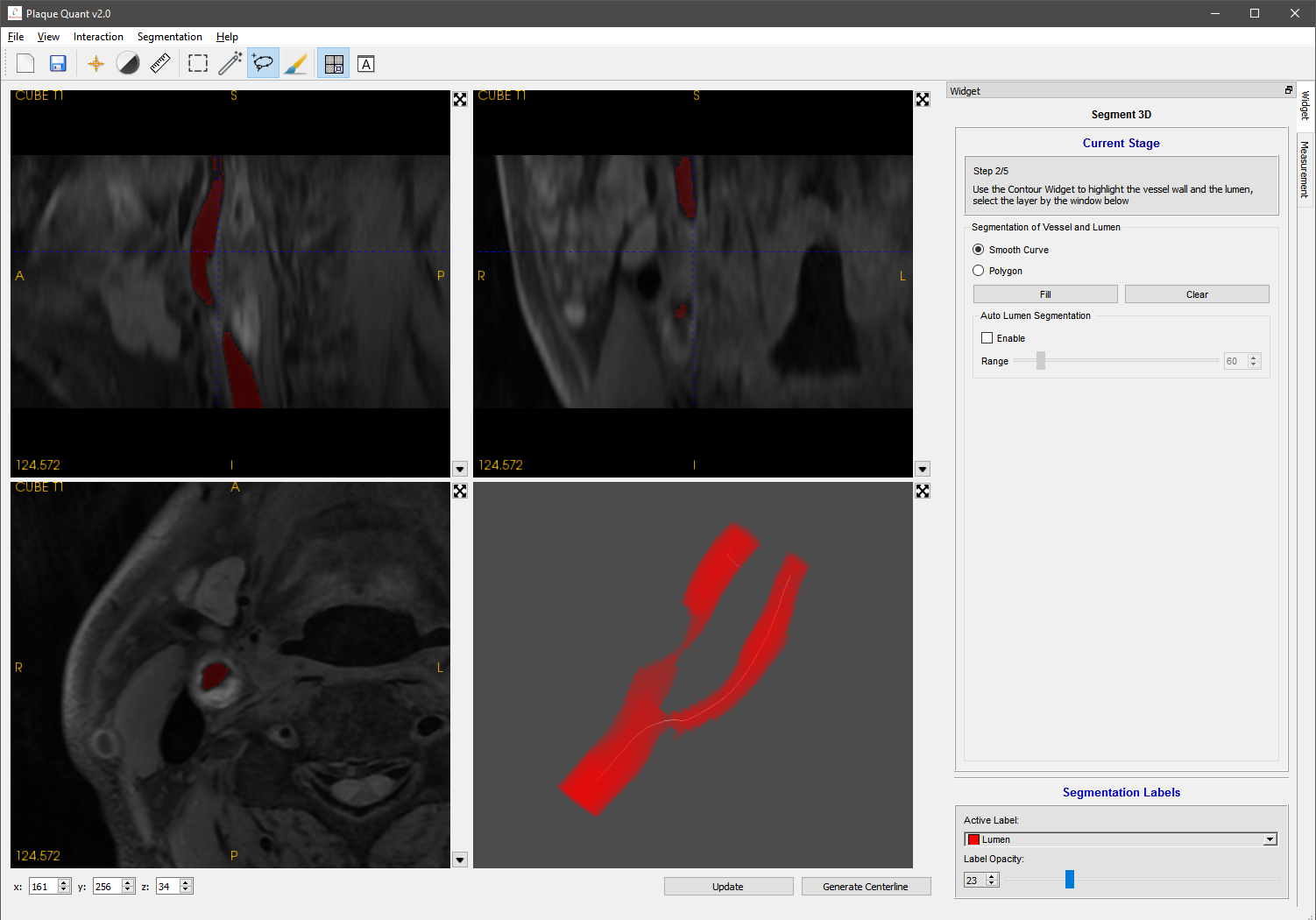


Figure 9 Multi-planar view

#### Axial view of multi-modality C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\dl_axial copy.png

Pressing the icon, C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\dl_axial copy.png, switch the view mode to axial view mode.

Three 2D viewers are displaying different modalities and all of them are in axial view. Normally, vessel wall and lumen are easily recognizable in axial view.

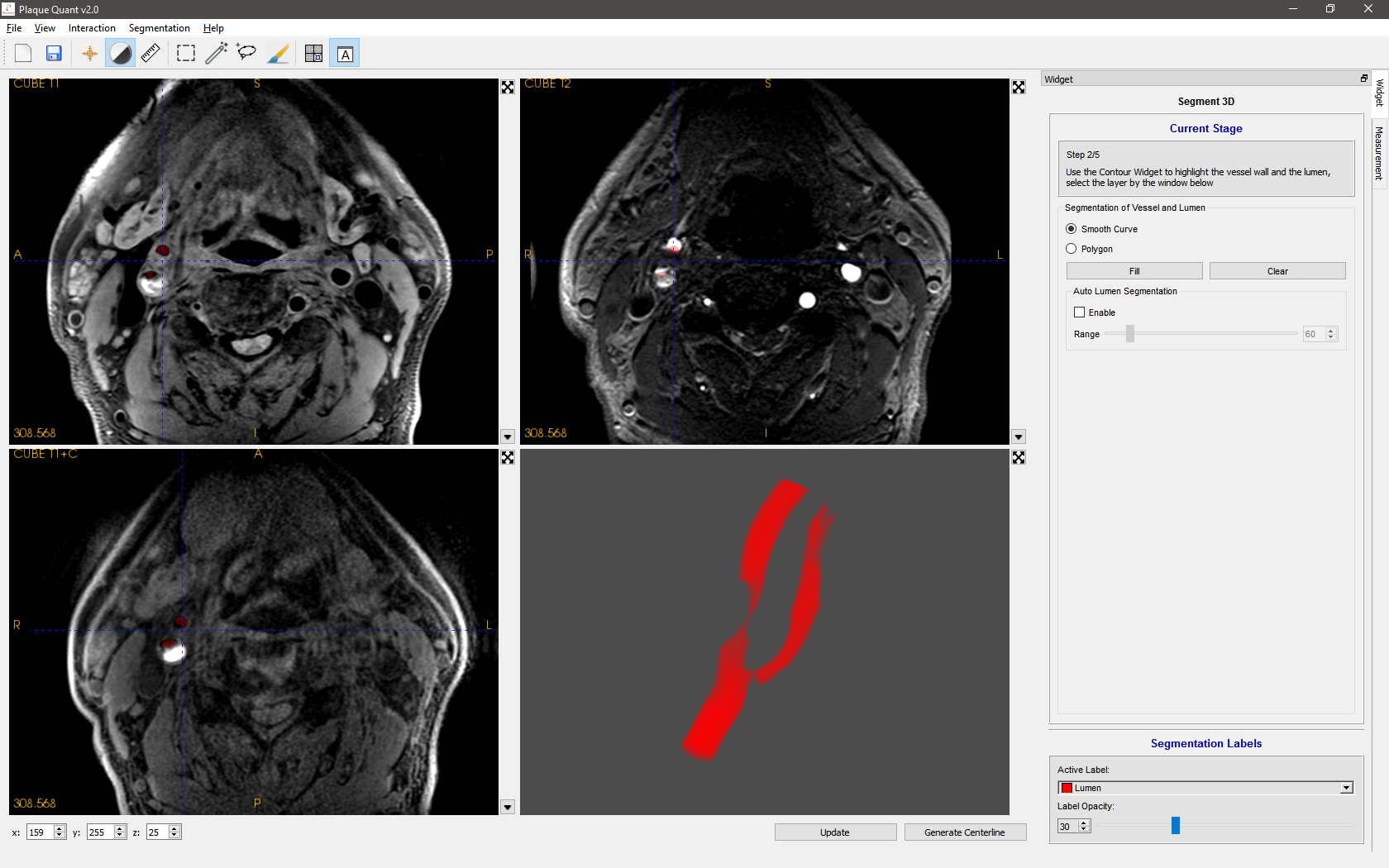


Figure 10 All axial view

### Image Examining

As it has already been written in 3.1, Navigation mode, level & width mode and distance mode are 3 modes for user to examine their images.

#### Navigation C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\Navigation.png

Holding left click: drag the blue cursor and the intensity in the lower left will update synchronously.

Middle button: drag the image position.

Holding right click: up to zoom-in, down to zoom-out.

Keyboard “r”: reset the image position.

#### Level & Width C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\WindowLevel.png

Holding left click: change the 2D viewer’s window level and window width. While moving vertically, the window level will change. While moving horizontally, the window width will change.

#### Distance Measurement C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\Ruler.png

The first left clicks: place a begin point of the distance widget.

The second left click: place an end point of the distance widget.

Both points have been placed: left click to drag one of those points to alter points’ positions.

By checking “Show Maximum Wall Thickness” checkbox, the distance widgets will automatically pair to the current position where maximum wall thickness locates.

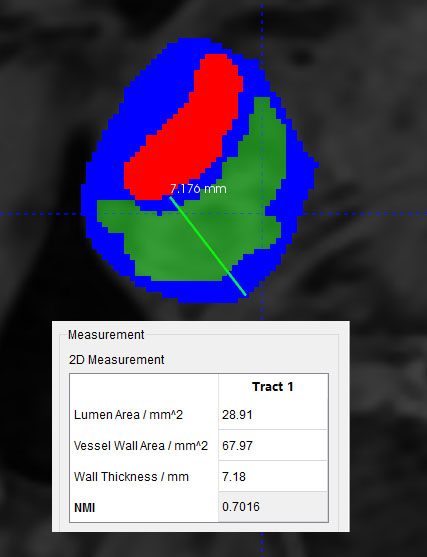


Figure 10 Show Maximum Wall Thickness

### Image Editing

As it has already been written in 3.1, ROI mode, contour mode and paint brush mode are 3 modes for user to do segmentation. User is supposed to follow the hint on the right. Extracting ROI(Optional) -> Using contour widget for doing segmentation -> Using paint brush for optimizing segmentation

#### ROI(Optional) C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\roi.png

In this mode, user is supposed to select their region of interesting for segmentation, but this is not compulsory.

In every view, the frame has borders which are used as change its sizes. Anytime the size of the frame is changed, its configuration will be updated on the right.

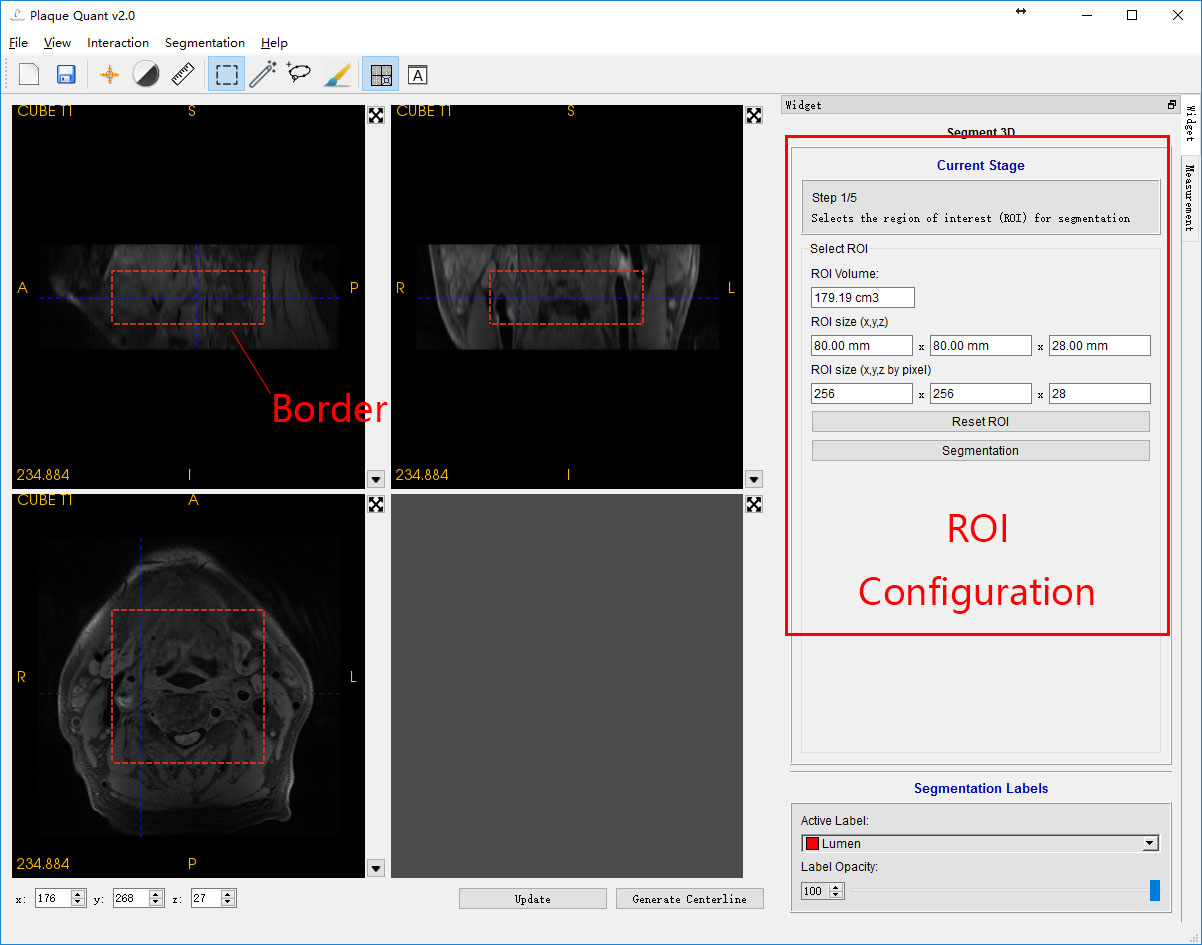


Figure 11 ROI selection

After finishing changing the frame, user can click segmentation to extract the ROI.

If user is not satisfied, please click Reset ROI again and redo the upper procedures.

#### Seeds Placer

In this mode, user is supposed to place seeds inside the lumen to extract the draft of lumen. Here an algorithm using region grow method for rapid lumen and vessel wall segmentation.

Normally, the lumen can be easily recognized because its homogeneous character. In this mode, User first needs to select one of the images whose lumen can be easily recognized by “Target Image”. For doing the lumen segmentation, it need to a few seeds for input. User needs to place seeds on lumen volume of 2D viewers. The seeds they place will display in the “seed browser” by their indexes and coordinates.

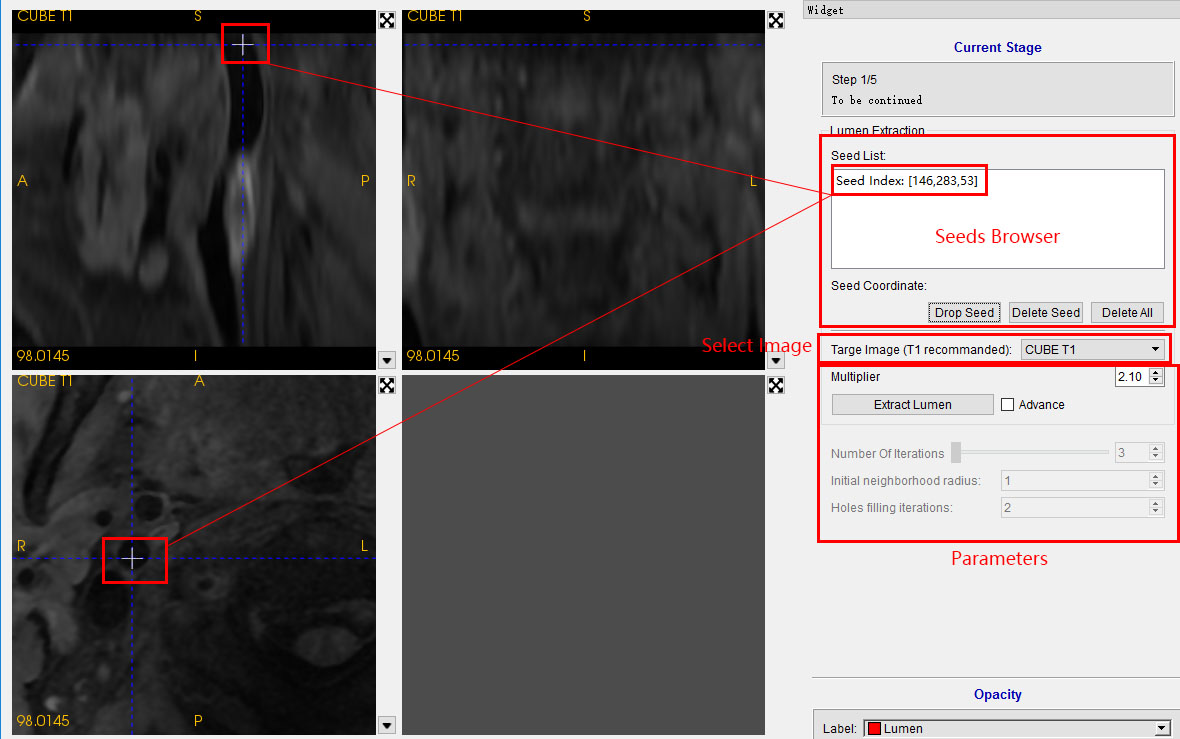


Figure 12 Placing seeds

Using these seeds and the parameters, “Multiplier” and “Initial Neighborhood Radius”, Smart contour can generate a new segmentation of lumen to replace the current segmentation by clicking “Extract lumens”. User is supposed to do some examining of the lumen segmentation and modifying. After that, user can generate the lumen and vessel wall contour on the 2D viewers which are axial view by clicking “Generate Contour”. User is supposed to do some examining and modifying of the contour. By clicking “Draw Segmentation”, smart contour can generate a new segmentation of lumen and vessel wall to replace the current segmentation.

Generally, users can take reference to the follow the steps:

1. Place one to three seeds inside lumen as separated as possible.
2. Press “Extract Lumen” to automatically calculate the lumen.
3. If the resultant red label fill the whole viewer, reduce the value of “Multiplier” and retry step 2 until satisfied.
4. If the resultant red label is fills up only small portion of lumen, increase the parameters “Multiplier” and “Initial Neighborhood Radius” and retry step 2 until satisfied.
5. If there are still unsatisfactory holes at the top/bottom of the segmentation, use “Paint Brush” mode to fill them up. (reference to 3.6.C)

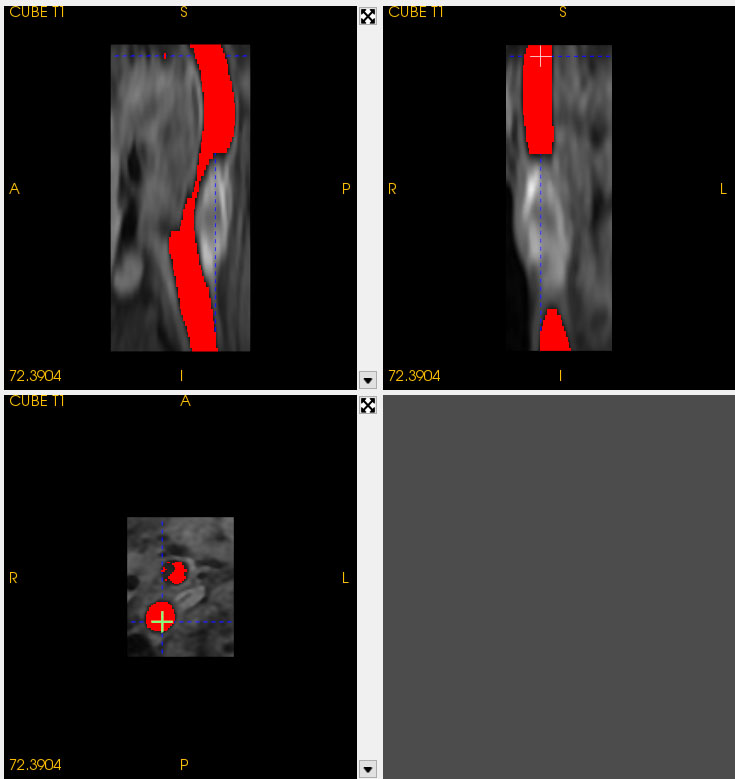


Figure 13 the roughly highlighted lumen

The overall workflow of Smart contour is the following:

Figure 14 Smart Contour Workflow

**Placing seed:**

Left click on 2D viewer: place a seed on the cursor position.

Hold left click on seed: modify a seed’s location

Left click on the seed of seed browser: Set cursor of 2D viewers to the highlighted seed.

“Drop Seed” button: Drop a seed on the current cursor position.

“Delete Seed” button: Delete the highlighted seed.

“Delete All” button: Delete all seeds

#### Contour C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\contour.png

In this mode, user is supposed to use contour to do the lumen and vessel wall segmentation.

Normally the vessel wall and lumen are easily recognizable in axial view. So, user is suggested to only using contour in axial-view 2D viewer or change to axial view of multi-modality. User is also suggested to maximize the working 2D viewer for better performance (3.1 viewer).

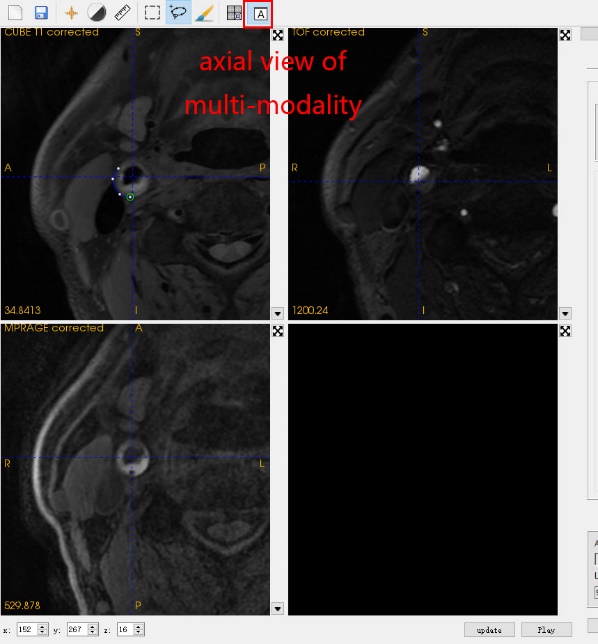
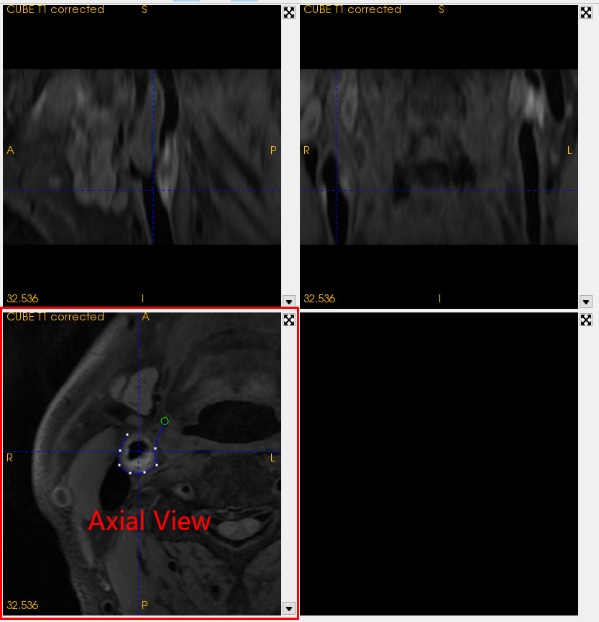


Figure 12 Axial view

One the right is the configuration of contour mode. User can select using polyline contour or smooth curve contour to do segmentation. The software also provides algorithms for doing vessel wall and lumen segmentations in different contour mode.

No Segmentation:

A normal contour, user can use it to fill up voxels inside the contour with different labels.

Lumen Segmentation:

User is supposed to use contours to specify the vessel wall contour manually. By setting range in “Auto Lumen Segmentation”, contours of the lumen can be generated automatically.

Vessel Wall Segmentation:

User is supposed to highlight the lumen with lumen label beforehand (Please reference to 3.6.B, “Seeds Placer” can highlight a rough lumen automatically). The mode is suggested to use in generating all the rough vessel wall contour by doing expanding the lumen. By setting the range in “Auto Vessel Wall Segmentation”, user can decide the expanding rate. This mode can generate lumen contours and vessel wall contours at the same time.

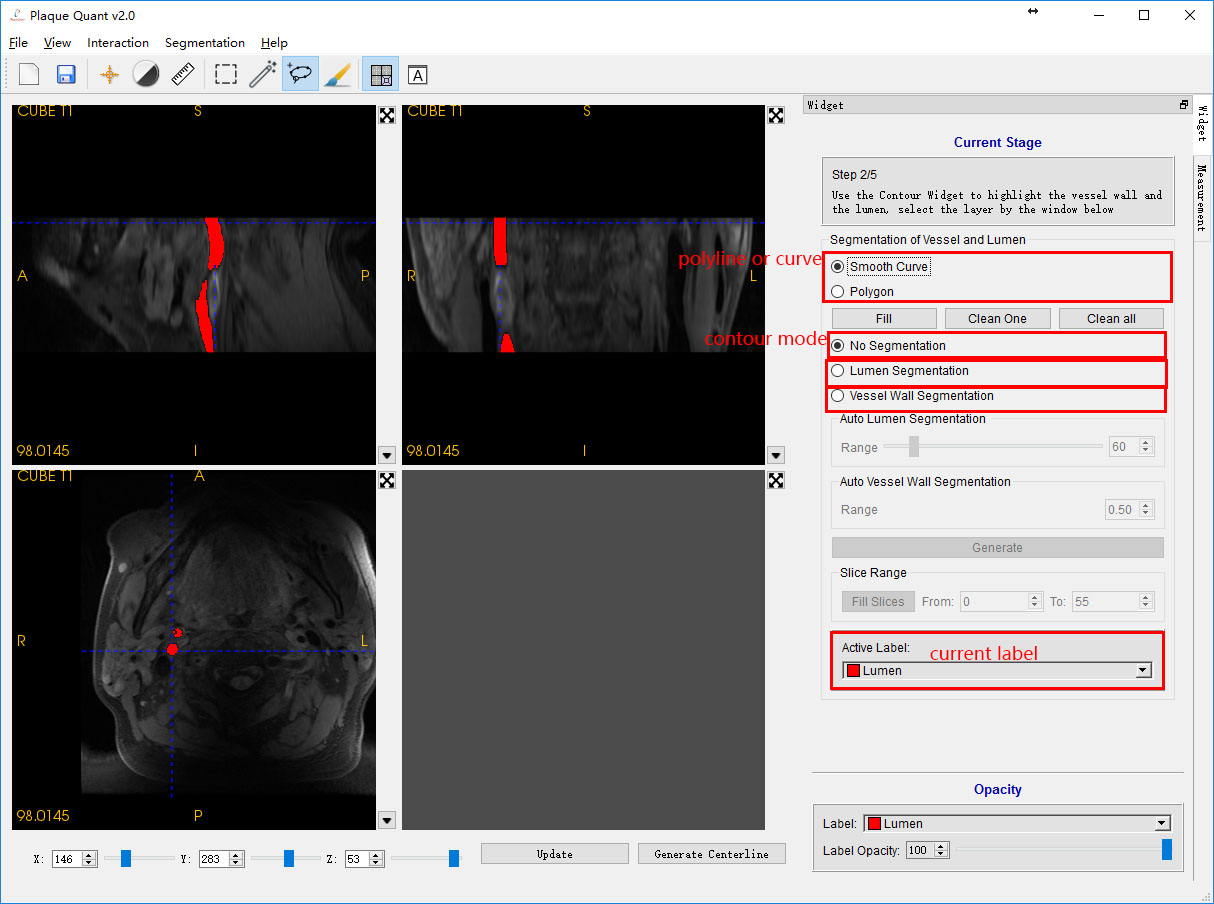


Figure 12 Contour Drawing

**General:**

Keyboard “Esc”: delete the whole contour widget

Keyboard “Delete”: Delete a last node if contour is not close loop, or delete the close node.

Left click: Placing a new contour node or manipulate a close node.

Holding left click: Continuously placing contour nodes.

Right click: Placing the last contour node of the current contour and close loop.

“Fill” button: Fill all contours with the current label.

“Clean One” button: Delete the last contour.

“Clean all” button: Delete all the contours in 2D viewer.

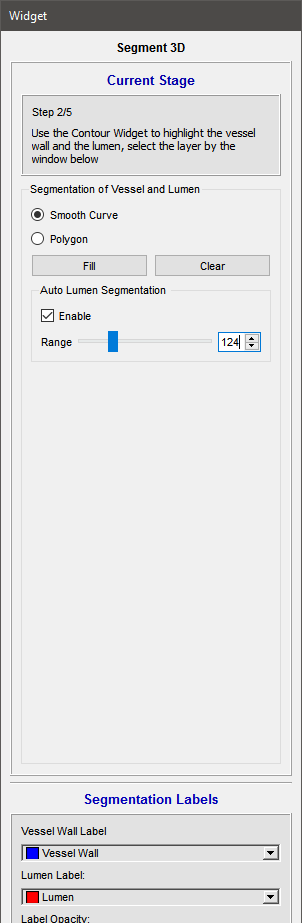
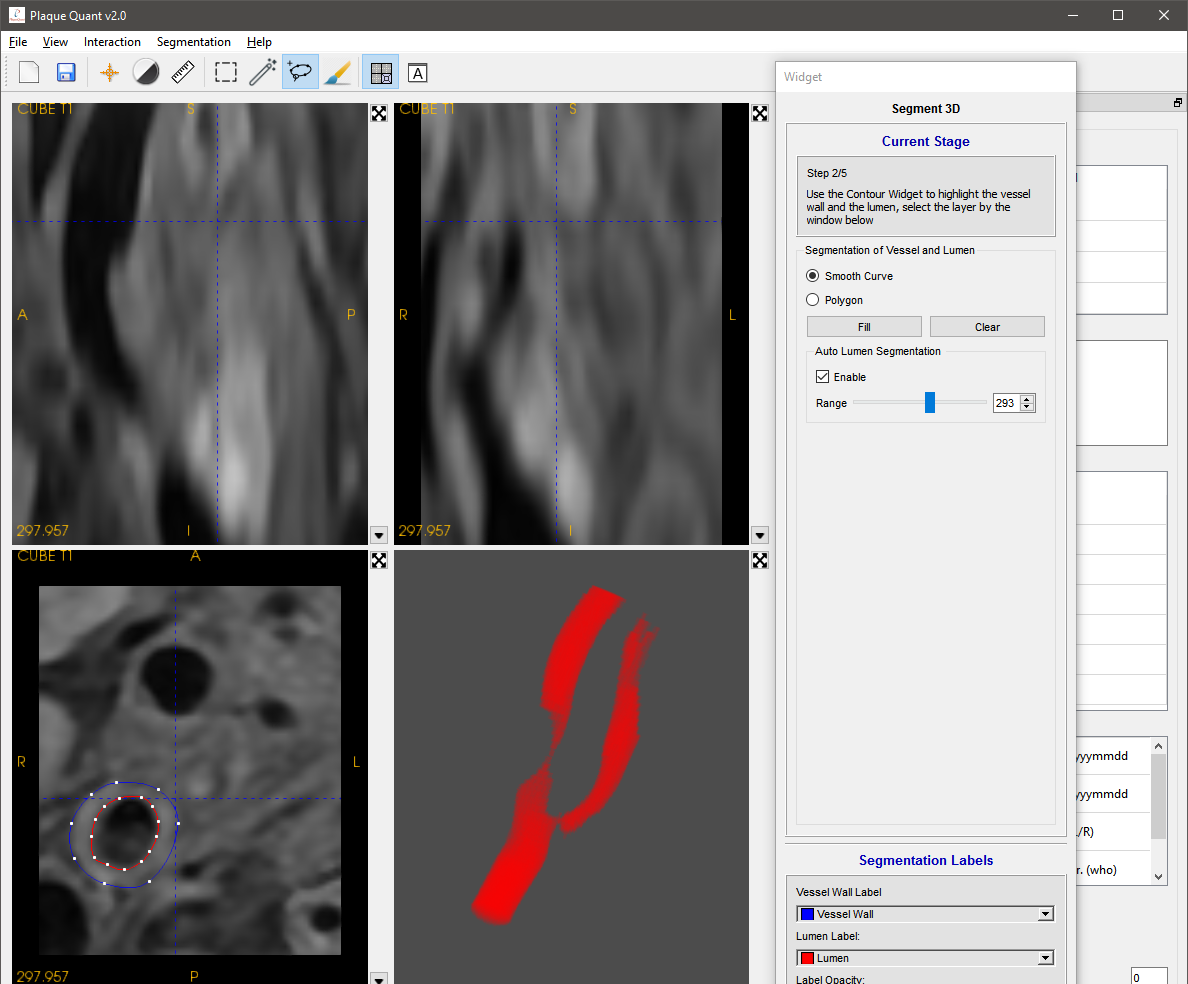
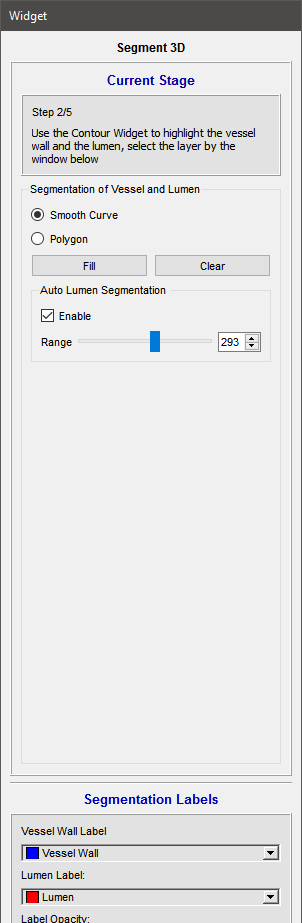
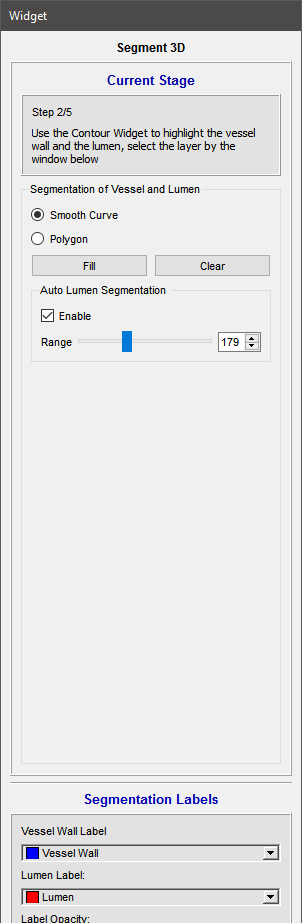
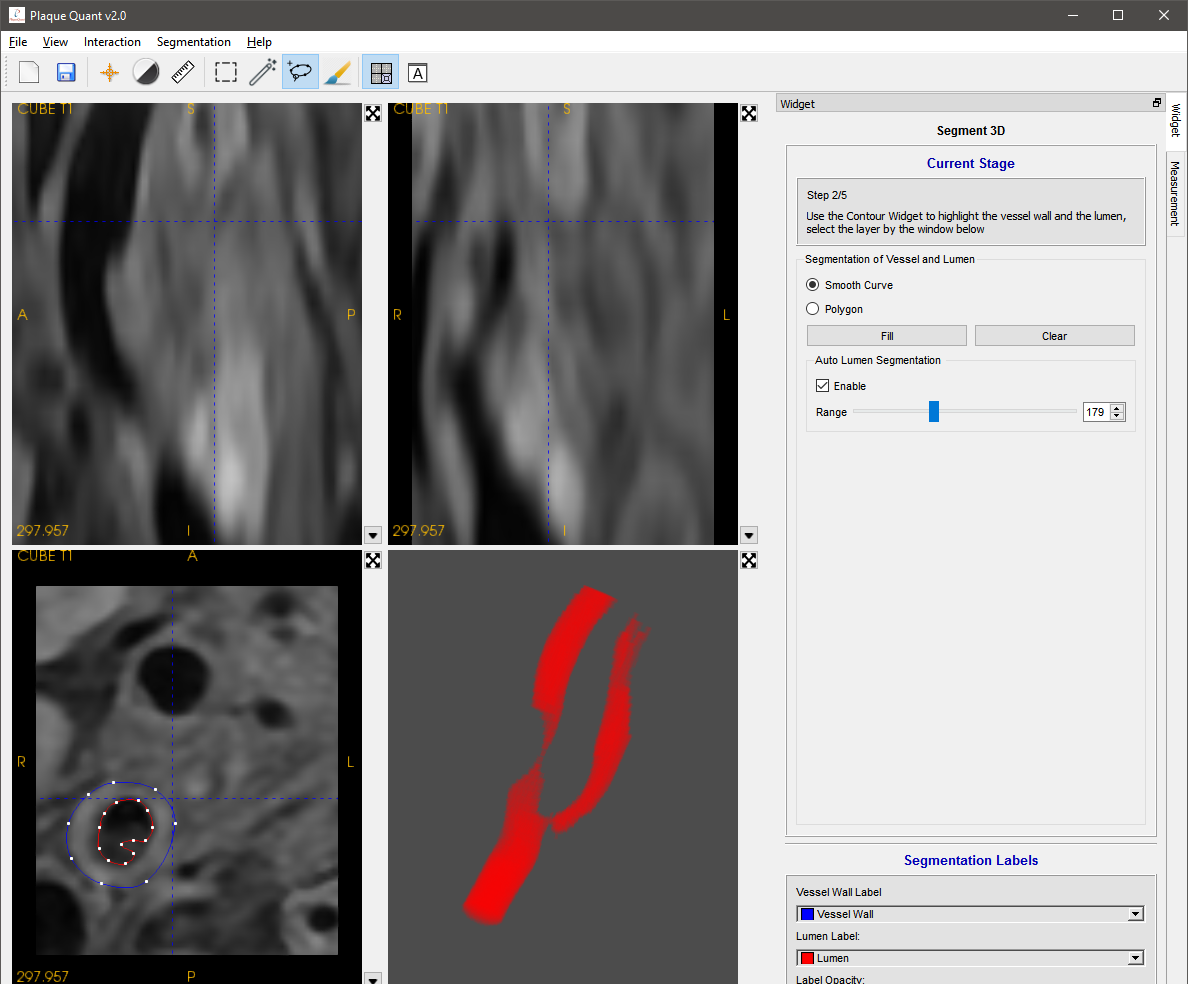
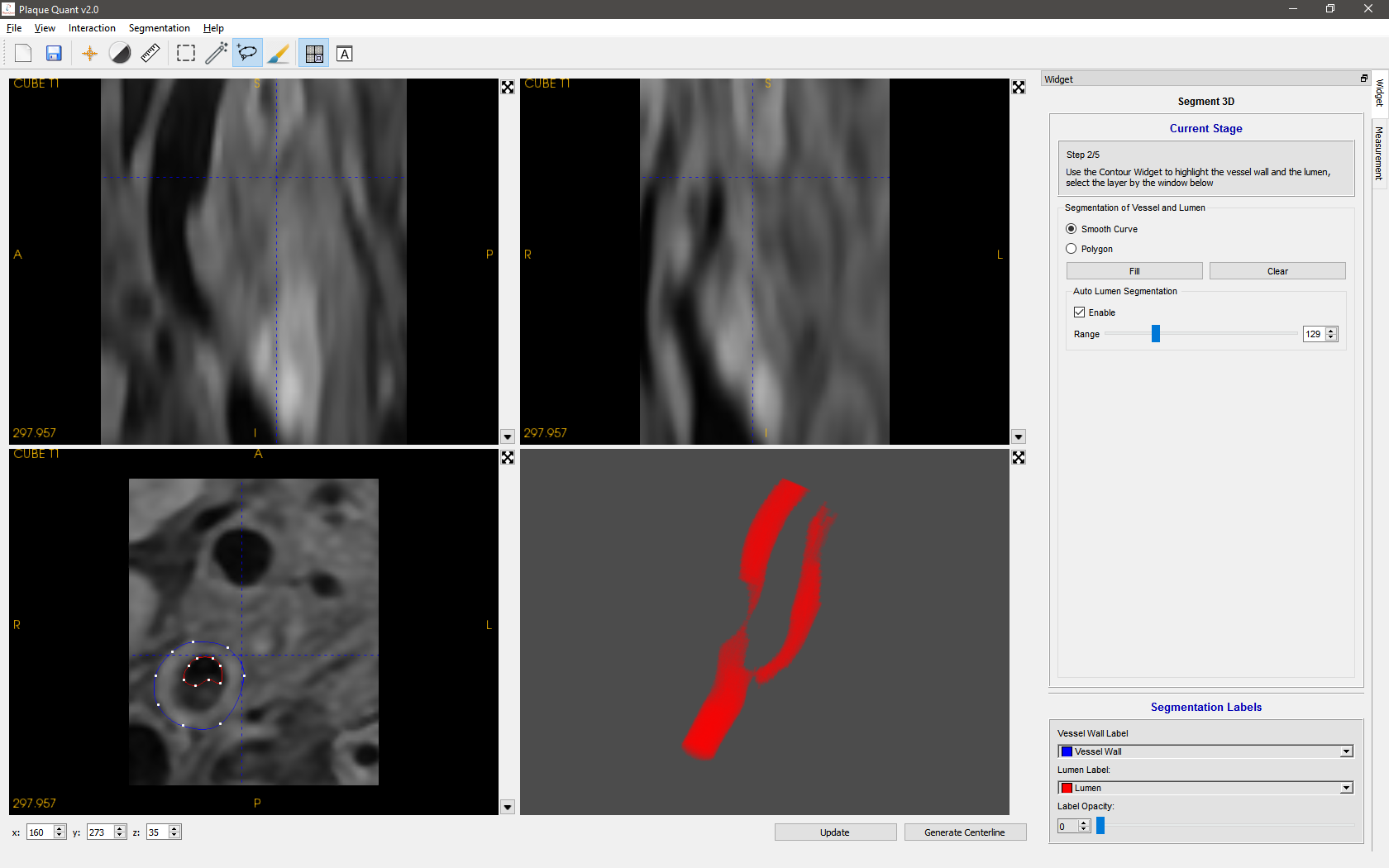
**No Segmentation:**

The contour can be used in any situation. This general contour will not be record.

**Lumen segmentation mode:**

The contour is specified to highlight lumen in axial view.

Modifying the range of “Auto Lumen Segmentation” to determine the threshold used to estimate the lumen, which generally has a much lower intensity.



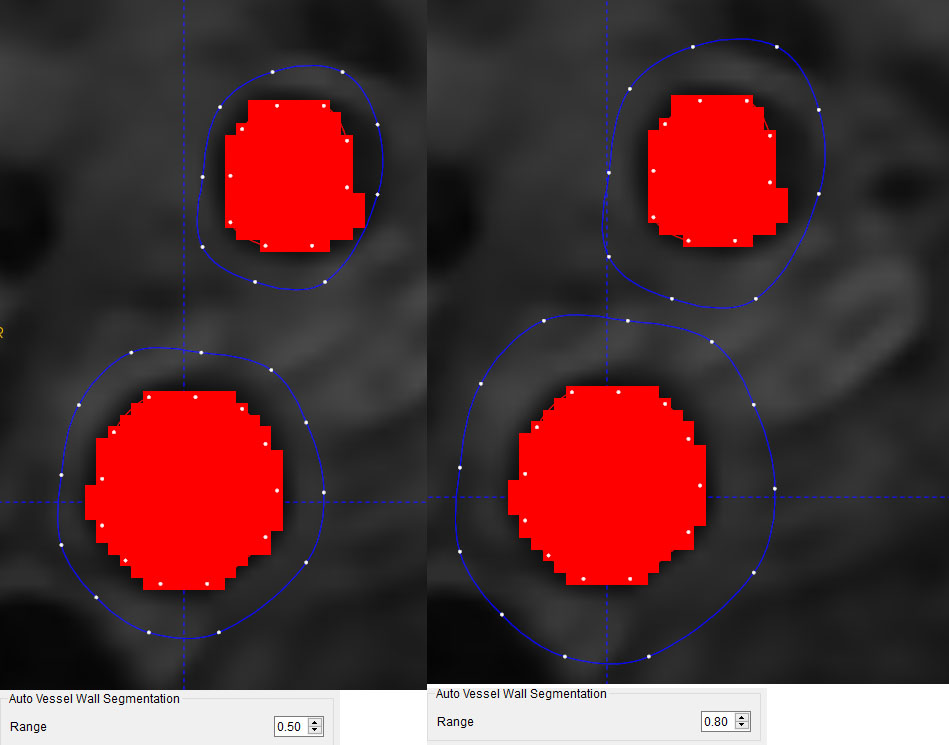
Any modification of the lumen and vessel wall contours can be record in real time.

“Fill Slices” button: Fill all slices with the current labels in the specified range.

**Vessel wall segmentation mode:**

The contour is specified to highlight Vessel Wall in axial view.

Modifying the range of “Auto Vessel Wall Segmentation” to determine expanding vessel wall contour.



Any modification of the lumen and vessel wall contours can be record in real time.

“Fill Slices” button: Fill all slices with the current labels in the specified range.

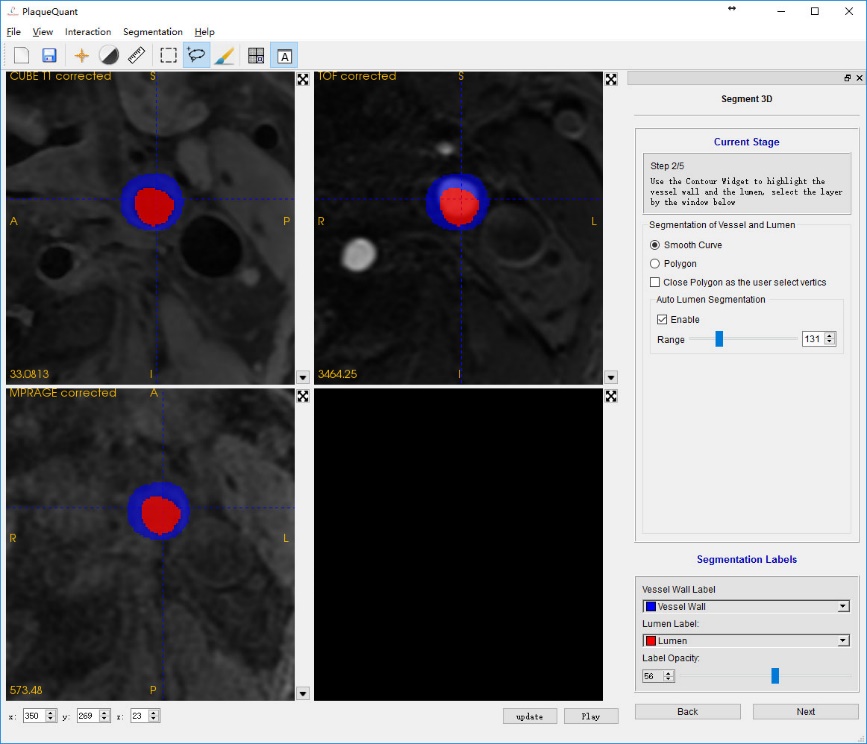


Figure 13 Segmentation result

In axial view of multi-modality mode, user can compare the segmentation result in different modality.

#### Paint brush C:\Users\jieji\AppData\Local\Microsoft\Windows\INetCacheContent.Word\Draw.png

In this mode, user is supposed to use paint brush to optimize their segmentation result.

Paint brush is a quite straight forward widget for user to do segmentation. However, it is too time consuming to do all segmentation manually. Using contour should be the best option. But user can still use paint brush to optimize their segmentation and add other label, such as calcification, hemorrhage.

On the right side is the paint brush configuration. User can change the brush size and brush shape. The lower part is for selecting paint brush label.

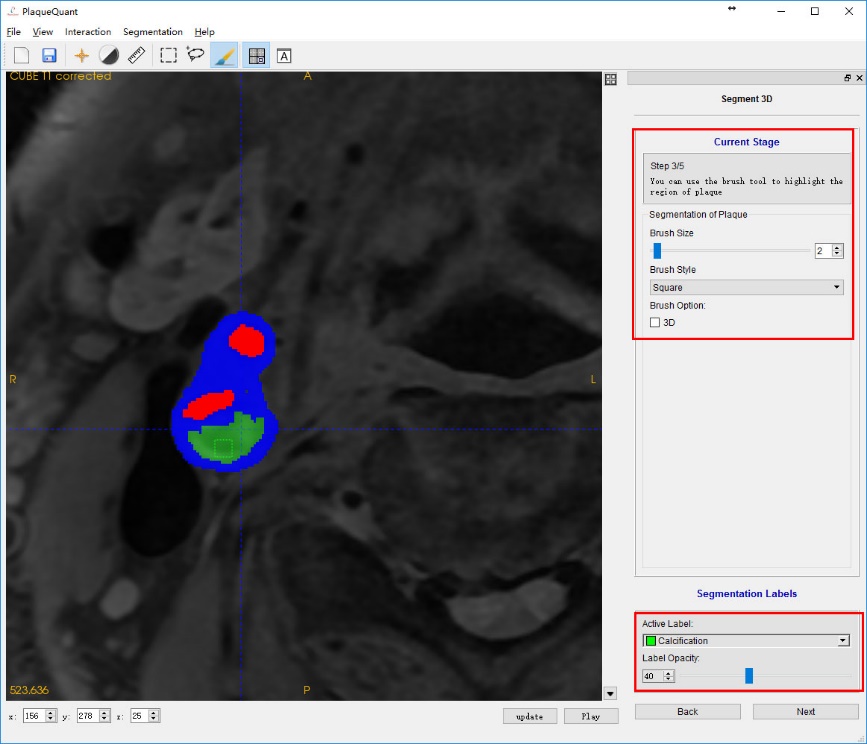


Figure 14 Paint brush

Holding left click: Draw with the active label.

Holding right click: erase the label and replace with nothing.

### 2D & 3D Numerical Measurements

After finishing editing segmentation, user can get 2D & 3D numerical measurements from the software. All the measurements can be updated in real time when user changes the current slice.

#### 2D Numerical Measurements

2D numerical measurements provide following straight forward data of current slice:

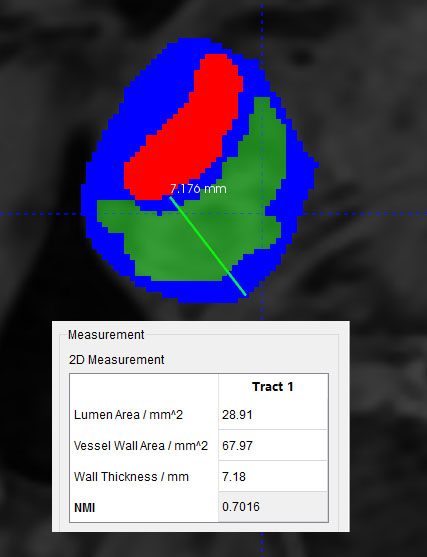


Figure 17 Maximum Wall Thickness

|  |  |
| --- | --- |
| Quantity | Details |
| Lumen area (mm2) | the area of label “lumen” of current slice |
| Vessel wall area (mm2) | the area of label “vessel wall” of current slice |
| Wall thickness (mm) | the maximum distance between the lumen wall and vessel wall |
| Normalized Wall Index (1) |  |

#### 3D Numerical Measurements

3D numerical measurements provide following straight forward data of the segmentation results:

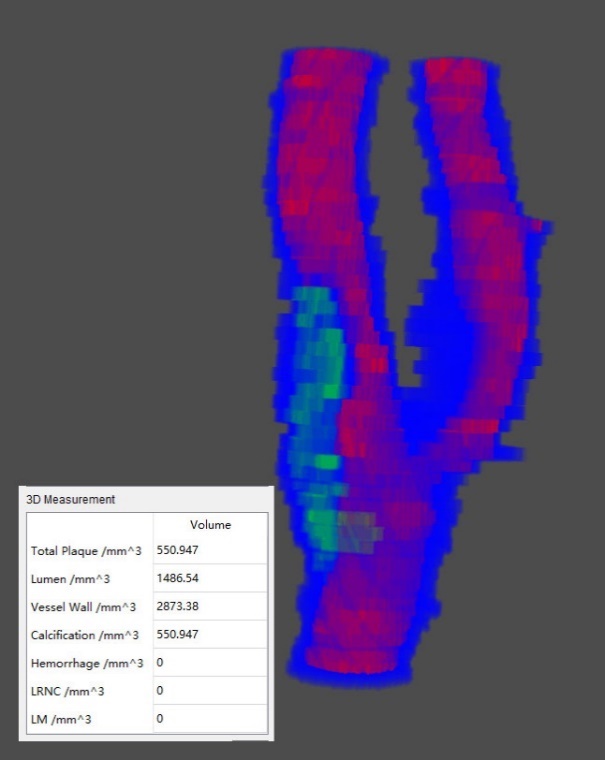


Figure 18 3D Measurements

|  |  |
| --- | --- |
| Quantity | Details |
| Total plaque (mm3) | calcification + hemorrhage + LRNC + LM |
| Lumen (mm3) | lumen volume |
| Vessel wall | vessel wall volume |
| Calcification | calcification volume |
| Hemorrhage | hemorrhage volume |
| LRNC | LRNC volume |
| LM | LM volume |

#### Stenosis

The software also provides an intuitive quantity named “Normalized Wall Index” (NMI) for user to measure severity of stenosis:

The user is supposed to use ROI mode to remove redundancy (the bottom part and the top part of the segmentation should be removed). By selecting ROI and click “segmentation” on the segmentation window. Then changing the opacity of every label (such as 5) in case of blocking the sight

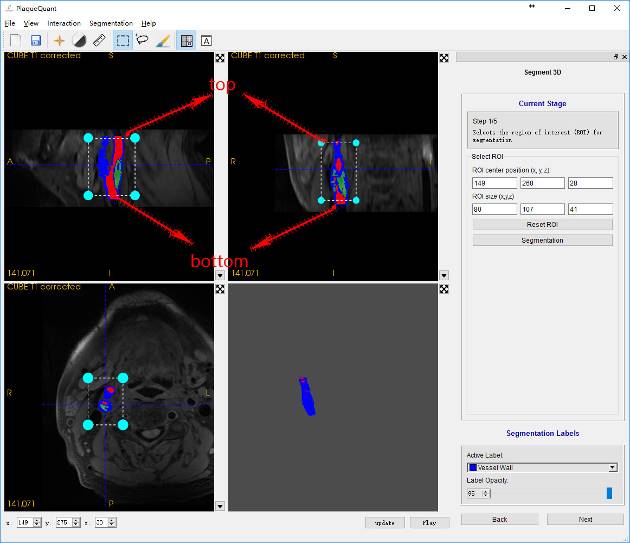


Figure 19 ROI selection

After that user is supposed to click “update” to render their segmentation. This time the center line of the vessel can be seen clearly in the 3D viewer.

User should select 2 points on the center line by pressing keyboard “Enter”, a sphere on the center line will label the selected location and keyboard “Delete” will clear all spheres. User should define their own 2 spheres location. After 2 spheres have been specified, the stenosis will be automatically filled for the user.

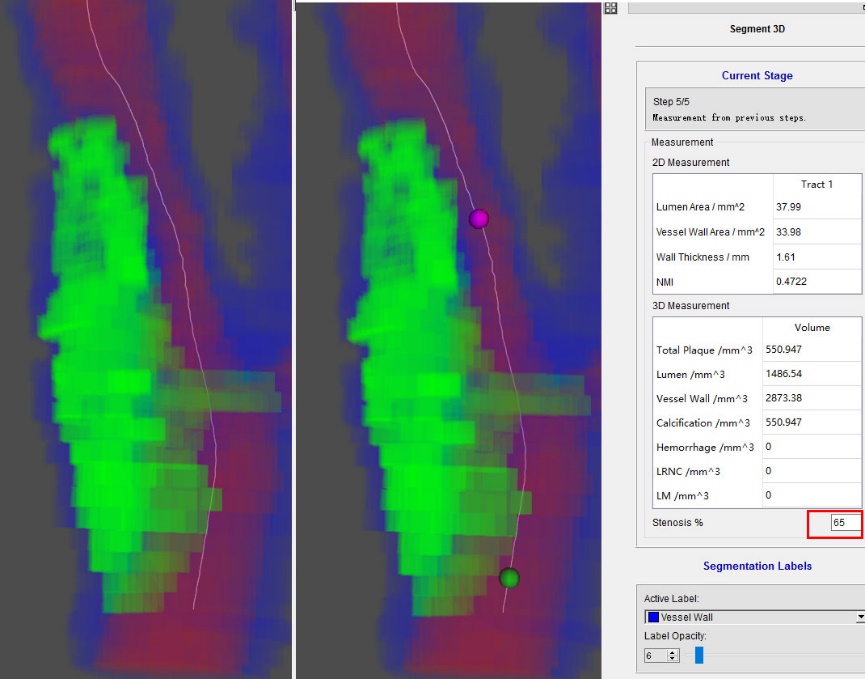


Figure 20 Reference & Stenosis point selection

### Generate Report

After finishing all segmentation, user can generate their own report for their particular images. The report generated by the software have all most important data from the segmentation.

The user is supposed to change the slice of lower left 2D viewer and view angle of 3D viewer which they are interested in. The report generator will generate a report which is based on these 2 viewers, the 2D & 3D numerical measurements and information from DICOM images.

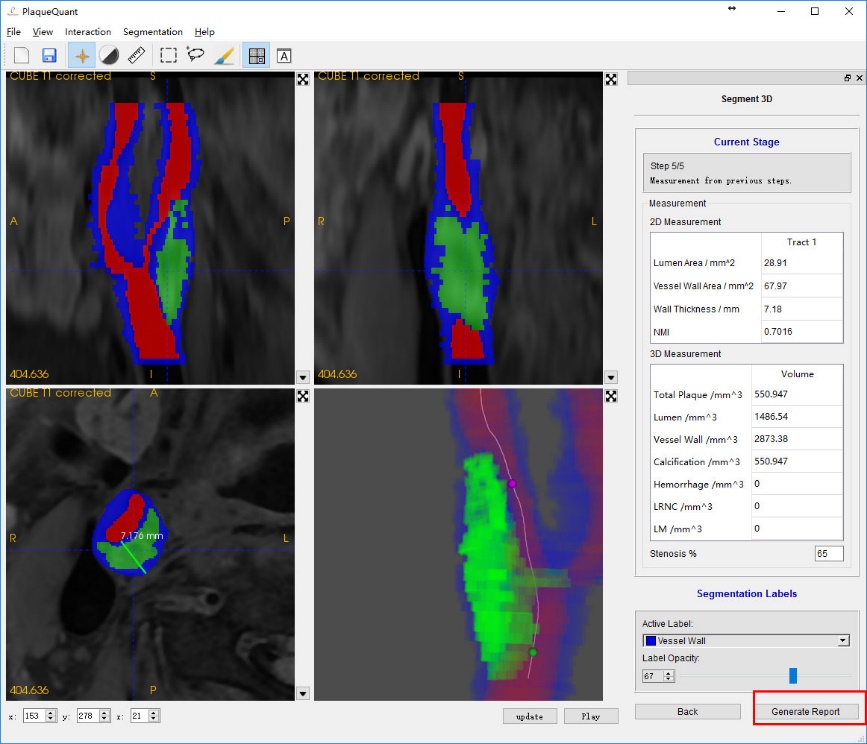


Figure 21 Generate report

### Saving & Opening Segmentation

Users are advice to save their segmentation from time to time since the auto recovery function is yet to be implemented.

User can click “File->save” on the menu bar or “save” on the tool bar to save their segmentation result. The segmentation will be saved in NIFTI format.

User can also open their segmentation again after open their original image, by clicking “segmentation->open segmentation” on the menu bar.

## Known Issues

1. Discontinuous segmentation results in several functions failures.
2. Opacity cannot be updated real time for 3D volume rendering.
3. Centerline extraction might fail if there are outliners, such as miss drawn point outside of the vessel or a hole inside the lumen, in the segmentation.