NA-MIC
National Alliance for Medical Image Computing
http://www.na-mic.org

Cardiac Agatston Scoring

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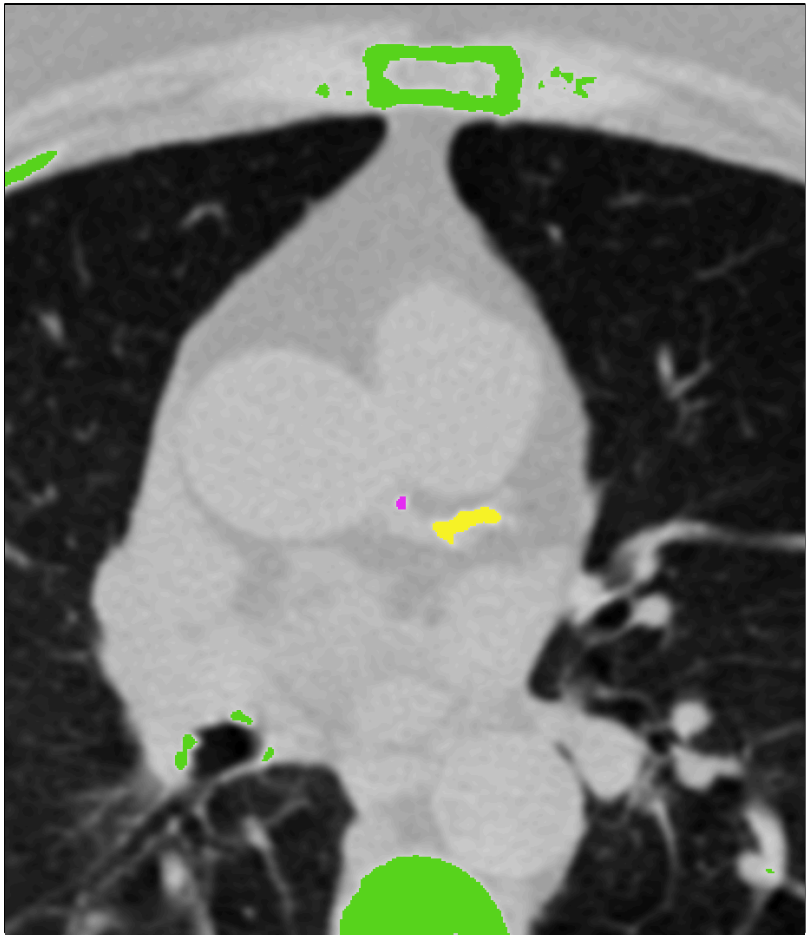
NA-MIC Tutorial Contest: Summer 2014

Learning Objective

This tutorial demonstrates a semi-automated method to segment and identify coronary artery calcium plaques from EKG-gated non-contrast cardiac CT scans. Then calculate the Agatston score.

Following this tutorial, the user will be able to load scans into Slicer4.3.1, segment calcium plaques, then calculate the Agatston score and label statistics.



Pre-requisite

Pre-requisite Slicer tutorial:

"Data loading and 3D visualization"

Author: Sonia Pujol, Ph.D.
http://www.slicer.org/slicerWiki/index.php/Documentation/4.3/Training

Pre-requisite heart anatomy tutorial:

"Coronary anatomy and anomalies"

http://www.radiologyassistant.nl/en/p48275120e2ed5/coronary-anatomy-and-anomalies.html

Pre-requisite

Pre-requisite heart anatomy tutorials (suggested):

Useful 5 minute video tutorials for identifying coronary arteries in CT scans

- “Left Main Coronary Artery on Axial Coronary CTA”
  https://www.youtube.com/watch?v=L-p6ccODSps
- “Left Anterior Descending Coronary Artery Anatomy on CTA”
  https://www.youtube.com/watch?v=eogwmcCnnlY
- “Left Circumflex Coronary Artery Anatomy on CTA”
  https://www.youtube.com/watch?v=erijmkOR1IM
- “Right Coronary Artery on Axial CT”
  https://www.youtube.com/watch?v=4hSaJqEyRCc

Material

This tutorial requires the installation of the Slicer4.3.1 release built after 06-05-2014 and the tutorial dataset. They are available at the following locations:

Slicer download page:

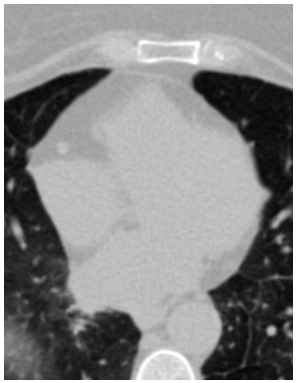
http://download.slicer.org/

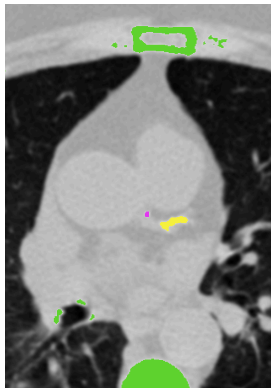
Tutorial dataset:

http://wiki.na-mic.org/Wiki/index.php/File:CardiacAgatstonMeasures_TutorialContestSummer2014.zip

Note: A SimpleITK bug fix occurred on 06-04-2014 that is necessary for this module to function.

Overview





	Index	Label Name	Agatston Score
	2	Left Main (LM)	4.5229
	3	Left Arterial Descending (LAD)	88.3706
	5	Right Coronary Artery (RCA)	24.2671
	6	Total	117.161

Part 1: Load module and data

Part 2: Threshold scan

Part 3: Identify calcium plaques

Part 4: Calculate scores and label statistics

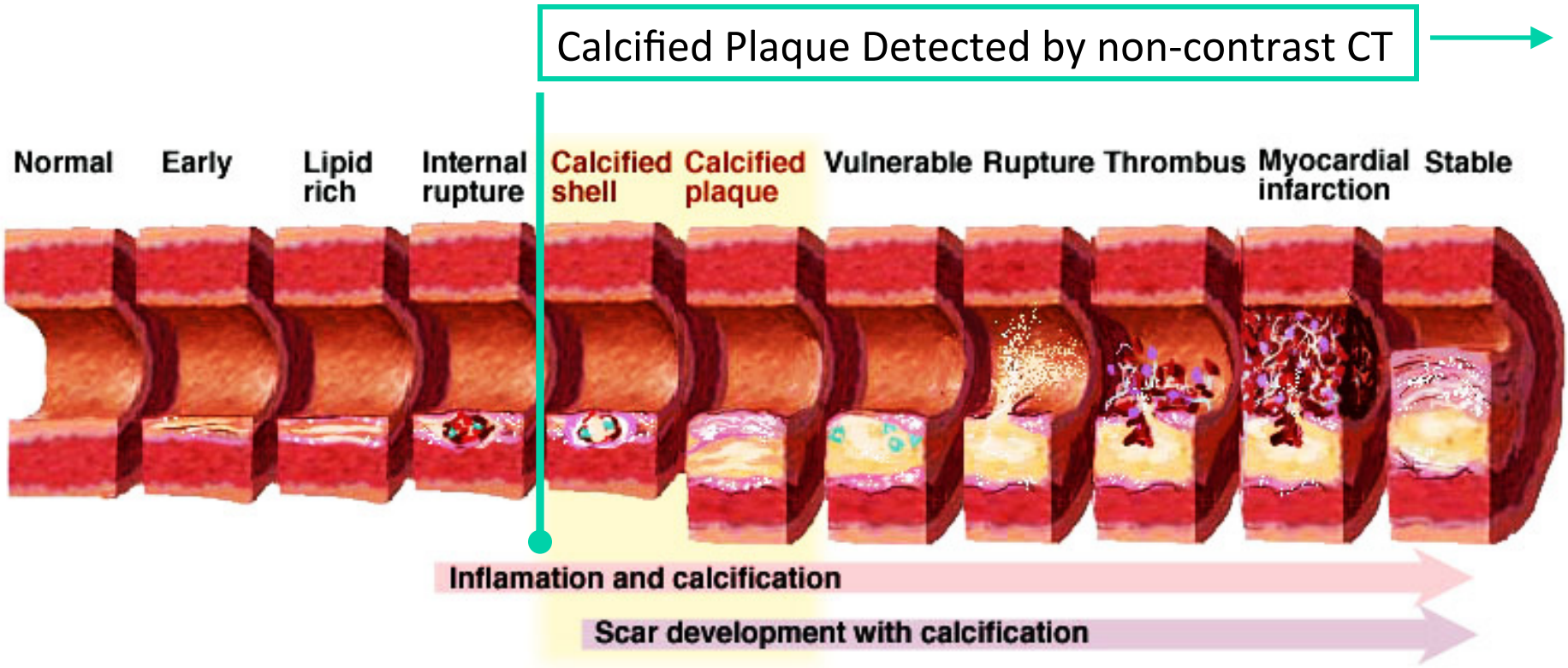
Part 5: Save results

Background

- Cardiovascular Disease is the leading global cause of death: 17.3 million deaths/year
- USA: 600,000 of heart disease per year*
  - Equates to 1 in every 4 deaths
- 40-60% have no cardiac symptoms before the event**
- Important to identify asymptomatic patients at risk of coronary events

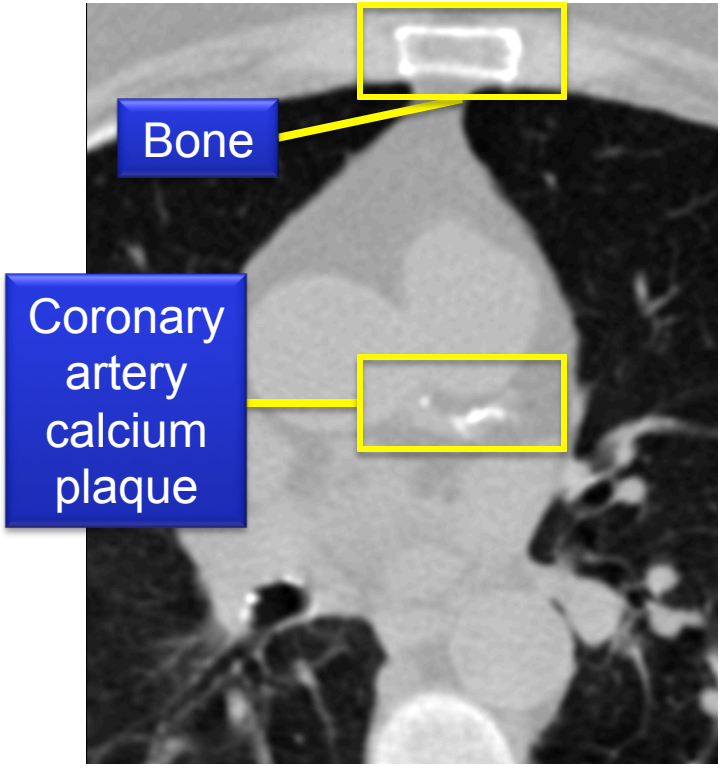
*http://www.cdc.gov/heartdisease/facts.htm, February 19, 2014
**Myerburg et al. *Am J Cardiol 1997* Virmani et al. *Cardiovasc Pathol. 2001*

Background



Coronary arterial calcification is part of the development of atherosclerosis, it occurs almost exclusively in atherosclerotic arteries.

Background

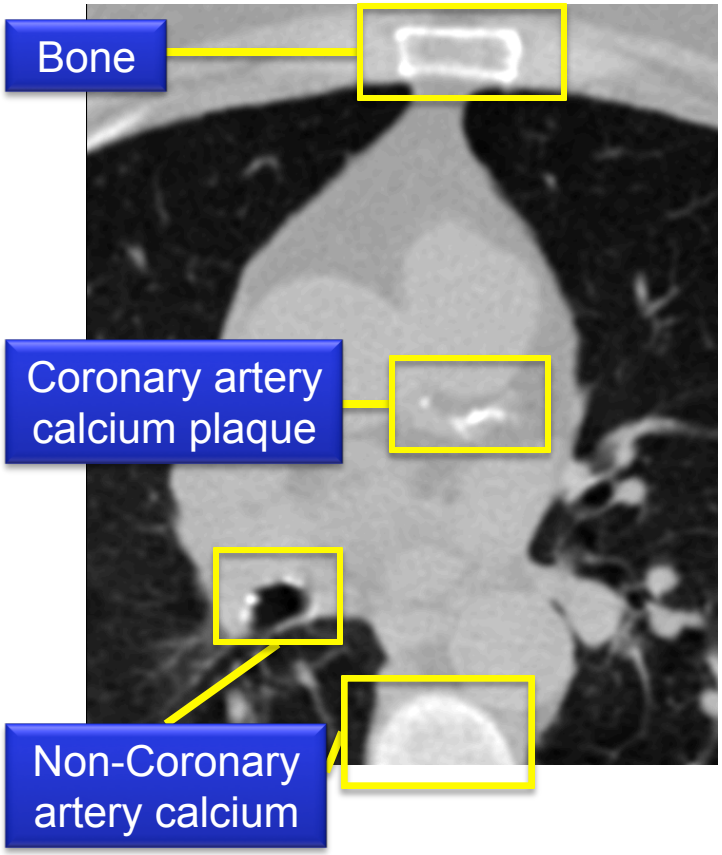


Each pixel of an EKG-gated non-contrast cardiac CT scan has an attenuation/density unit called Hounsfield Unit (HU).

- Water = 0 HU
- Air = -1000 HU
- Calcium > 130 HU

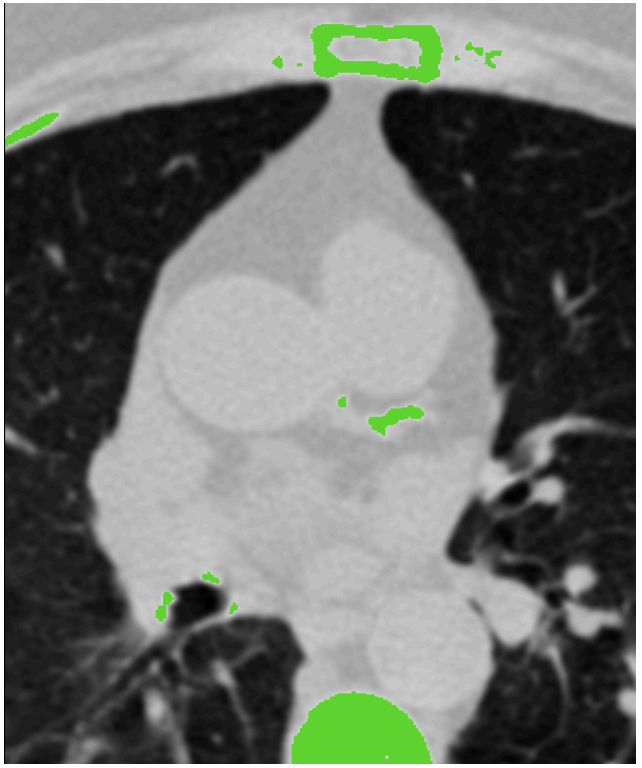
Pixels with an intensity/HU value greater than 130 represent calcium (such as calcium plaque or bones).

Background



A label map representing calcium is created when

the scan is thresholded at a minimum of 130 HU



Background

120 KEV Ranges

HU Range	X-Factor
130-199	1
200-299	2
300-399	3
>= 400	4

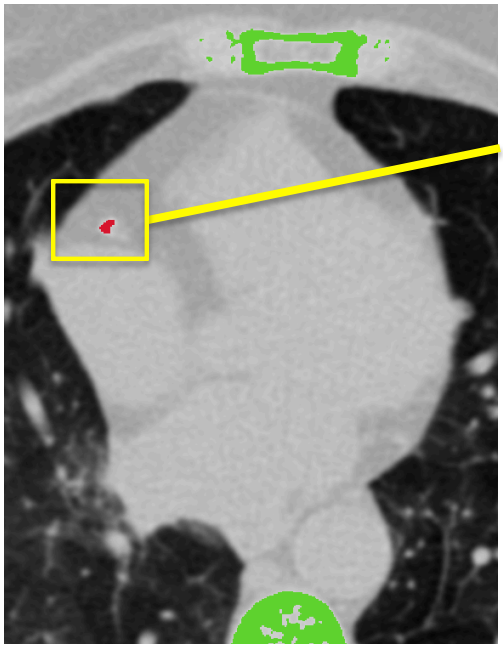
A measurement for quantifying the amount of coronary artery calcium plaque is called the **Agatston score**.

Agatston score = *Area* x *X-Factor*

The score for a single plaque is simply the product of the plaque **area** in that slice and a weighting factor called the **X-Factor**.

The X-Factor is a value between 1 and 4 based on set ranges for the value of the **largest** intensity pixel in the plaque.

Background



Largest Intensity Pixel
190 HU

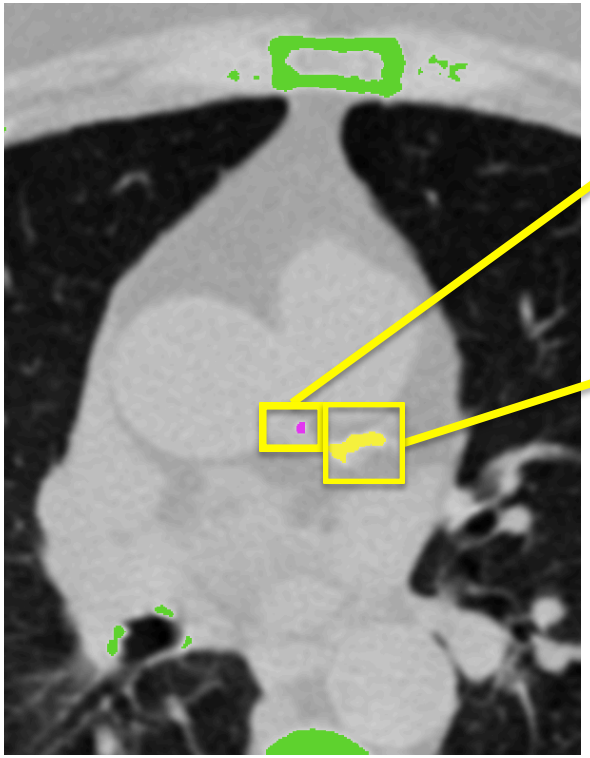
HU Range	X-Factor
130-199	1
200-299	2
300-399	3
>= 400	4

X-Factor = 1

Agatston score = *Area* x *X-Factor*

18 = 18 x 1

Background



Agatston Score = Area x X-Factor
6 = 3 x 2

Agatston Score = Area x X-Factor
88 = 22 x 4

Total Agatston Score = sum of all island Agatston Scores from all slices
94 = 6 + 88 + (scores on other slices)

Background

The Agatston score helps doctors identify pre-symptomatic patients at risk for a cardiac event.

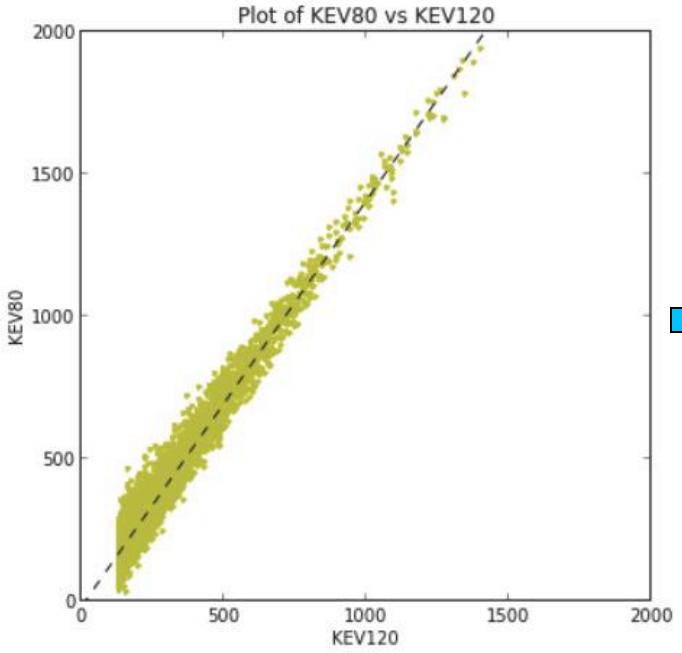
It was developed for use with **120 KEV** scans, but **lower radiation dose** scans such as **80 KEV** scans could give similar scores with **less radiation** exposure to the patient.

Total Agatston Score	Prognosis
0	No identifiable disease
1 - 99	Mild Disease
100 - 399	Moderate Disease
> 400	Severe Disease (>2% annual event rate)

Background

120 KEV Ranges

HU Range	X-Factor
130-199	1
200-299	2
300-399	3
>= 400	4



80 KEV New Ranges

HU Range	X-Factor
167-265	1
266-407	2
408-550	3
>= 551	4

X-Factor ranges were developed for 120 KEV only, so we calculated **new** ranges for **lower radiation** **80 KEV** scans based on HU intensity values.

Background

120 KEV Ranges

HU Range	X-Factor
130-199	1
200-299	2
300-399	3
>= 400	4

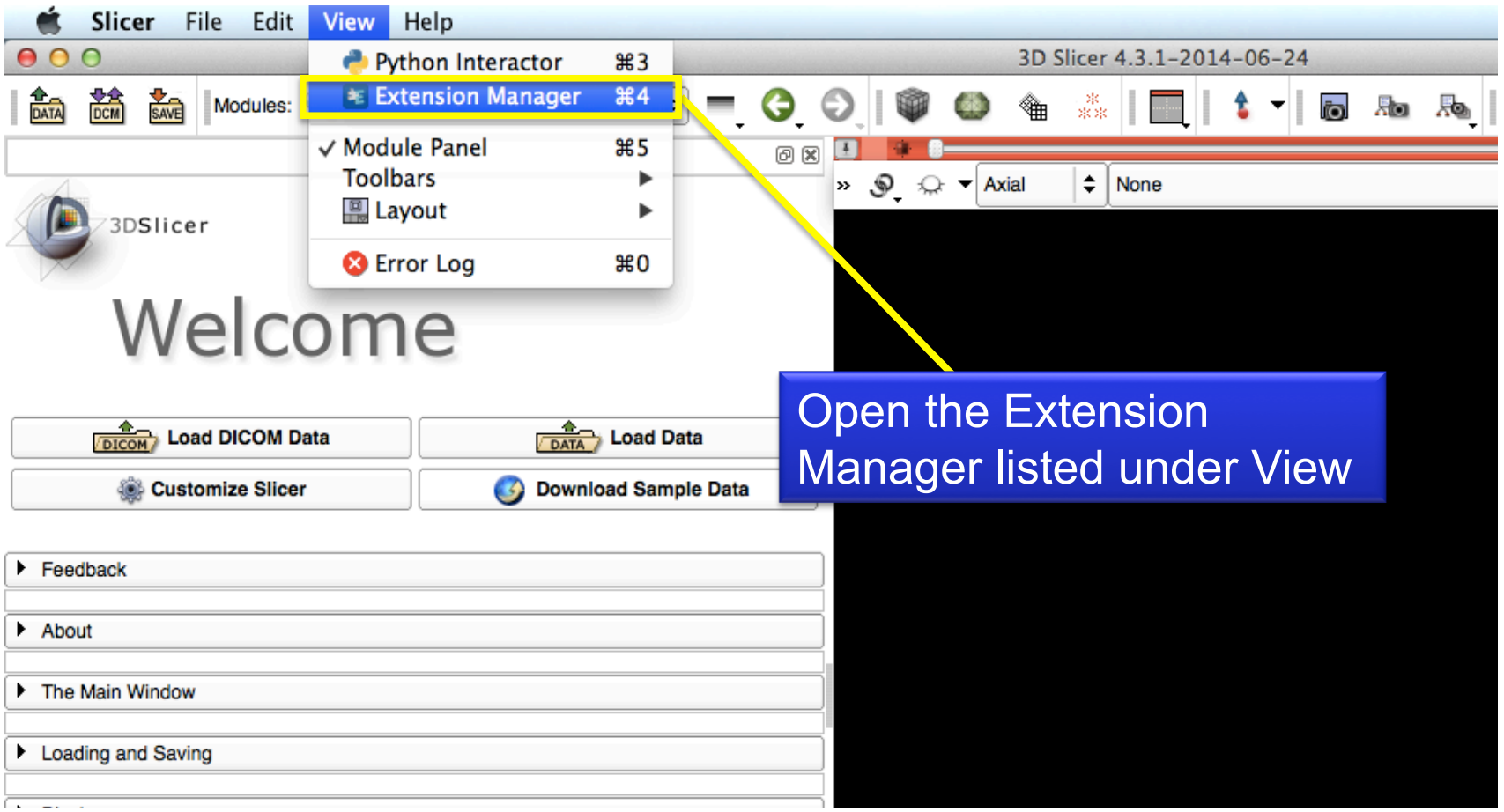
This module allows the user to calculate an Agatston score for either 120 KEV scans **or** 80 KEV scans.

The minimum threshold is set to **167 HU** for 80 KEV based on the new X-Factor ranges and **130 HU** for 120 KEV.

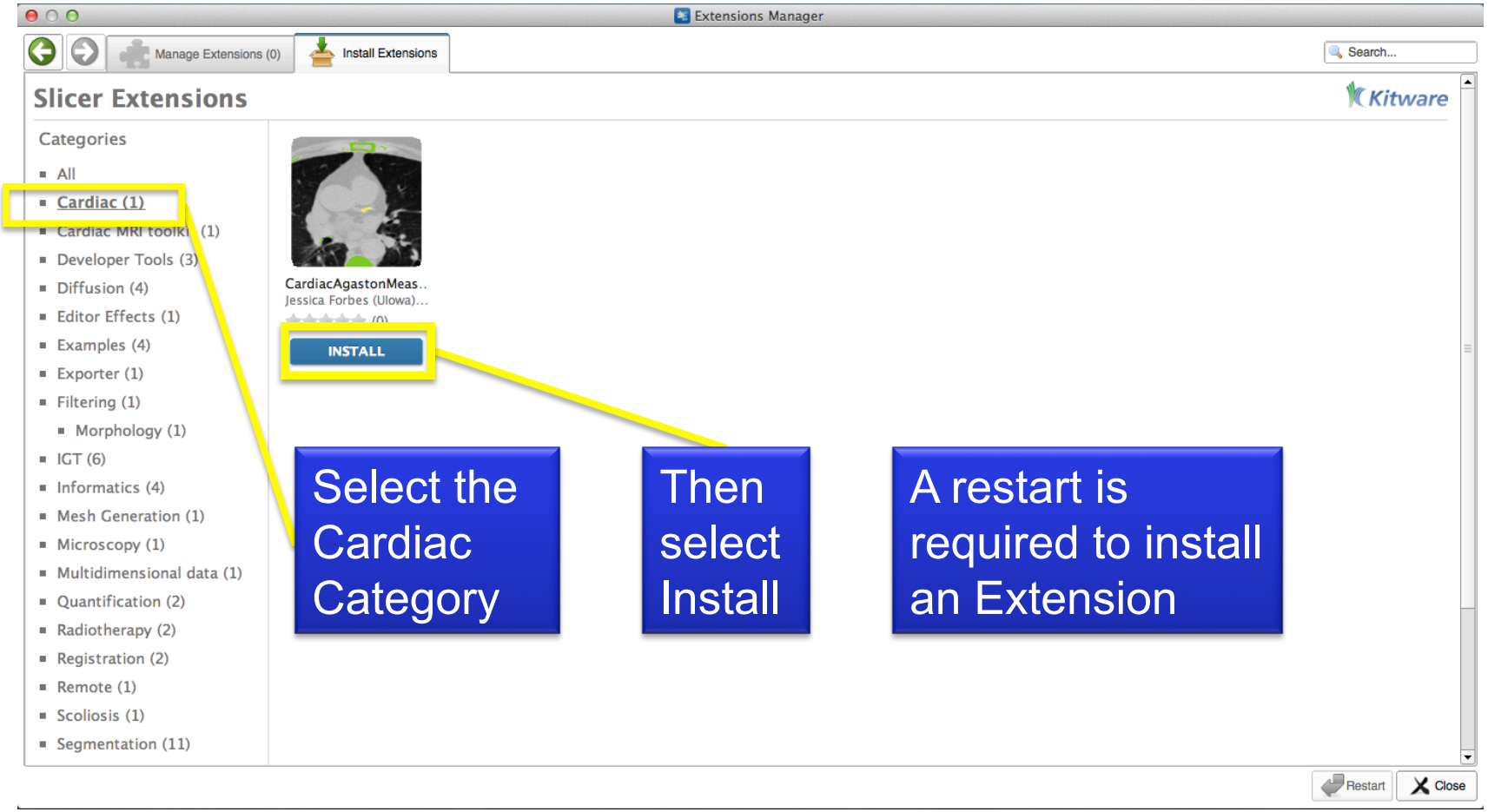
80 KEV New Ranges

HU Range	X-Factor
167-265	1
266-407	2
408-550	3
>= 551	4

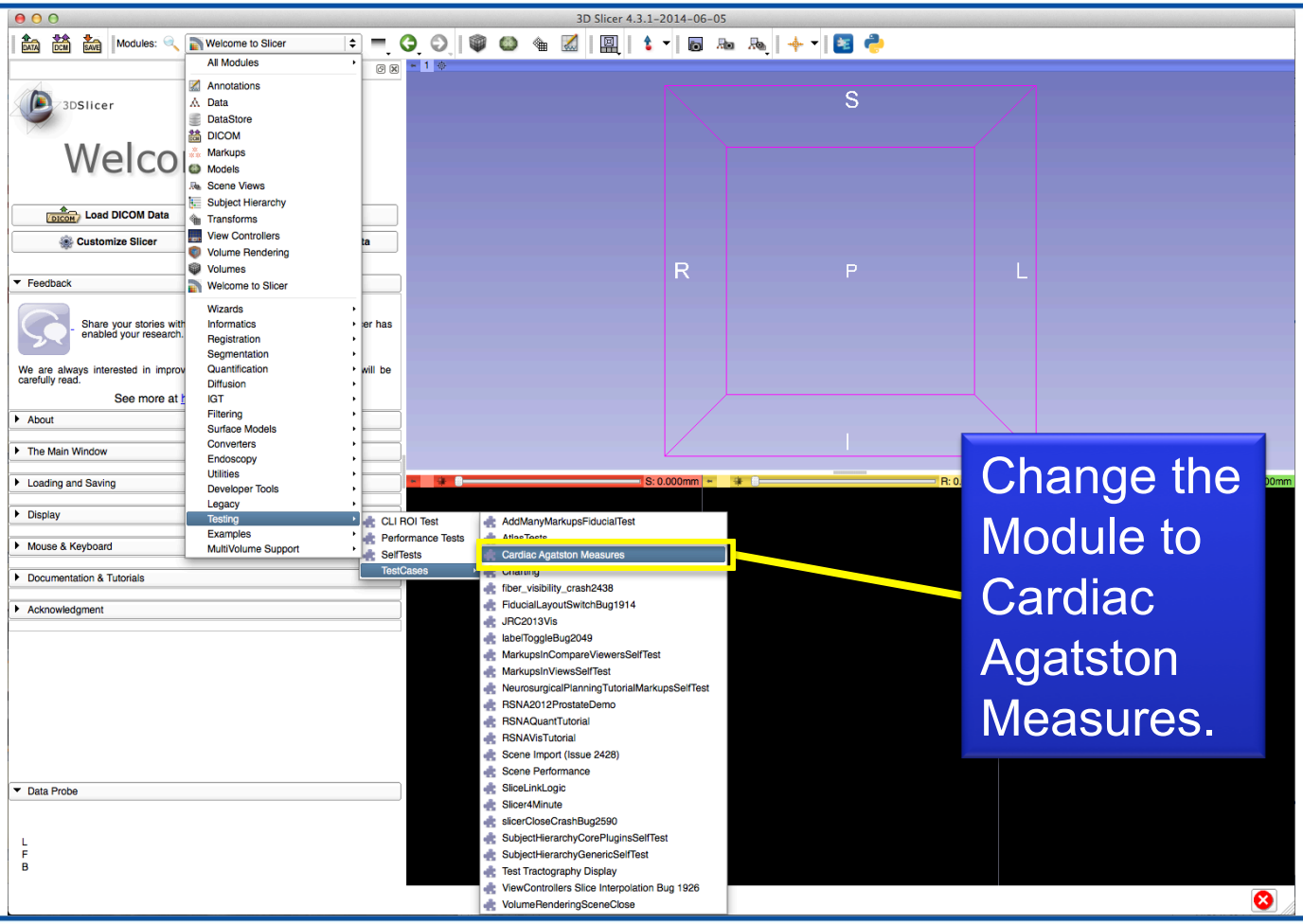
Part 1: Loading Extension



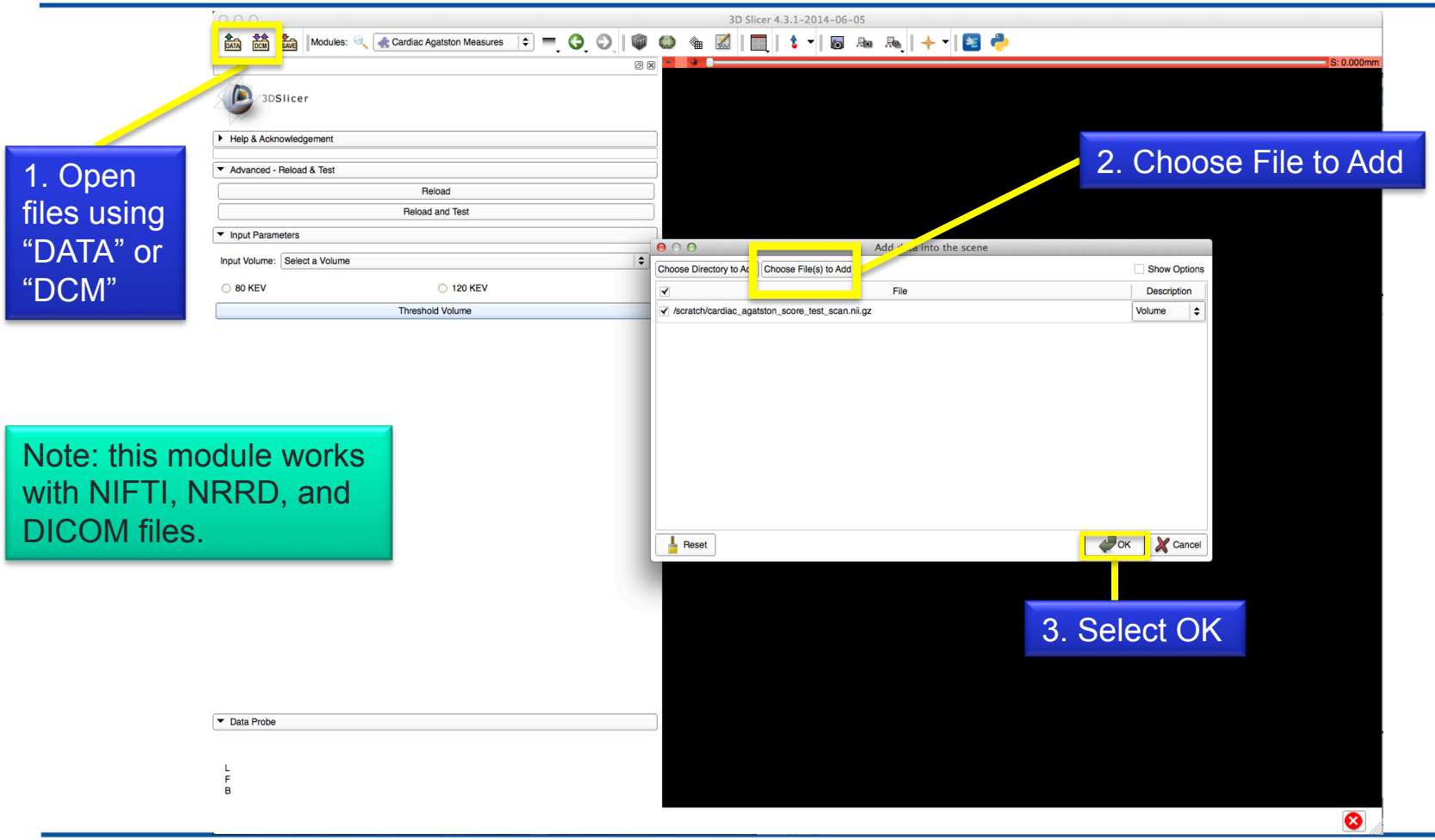
Part 1: Loading Extension



Part 1: Loading Extension

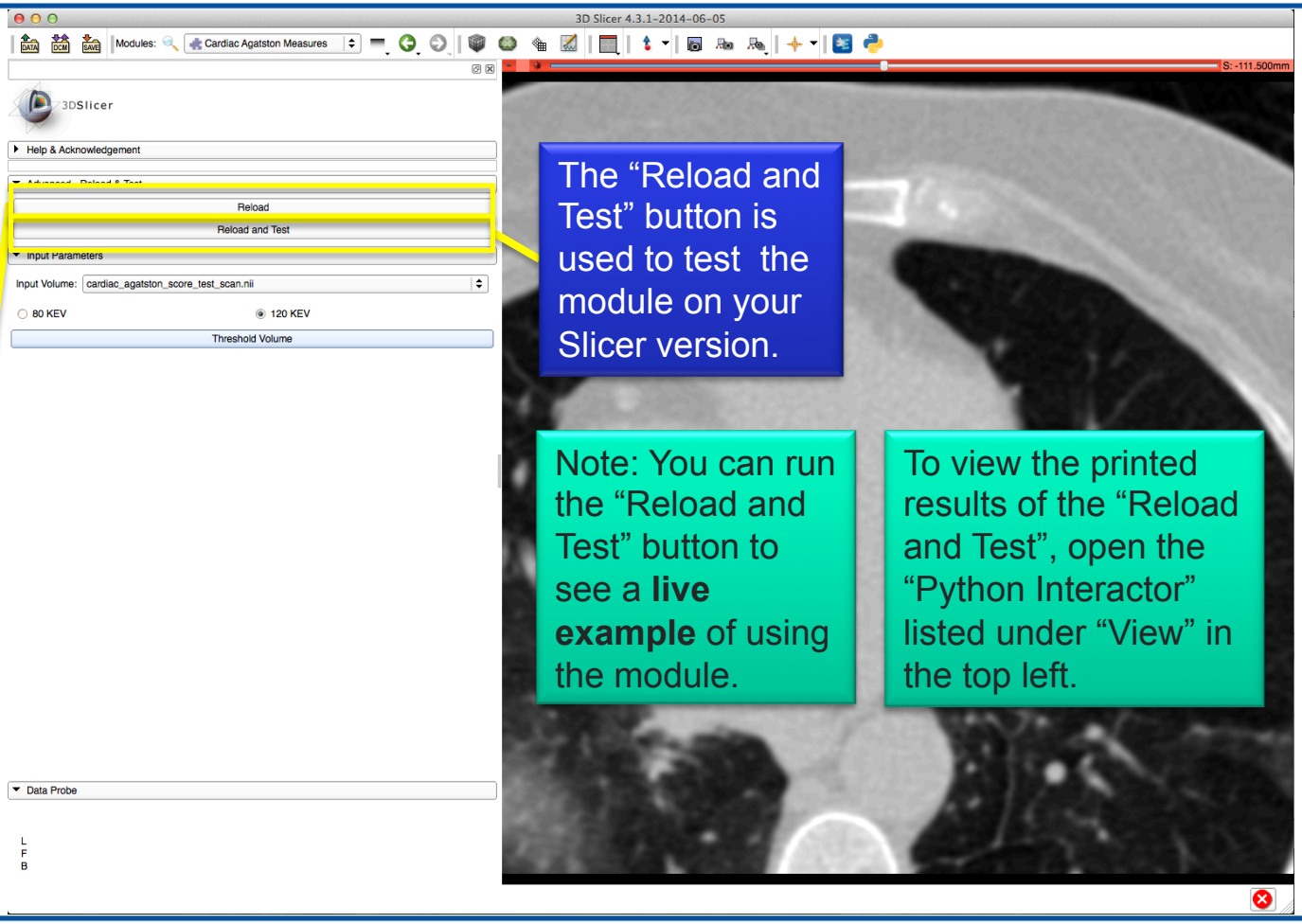


Part 1: Loading Data



Part 1: Module Overview

The “Reload” button is used to close out all open images and reload the module for the next CT scan calcium scoring.

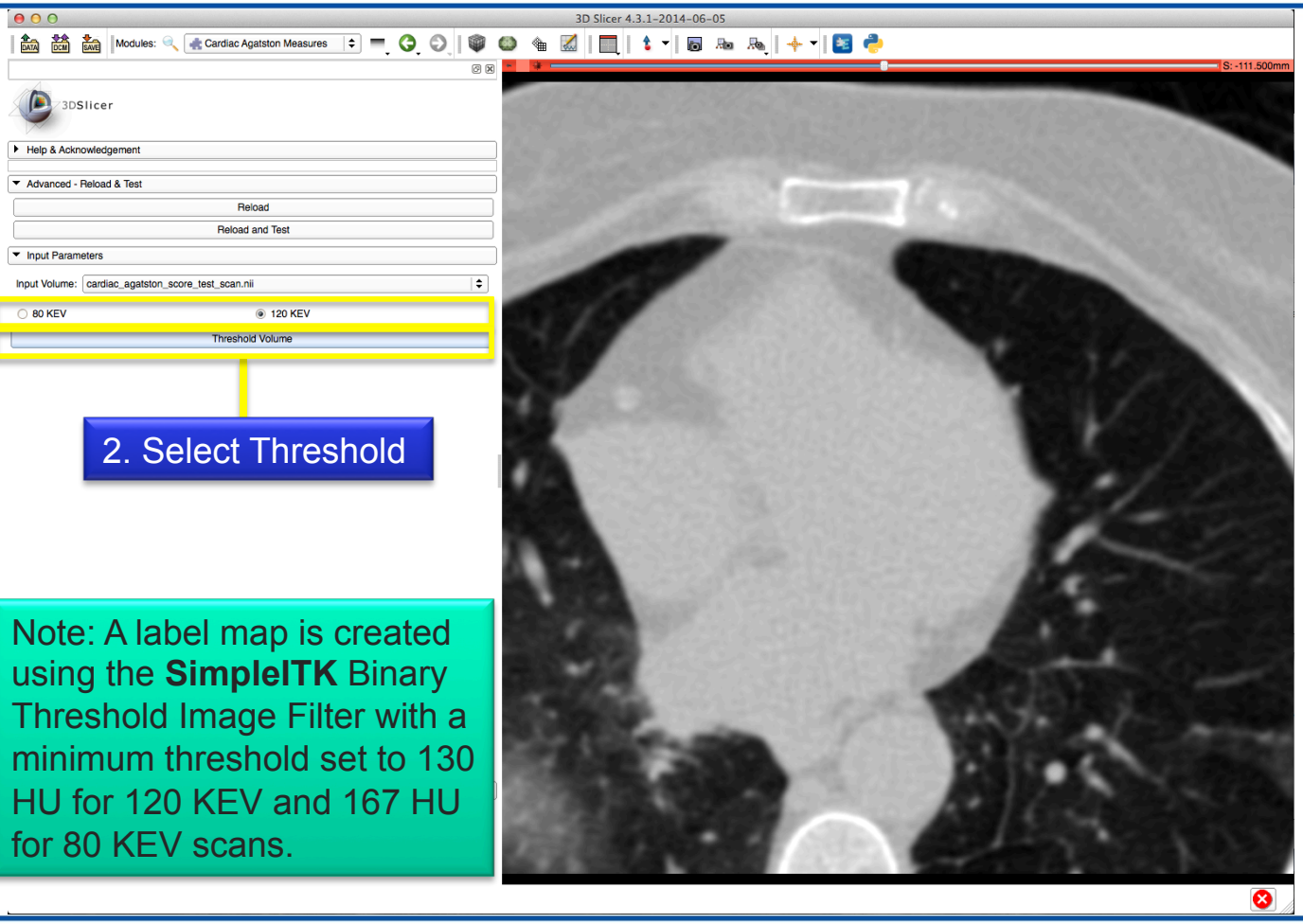


The “Reload and Test” button is used to test the module on your Slicer version.

Note: You can run the “Reload and Test” button to see a **live example** of using the module.

To view the printed results of the “Reload and Test”, open the “Python Interactor” listed under “View” in the top left.

Part 2: Thresholding Scan

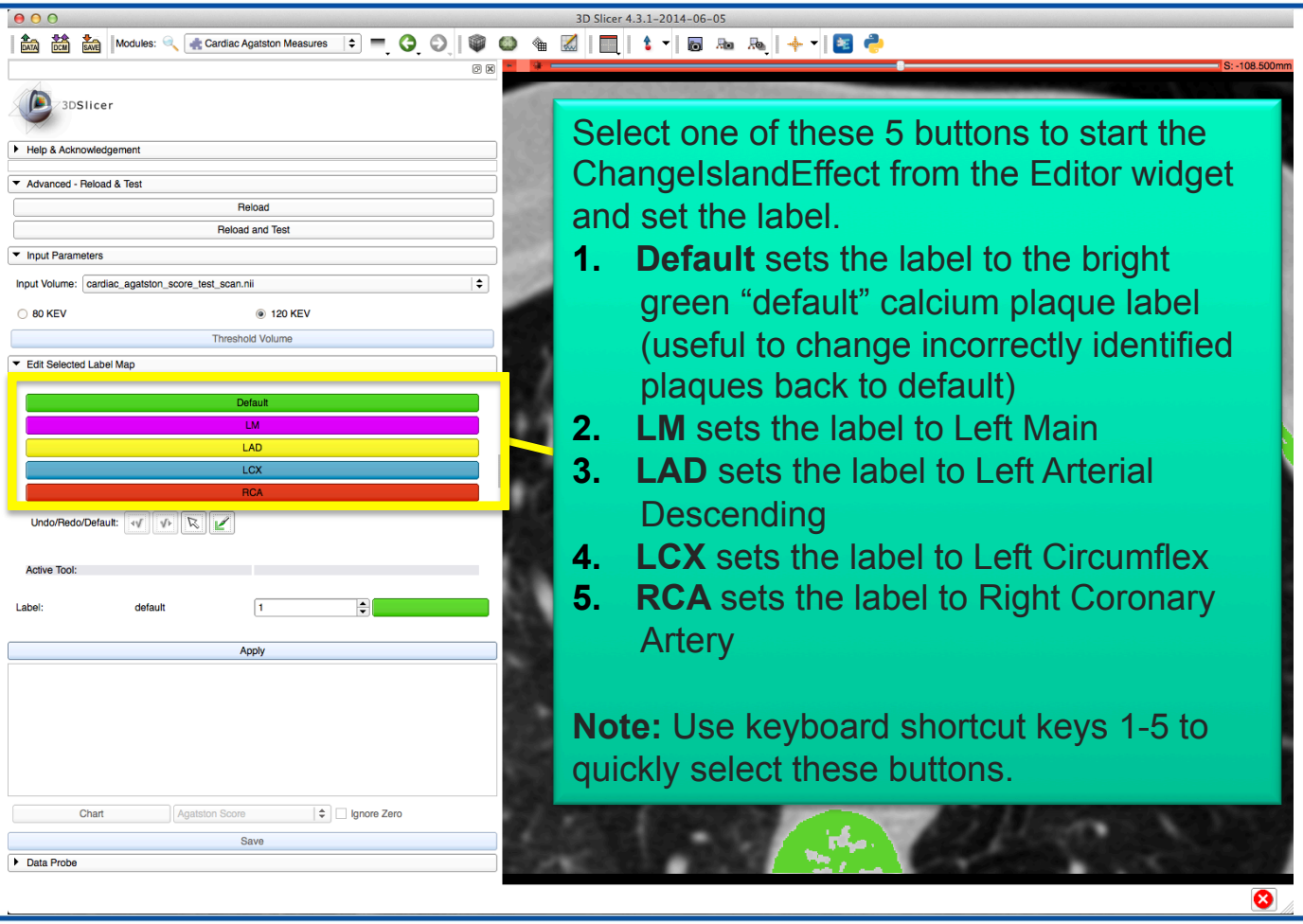


1. Choose if scan is 80 KEV or 120 KEV

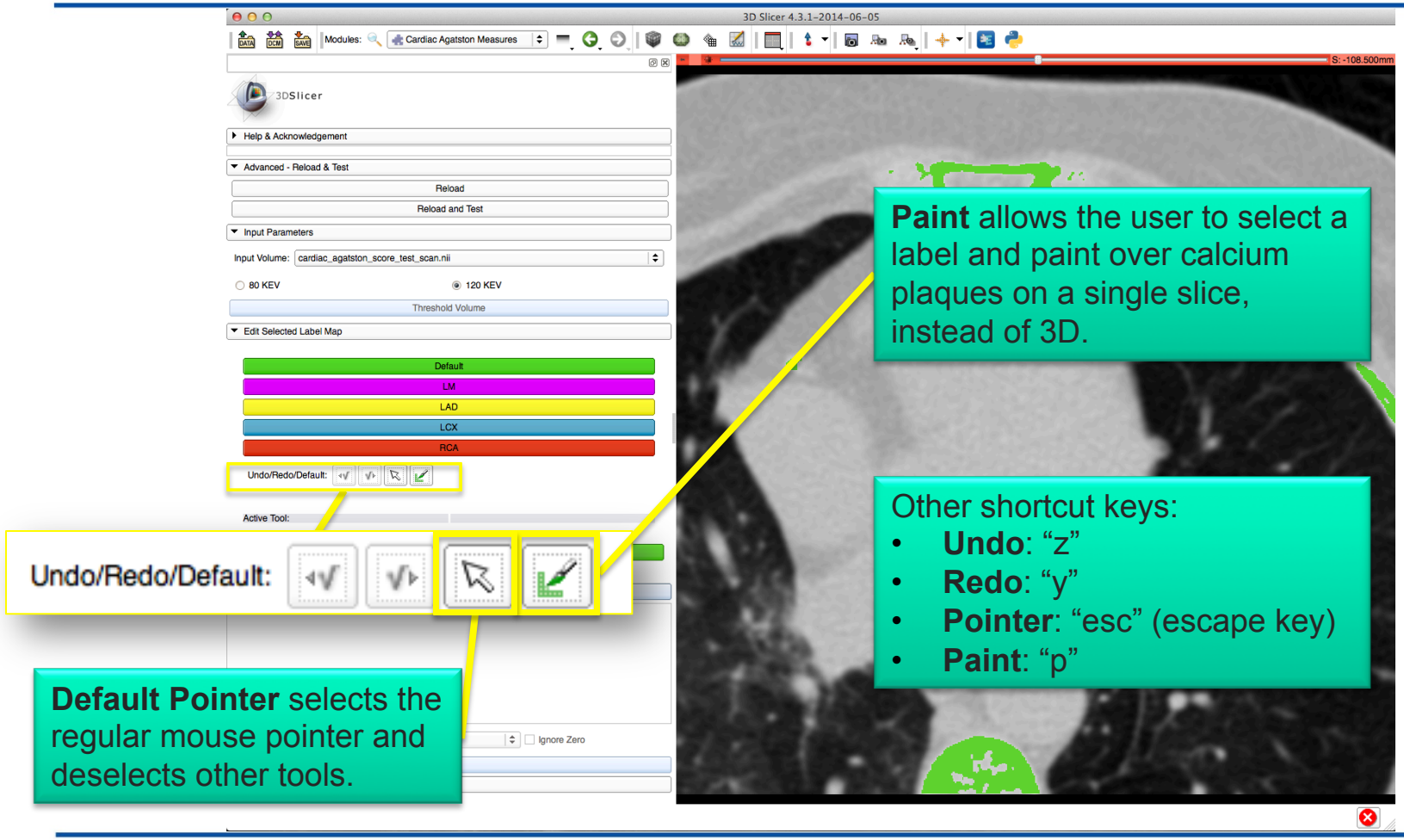
2. Select Threshold

Note: A label map is created using the **SimpleITK** Binary Threshold Image Filter with a minimum threshold set to 130 HU for 120 KEV and 167 HU for 80 KEV scans.

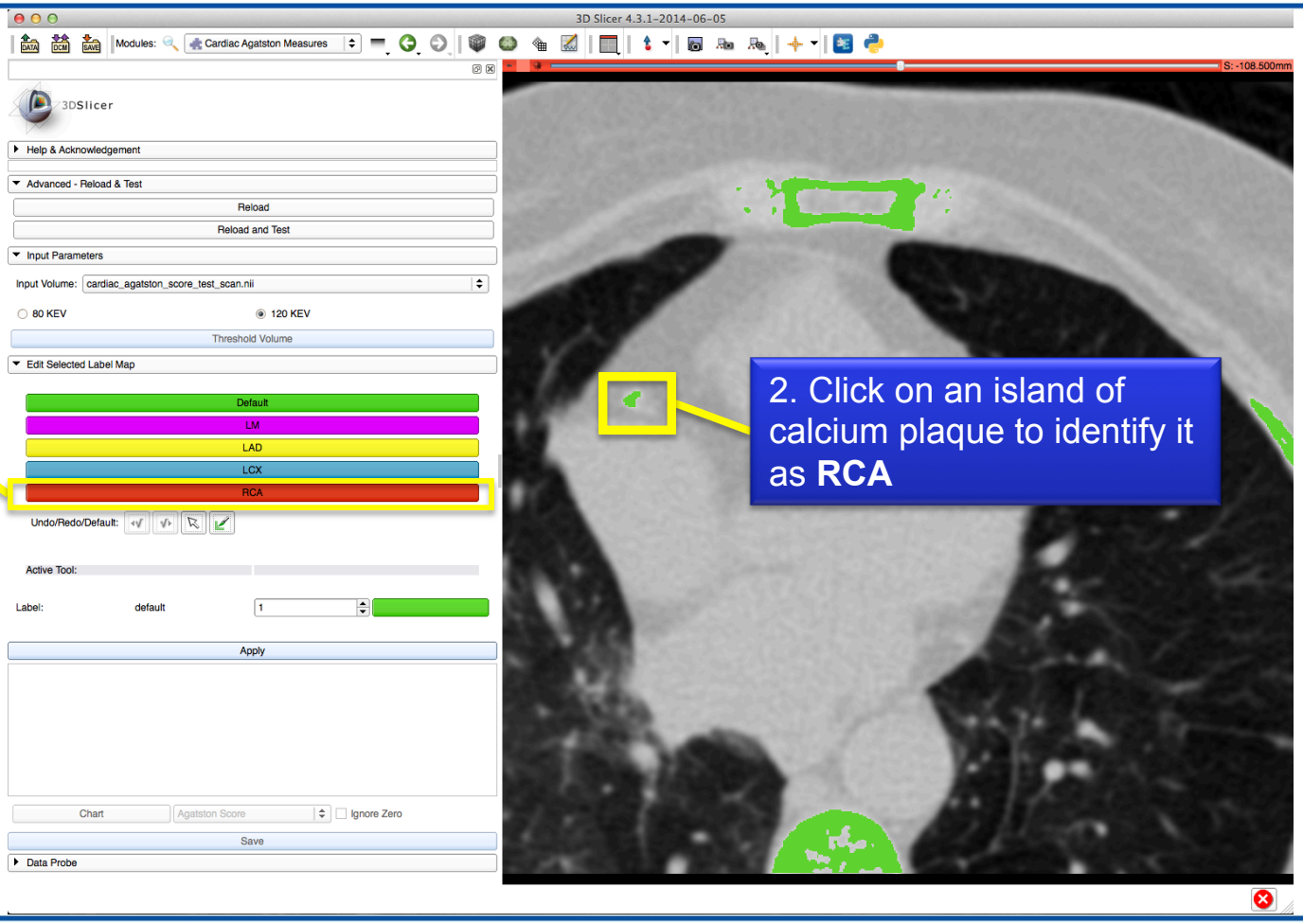
Part 3: Identifying plaques



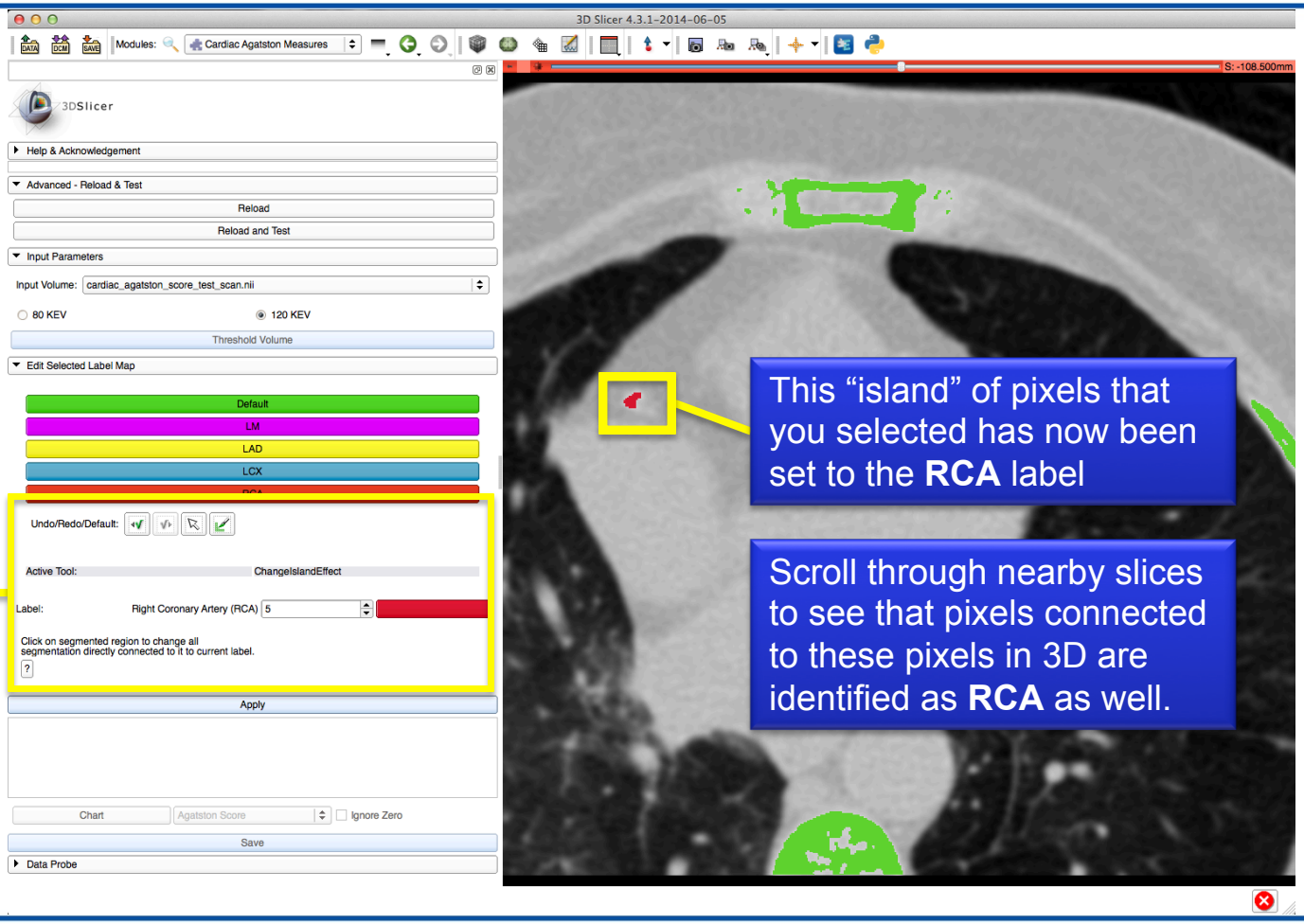
Part 3: Identifying plaques



Part 3: Identifying plaques

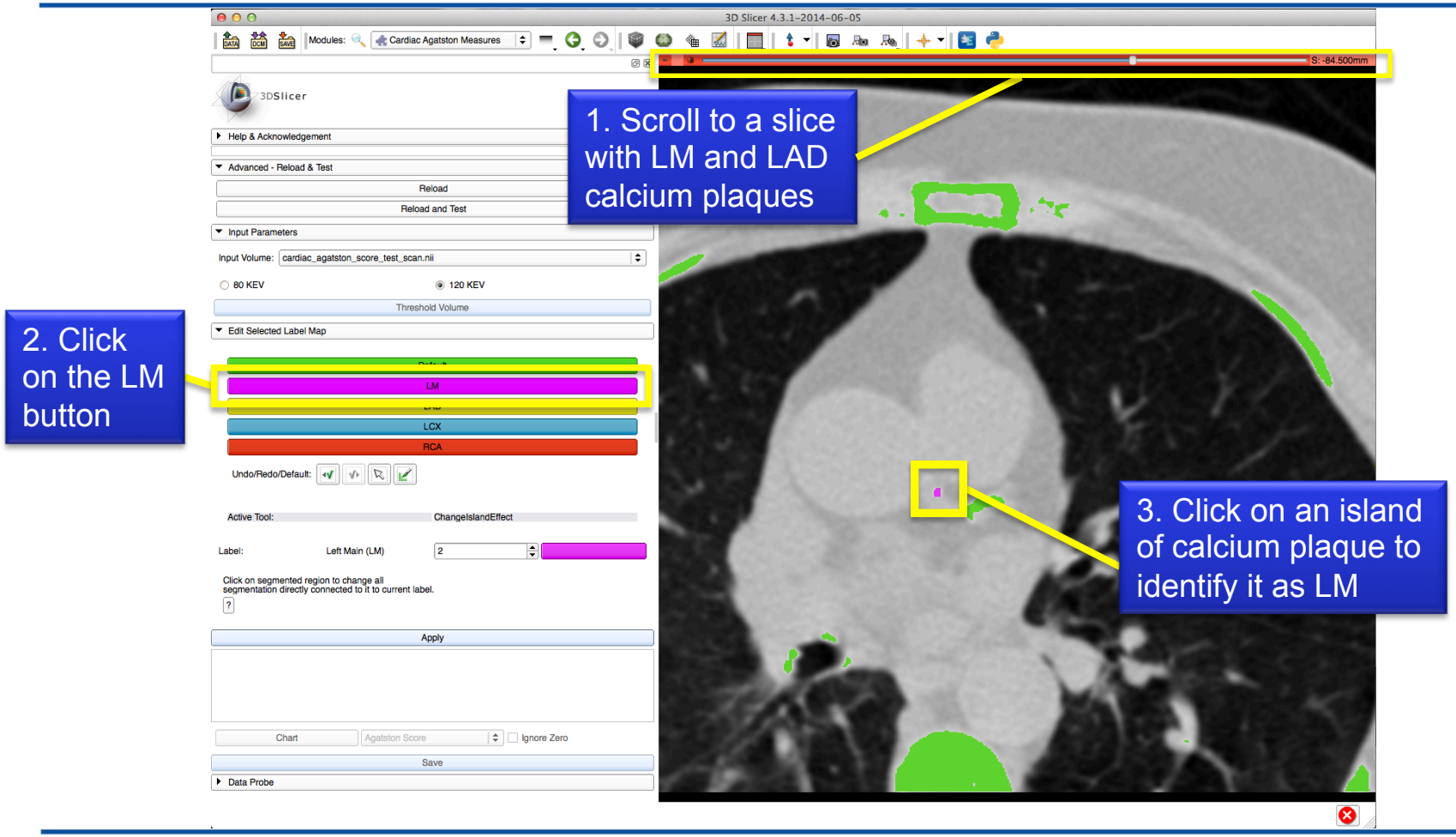


Part 3: Identifying plaques

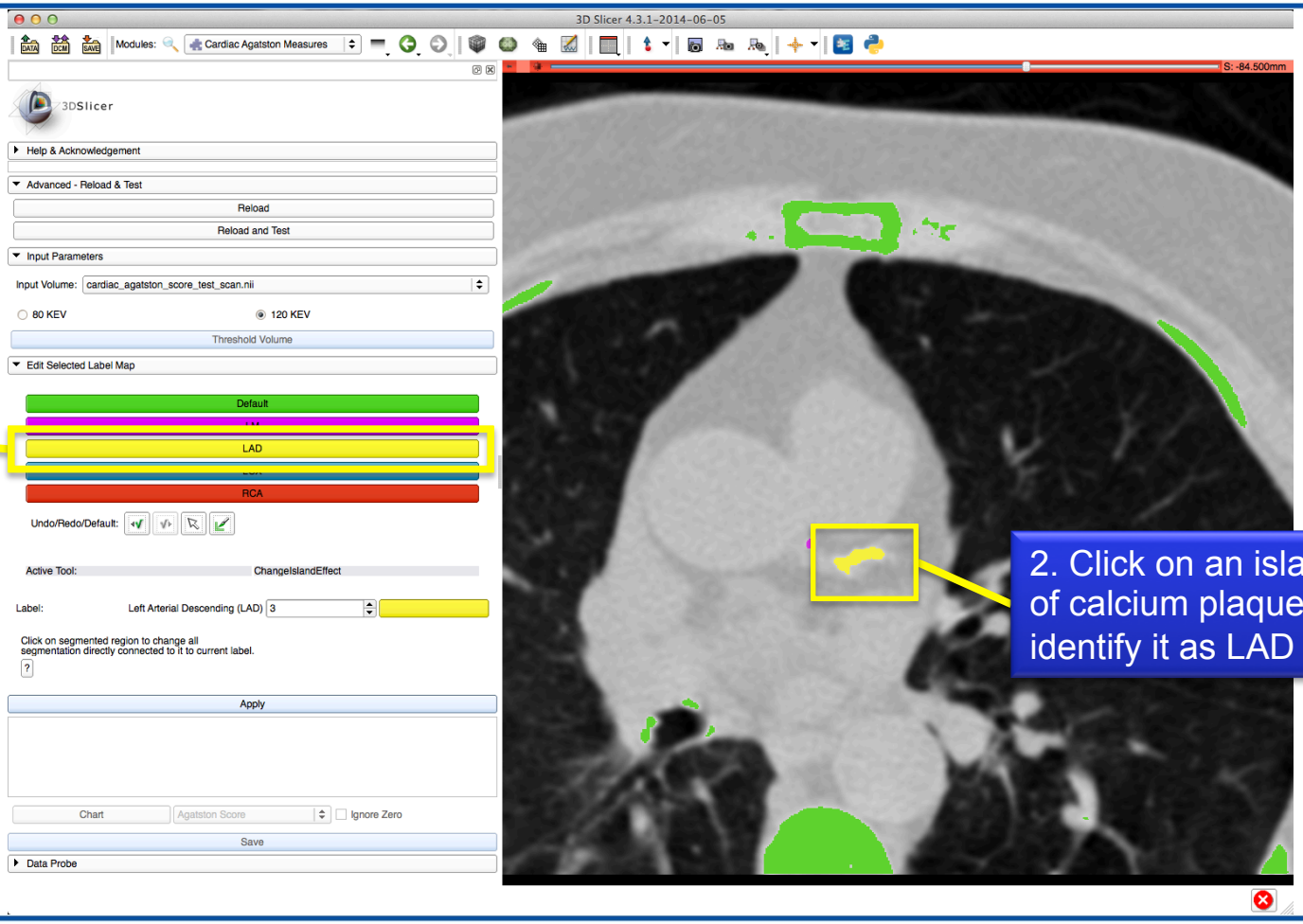


Note that the Change Island Effect is selected for the red RCA label number 3

Part 3: Identifying plaques

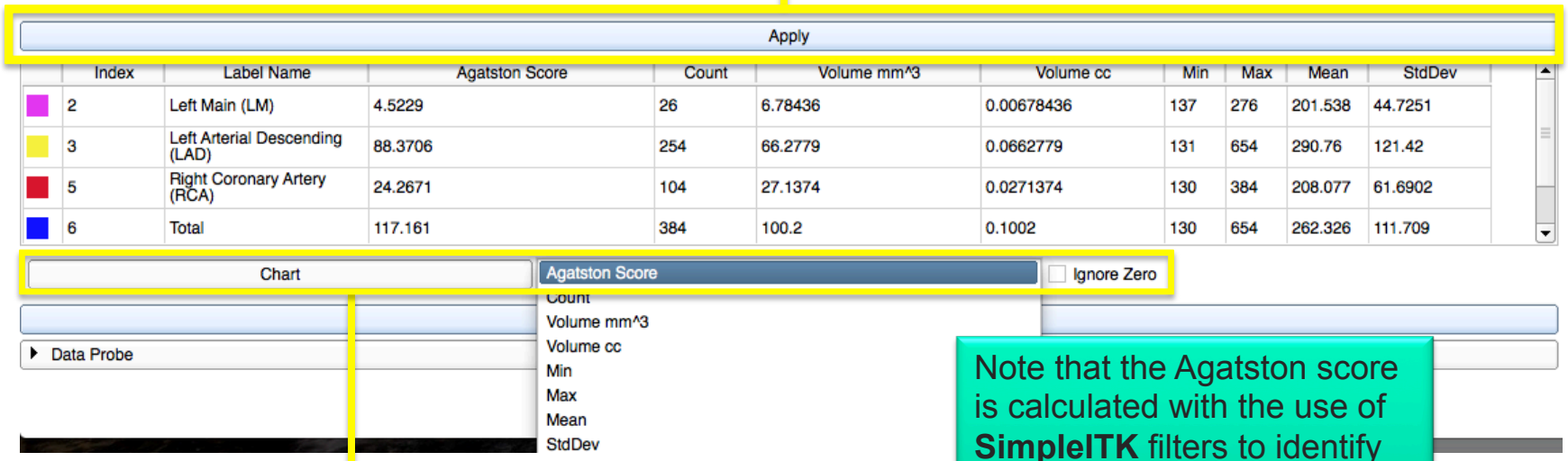


Part 3: Identifying plaques



Part 4: Calculating Scores

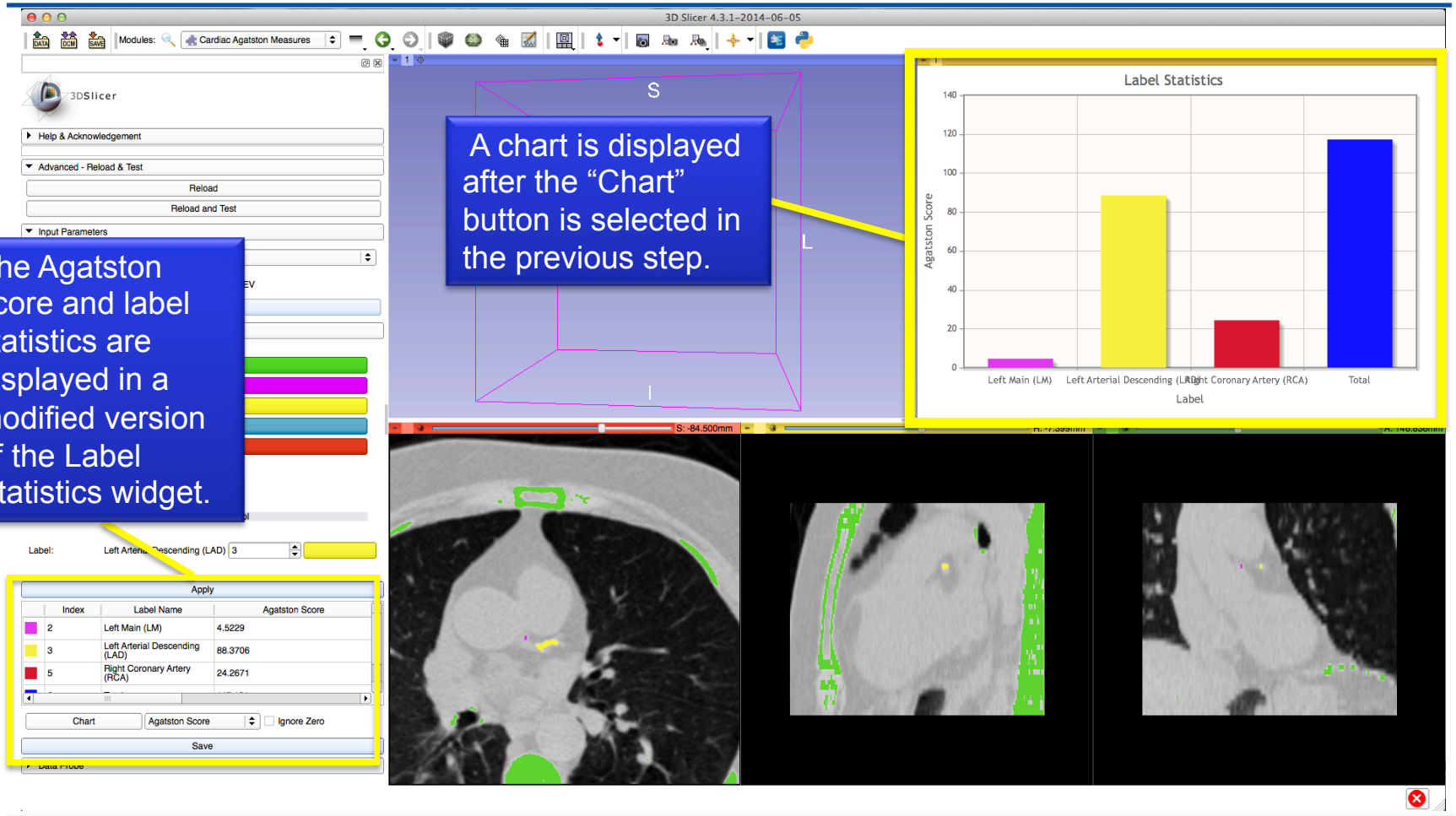
1. Select Apply to calculate the Agatston score and label statistics for individual labels and the total



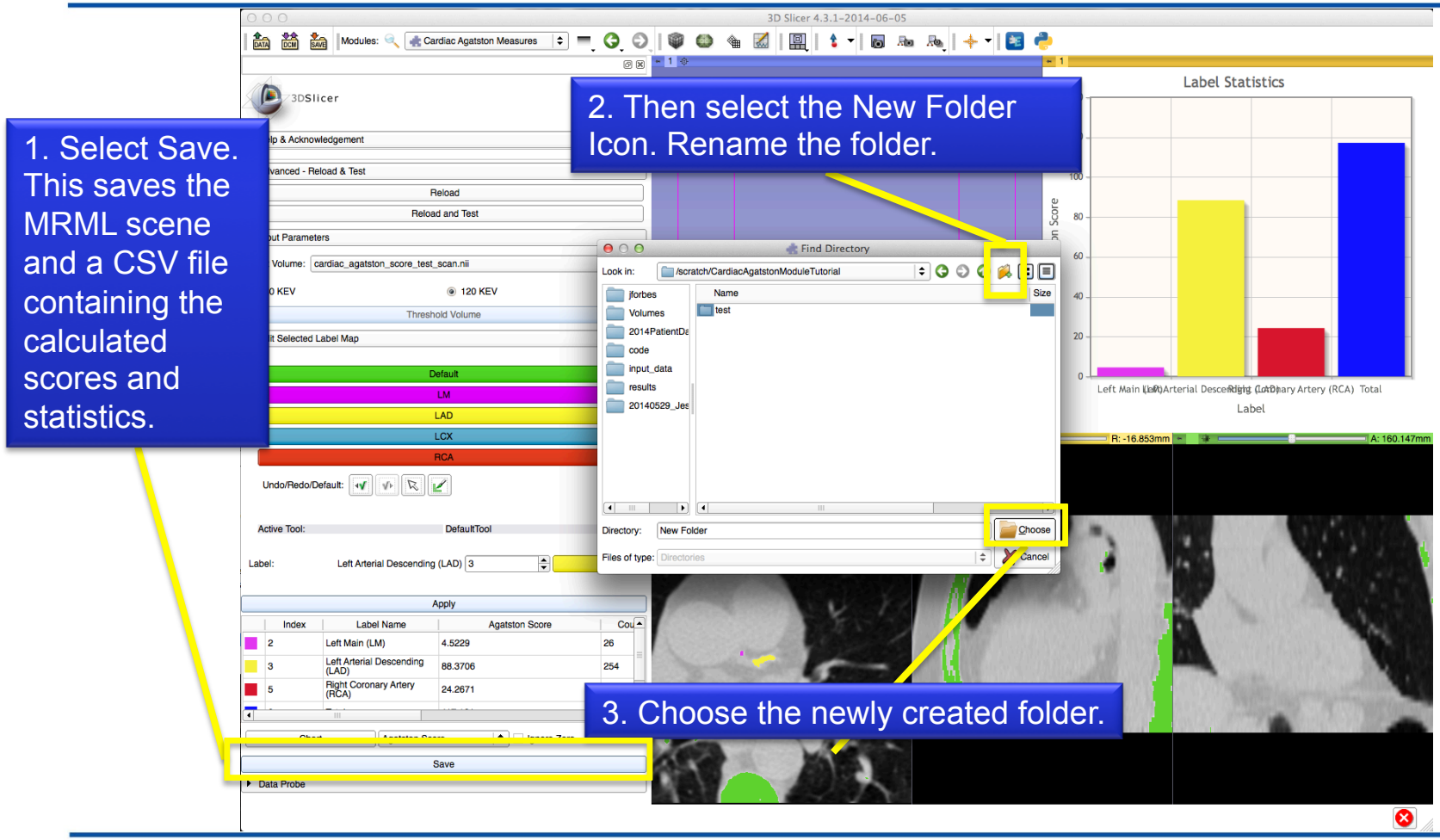
2. (Optional) Select Chart and Column to compare the values for each label

Note that the Agatston score is calculated with the use of **SimpleITK** filters to identify user labeled calcium islands in each slice, find the area, and find the maximum HU pixel intensity.

Part 4: Calculating Scores



Part 5: Saving Results



Conclusion

Congratulations!

- You have just completed the Agatston score for your pre-symptomatic patient and will be able to make a more informed decision about the chances of a cardiac event.
- If you used 80 KEV scans, you have also reduced the radiation exposure of your patient.
- Your data is saved and can be easy re-opened for review.

Acknowledgments

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