



NA-MIC

National Alliance for Medical Image Computing

<http://www.na-mic.org>

Cardiac Agatston Scoring

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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 06-25-2014 and the tutorial dataset. They are available at the following locations:

Slicer download page:

<http://download.slicer.org/>

Tutorial dataset:

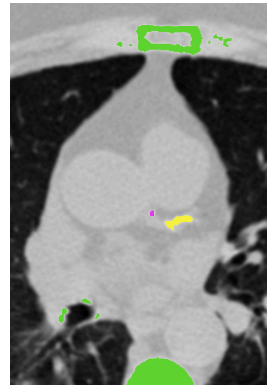
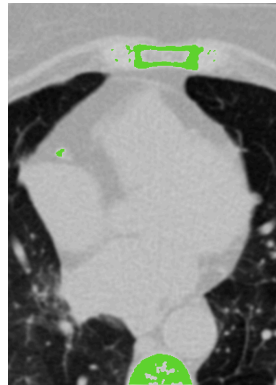
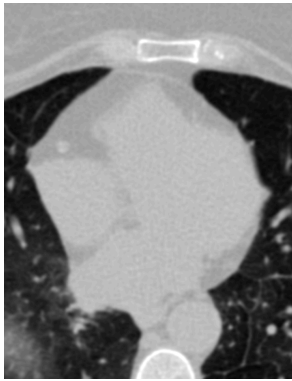
<http://wiki.na-mic.org/Wiki/index.php/>





[File:CardiacAgatstonMeasures_TutorialContestSummer2014.zip](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. The extension was added to the Extension Manager 06-24-2014.



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

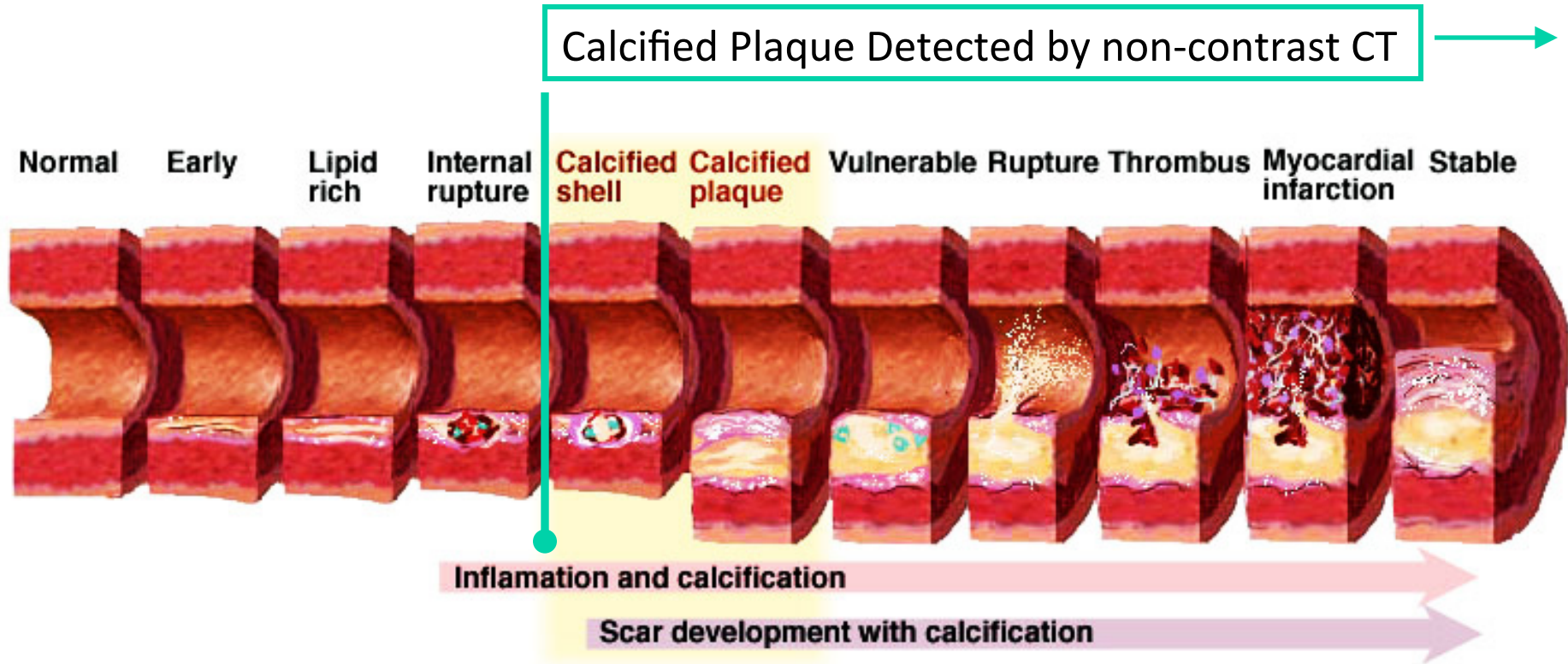
- Cardiovascular Disease is the leading global cause of death: 17.3 million deaths/year
- USA: 600,000 of heart disease per year*
 - Equates to 1 in every 4 deaths
- 40-60% have no cardiac symptoms before the event**
- Important to identify asymptomatic patients at risk of coronary events

*<http://www.cdc.gov/heartdisease/facts.htm>, February 19, 2014

**Myerburg et al. *Am J Cardiol* 1997 Virmani et al. *Cardiovasc Pathol*. 2001



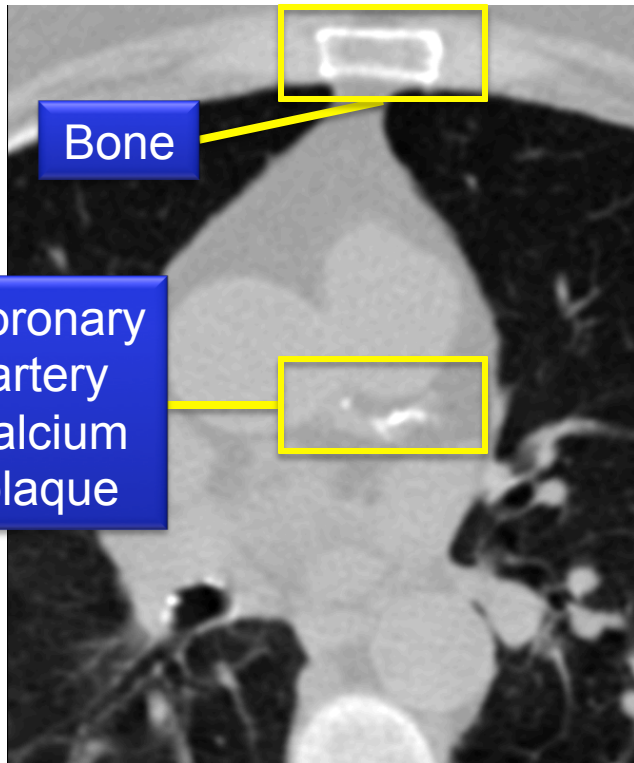
Background



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



Background



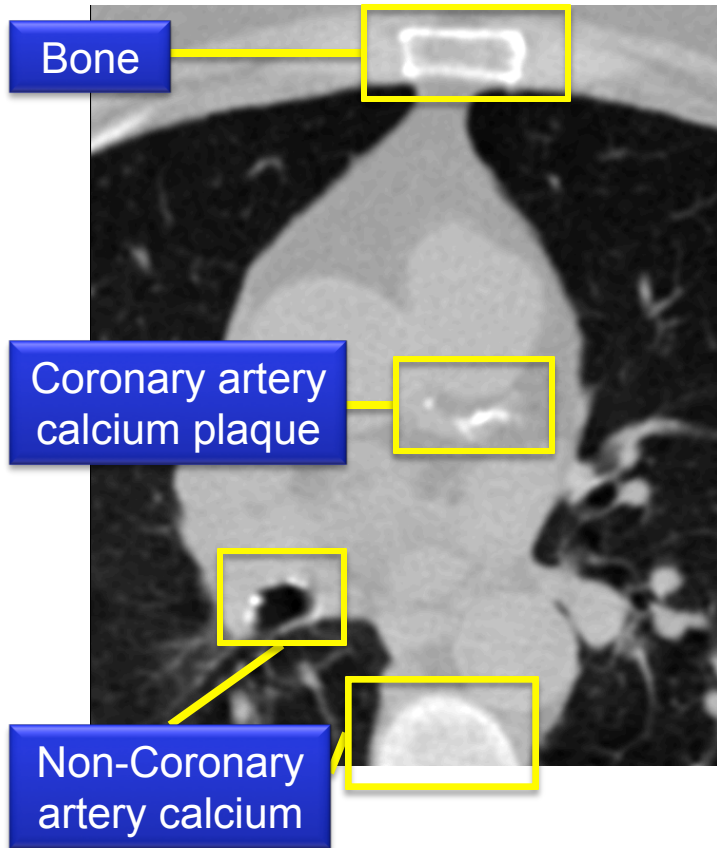
Each pixel of an EKG-gated non-contrast cardiac CT scan has an attenuation/density unit called Hounsfield Unit (HU).

- 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).



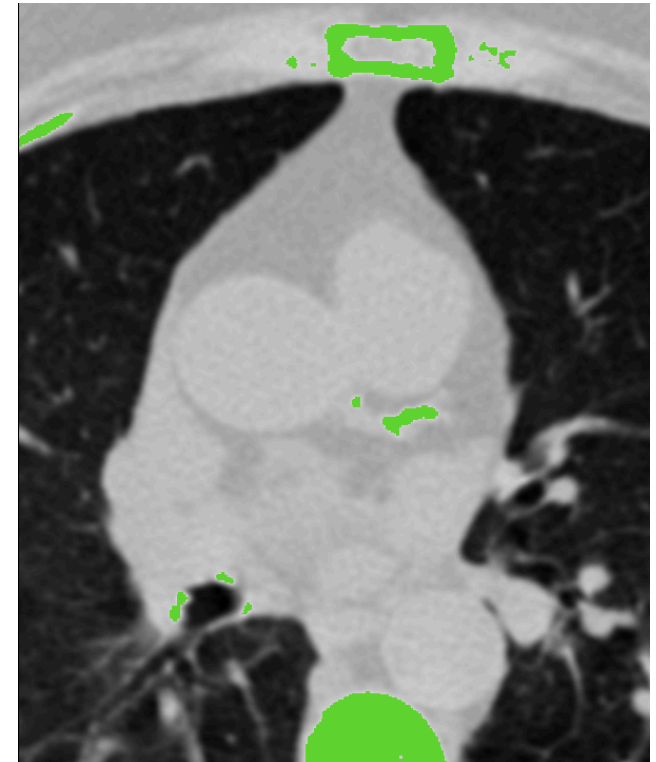
Background



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**.

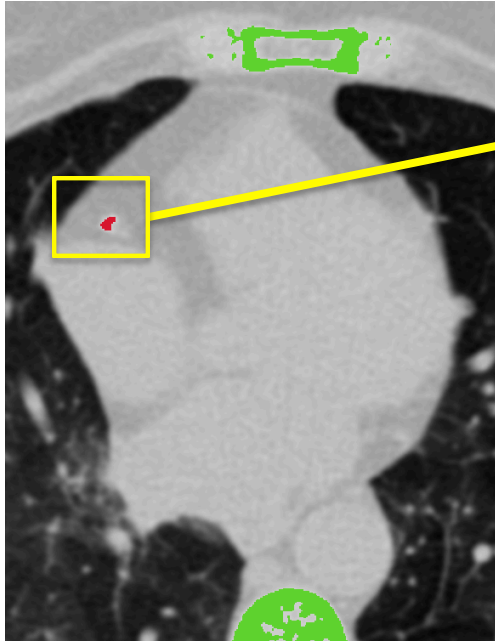
$$\text{Agatston score} = \text{Area} \times \text{X-Factor}$$

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



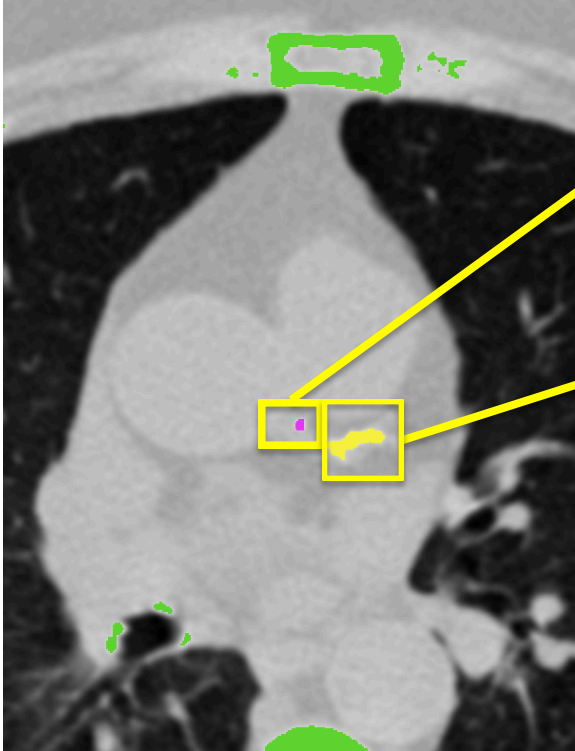
X-Factor = 1

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

$$18 = 18 \times 1$$



Background



$$\text{Agatston Score} = \text{Area} \times \text{X-Factor}$$
$$6 = 3 \times 2$$

$$\text{Agatston Score} = \text{Area} \times \text{X-Factor}$$
$$88 = 22 \times 4$$

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



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.

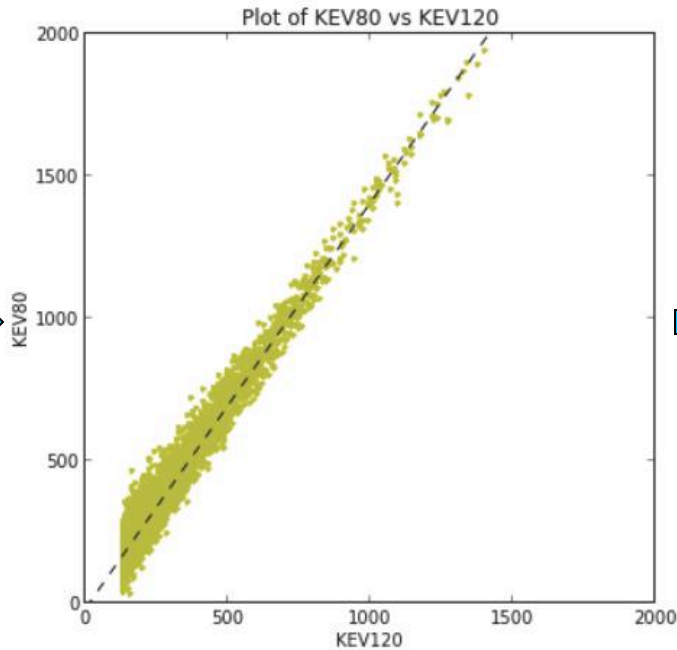
Total Agatston Score	Prognosis
0	No identifiable disease
1 - 99	Mild Disease
100 - 399	Moderate Disease
> 400	Severe Disease (>2% annual event rate)



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: Load Extension

The screenshot shows the 3D Slicer application window. The menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The 'View' menu is open, displaying several options: 'Python Interactor' (⌘3), 'Extension Manager' (⌘4), 'Module Panel' (⌘5), 'Toolbars', 'Layout', and 'Error Log' (⌘0). The 'Extension Manager' option is highlighted with a yellow box. A yellow arrow points from this box to a blue callout box containing the text 'Open the Extension Manager listed under View'. The main window area shows a 'Welcome' message and several buttons: 'Load DICOM Data', 'Load Data', 'Customize Slicer', and 'Download Sample Data'. The bottom of the window has a sidebar with expandable sections: 'Feedback', 'About', 'The Main Window', and 'Loading and Saving'.



Part 1: Load Extension

Extensions Manager

Manage Extensions (0) Install Extensions

Search...

Slicer Extensions

Categories

- All
- Cardiac (1)**
- Cardiac MRI toolki (1)
- Developer Tools (3)
- Diffusion (4)
- Editor Effects (1)
- Examples (4)
- Exporter (1)
- Filtering (1)
 - Morphology (1)
- IGT (6)
- Informatics (4)
- Mesh Generation (1)
- Microscopy (1)
- Multidimensional data (1)
- Quantification (2)
- Radiotherapy (2)
- Registration (2)
- Remote (1)
- Scoliosis (1)
- Segmentation (11)

CardiacAgastonMeas...
Jessica Forbes (Ulowa)...
(0)

INSTALL

Select the Cardiac Category

Then select Install

A restart is required to install an Extension

Restart Close



Part 1: Load Extension

3D Slicer 4.3.1-2014-06-05

Modules:

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- Testing
- Examples
- MultiVolume Support

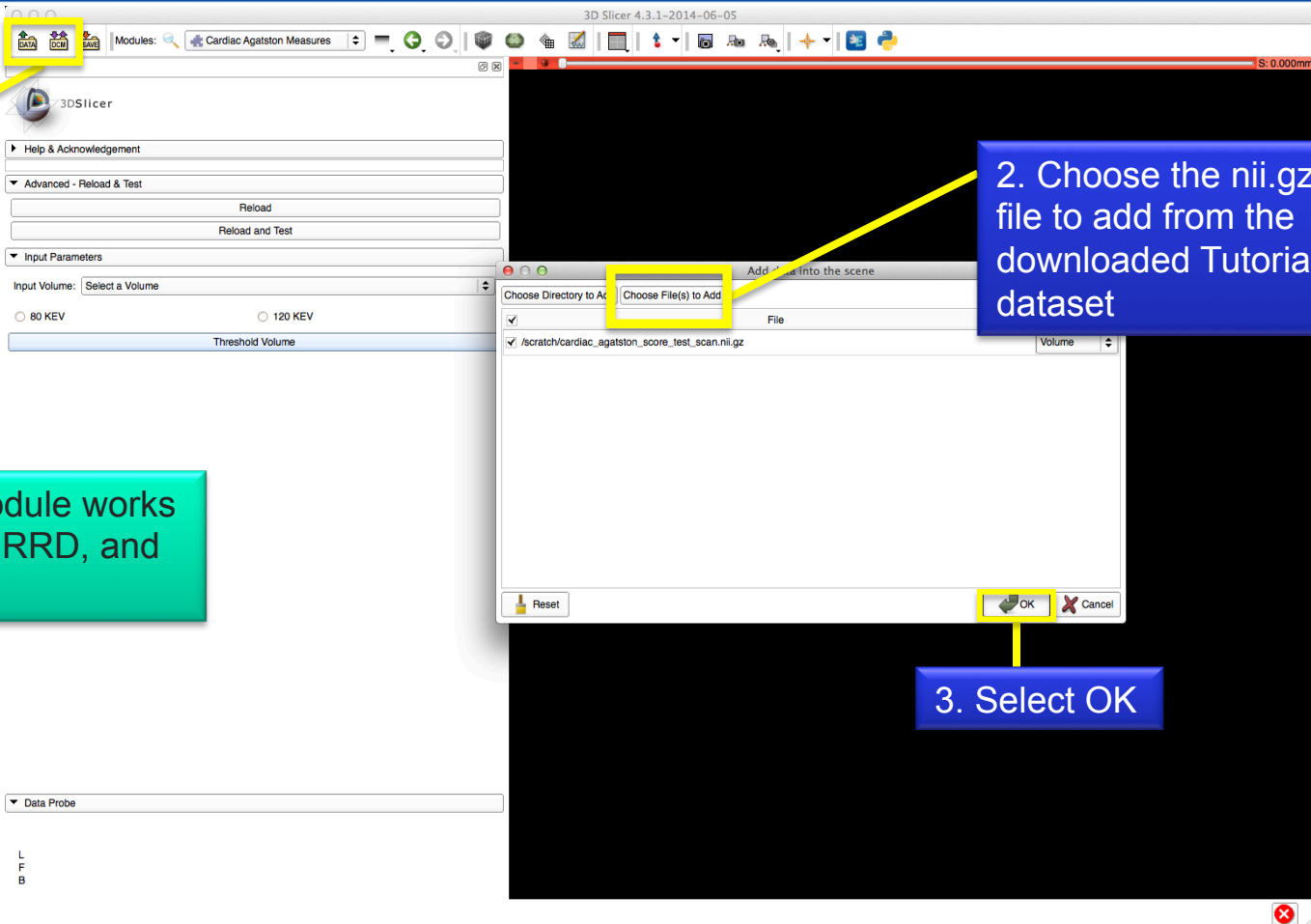
Cardiac Agatston Measures

Change the Module to Cardiac Agatston Measures.



Part 1: Load Data

1. Open files using "DATA" or "DCM"



Note: this module works with NIFTI, NRRD, and DICOM files.

3. Select OK



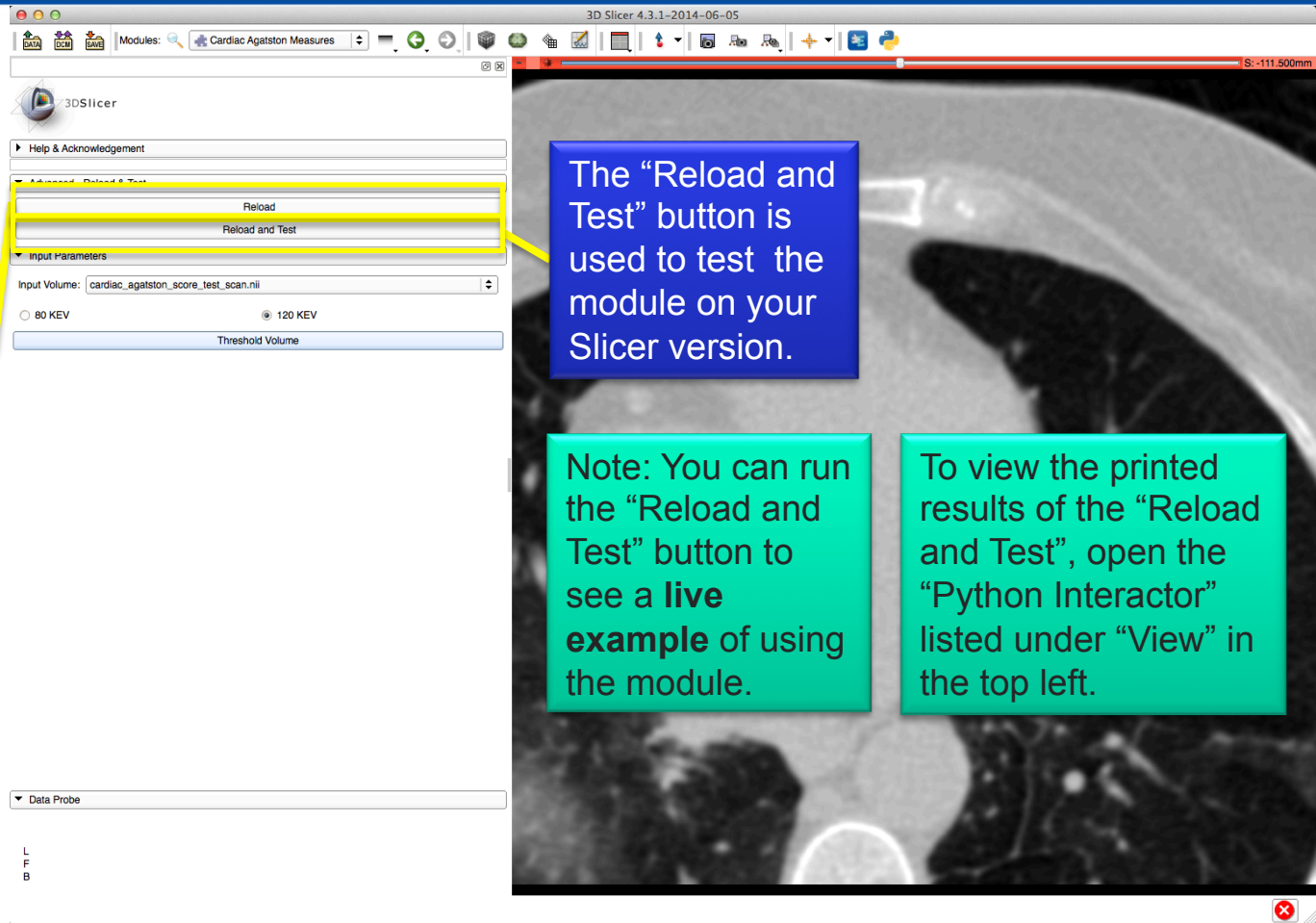
Part 1: Module Overview

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: Threshold 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: Identify plaques

Select one of these 5 buttons to start the ChangelandEffect from the Editor widget and set the label.

1. **Default** sets the label to the bright green “default” calcium plaque label (useful to change incorrectly identified plaques back to default)
2. **LM** sets the label to Left Main
3. **LAD** sets the label to Left Arterial Descending
4. **LCX** sets the label to Left Circumflex
5. **RCA** sets the label to Right Coronary Artery

Note: Use keyboard shortcut keys 1-5 to quickly select these buttons.



Part 3: Identify plaques

3D Slicer 4.3.1-2014-06-05

Modules: Cardiac Agatston Measures

3DSlicer

Help & Acknowledgement

Advanced - Reload & Test

Reload

Reload and Test

Input Parameters

Input Volume: cardiac_agatston_score_test_scan.nii

80 KEV 120 KEV

Threshold Volume

Edit Selected Label Map

Default

LM

LAD

LCX

RCA

Undo/Redo/Default:

Active Tool:

Undo/Redo/Default:

Default Pointer selects the regular mouse pointer and deselects other tools.

Paint allows the user to select a label and paint over calcium plaques on a single slice 2D, instead of 3D.

Other shortcut keys:

- **Undo:** "z"
- **Redo:** "y"
- **Pointer:** "esc" (escape key)
- **Paint:** "p"
- **Toggle label outlines on/off** using "o"



Part 3: Identify plaques

3DSlicer

Help & Acknowledgement

Advanced - Reload & Test

Reload

Reload and Test

Input Parameters

Input Volume: cardiac_agatston_score_test_scan.nii

80 KEV 120 KEV

Threshold Volume

Edit Selected Label Map

Default

LM

LAD

LCX

RCA

Undo/Redo/Default:

Active Tool:

Label: default 1

Apply

Chart Agatston Score Ignore Zero

Save

Data Probe

2. Click on an island of calcium plaque to identify it as RCA

1. Click on one of the five label buttons. For now click on the red button for RCA



Part 3: Identify plaques

3D Slicer 4.3.1-2014-06-05

Cardiac Agatston Measures

3DSlicer

Help & Acknowledgement

Advanced - Reload & Test

Reload

Reload and Test

Input Parameters

Input Volume: cardiac_agatston_score_test_scan.nii

80 KEV 120 KEV

Threshold Volume

Edit Selected Label Map

Default

LM

LAD

LCX

RCA

Undo/Redo/Default:

Active Tool: ChangeIslandEffect

Label: Right Coronary Artery (RCA) 5

Click on segmented region to change all segmentation directly connected to it to current label.

Apply

Chart Agatston Score Ignore Zero

Save

Data Probe

S: -108.500mm

This "island" of pixels that you selected has now been set to the **RCA** label

Scroll through nearby slices to see that pixels connected to these pixels in 3D are identified as **RCA** as well.

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



Part 3: Identify plaques

1. Scroll to a slice with LM and LAD calcium plaques

2. Click on the LM button

3. Click on an island of calcium plaque to identify it as LM



Part 3: Identify plaques

1. Click on the LAD button

2. Click on an island of calcium plaque to identify it as LAD



Part 4: Calculate Scores

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

Apply										
	Index	Label Name	Agatston Score	Count	Volume mm ³	Volume cc	Min	Max	Mean	StdDev
	2	Left Main (LM)	4.5229	26	6.78436	0.00678436	137	276	201.538	44.7251
	3	Left Arterial Descending (LAD)	88.3706	254	66.2779	0.0662779	131	654	290.76	121.42
	5	Right Coronary Artery (RCA)	24.2671	104	27.1374	0.0271374	130	384	208.077	61.6902
	6	Total	117.161	384	100.2	0.1002	130	654	262.326	111.709

Chart

Agatston Score Ignore Zero

Count

Volume mm³

Volume cc

Min

Max

Mean

StdDev

► Data Probe

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: Calculate Scores

A chart is displayed after the "Chart" button is selected in the previous step.

The Agatston score and label statistics are displayed in a modified version of the Label Statistics widget.

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

Label	Agatston Score
Left Main (LM)	4.5229
Left Arterial Descending (LAD)	88.3706
Right Coronary Artery (RCA)	24.2671
Total	117.1606



Part 5: Save Results

1. Select Save.
This saves the MRML scene and a CSV file containing the calculated scores and statistics.

2. Then select the New Folder icon. Rename the folder.

3. Choose the newly created folder.

The screenshot shows the 3D Slicer interface with the Cardiac Agatston Measures module active. The 'Save' button is highlighted in a blue box. A 'Find Directory' dialog box is open, showing a 'test' folder in the directory tree, with the 'Choose' button highlighted. A 'Label Statistics' bar chart is visible on the right, showing scores for different labels. A table at the bottom displays the following data:

Index	Label Name	Agatston Score	Count
2	Left Main (LM)	4.5229	26
3	Left Arterial Descending (LAD)	88.3706	254
5	Right Coronary Artery (RCA)	24.2671	



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 easily re-opened for review.



Acknowledgments



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