Calcium Scoring

OVERVIEW

The Calcium Score (Ca Score) for an individual, also known as an Agatston Score, is calculated from a CT acquisition of the heart and measures the level of calcium plaque burden within the coronary arterial vessel. The Calcium Score CT can be acquired in conjunction with a SPECT or PET myocardial perfusion study to provide additional diagnostic and prognostic information represented by the Calcium Score, but a SPECT or PET study is not required.

Coronary arterial calcification is a component in the development of atherosclerosis and the Calcium Score can assess the presence of obstructive coronary heart disease (CHD) and the probability that an individual may have a future myocardial event[1]. The goal of the Calcium Score CT is to detect CHD at an early stage so further development of the disease can be prevented. The multi-ethnic study of atherosclerosis (MESA) demonstrates the prevalence and amount of coronary calcium for individuals are influenced by ethnicity, age, and gender[3].

The 4DM Calcium Scoring screen provides quantification and review of coronary artery calcium deposits within the coronary arteries of the heart that are visualized on non-contrast Ca Score CT acquisitions. The Calcium Scoring screen is available within 4DM for users who purchase the CT option. The Hounsfield Unit (HU) threshold defines which areas (displayed in blue) represent calcium deposits, and the user can choose between the Region-growing technique and the Region of Interest (ROI) method to quantify the calcium score. 4DM strongly recommends that physicians review the calcium scores calculated within the Calcium Scoring screen for quality assurance.

CAMERAS & SETTINGS

The table below provides a current sampling of SPECT/CT and PET/CT cameras that allow users to acquire non-contrast Ca Score CT acquisitions in conjunction with myocardial perfusion studies. 4DM requires that a non-contrast Ca Score CT dataset is loaded into the program and displayed on the Ca Scoring screen prior to assigning Ca scores.

Manufacturer	SPECT/CT	PET/CT
GE Healthcare	Discovery 570 Discovery 670 StarGuide NM/CT 870 CZT NM/CT 860	Discovery 600, 610, 690, 710 Discovery LS, ST, RX, STE Discovery IQ PET Gen 2 Discovery MI, MI Gen 2, DR Discovery IQ PET (BGO)
Philips Healthcare		Gemini Ingenuity TF Gemini GXL Vereos Gemini TF
Siemens	Symbia T6, T16 Intevo 6,16 Pro.SPECTA 32,64	Biograph TruePoint, mCT, Duo/B16, Horizon Biograph Vision 450, 600
Spectrum Dynamics	Veriton 16, 64	
United Imaging		uEXPLORER uMI 780 uMI 550
Canon		Cartesion Prime & Celesteion

ECG-triggered (prospective) and ECG-gated (retrospective) acquisition protocols are both available for Ca Scoring. For Ca Score acquisitions where slice thickness differs from the standard 3.0mm, 4DM will automatically scale the Agatston score accordingly to match a presumed slice thickness of 3.0mm. For CT systems with fewer than 8 slices, longer breath-holds are necessary, which is more problematic for patients with high heart rates. Users should follow the acquisition protocol recommendations provided by the camera manufacturer and should contact the camera manufacturer directly with specific questions related to camera settings or Ca Score capabilities.

HOW TO GUIDE

QUANTIFY AND REVIEW CALCIUM SCORE

The default method for calcium score quantification within 4DM is the **Region-growing Technique**. The **Region-growing technique** should be used when the blue calcified areas do not spill into adjoining vessels. The default threshold for identifying coronary artery calcification within 4DM is 130 Hounsfield Units (HU) and calcifications are highlighted in blue. The quantified calcium score is displayed in the results table.

Quantify Calcium using the Region-growing technique:

Figure 1: Ca Scoring Screen button

1. Launch a non-contrast Ca Score dataset into 4DM.
2. Select the **Ca Scoring** screen (Figure 1) from either the SPECT/CT or PET/CT workflow.
3. Left-click within the quantification viewport to activate the image and translate through the Transverse Thin Maximum Intensity Projection (Thin MIP) CT volume by left-clicking the **dog-ear control** (see ❶ Figure 2) or by using the mouse scroll wheel. Users can also left-click and drag the blue reference lines within the Coronal and Sagittal 3-CT viewports (see ❷ Figure 2) to translate through the Transverse CT volume.
4. Left-click a coronary **Vessel** (see ❸ Figure 2) to select it.
5. Left-click a blue calcified area throughout the CT volume (see ❹ Figure 2) associated with the selected **Vessel** to designate a lesion with the corresponding color.

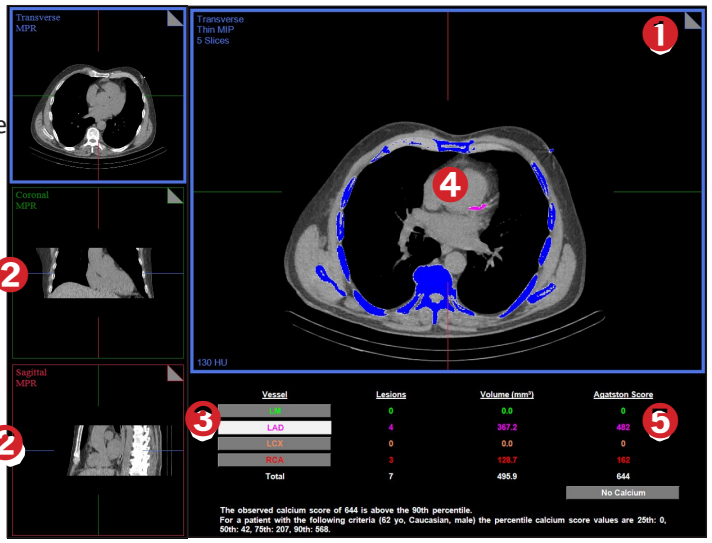

Figure 2: CT Volume with Region-growing Technique

- The **Region-growing Technique** assigns the corresponding **Vessel** color to the entire calcified region and all pixels attached to it throughout the CT volume.
- The **Delete Calcium** tool (Figure 3) deletes an assigned calcium area.

Figure 3: Delete Calcium tool

6. 4DM quantifies the calcium score for the designated lesion(s) and displays the calcium (Agatston) score within the **Results Table** (see ❺ Figure 2).
7. Once processing has been completed on the **Ca Scoring** screen, the user should click on the **MPI Summary** screen and select **Save** to save the processed results.

Quantify Calcium using the ROI Method:

The **ROI Method** should be used where blue calcified areas are present at vessel junctions and where calcification overlaps between adjoining vessels. The quantified calcium score is displayed in the results table.

1. Launch a non-contrast Ca Score dataset into 4DM.
2. Select the **Ca Scoring** screen from either the SPECT/CT or PET/CT workflow.
3. Left-click within the quantification viewport to activate the image and translate through the Transverse Thin Maximum Intensity Projection (Thin MIP) volume by left-clicking the **dog-ear control** (see ❶ Figure 4) or by using the mouse scroll wheel. Users can also left-click and drag the blue reference lines within the Coronal and Sagittal 3-CT viewports (see ❷ Figure 4) to translate through the Transverse CT volume.
4. Left-click a coronary **Vessel** (see ❸ Figure 4) to select it.
5. Left-click the **ROI tool** (see ❹ Figure 4) from the 4DM toolbar to activate and draw the ROI.

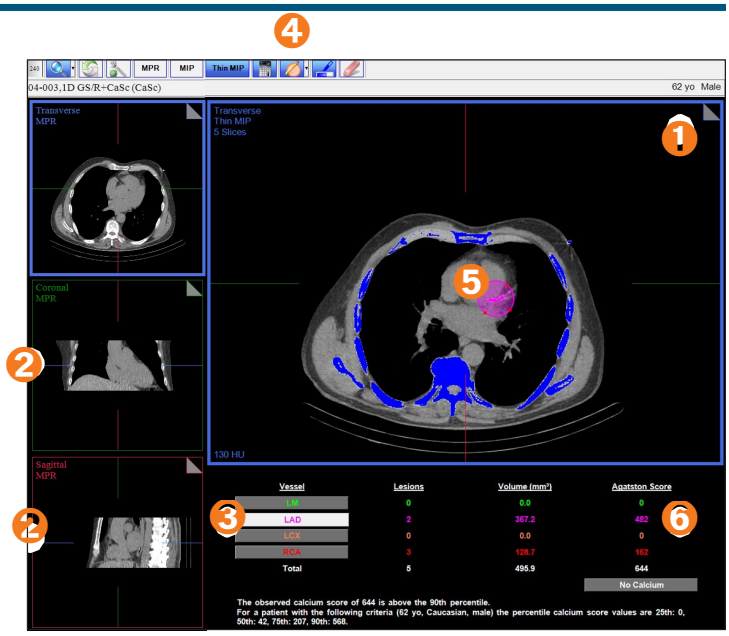

Figure 4: CT Volume with ROI Method

6. Draw an ROI (see ❺ Figure 4) around the desired blue calcified coronary vessel.
   - The **ROI Method** assigns the corresponding **Vessel** color to the blue calcified area contained within the user-defined ROI.
   - The **Delete Calcium** tool deletes an assigned calcium area.
7. 4DM will quantify the calcium score for the designated lesion(s) and display the volume and calcium (Agatston) score within the **Results Table** (see ❻ Figure 4).
8. Once processing has been completed on the **Ca Scoring** screen, the user should click on the **MPI Summary** screen and select **Save** to save the processed results.

Making Changes to Processing Options

The **Processing Options** tool allows the user to make changes to the calcium score quantification settings within the *Advanced Algorithm Options window*.

Figure 5: Processing Options tool

1. Select the **Processing Options** tool (Figure 5) from the 4DM toolbar.
2. The **Ca Threshold** can be modified by left-clicking the up/down arrows (see ❶ Figure 6) or by entering a numerical value for studies where the desired calcium threshold is different than the default 130 HU setting (e.g., changes in tube kVp settings).
3. In the *Advanced Algorithm Options window* (Figure 6), the **Show Percentiles** checkbox (see ❷ Figure 6) toggle includes or excludes the calcium percentiles from the results table.

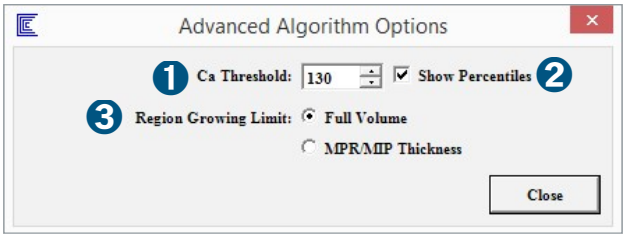

Figure 6: Advanced Algorithm Options window

The percentiles were designed to evaluate the prevalence, risk factors, and progression of cardiovascular disease based on the Multi-Ethnic Study of Atherosclerosis (MESA) study[2]. The percentile values are displayed when the required patient demographic information (age, sex, and ethnicity) has been defined within 4DM Patient Information.

4. Use the **Region-growing Limit** radio buttons to define the region growing algorithm on the Ca Scoring screen (see ❸ Figure 6).

   a. **Full Volume** – This is the default algorithm for the Region-growing technique. Full Volume should be used to assign calcium data to a vessel that is only limited by the size of the CT volume being displayed.
   b. **MPR/MIP Thickness** – MPR/MIP Thickness should be used to assign calcium data to a vessel that is limited to the slice stack thickness used for the current MPR/MIP display.

Making Changes to Display Options

The **MPR**, **MIP**, and **Thin MIP** options in the toolbar allow the user to vary the slice thickness of the volumes displayed within the 3-CT and quantification viewports.

1. Left-click one of the image viewports (3-CT, Transverse, Coronal, and Sagittal) to activate the image (Figure 7).

2. Select one of the following display options (Figure 8) to review through the activated CT volume:

   a. **MPR –** Multi-Planar Reconstruction (MPR) displays coronary calcium present within each individual slice.
   b. **MIP –** Maximum Intensity Projection (MIP) displays the coronary calcium present within each 9-slice stack.
   c. **Thin MIP** – Thin Maximum Intensity Projection (Thin MIP) displays the coronary calcium present within each 5-slice stack.

   Right-click on the MIP or Thin MIP buttons to specify the thickness in the *Default MIP Thickness window* (Figure 9).

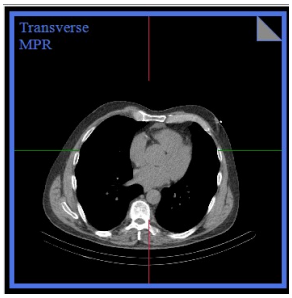

Figure 7: Transverse Viewport activated

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Figure 8: MPR, MIP, and Thin MIP display options

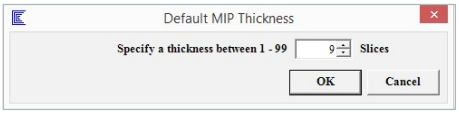

Figure 9: Default MIP Thickness window

INTERPRETING THE RESULTS TABLE

The calculated calcium (Agatston) score for individuals can range from 0 to several thousand. Higher Agatston scores indicate an increased level of plaque which leads to a greater risk for cardiovascular disease. 4DM quantifies the Agatston score and defines a qualitative extent of coronary artery atherosclerosis according to the following thresholds:

Extent of Coronary Artery Atherosclerosis	Score
"No significant"	0
"Minimal extent of"	1-9
"Mild extent of"	10-100
"Moderate extent of"	101-400
"Severe extent of"	Above 400

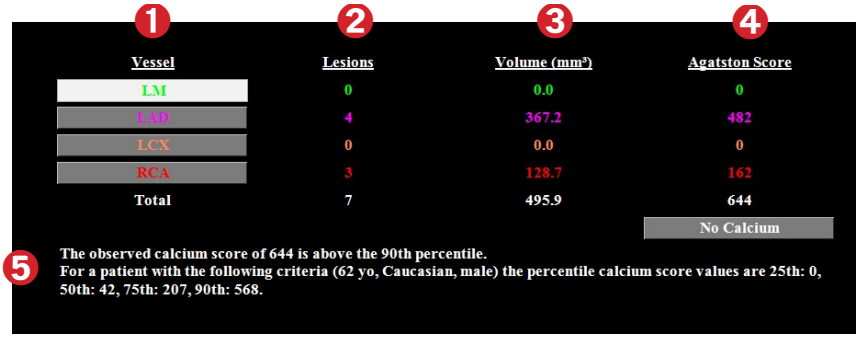

Figure 10: Results Table

The following information is available within the Results Table (Figure 10) after quantifying a Ca Score within 4DM:

1. **Vessel** ❶ – The four main coronary vessels are listed, each with its own color
2. **Lesions** ❷ – Automatic calculation of the number of calcified lesions within the corresponding coronary vessel after a volume has been manually assigned with the **Region-growing Technique**, or the **ROI Method**.
3. **Volume (mm3)** ❸ – The total volume of all calcified lesions within the corresponding coronary vessel that is automatically calculated after a volume has been manually assigned with the **Region-growing Technique**, or the **ROI Method**. The volume (mm^3) represents the area of the user-defined lesions multiplied by their weighted score, which is used in the calculation of the Agatston Score.
4. **Agatston (Calcium) Score** ❹ – A weighted score based on HU value of the calcified lesions in the coronary arteries. This weighted value is then multiplied by the area of the lesion to provide the Agatston Score which is automatically calculated once an area of calcium for the corresponding coronary vessel has been manually assigned.
5. **Calcium Percentile Findings** ❺ – Prognostic risk stratification of a patient's calcium score. The percentile values are automatically calculated for the individual based on total Agatston score and their demographic information (age, gender, ethnicity)[2].

REFERENCES

1. Greenland P, et al. ACCF/AHA 2007 clinical expert consensus document on coronary artery calcium scoring by computed tomography in global cardiovascular risk assessment and in evaluation of patients with chest pain: a report of the American College of Cardiology Foundation Clinical Expert Consensus Task Force (ACCF/AHA Writing Committee to Update the 2000 Expert Consensus Document on Electron-Beam Computed Tomography). Circulation. 2007;115:402– 426

2. Mcclelland, R. (2005). Distribution of Coronary Artery Calcium by Race, Gender, and Age: Results from the Multi-Ethnic Study of Atherosclerosis (MESA). *Circulation*. 2005;113:30-37.