# CARDIAC COMPUTED TOMOGRAPHY: IS IT READY FOR PRIMETIME?

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## INTRODUCTION

**The last decade has witnessed dramatic improvements in computed tomography (Cn technology with the development of both electron beam (EB) and multi-detector (MD) CT systems. EBCT provided the first attempt at high-resolution "freeze frame" images of the heart and coronary arteries, with 50 msec image acquisition times obviating distortion and blurring of the continuously moving myocardium. Developments in MDCT have included increasing gantry speeds to improve temporal resolution and the addition of multiple detector arrays that allow submillimeter spatial resolution and reduced image acquisition times.**

**Although EBCT has higher temporal resolution than MDCT and lower radiation exposure through prospective triggering of the X-ray beam at a specific time in the cardiac cycle, MDCT provides higher spatial resolution and is generally more accessible to the medical community. Both techniques can be used to assess cardiac structure, determine the presence and extent of coronary artery calcification and provide high-resolution, noninvasive coronary angiography.**

**The following article describes the current proposed uses of cardiac CT and its potential integration with other imaging modalities such as stress tomographic myocardial perfusion imaging (SPECT).**

## CORONARY ARTERY CALCIUM SCORING - SCREENING FOR CORONARY ARTERY DISEASE

Despite improvements in the treatment of patients with advanced coronary artery disease (CAD), early detection and prevention remains the best long-term solution. While traditional risk factor analysis defines populations at risk for CAD, the commonly used Framingham risk score is imprecise at identifying CAD in asympwmatic individual patients. CT scanning can detect coronary artery calcification, which is highly specific for the presence of coronary atherosclerosis and increases relative to the extent of CAD (Figure 1).[1]

The coronary arcery calcium score (CACS) is based on the extem and density of coronary calcification and can be used co guide therapeutic decision making, determine rhe need for additional diagnostic testing and predict subsequent patient outcome. Subjects with a CACS of 0 represent approximately 40% of all screened patients,[2] have a very low likelihood (<0.5%) of significant (>50%) coronary artery stenosis[3] and have an excellent long-term prognosis (Figure 2).[4]

Multiple studies in more than 20,000 patients have shown an increase in cardiac event rates with higher CACS[4-10] and independent of biomarkers (C-reactive protein)[11] or risk predicted by clinical variables (i.e. Framingham Score).[4,6,9] Consistent with these prognostic studies, the likelihood of stress-induced ischemia increases with a higher CACS as

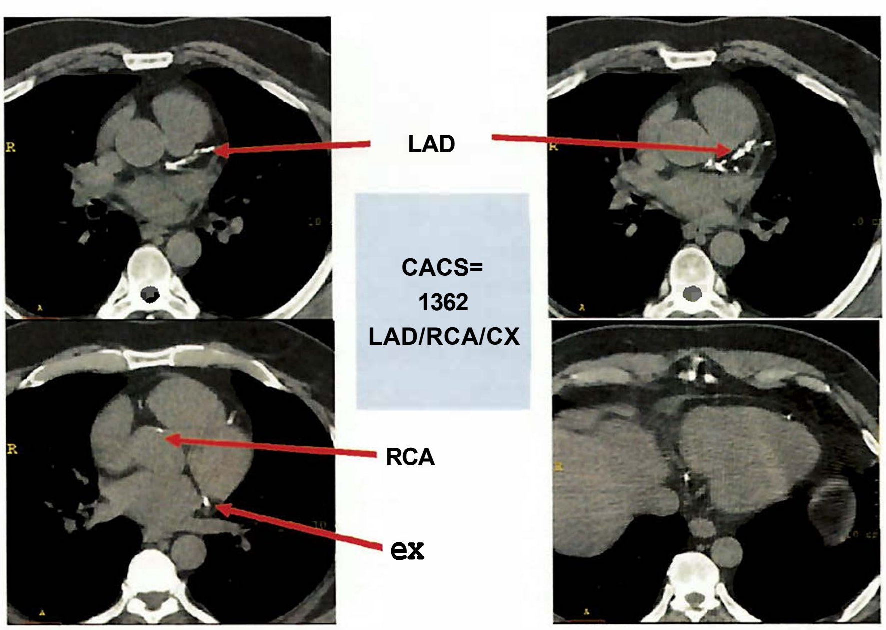


**Figure 1.** Representative multidetector CT scan showing extensive coronary artery calcification (arrows) in all three major coronary arteries. The coronary artery calcium score (GAGS) was severe at 1362. Cx = circumflex; LAD= left anterior descending; RCA = right coronary artery

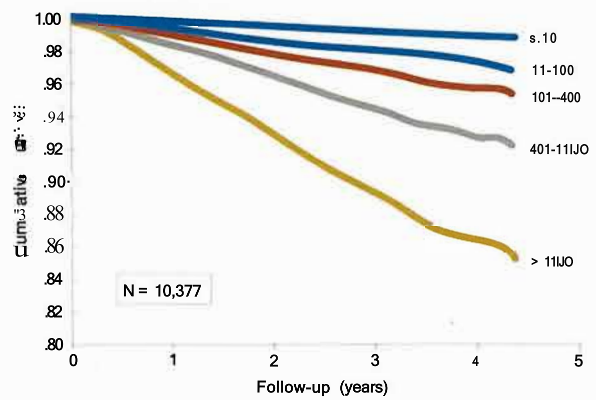


**Figure 2.** Survival curves based on CACS as determined by electron beam computed tomography in 10,377 subjects. A>1% mortality/year occurs when the CACS exceeds 400. Abbreviations as in Figure 1.

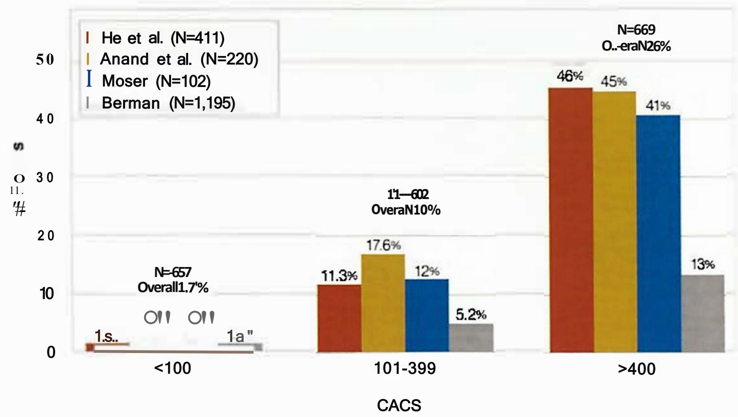


**Figure 3.** Relationship between coronary artery calcium score (CACS) results and an abnormal stress tomographic myocardial perfusion (SPECT) study. Patients with a CACS<100 have a low likelihood of SPECT positivity with a dramatic increase when the CACS is >400.

assessed by myocardial perfusion SPECT imaging. Published studies from investigators at Methodist DeBakey Heare Cenrer2 and others[12-14] indicate that less than 2% of patients with a CACS<100 will have ischemia by mess SPECT, whereas chis increases to more than 40% in the 10% of patiencs who have a CACS>400 (Figure 3).

Pariems with coronary calcification should be created the same as those with documented obstructive CAD, with aggressive risk factor modification and treatment of hyperlipidemia. Recent guidelines recommend that patients with a CACS<100 not undergo additional functional testing with stress SPECT unless they develop symptoms suggestive of ischemic heart disease, whereas patiencs with a CACS>400 should routinely be referred for functional testing due to the high bur variable likelihood of significant CAD and silent myocardial ischemia.[15-16]

Patients with a moderate CACS of 100-400 may warrant further diagnostic testing depending on their risk factor profile and symptom status. Ir is generally recommended that asymptomatic men over age 45 and women over age 55 undergo CT screening for coronary artery calcification.[16] Recent studies also suggest that routine CT calcium scoring may be warranted in patients who have a normal initial SPECT scudy since approximately 12% of chem will have severe calcification and 18% will have a CACS > 100.[17]

## CT CORONARY ANGIOGRAPHY

Contrast-enhanced CT coronary angiography became the next predictable technologic advancement beyond CAC scoring alone.18-36 Boch 16- and 64-slice multiderecror CT scanners can be used to noninvasively visualize the coronary arteries.[24-36] Alchough there is lirrle difference in diagnostic accuracy between these systems, the 64-slice scanners reduce the breach hold requirement by allowing faster acquisition of all CT image slices. However, the temporal resolution (i.e. imaging rime per slice) is similar for both 16 and 64 MDCT systems since this is dependent on gantry rotation speed and not the number of detectors.

As shown in Table 1, the percentage of analyzable arteries increases significantly from 4- to 16-slice detector systems but with similar diagnostic accuracy across all systems when the anery can be properly assessed. CT coronary angiography is very effective at excluding the presence of significant CAD, with a negative predictive value approaching 100%. However, the severity of arterial stenosis is overestimated approximately 30% of the time due to technical issues of spatial and temporal resolution and inadequate visualization of the lumen due to excessive coronary

| | 4 Detector· (N=390) | 16 Detector•• (N:670) | 64 Detector (N:::129) |
|---|---|---|---|
| Analyzable Arteries | 70% | 90% | 89% |
| Sensitivity | 80% | 85% | 82% |
| Specificity | 96% | 95% | 96% |
| PPA | 76% | 76% | 64% |
| NPA | 97% | 97% | 98% |

• Restricted generally to proximal and mid segments
" Restricted generally to arteries ◊2mm

**Table 1.** Multide1ector CT for identifying coronary artery stenosis.

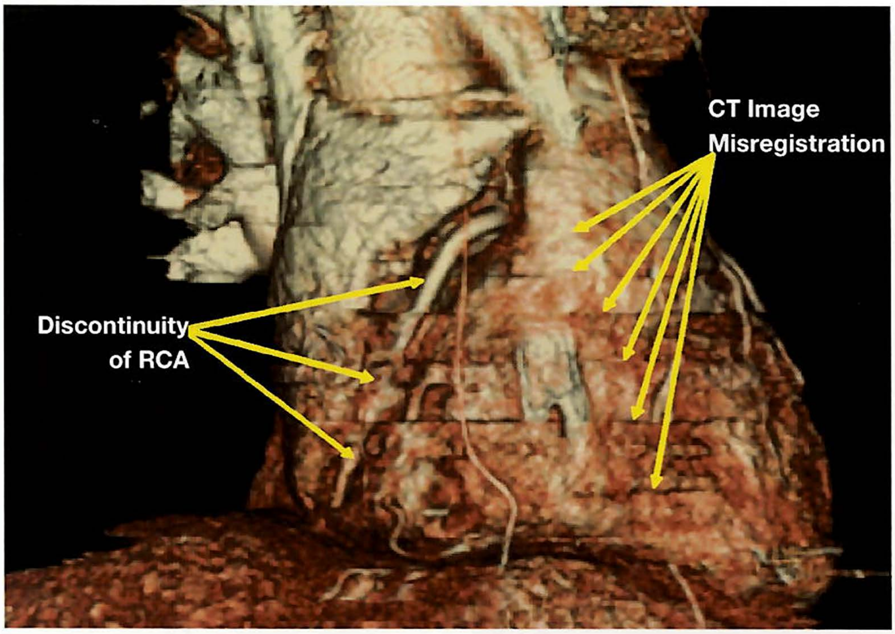


**Figure 4.** Volume rendered view from a patient who moved during study acquisition. The misregistration of CT slice data prevented adequate coronary artery assessment. RCA = right coronary artery.

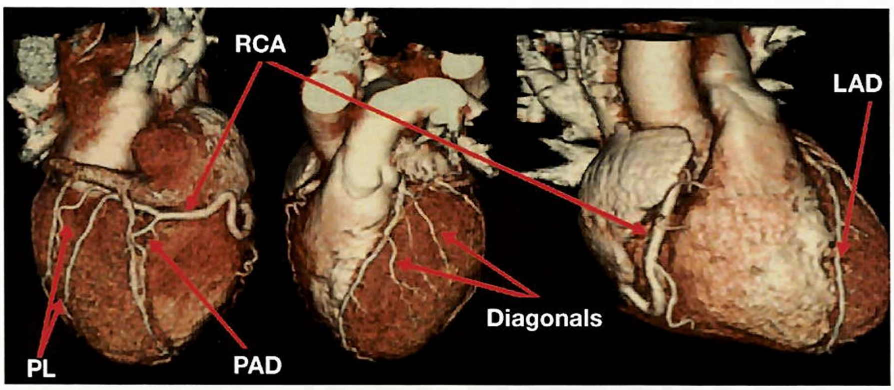


**Figure 5.** Volume rendered views of a CT angiography study acquired under optimal technical conditions. LAD = left anterior descending; PDA = posterior descending artery; PL = posterolateral branch; RCA = right coronary artery.

**Screen for contraindications**
- Atrial fibrillation, bigeminy, trigeminy
- Severe asthma - inability to use beta-blockers
- Creatinine>1.5 mg/dl
- Pacemakers/defibrillators
- Contrast allergy
- Morbid obesity (BMI>40)
- Poor IV access (antecubital vein with 18-gauge IV)
- Inability to follow breath hold commands
- Inability to hold breath 10-20 seconds (depending on CT scanner)

**No caffeine for at least 12 hours prior to study**

**NPO for two hours**

**Beta-blockers to reduce heart rate, preferably<65 BPM**

**Patient education**
- Breath hold
- Motion
- Contrast bolus effects

**Table 2.** Proper patient preparation and screening prior to CT angiography.

calcification or poor contrast opacification.[34] Thus, for patients in whom CT angiography detects significant stenosis, either invasive coronary angiography or a noninvasive functional assessment of ischemia is still recommended.

Proper patient preparation and screening for contraindications is essential for safely ensuring the highest quality studies (Table 2). Patients who have dysrhythmias are not optimal candidates for CT angiography since irregular rhythms will distort the images and render them uninterpretable. Due to the limited temporal resolution of all current MDCT systems (-180 msec), heart rate needs to be reduced with beta-blockers (preferably below 65 beats/minute) to ensure imaging at end-diastole when there is minimal cardiac motion. This requirement may change in the future if dual source detector CT systems are shown to increase temporal resolution to <100 msec.[37] Adequate IV access is necessary since contrast is injected at 4-5 ml/sec. Of prime importance is a cooperative patient who can comply with directions and remain motionless throughout the 10-20 second breath hold that is required for image acquisition. Any chest motion resulting from coughing, swallowing or breathing will result in misregistration of the CT image and a suboptimal study (Figure 4). Additional contraindications include severe asthma with the inability to receive beta-blockers, renal insufficiency from the 80-120 ml of contrast administered or a known allergy to iodinated contrast materials. Diabetics taking metformin must discontinue using it the morning of the study and for several days thereafter. Excellent images can be obtained when patients are properly selected and prepared for CT angiography (Figure 5).

## SUMMARY

While still evolving, CT coronary angiography has already proven effective at diagnosing significant CAD (Figure 6), assessing coronary artery bypass graft (Figure 7) and stent patency (Figure 8) and identifying coronary artery anomalies (Figure 9).[38-40] CT angiography may also ultimately characterize and quantify the presence and extent of

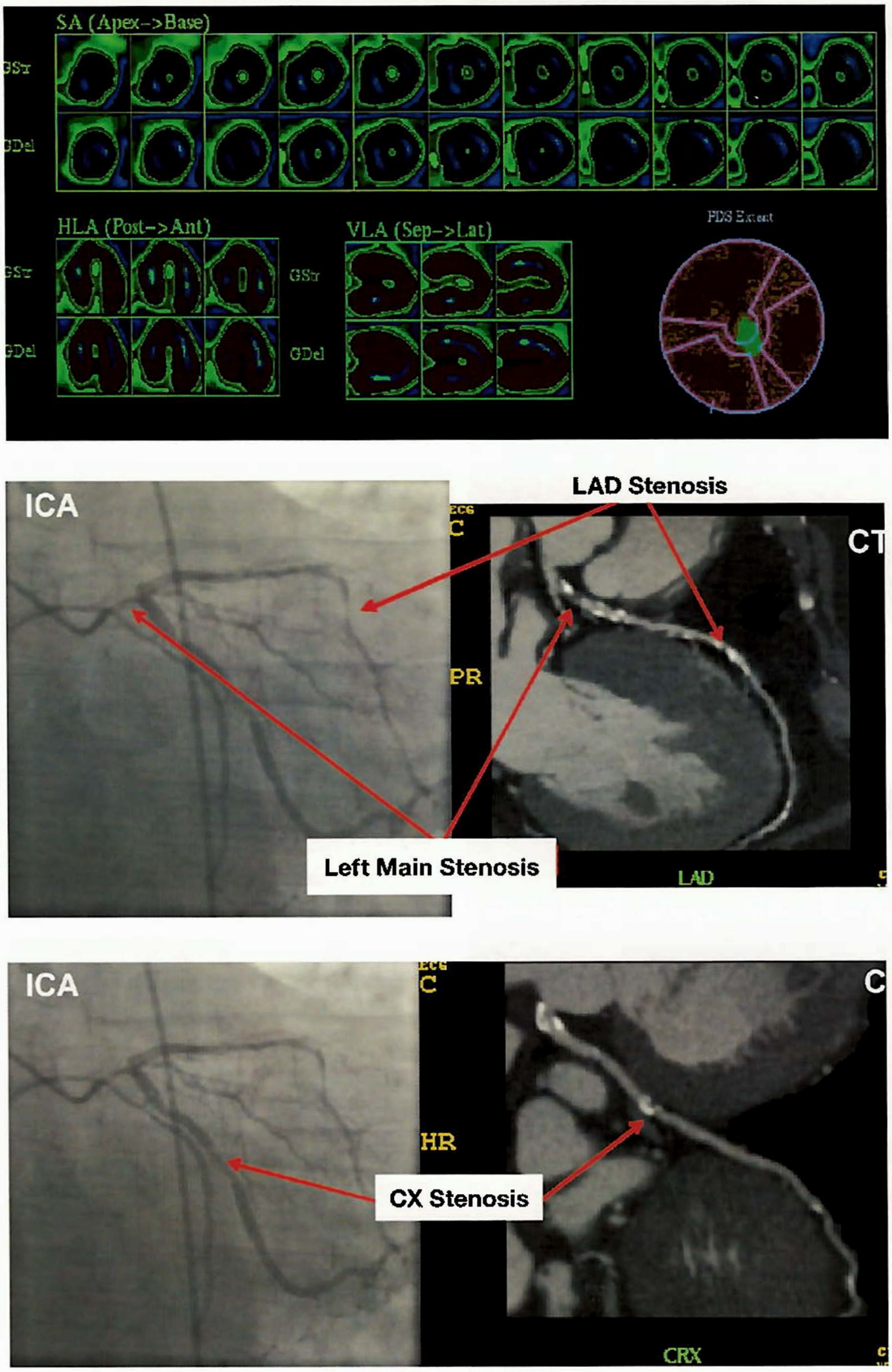


**Figure 6.** Representative case illustrating the integration of CT coronary angiography and exercise SPECT results. This 52 year-old asymptomatic man was referred for SPECT due to nonspecific ST changes on the ECG. He exercised 6-1/2 minutes on the Bruce protocol, had no cardiac symptoms but developed 2.5 mm ST segment depression in the inferolateral leads. The SPECT images show only a small 4% ischemic defect in the apex (A). CT coronary angiography (CTA) was performed to define whether he had limited stenosis to the distal left anterior descending (LAD) or more advanced coronary artery disease. Although severe stenosis of the distal LAD was seen on CT, the patient also had severe stenosis of the left main extending into the proximal LAD (B) as well as moderate stenosis of the circumflex artery (Cx) (C). A good correlation was seen between invasive coronary angiography (ICA) and CTA. The patient underwent coronary artery bypass surgery for treatment of his left main stenosis.

both calcified and noncalcified athero-scleroric plaque, which might berrer refine risk stratification.41-43

Another important area of research is the fusion of anatomic CT data with the functional information obtained during stress myocardial perfusion SPECT. Methodist DeBakey Heart Center currently has a SPECT-CT syscem chat will allow coregistration of CT and nuclear perfusion data sets. This fusion of information should improve the diagnostic accuracy of CT and SPECT results (Figure 10) and more precisely cailm percutaneous coronary interventions by identifying which arteries in a specific patient supply ischemic myocardium.

Finally, CT angiography will function as an essential roadmap for hot spot nuclear tracers currently being developed co target specific components of unstable atherosclerotic plaque. These future applications of fusion technology may berrer identify which patients with ischemia are at high risk for clinical events and thereby better guide therapeutic decision making.

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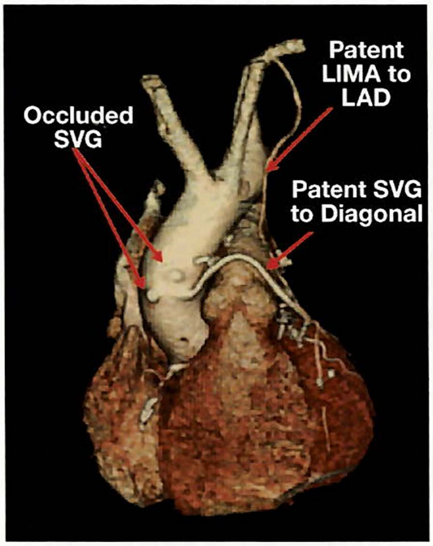


**Figure 7.** Representative volume rendered image of a patient with prior coronary artery bypass grafting. Saphenous vein graft (SVG) stumps are easily seen as well as a patent graft to the first diagonal and a patent left internal mammary artery (LIMA) graft to the distal left anterior descending (LAD) coronary artery.

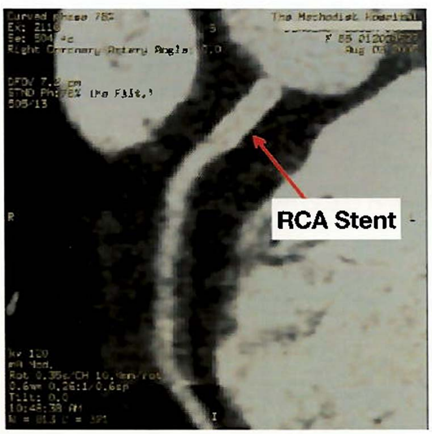


**Figure 8.** A patent stent in the proximal right coronary artery is well visualized.


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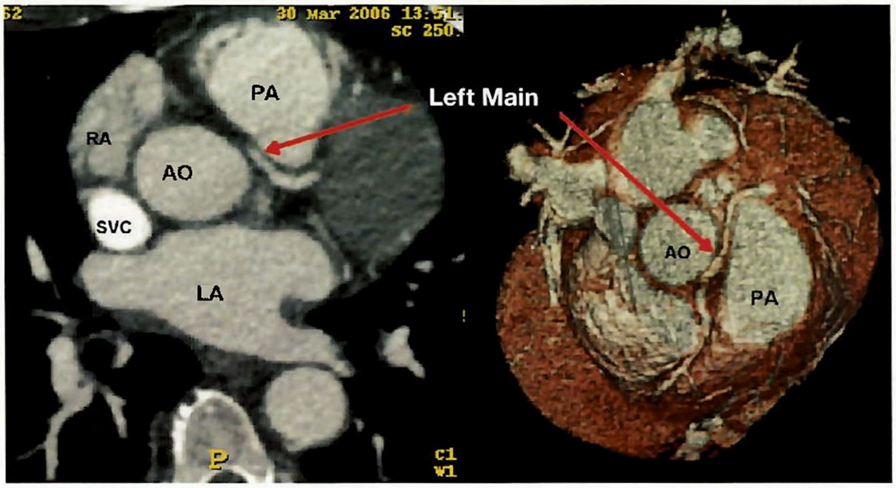


**Figure 9.** Coronary anomaly with **the left** main arising from the right sinus of Vatsalva and tracking between the pulmonary artery (PA) and ascending aorta (AO). The patient had exertional chest pain and a stress echocardiogram demonstrating ischemia in the anterior wall. At the time of invasive coronary angiography, the left main ostium could not be found. CT angiography was diagnostic and the patient was referred for coronary artery bypass surgery. LA = left atrium; RA = right atrium; SVC = superior vena cava.

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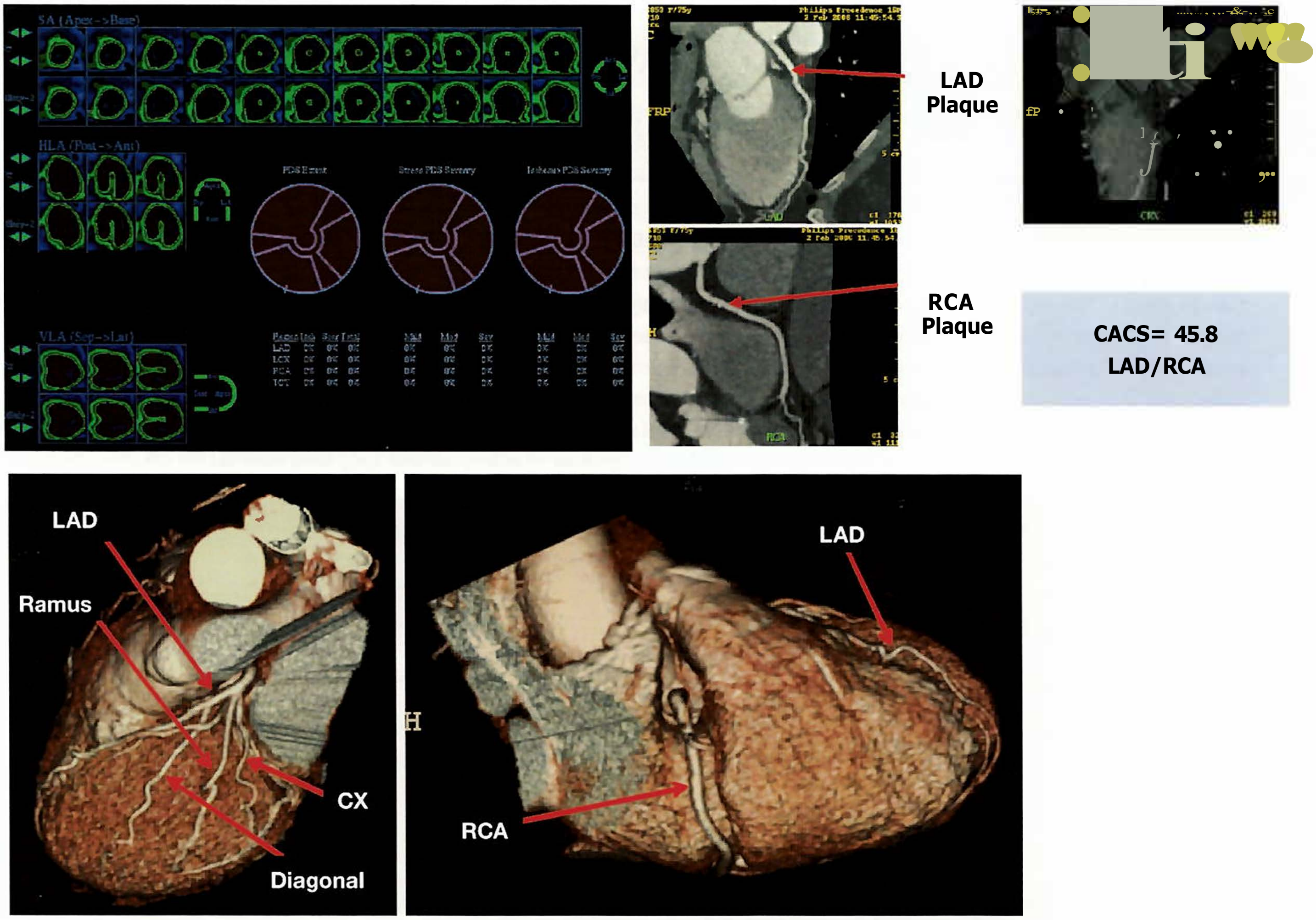


**Figure 10.** Computed tomography for clarifying equivocal SPECT results. This 75-year old woman was referred for exercise SPECT due to a history of atypical chest pain. The patient exercised for seven minutes on the Bruce protocol but developed 2 mm ST-segment depression with chest pressure radiating to the jaw. The SPECT images (A) show normal perfusion. The post-stress ejection fraction by gated SPECT was 75%. CT angiography was performed to clarify whether significant coronary artery disease was present. The volume rendered images (B) show a high qualify study. By CT, the patient had a mild CACS (45.8) with the coronary arteriograms showing no significant obstructive CAD (C). Abbreviations as in other figures.

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