MDCT Cardiac Angiography: The clinical value proposition shown with selected case studies

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Introduction

The growing interest and ever increasing number of users of cardiovascular CT, particularly CT with intravenous contrast administration, has heralded an era of discovery and rapid change. The ability to safely and non-invasively image the arterial and venous system and all the organs is fundamentally new to medicine. Just as we are confident that imaging technology will continue to improve, we can also be sure that it will guide medical decision-making in new and better ways.

Cardiovascular CT solves the problem of overlapping structures. It allows us to visualize ever-smaller elements or anatomy and distinguish them from adjacent structures that are similar in X- ray attenuation properties. Thus, we can resolve the irregular pathways of diseased arteries transporting an iodinated contrast agent, as well as identify the uncalcified atherosclerotic plaque within the walls of the artery. Although the value of this information is theoretically unproven in clinical outcomes analysis, it is intuitive that this tool will serve a triage function for symptomatic individuals. This will save money and will result in better utilization of healthcare services.

I have chosen actual clinical cases to illustrate the value that MSCT and 3D workstations bring to everyday cardiology practice. These cases have originated from a busy cardiology group practice with embedded 16 and 64-slice scanners operating as diagnostic MSCT tools along side echocardiog-

Figure 1 Large RV, RA, and pulmonary artery.

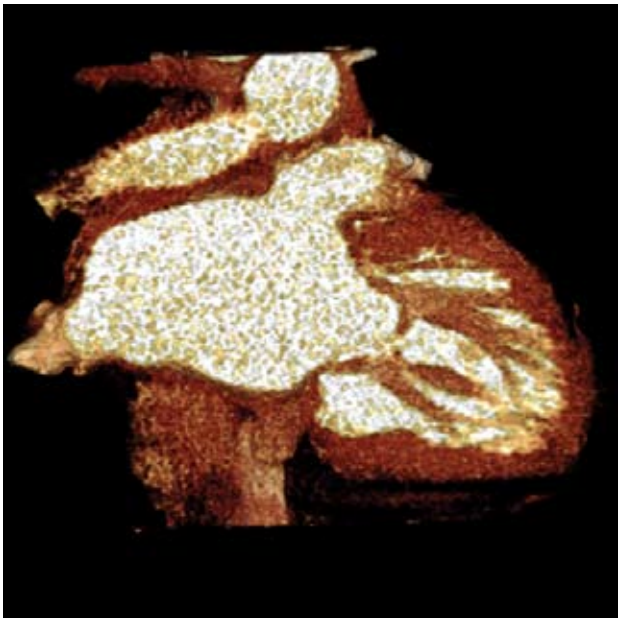

Figure 2 Thickened cordae tendenae and mitral leaflets.

raphy and nuclear perfusion imaging. These cases were not chosen as perfect studies: indeed some are technically sub-optimal. However, they prove that CT and advanced imaging tools can provide vital information that can improve patient outcomes.

A Multi-slice CT Scanner is much like a camera, and the photographer is akin to the CT technician. The CT technician selects the imaging protocols and adjusts the scanner variables to optimize its performance in each clinical situation minimizing radiation exposure while assuring uncompromised image quality. The 3D Workstation, however, is the clinical interpretive tool – rather, it is the suite of reading visualization tools that the cardiologist or the radiologist must master. It is the 3D workstation (and the interpretive software it contains) that delivers complex imagery for interpretation and physician communication. Optimizing the imagery and eliminating unnecessary image content is required for successful interpretations of CT studies. For ease-of-use, versatility, and speed of image processing, the Aquarius Workstation from TeraRecon, Inc. is an excellent choice as a real time image-processing system and efficient clinical workflow tool.

Case 1:

This is a CT study of a young woman who had rheumatic fever as a teenager. Following antibiotic therapy, she participated normally in sports but had twice fainted after intense exercise. As an adult, sports led to a classic anginal syndrome. Activity was curtailed and she was comfortable with normal adult activities other than sports. Her physical examination was consistent with moderate mitral insufficiency and she was in sinus rhythm. A transesophageal echocardiogram showed severe mitral insufficiency and moderate pulmonary hypertension. Valve replacement was recommended and a MSCT angiogram was performed in lieu of a direct catheterization since atherosclerosis was considered unlikely given her age and risk factors.

CT volume imagery was obtained with a 64-slice scanner, with 32 x 0.75 mm collimation reconstructed in 0.75 mm slices with 0.4 mm overlap. The expected findings of thickened mitral leaflets and thickened chords are seen along with right atrial, right ventricular and pulmonary arterial dilatation (Fig 1-3). The easily demonstrated finding of the origin of the left main coronary artery arising from the right Sinus of Valsalva was unexpected (Fig 4-5). Slightly off-axial viewing of the origin of the Left Main Stem also demonstrates its passage between the Aorta and Pulmonary Artery, a potentially lethal congenital abnormality. This finding led to a change in the surgical plan wherein the mitral valve was replaced, the left coronary circulation was

Figure 3 Mitral valve in cross-section.

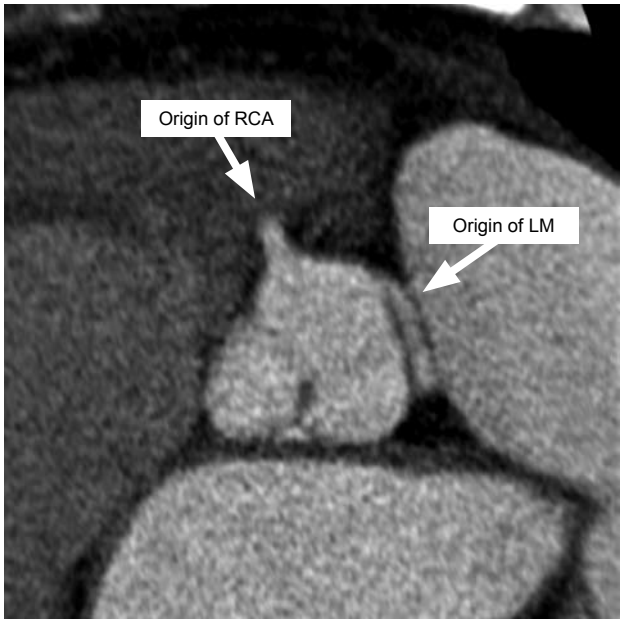

Figure 4 Mitral valve in cross-section.

bypassed, and the native left main ligated. Had the CTA not been performed, her surgery would have been incomplete and a lethal coronary anatomy gone un-repaired.

Missing this abnormality would be easy were it not for the ease of quickly panning to center the focus of interest (in this case the origin of the Right and Left Coronary arteries) and then selecting a MPR rendering and rotating the image plane away from the standard axial view to perfectly relief the intersection of the Left Sinus of Valsalva with the Left Coronary origin. This simple routine is done in each case without the readers' eyes ever having to leave the area-of-interest. These left and right mouse click steps are particularly fast with the Aquarius Workstation and it enables readers to determine the correct anatomic origin or the primary coronary arteries for each case.

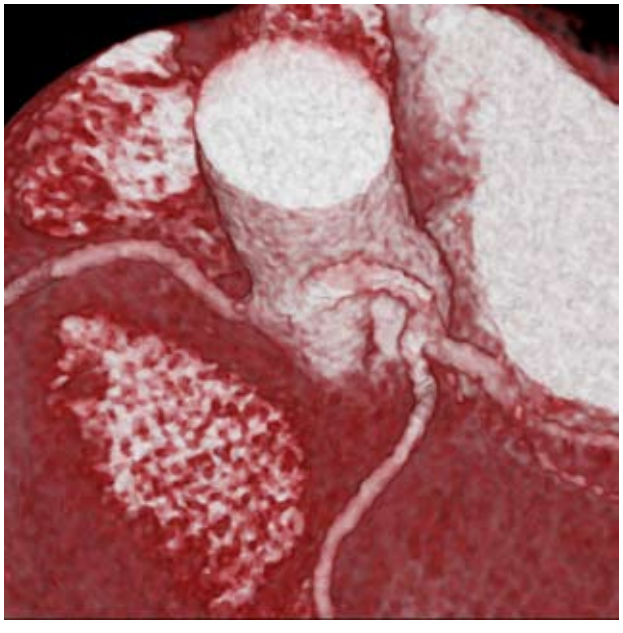

Figure 5 Left main origin from right Sinus of Valsalva.

Case 2.

This is the case of a young woman who developed an anginal syndrome on the backdrop of a very low Framingham Cardiovascular Risk Profile. However, despite the symptoms, her physiologic nuclear stress test images and the EKG response to moderate exercise was interpreted as "equivocal". Furthermore, the clinical possibility of scleroderma was raised, and a coronary vasculitis process was included in the differential diagnosis.

A CT coronary angiogram was carried out using a 64-slice scan, as the patient was frightened at the thought of going directly to the cardiac catheterization lab. Again with 32 x 0.75 mm collimation, 0.75 mm slices were reconstructed with 0.4 mm of overlap.

For efficient image interpretation, the Aquarius Workstation provides a number of "Super Templates," one of which if selected by default opens a volume of images in a steep caudal LAO projection with a cut-plane established that nearly always presents the Left Main Stem origin from the Left Aortic Sinus (Fig 6a, 6b). Preset opacity and color assignments provide a very realistic biologic appearance to the image. This shortcut is a quick route to that particularly important anatomic region.

In this case, the very high takeoff of the left main coronary artery is immediately visible at the start of the analysis (Fig 7).

The coronary details are usually explored as the last phase of a structured interpretive sequence in reading CTAs, but here this Super Template starts us off with a key finding at the starting part of the initial image perusal. From this image (Fig 8), it is

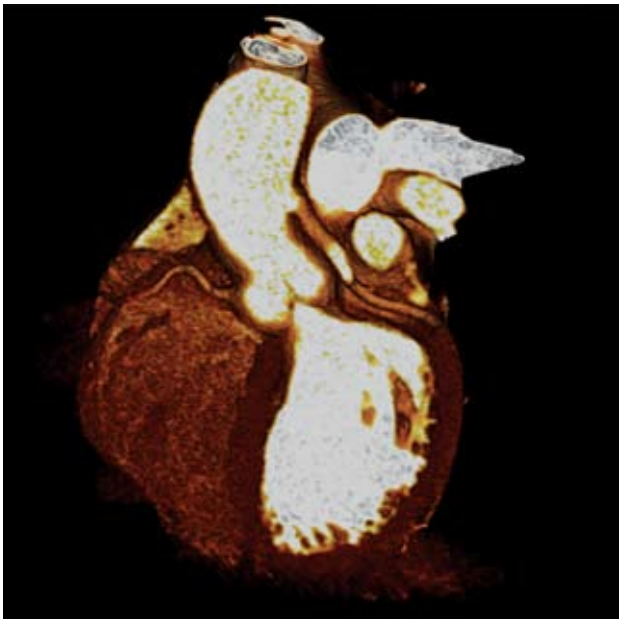

Figure 6A High Left Main Origin from the body of the Ascending Aorta.

Figure 7 One mouse click reveals the Left Main to be free of abnormalities other than the high takeoff.

possible to trace the Left Main tributaries quickly and zero in on the lengthy severely narrowed Left Anterior Descending Coronary artery. The anatomy here and in the remaining coronaries thus clarified, the diagnosis of single vessel disease is established. A serologic panel to rule out scleroderma was performed and returned negative.

After the patient was shown her exact problem, she underwent a successful percutaneous coronary intervention. Her interventionalist could see ahead of time the unusual roadmap to the targeted lesion.

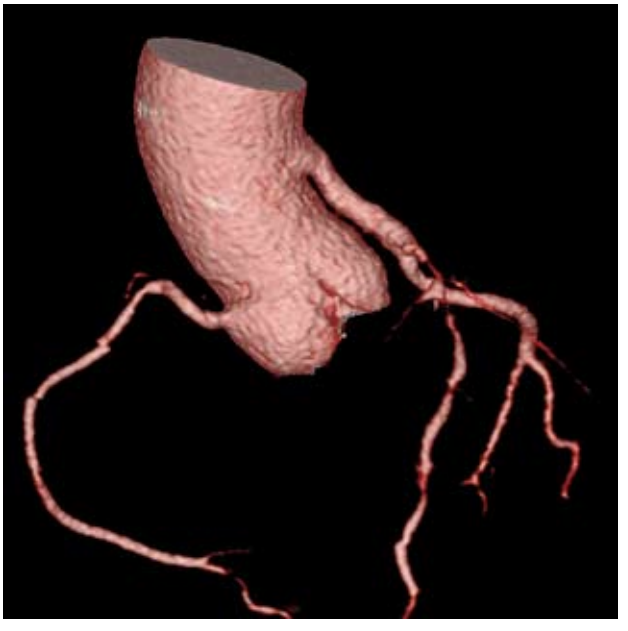

Figure 6B Coronary artery trees showing the origin from the body of the Ascending Aorta.

Figure 8 Single left mouse drag function centers the diseased Left Anterior Descending and relieves this segment to optimally assess this vessel and the first septal perforator. Total time to present this image from the start of the analysis is about 5 seconds.

Case 3

Part of the public appeal of non-invasive coronary imaging is that it is non-threatening, given its low risk and the fact that it is a minor clinical ordeal. The next case is that of a middle aged man of moderate cardiovascular risk who was vaguely unwell when walking; he was untrusting of doctors and criticized the safety of exercise tests; he would only have a CT angiogram and didn't want to be on a "slippery slope" in a catheterization lab. We accommodated his (and his referring physician's) requests and we anticipated that we would probably find something serious. This patient dropped in after lunch announcing that if we did not do it then, we might not get another chance. A 64-slice study was performed, with 32 x 0.75 mm collimation reconstructing 0.75 mm slices with 0.4 mm overlap.

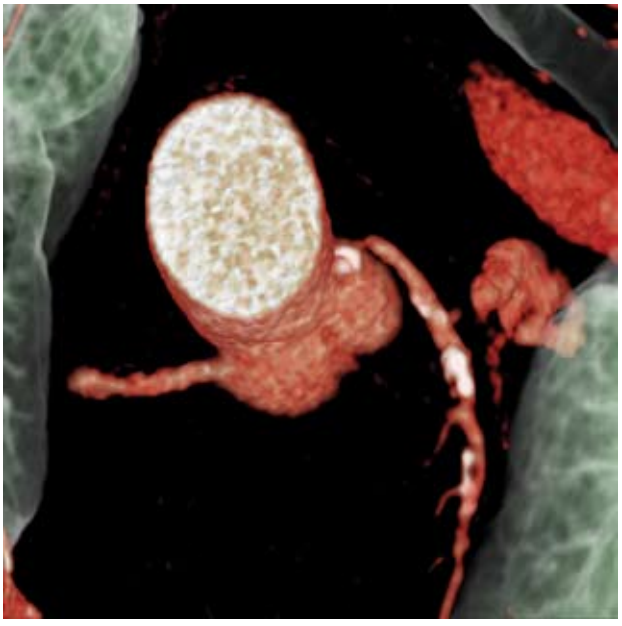

Figure 9 Volume rendering of the narrowed Left Main Coronary Artery origin from the Left Sinus of Valsalva.

In many ways the study was sub-optimal: his breath hold was shallow, the timing of the injection bolus of contrast was not correct and his heart rate accelerated during the study. Nonetheless, the critical part of his coronary anatomy, that is the origin of the Left and Right Main and the proximal tributaries could be adequately imaged.

A Left Main Coronary stenosis can be easily missed in directly injected coronary arteriography. I believe it will never be missed with satisfactory MSCT coronary imagery. This is because it is easy to locate the left main orifice (Figures 9, 11, 12) and establish an MPR image with the viewing angle perfectly orthogonal to the aortic sinus and vessel origin (Fig 10). This is done with left mouse panning, imaging plane rotation, and translation with a mouse scroll wheel function. The reader's eyes never leave the area of interest. What proved most effective in this case was our ability to adjust the opacity transfer functions slightly and allow the patient to manipulate the images himself while watching the severe left main blockage come in and out of the picture. He was convinced, hospitalized, directly catheterized, and operated on for multi-vessel bypass the following morning.

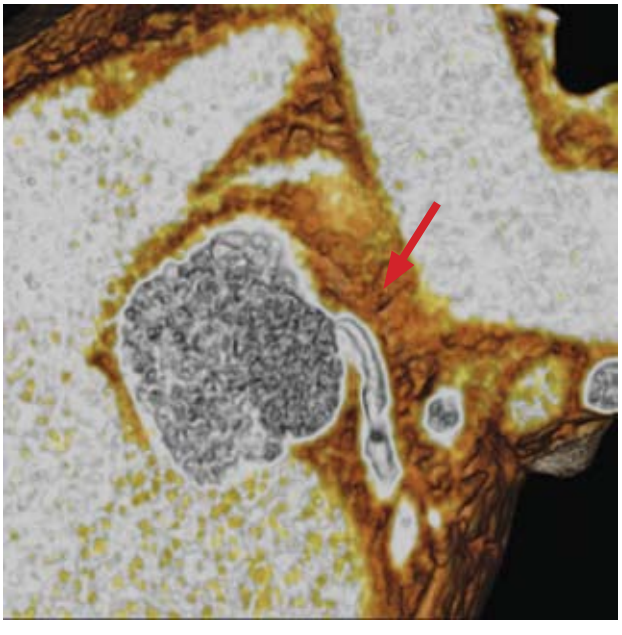

Figure 10 Narrow Left Main Takeoff rendered so the patient himself could control the image depth and assess the obvious findings.

Figure 11 Curved Planar Reformation of Left Anterior Coronary Artery (Axial Projection).

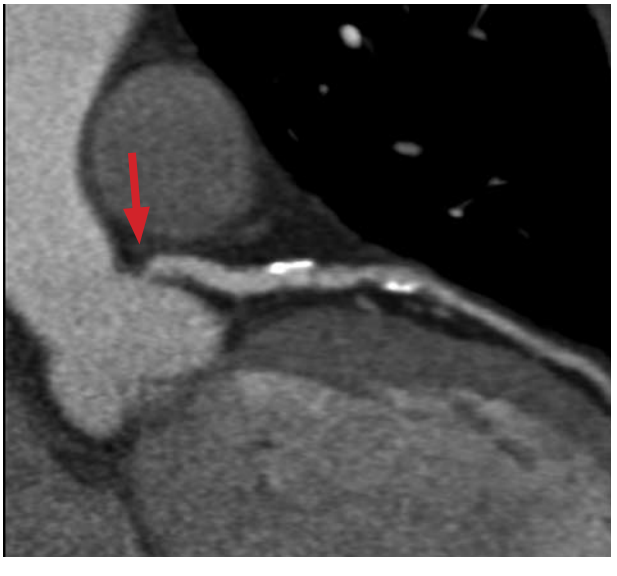

Figure 12 Curved Planar Reformation of Left Anterior Coronary Artery (Coronal Projection).

Case 4

This is a study of a middle-aged man who is overweight and is unable to quit smoking. He has recently been found to have hypertension and acknowledged that heart diseases run in his family. Despite this, he feels "great" and has started taking an aspirin a day for good luck. A month earlier he actually underwent a coronary arteriogram because of atypical chest pains, which have since disappeared. He was told that only minor abnormalities were found and he was reassured. His primary care physician ordered a MSCT coronary angiogram having read that the arteries themselves could be seen, not just the arterial lumen.

A 64-slice study was performed with 32 x 0.75 mm collimation 0.75 mm slices reconstructed again with 0.4 mm overlap.

The non-invasively acquired images showed coronary imagery quite contrary to the "minor abnormalities" description from the directly injected angiogram. In fact, a severe and critically located burden of un-calcified coronary plaque is very easily identified both in the proximal Left and Right Coronary Artery segments. With the advance in MSCT scanner technology and optimized intravenous contrast delivery, it is possible to resolve the boundaries between the peri-vascular fat, the arterial wall, and the vascular lumen. Here, the arterial wall contents can be readily shown to bulge with plaque that may well have been dangerously biologically unstable in the proceeding month, leading to his visit to the emergency room. The gratifying part of this case review with the patient and his referring doctor was the ease with which the totality of the disease could be illustrated. The "Super Template" in the Aquarius Workstation took us straight to the core of the problem. After minor adjustments of the opacity transfer functions with the left and right mouse dragging, the actual plaque in the arterial wall could be dramatically illustrated to the patient (Figures 13, 14).

The power of the imagery to compel patient compliance is very real (Figures 15, 16). Here again, the study could be interactively read quickly with the patient in attendance. An endovascular intervention

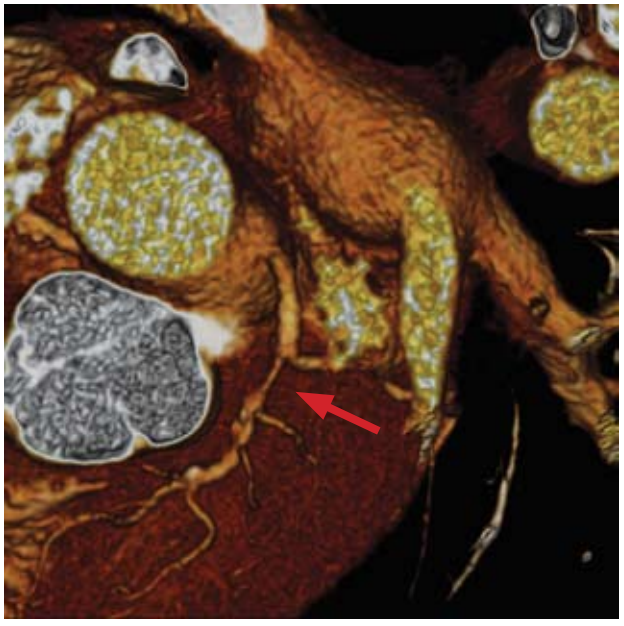

Figure 13 Narrowed lumen of the Left Anterior Descending Coronary Artery.

Figure 15 Curved Planar Reformation of Left Anterior Descending Coronary Artery (Actual Projection).

is not indicated; but the opportunity to change the natural history of the disease with very aggressive medical therapy is very likely to be an effective plan. This study will be repeated yearly for the next several years. It may well be possible to track the changes in the obvious plaque burden over time and assess the course of therapy with something other than clinical endpoints. Being able to configure the subsequent images exactly as they are set up in this first study is a straightforward process using the TeraRecon toolkit. It may enable MSCTA to be a non-invasive surrogate for plaque burden assessment, now done only by intra-arterial ultrasound.

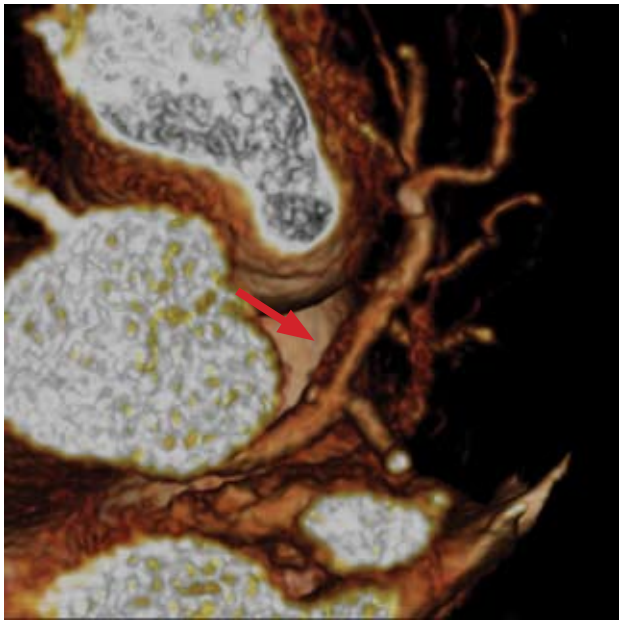

Figure 14 "Soft" Atheroma in the wall of the Left Anterior Descending Coronary Artery.

Figure 16 Curved Planar Reformation of Left Anterior Descending Coronary Artery (Coronary Projection).

Conclusion

I believe all these cases illustrate that the applications for non-invasive coronary artery imaging by MSCT are numerous. The technology has surged ahead of the understanding of how it will be applied, who will pay for it, and what imaging modalities it might supplant. These issues will be clarified as familiarity with CT imagery accrues amongst physicians. The starting point for quality imagery is patient selection and preparation. This is followed by proper technique use of protocols for scanner operation, this being mainly the domain of the CT Technician. Finally it involves the mastery of a 3D workstation for viewing and interpretation, an absolute prerequisite for physicians considering entering this field. Here the Aquarius Workstation from TeraRecon particularly excels: the learning curve is not steep and once mastered, interpreting cases with high accuracy can be accomplished quickly.

Case Studies have been kindly provided by the South Carolina Heart Center Columbia, SC, and the Heart Center, Huntsville, AL.