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CONTINUING EDUCATION FOR MEDICAL PROFESSIONALS

How to Use CT in Clinical Practice: Solving Problems Cardiologists Face

By Dr. James Earls

LEARNING OBJECTIVES

Upon completion of this activity, participants should be able to:

- Describe the key elements and basic uses of coronary CT angiography (CTA).
- Explain how coronary CTA can help cardiologists solve problems in clinical practice.
- Discuss the basic exam method and risks of coronary CTA.
- Identify clinical situations in which coronary CTA may be useful.

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Cardiac applications for CT have evolved rapidly in the last several years. The introduction of multidetector-row CT (MDCT) scanners has led to new ways of evaluating the heart and coronary arteries noninvasively. Coronary CT angiography (CTA) has emerged as an accurate and reliable method of performing noninvasive coronary angiography.[1-12] We have found that coronary CTA can be very useful in solving a number of clinical problems routinely faced by cardiologists. The following will provide specific information to cardiologists considering using this new technique as a diagnostic tool on their patients with known or suspected coronary artery disease.

In our practice we have performed approximately 500 coronary CTA studies in the past year. Cardiologists ordered more than 50% of these studies. This experience has led us to recognize several groups of patients in whom CT coronary angiography is most helpful.

The most common indication is chest pain, usually atypical or chronic. In many cases it is unclear whether the pain is cardiac in origin. Coronary CTA can effectively establish the presence of coronary artery disease (CAD), or it can exclude CAD and assess for other thoracic pathology. Another indication is for clarification of inconclusive noninvasive studies, commonly a suspected false-positive nuclear stress test. Other common reasons include screening in high-risk patients, interval evaluation of known CAD, patients refusing conventional coronary angiography, incomplete coronary angiography, known or suspected anomalous coronary arteries, and evaluation of bypass grafts and coronary stents.

Coronary CTA image quality is degraded at high heart rates or when there is a rate change during

FIGURE 1. REVIEW OF MULTIDETECTOR-ROW CTA STUDIES

Year	Study	CT detector rows	No. of points	% Coronary segments assessed	Sensitivity	Specificity	PPV	NPV
2001	Achenbach S, *Circulation*	4	64	68	91	84	NA	NA
2002	Nieman K, *Am J Cardiol*	4	53	70	82	93	66	97
2002	Giesler T, *AJR*	4	100	71	91	89	66	98
2002	Bellinger R, RSNA	8	25	91	92	94	NA	97
2002	Nieman K, *Circulation*	16	59	93	95	86	80	97
2003	Ropers D, *Circulation*	16	77	88	92	93	79	97
2004	Mollet N, *J Am Coll Cardiol*	16	128	NA	92	95	79	98

scanning. Beta-blockers effectively lower the heart rate and substantially improve image quality.[13] We administer 50 mg of metoprolol orally at 12 hours and one hour prior to the exam, unless the patient has a contraindication or is already taking a beta-blocker.

The exam takes approximately 15 minutes on the CT scanner, although the actual image acquisition for the angiogram is typically 18 to 26 seconds. An 18- or 20-gauge IV needle is placed in an antecubital vein and ECG electrodes are positioned on the chest. A small bolus of contrast is given to determine circulation time. After a rapid (4 to 5 cc/s) bolus of 75 to 100 mL of nonionic contrast, followed immediately with 50 cc of saline, the scanner acquires enough 0.4 to 0.75-mm thick slices to cover the entire heart and portions of the ascending aorta.

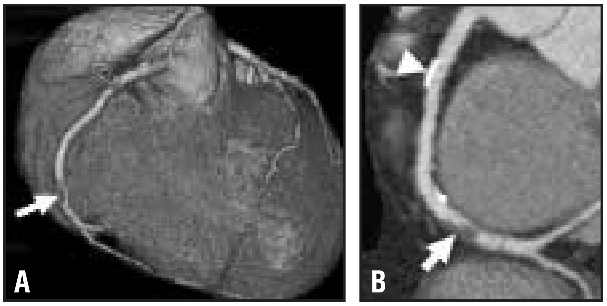

Figure 2. A: 64-year-old with an RCA stenosis depicted on coronary CTA (arrow). B: Reformatted image depicts a large soft plaque (arrow) and a smaller calcified plaque (arrowhead).

Coronary CTA is FDA approved. The CT technique results in a radiation dose of 4 to 12 mSv, depending on the technique and CT scanner used. We use 80 cc of nonionic contrast agent for a study. Patients are screened for renal insufficiency and informed consent is obtained. Relative contraindications for the exam are reactive airway disease, significant arrhythmias, and a history of contrast allergy, although this can be treated in advance with a steroid/antihistamine prep. Patients with coronary artery calcium scores of greater than 400 to 800 may not benefit from CT coronary angiography. High calcium loads cause artifacts that can lower the exam sensitivity substantially.

A physician and technologist generate 2D and 3D images of the heart and coronary arteries interactively on a 3D workstation. Volume-rendered 3D images depict the heart and coronary arteries. Curved multiplanar reconstructions of the coronary arteries and branches are generated. This includes a technique that straightens the artery, allowing examination of the vessel in 360º of rotation, which is critical to the detection and assessment of eccentric plaques and stenoses. A functional CT program is also performed, which permits quantitative analysis of cardiac function.

CTA VERSUS CA

Cardiac-capable CT scanners were developed in the late 1990s. Initial studies using scanners with four detector rows were promising; these had an 82% to 91% sensitivity for depicting coronary stenoses of 50% or greater when compared with conventional coronary angiography (CA).[1-8] Unfortunately, the four-detector-row scanners were not reliable enough for clinical use because they were able to routinely assess only 70% of the coronary segments.

The development of 16-detector-row scanners has markedly improved the performance of coronary CT angiography (Figure 1). Correlative studies with CA show 92% to 95% sensitivity for stenoses of 50% or greater.[10,11] A major advantage of the 16-row system is improvement in spatial resolution; the new scanners acquire slices as thin as 0.4 mm. When combined with increased rotation speed, 16-slice MDCTs allow for reliable assessment of a greater number of coronary segments (88% to 95%) than the four-slice devices (70%).[10-12] These studies have also reported a 97% to 98% negative predictive value—a critical value when coronary CTA is used as a screening exam.[10-12]

There are physiologic and resolution differences between CA and cardiac CTA that need to be considered. With CA the arteries are imaged after a rapid bolus of contrast has been injected under pressure via a catheter placed directly in the lumen of the vessel. With CTA the vessels are not provocatively distended and they are filled with contrast that has been diluted following a peripheral venous injection. As a result the vessels appear smaller, and some branches may not be apparent. Image resolution of CTA is approximately 0.625 to 0.75 mm, almost an order of magnitude less than CA. Despite these differences, there is very good correlation between CA and coronary CTA for detection of stenoses of 50% or greater (Figure 1).

Figure 3. Atypical chest pain in a 58-year-old patient. Coronary CTA depicts a high-grade stenosis in the LAD (arrow).

One unique and potentially useful aspect of coronary CTA is its ability to both depict and characterize atherosclerotic plaque. Plaques are complex and contain a mixture of lipid, calcium, fibrous tissue, blood, and other material. Cardiac CTA can characterize the components of larger atherosclerotic plaques based on their Hounsfield unit (HU) density.[14] Atheromatous plaques are typically in the 50-HU range while fibrotic plaques are in the 80 to 90-HU range, and calcium is >400 HU. In the future, "vulnerable" noncalcified atheromatous plaques may be managed differently than calcified stable plaques (Figure 2). CTA has the ability to noninvasively characterize them and can identify nonobstructive "vulnerable" plaques based on their histology and morphologic features.[15]

CLINICAL USES

Determining the cause of atypical chest pain is a common problem encountered by cardiologists. In some cases it is unclear whether pain is cardiac or noncardiac in origin. Coronary CTA is very helpful in making this determination, and atypical chest pain is one of the most frequent indications for coronary CTA in our center. In cases when symptoms are nonspecific and not clearly cardiac in origin, CT coronary angiography can establish or exclude the presence of CAD (Figure 3).

If disease is depicted with coronary CTA, its severity can be immediately determined without additional studies. If no coronary disease is depicted, the study can effectively exclude atherosclerosis as a causative factor for the patient's chest pain. With a negative predictive value of 97% to 98%, coronary CTA can reliably exclude the presence of significant disease in most patients.[10-12]

Since patients undergoing coronary CTA get 2D CT images of most of the chest and portions of the upper abdomen, noncardiac causes of chest pain may be diagnosed. Noncardiac causes of chest pain that can be diagnosed on coronary CTA include pulmonary emboli, aortic dissections, intramural hematomas, liver disease, bony metastases, hiatal hernias, mediastinal masses, pulmonary infiltrates, bronchogenic carcinomas, mediastinal lymphadenopathy, emphysema, and pulmonary fibrosis. Coronary CTA effectively rules in or rules out coronary atherosclerosis, as well as many noncardiac causes of chest pain, in a single comprehensive exam.

Cardiologists are faced with a diagnostic dilemma when they have a positive nuclear stress perfusion exam for a patient in whom they have a low clinical index of suspicion. Despite a low pretest probability, the positive nuclear study may obligate the cardiologist to perform coronary angiography that is frequently normal, or there may be lingering doubts if the physician elects to medically manage the patient. Cardiologists know that nuclear perfusion studies lack specificity,[16] but before CTA they had no way of noninvasively determining whether the studies were false positive or true positive.

There are many well-known causes of false-positive stress myocardial perfusion studies.[16] Common causes include patient motion during image acquisition, diaphragmatic attenuation, breast attenuation, underlying cardiomyopathy, bundle branch block, and ventricular pacemakers. Prone imaging, attenuation correction, and use of pharmacologic stress agents can improve specificity, but myocardial perfusion SPECT imaging still frequently results in false-positive exams.

Coronary CTA can clarify cases in which a nuclear study is suspected to be false positive. By depicting normal or minimally diseased coronary arteries, the cardiologist can feel more confident that no significant disease is present and that the low clinical index of suspicion was correct. Patients can be managed without undergoing conventional coronary angiography, avoiding the expense and morbidity of the invasive exam.

Occasionally, significant disease is present despite the low clinical suspicion. In these patients, coronary CTA will depict the coronary stenoses, and intervention can be planned. When coronary CTA is used judiciously, it can help the cardiologist lower the negative catheterization rate, reduce unnecessary catheterizations, and help ensure that all patients are treated appropriately.

Cardiologists know that coronary atherosclerosis is a progressive disease requiring intermittent diagnostic testing and intervention. Reevaluation is required when a patient's clinical symptoms recur or progress, or if there are new findings on other diagnostic tests. While it might be useful to perform a coronary angiogram every time a patient's clinical course changes, it is not always practical to do so. Deciding whether to manage the patient medically or perform diagnostic angiography can be difficult in some patients.

When the clinical situation is unclear, coronary CTA offers a new option for noninvasively obtaining an angiogram to intermittently assess the status of known disease (Figure 4). Coronary CTA accurately depicts the anatomy and immediately allows the cardiologist to make management and therapeutic decisions based upon actual morphology rather than inference.

When patients with CAD develop new symptoms or other changes, coronary CTA offers a tool that can assist in the decision-making process by providing useful information that can complete the diagnostic puzzle. If used judiciously, coronary CTA can help identify patients without significant CAD before they end up undergoing an unnecessary cardiac catheterization.

SCREENING HIGH-RISK PATIENTS

Cardiologists are often asked to evaluate patients who are at elevated risk for the development of CAD. Currently, many patients undergo calcium-scoring studies using spiral or electron-beam CT. The amount of calcium present is a marker for the presence and severity of coronary disease and it can be used to predict the statistical likelihood of a future coronary event. Unfortunately, calcium-scoring studies can depict only calcified plaques, are insensitive to noncalcified plaque, and cannot show on an individual basis whether a coronary stenosis is present, how severe it may be, or even if the coronary artery is patent or occluded.

Coronary CTA can be used to screen patients with elevated risk factors and it has significant advantages over calcium-scoring CT exams. Cardiac CTA depicts calcified and noncalcified plaque, can determine the presence and degree of coronary stenoses, and can determine whether a vessel is occluded. Coronary CTA is both sensitive (>90%) and has a high negative predictive value (97% to 98%)—an excellent combination for a screening exam.[10-12] There are drawbacks to coronary CTA, however: coronary CTA results in higher radiation dosage to the patient and uses nephrotoxic iodinated contrast.

If disease is identified, the patient can be effectively triaged to medical management, additional diagnostic testing, or intervention (Figure 5). If no disease is present, additional diagnostic testing may be avoidable. In our practice, screening patients receive color 3D images and movies following the study. We find this to be a very powerful motivator to affect real lifestyle changes in those with positive findings.

Occasionally, cardiologists encounter patients with documented evidence of ischemia, or other positive findings, who refuse to undergo CA. Despite positive objective data and the recommendations of their physician, patients may persist in their refusal. Reasons vary but include denial, fear, or prior bad experience. This refusal may place them at increased risk and puts the cardiologist in a difficult position.

Coronary CTA can assist the cardiologist by offering a noninvasive alternative that will appear less threatening or risky to hesitant patients. Because there is little risk of injury, patients may agree to undergo coronary CTA while refusing CA. We have found that when CTA results are positive, this is usually enough to convince patients that a catheterization with possible intervention is needed. If the CTA results are negative, the hesitant patient will be spared conventional CA and the cardiologist can be assured that the patient has been well cared for.

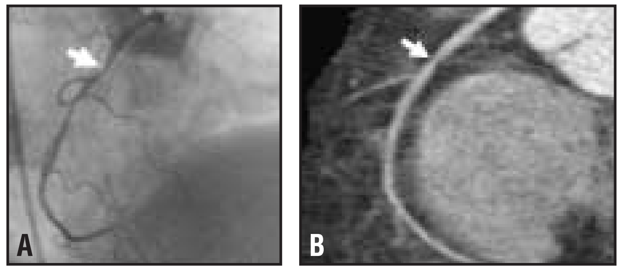

Figure 4. Follow-up exam of a 57-year-old with a questionable new inferior wall ischemia. A: 30% RCA stenosis was previously noted at conventional angiography (arrow). B: Coronary CTA confirmed that the stenosis (arrow) was unchanged two years later.

On occasion, cardiologists are unable to complete all desired views during diagnostic CA. This may be because of difficulty cannulating one of the coronary arteries, anomalous anatomy, or medical instability requiring early termination of the procedure. Rather than bringing the patient back to the catheterization laboratory to complete the study, coronary CTA now offers an alternative. Coronary CTA can accurately depict the coronary segments not visualized on the initial angiogram. In cases where intervention is not required, performance of the CTA will spare the patient from repeat catheterization while completing the diagnostic work-up.

Coronary artery anomalies can be clinically important. This is especially true for anomalies in which the right or left coronary

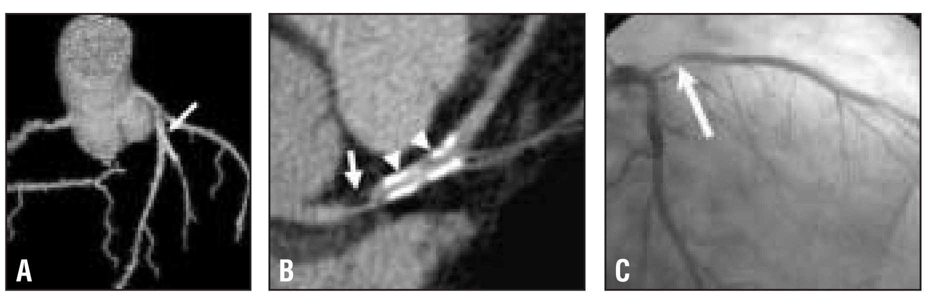

Figure 5. Screening coronary CTA of a 57-year-old with hyperlipidemia. A: 3D image depicts a densely calcified LAD plaque (arrow). B: Reformatted view depicts soft plaque (arrow) creating a high-grade stenosis proximal to a region of circumferential calcification (arrowheads). C: Stenosis (arrow) was confirmed with conventional angiography.

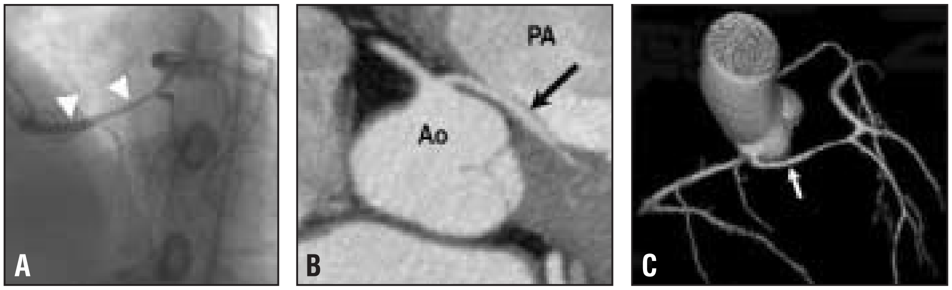

Figure 6. Anomalous left main coronary artery in a 47-year-old. A: Conventional angiography depicted a very long left main (LM) coronary artery, but its course was unclear. B: Coronary CTA depicts a common origin of the left and right coronary arteries from the right coronary sinus. The anomalous LM courses between the aorta (Ao) and pulmonary artery (PA). C: 3D view of the CTA depicts the elongated LM.

arteries originate from the opposite sinus and pass between the aorta and pulmonary outflow track. The location and course of anomalous arteries can sometimes be difficult to determine using CA. Management and therapeutic decisions require that the exact relationships be determined.

Coronary CTA accurately depicts the anomalous origin and the exact anatomic course of the vessel. Because of the 3D nature of MDCT, complex anatomic relationships are well depicted. Cases in which coronary anomalies are diagnosed during CA but in which the exact vessel location is unclear can be comprehensively evaluated with coronary CTA (Figure 6).

Following surgical or percutaneous intervention, cardiologists currently have no reliable method for periodically assessing the patency of bypass grafts or intracoronary stents. Both coronary stents and venous and arterial bypass grafts may be evaluated with cardiac CTA.

Proximal stents located in the first or second coronary segments are more easily evaluated than distal stents. Cross-sectional images of the stent may reveal intimal hyperplasia or occlusion. Preliminary studies found excellent agreement for depiction of occluded stents.[17-19] While not routinely performed, coronary CTA appears promising for this application and it may play a major role following coronary intervention in the near future.

Cardiac CTA has shown excellent results in the evaluation of coronary artery bypass grafts. Studies have shown 93% to 98% sensitivity for restenosis of either vein or internal mammary/radial artery grafts and 98% to 100% sensitivity for depicting bypass graft occlusion.[20-22] Evaluation of vein grafts and bypass arterial conduits is relatively uncomplicated by cardiac motion. Endogenous collaterals from native artery branches may also be assessed, as well as the patient's remaining native vessels and bypass grafts.

CONCLUSION

Coronary CTA is a new tool that can be useful in solving everyday problems encountered by cardiologists. It is an accurate, noninvasive method of performing coronary angiography. Clinical problems in which coronary CTA is useful include the evaluation of patients with atypical chest pain, inconclusive non-invasive studies, known CAD, incomplete catheterization, anomalous coronary arteries, and those refusing coronary angiography, as well as assessment of the patency of coronary grafts and stents.

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