Optimizing Outcomes in Coronary CT Imaging

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Cardiac computed tomographic angiography (CCTA) is revolutionizing our approach to the identification and management of coronary artery atherosclerosis. CCTA has the unique ability to assess extracoronary cardiac findings within the standard field of view, including the anatomy of cardiac structures—the atria, ventricles, valves, pericardium, great vessels, and venous anatomy—and any related abnormalities. Appropriate clinical applications include evaluation of intermediate-risk patients with acute chest pain and those with suspected coronary anomalies, uninterpretable or equivocal stress test results, or suspected cardiac morphologic abnormalities. Optimization of this diagnostic examination requires close attention to details such as minimizing motion and attaining sufficient contrast opacification. Iso-osmolar contrast can help achieve maximum patient comfort with the smallest elevation of heart rate and variability, as well as minimize the risk of acute kidney injury. Newer scanning equipment and protocols have improved image quality in difficult cases, including obese patients and those with heavy coronary calcification or metal artifacts. Current imaging protocols have reduced exposure to ionizing radiation and continue to improve safety.

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Coronary atherosclerosis is anatomically present in nearly all adults, yet a smaller proportion of people will develop symptomatic acute and chronic coronary symptoms over the course of a lifetime. In 1965, Eggen and colleagues[1] reported autopsy results from 1242 adults and found that about 50% of all individuals older than 40 and about 75% of those older than 60 had atherosclerosis in the left anterior descending artery, irrespective of the cause of death. Tuzcu and colleagues[2] found that among patients who sustained noncardiac death and underwent intravascular ultrasound (IVUS) prior to heart donation for transplantation, the prevalence of coronary atherosclerosis varied from 17% in subjects younger than age 20 years to 85% in subjects aged 50 years and older. Coronary artery disease (CAD) is the most common cause of death in the industrialized world and results in more than half of the cardiovascular deaths in the United States. Invasive coronary angiography, since its launch more than 30 years ago, has largely defined our understanding of normal and pathologic coronary anatomy and has been established as the reference standard.[3-5] However, because of its attendant risks and costs, invasive coronary angiography is appropriately confined to high-risk patients. Despite careful patient selection, 20% to 27% of the invasive angiograms performed for evaluation of CAD are normal.[6,7] In addition, because only the lumen is displayed on coronary angiography, the data provided regarding plaque burden and early atherosclerosis are not complete. Diagnostic cardiac catheterizations, particularly those that might result in normal angiograms, could potentially be replaced by a noninvasive method such as cardiac computed tomographic angiography (CCTA).

Since the introduction of 4-slice spiral CT systems in 2000, there have been rapid and revolutionary technological advances in the spatial and temporal resolution of multidetector row computed tomography (MDCT).[8] Electrocardiogram (ECG)-triggered and ECG-gated MDCT examinations came into clinical practice with the development of 16-slice systems. The latest generation of the 64-slice systems has reduced scan time to 5 to 10 seconds, with a spatial resolution of 0.4 mm. This technology is now approaching a level of detail that will allow it to guide interventional cardiologists and radiologists in pre-procedure planning for vascular interventions.

Data Derived From CCTA

CCTA provides data that are analogous to those obtained from intravascular ultrasound. In addition, CCTA provides information regarding the presence and severity of luminal narrowing (with images that are similar to those produced by invasive angiography). Like IVUS, CCTA provides images with submillimeter resolution of the vessel wall and insights regarding the presence, extent, and character of intramural plaque.[9] It can also show features such as positive remodeling associated with extraluminal plaque (which is not visible on traditional coronary angiography). CCTA can differentiate calcific plaque from radiolucent fibrous plaque or lipid-rich plaque.

Although CCTA provides information that is complementary to data obtained by stress testing in patients with intermediate probability of CAD,[10] anatomic data alone do not necessarily provide insight regarding the physiologic impact of a given lesion on coronary blood flow, a similarity to invasive coronary angiography. Thus, determination of the hemodynamic significance of intermediate severity lesions (25%-70%) on CCTA requires additional physiologic testing, as with invasive coronary angiography.

CCTA has the unique ability to assess extracoronary cardiac findings within the standard field of view, including the anatomy of cardiac structures—the atria, ventricles, valves, pericardium, great vessels, and venous anatomy—and any related abnormalities. CCTA is a good technique for evaluation of anomalous coronary artery anatomy and assessment of structures within the thoracic cavity, particularly the pulmonary vasculature and parenchyma.[11-13] Evolving applications of this technology include evaluation of pulmonary venous anatomy before and after radiofrequency ablation for atrial fibrillation, noninvasive mapping of coronary veins prior to biventricular pacemaker lead placement, evaluation of suspected pulmonary embolism, and emergency imaging to evaluate aortic dissection.

The ability to simultaneously image the thorax and the coronary arteries has allowed the development of "triple rule-out" protocols to evaluate patients with chest pain who may have CAD, aortic dissection, and/or pulmonary embolism. The good clinical performance of CCTA in emergency departments for exclusion of acute coronary syndrome, as well as the widespread use and proven clinical accuracy of CT angiography for diagnosis of acute aortic dissection[14,15] and pulmonary embolism,[16,17] has made the triple rule-out protocol a feasible option. With the development of the current 64-slice CT scanners, technical limitations of this extended protocol have been largely overcome.[18] Although the triple rule-out technique can potentially exclude fatal causes of chest pain, the associated higher radiation dose of this method precludes its routine use except when there is sufficient support for the diagnosis of either aortic dissection or pulmonary embolism.[19]

In centers where cardiologists interpret the CCTA scans for CAD, it is essential to have a trained radiologist to review the noncardiac portion of the CCTA for additional findings. At our center, a cardiologist interprets every CCTA for CAD, and a radiologist interprets the noncardiac findings, generating 2 separate reports.

In patients with known, complex CAD, CCTA may aid in planning staged percutaneous or surgical revascularization procedures. However, the risk of radiation and contrast exposure must be weighed against potential benefits. In patients with chest pain after revascularization procedures, CCTA is deemed to be of uncertain appropriateness according to current criteria (Table 1).

CCTA is also of great interest to physicians who care for patients with multiple risk factors for CAD, such as internists, family practice physicians, nephrologists, and rheumatologists. Although CCTA is of immense value in excluding CAD in patients at high risk, the routine use of this procedure in asymptomatic patients is not recommended (Table 1). Large scale, long-term prognostic data would be needed before CCTA could be considered appropriate for asymptomatic patients.

Limitations of CCTA

Despite rapid advances in technology and the impressive images

Table 1
CCTA Appropriateness Criteria

Criteria	Symptomatic	Asymptomatic	Structure/Function
Appropriate	Intermediate PTP of CAD (unable to exercise or uninterpretable ECG) Acute chest pain + intermediate PTP of CAD (negative ECG changes + serial cardiac enzymes) Uninterpretable stress test New-onset heart failure	Uninterpretable or equivocal stress test	Suspected coronary anomalies Complex congenital heart disease Cardiac masses Pericardial pathology Pulmonary venous anatomy prior to RF ablation of atrial fibrillation Coronary vein mapping prior to BiV pacemaker placement Suspected aortic dissection, aneurysm, or pulmonary embolism Coronary arterial assessment, including internal mammary artery prior to repeat surgical revascularization
Inappropriate	High pretest probability of CAD Moderate or severe ischemia on stress test	Detection of CAD (low or moderate Framingham risk score) CCTA or invasive angiogram within 2 years with no obstructive disease Evaluation of bypass grafts In-stent restenosis after PCI Intermediate perioperative risk for low-risk noncardiac surgery	LV function postmyocardial infarction or in patients with CHF
Uncertain	Intermediate PTP of CAD (able to exercise + interpretable ECG) Low or high PTP of CAD in acute chest pain (negative ECG + serial cardiac enzymes) "Triple rule-out" with intermediate PTP for 1 of the conditions Chest pain post-revascularization (surgical or PCI)	High CAD Framingham risk Intermediate perioperative risk for intermediate or high-risk noncardiac surgery	Native and prosthetic cardiac valves

CCTA, cardiac computed tomographic angiography; PTP, pretest probability; CAD, coronary artery disease; ECG, electrocardiogram; RF, radiofrequency; BiV, biventricular; LV, left ventricular; PCI, percutaneous coronary intervention; CHF, congestive heart failure. Reprinted from the *Journal of the American College of Cardiology*, Vol 48, Hendel RC, Kramer CM, Patel MR, et al. ACCF/ACCR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR appropriateness criteria for cardiac computed tomography and cardiac magnetic resonance imaging, pages 1475-1497,[39] Copyright 2006, with permission from the American College of Cardiology Foundation.

produced by CCTA, many limitations exist, particularly with respect to data acquisition and reconstruction, which largely determine image quality.[20] Thus, an understanding of these limitations in the context of patient selection and optimization of image quality is of paramount importance.

Coronary Calcification and Metal Artifacts

Calcification is universally found within atheromata at necropsy and can be considered part of the pathogenesis of atherosclerosis.[1] On CCTA, however, extensive coronary calcium obscures the lumen and may substantially limit analysis of segments or even entire arteries. Thus, CCTA may be of limited application in patients with a high likelihood of significant coronary calcification, such as the elderly, those with chronic kidney disease, or those with prior calcium scores exceeding 1000 Agatston units.[21-23] Similarly, CCTA also has technical limitations in the assessment of in-stent stenoses because the density of the equipment metal can result in "blooming" and "beam-hardening" artifacts.[23] Although CCTA can reliably determine the patency of stents, its use in detecting in-stent stenosis is more challenging. Several recent studies employing the latest generation scanners and specialized image reconstructions report encouraging results in analysis of stents exceeding 2.5 mm,[24-27] but technical limitations may prevent the confident exclusion of hemodynamically important segmental stenoses. Therefore, although calcification readily identifies the presence of coronary atherosclerosis, it limits evaluation of luminal stenosis in many cases.

Fast Heart Rates and Arrhythmias

Although development of the 64-slice spiral computed tomography (CT) systems was accompanied by an increase in gantry rotation speed (330 ms) and improved temporal resolution (165 ms with half-scan reconstruction), the scanning algorithms of these systems display a nonlinear relationship with heart rate, making them sensitive to changes in heart rate during image acquisition.[28] Even with the new generation 64-slice CT scanners, image quality is inversely correlated to heart rate, so most patients will require premedication with β-blockers to lower heart rates during acquisition. Recently introduced dual-source CT systems consist of 2 x-ray tubes and 2 opposing detector arrays mounted onto the gantry with an angular offset of 90 degrees, enabling the gathering of information for an entire slice reconstruction during a 90-degree arc around the gantry ("quarter-scan"). The result is a reduction of temporal resolution from 165 ms on 64-slice CT systems to 83 ms, permitting diagnostic evaluation at higher heart rates compared with conventional multislice scanners. Because ECG-gating is critical to coronary imaging, any arrhythmias, ectopy, or ECG artifacts result in degradation of image quality. Although some vendors offer software to correct artifacts resulting from these events, extreme heart rate irregularity can result in unrecoverable scans. Finally, use of iso-osmolar contrast helps to minimize any hemodynamic changes that occur during the contrast injection.

Obesity

Obesity increases radiation scatter within the patient's body and, consequently, degrades image quality because of a reduced signal-to-noise ratio. Recently, dual-source CT scanners have demonstrated improved signal-to-noise characteristics when using a special "obese mode" reconstruction. In this mode, both x-ray tubes are used for a full half-scan reconstruction. This approach reduces temporal resolution to 165 ms, but it doubles the amount of information gathered during each gantry rotation. Use of this mode requires rigorous heart rate control, but it extends effective CCTA to patients with body mass indices over 40 kg/m^2 and achieves a significant improvement in objective parameters of image quality.[29]

Spatial Resolution

The spatial resolution (in the *x* and *y* axes) of modern scanners is very high (≤ 0.4 mm). However, in order to obtain high-quality images of coronary arteries, it is necessary to use very thin slices (< 1 mm) to avoid volume averaging and loss of edge definition,[20] as well as to create an isotropic dataset (where the resolution in the *z* axis or the axis of the patient's head-to-feet equals that of the *x* and *y* axes). Thin image slices result in greater image noise as well as lower contrast-to-noise ratio, which is problematic in morbidly obese subjects.

Motion

Cardiac and respiratory motion results in image degradation because the small targets (coronary arteries) are constantly moving. There are 2 very brief opportunities for imaging the coronaries—at the end of systole and during late diastole, the phase of diastasis.[30] As the heart rate increases, the length of diastasis decreases compared with the acquisition time for modern scanners. This results in image acquisition during cardiac motion, resulting in image distortion.

Respiratory motion results in unsalvageable image distortion. The smallest amount of intrathoracic motion results in severe misregistration artifacts due to the small size of the coronary arteries.[20] Thus, every attempt must be made to suppress respiration during scan acquisition. Use of iso-osmolar contrast can be helpful because it has the lowest rates of patient discomfort and a minimal influence on left ventricular end-diastolic pressure compared with low-osmolar contrast agents.[31]

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Radiation Exposure

Radiation exposure has been a limitation of CCTA, and it is being overcome with modern scanning protocols. Higher radiation is required primarily because of the need for a low pitch that results in overlapping image acquisition. Thus, the potential radiation exposure risk that is attendant to CCTA should be weighed against potential benefits. Although the risk of radiation-induced cancer in any 1 person is small (the increase in the possibility of fatal cancer is 1 chance in 2000, according to 1 estimate), this risk can become a major public health concern if large numbers of the population undergo CT scans for the purposes of screening.[32] Dose reduction techniques and avoidance of technical errors are of paramount importance, depending on the protocol used. The radiation dose can be modified by adjusting the tube voltage, tube current, pitch, and scan time. Although scan data are acquired and available for the entire phase of the cardiac cycle with retrospective gating, in most cases, scan data used for image reconstruction are selected only during the diastolic phase. Thus, a high tube current is required only during the diastolic phase (40%-80% of the R-R interval), and a low tube current (decrease by 80%) is acceptable during the remaining cardiac phase ("dose modulation"). Modulating the tube current on-line with prospective ECG control helps to reduce radiation exposure substantially (by up to 47%, depending on heart rate) without decreasing diagnostic image quality.[33] Also, some groups have recently investigated the use of "prospective" gating by itself for patients with low and very stable heart rate. This approach has yielded total radiation doses of less than 5 mSv (equivalent to 10 chest x-rays), with no compromise in image quality compared with retrospective gating.[34,35]

Exposure to Iodinated Contrast and Contrast-Induced Acute Kidney Injury

All available iodinated intravascular contrast agents cause a transient increase in renal blood flow over a matter of minutes followed by sustained intrarenal vasoconstriction (Figure 1). There is stasis of contrast in the urinary and peritubular space, which results in ischemic injury that sets off a cascade of events causing oxidative injury to renal tubular cells and loss of functional nephron units.[36] The serum creatinine, which is a crude measure of renal filtration, elevates significantly (≥ 0.3 mg/dL) from baseline in less than 5% of patients undergoing CCTA.[37] This rate is much lower than that noted with coronary angiography because there is greater admixture of contrast with

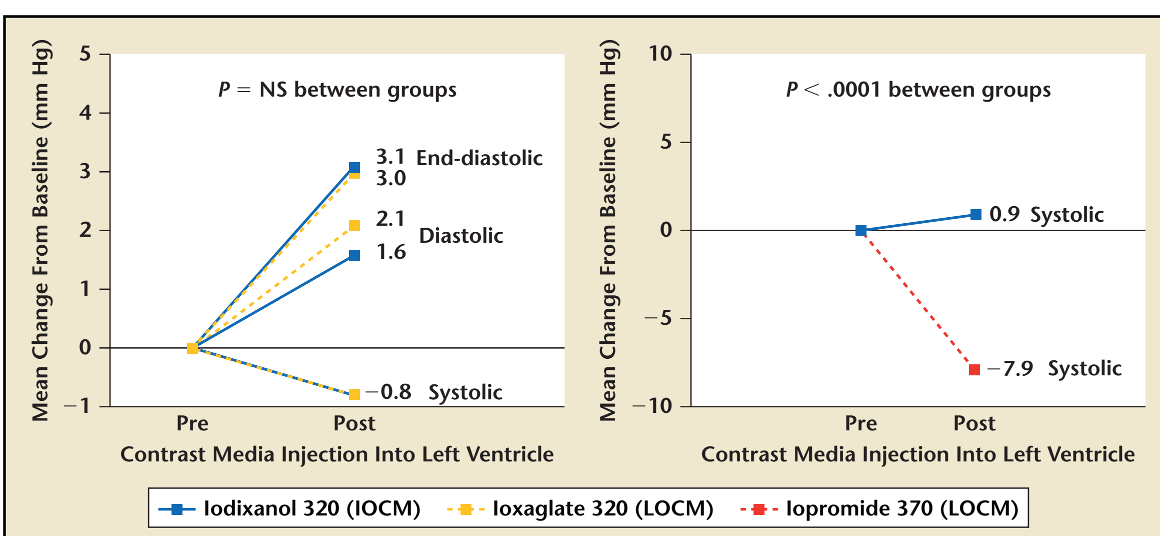

Figure 1. *Hemodynamic changes with the injection of iodinated contrast. IOCM, iso-osmolar contrast media; LOCM, low-osmolar contrast media; NS, not significant. Data on left from Tveit K et al[60] and figure on right reprinted with kind permission from Springer Science+Business Media: European Radiology. Iodixanol, a new non-ionic, dimeric contrast medium in cardioangiography: a double-masked, parallel comparison with iopromide. Volume 5, 1995, pages 354-337, Manninen H, Tahvanainen K, Borch KW, et al, Figure 3.[61]* www.medreviews.com

the blood pool in the venous phase before the kidneys receive the material in the arterial phase. In addition, there is no superimposed atheroembolism due to arterial catheter exchanges in CCTA. Finally, rates of contrast-induced acute kidney injury are probably lower in published studies because many CCTA centers have an upper limit of acceptable serum creatinine to proceed with the scan.

As mentioned above, iso-osmolar contrast offers an optimal CCTA profile with fewer hemodynamic effects. In addition, iso-osmolar contrast has the lowest rates of contrast-induced acute kidney injury when tested in the highest-risk patients.[38] Given this added benefit from a renal perspective, many CCTA programs have adopted iodixanol (320 mg I/mL) as the contrast agent of choice for these studies. Iodixanol is also associated with lower incidences of patient discomfort as compared with other iodinated contrast agents (Figure 2). Comparative images using 2 different contrast agents are shown in Figure 3. In patients with known chronic kidney disease who are under the care of a nephrologist, adequate preprocedure hydration and preparation may lower the risk of superimposed acute kidney failure.

Optimizing Outcomes in CCTA

In order to obtain the maximal clinical utility from CCTA (Figure 4), a working knowledge of the aforementioned limitations is necessary. Clinically useful information can be gathered by giving careful attention to the following factors that influence the quality of each scan.

Patient Selection

A joint statement of guidelines for appropriate use of CCTA was recently published by a collaboration of 8 professional societies, including the American College of Cardiology and the American College of

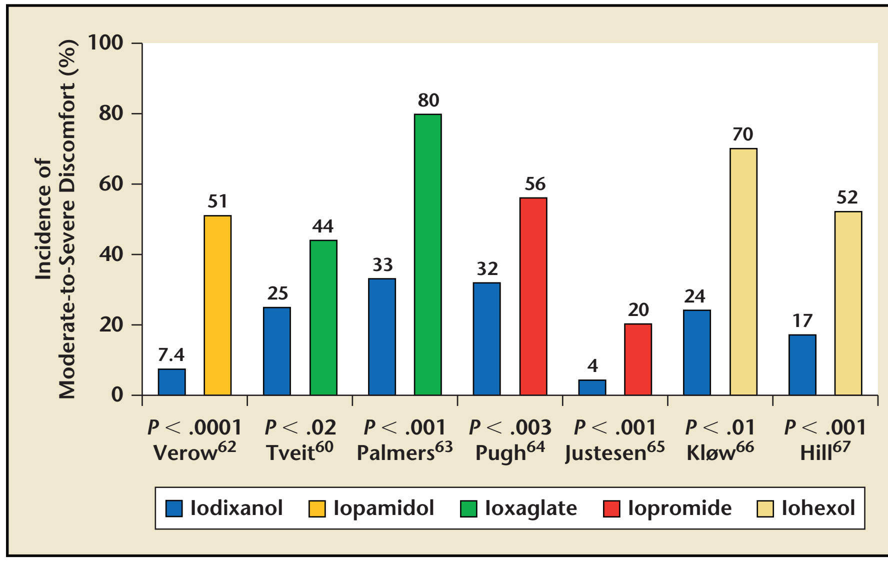

Figure 2. *Comparative incidence of patient discomfort with injections of iodinated contrast agents.*
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Figure 3. *Comparative images using 2 different contrast agents in 2 patients of the same age, sex, race, and body mass index. Both images were produced with identical scanner settings of 120 kV and 340 mAs. The contrast volume was 80 mL, and it was injected at 5 mL/sec (left, iopromide 300 mgI/mL; right, iodixanol 320 mgI/mL). Axial views of the left coronary system* **(A)** *and left ventricular opacification* **(B)** *are shown.*
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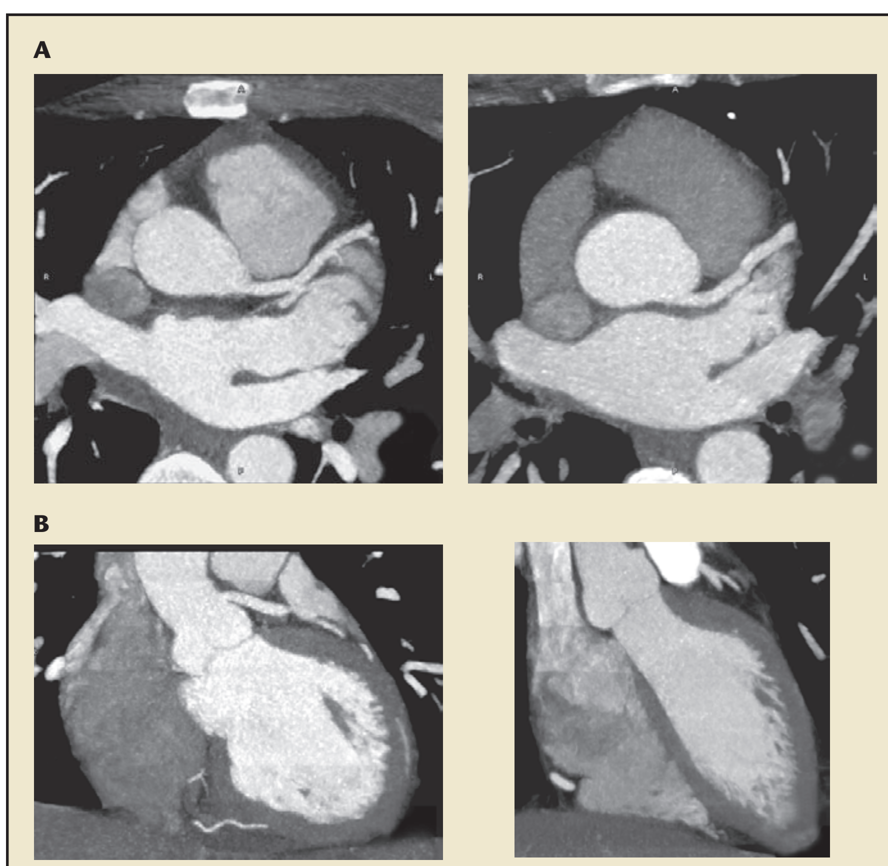

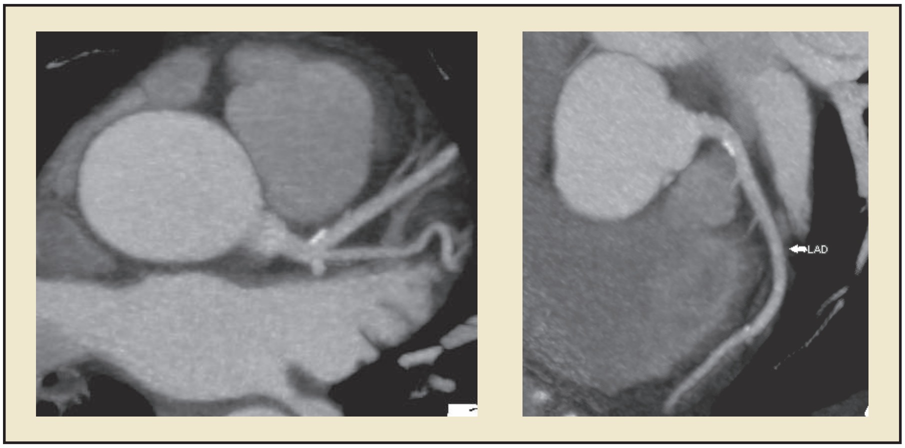

Figure 4. *Optimal cardiac computed tomographic angiography imaging using iso-osmolar iodixanol in a 70-year-old woman with body mass index of 41 mg/kg^2 and mild coronary calcification. Axial (left) and orthogonal (right) views of the left anterior descending artery (LAD) are shown.* www.medreviews.com

Radiology.[39] Appropriate clinical applications include evaluation of intermediate-risk patients with acute chest pain and those with suspected coronary anomalies, uninterpretable or equivocal stress test results, or suspected cardiac morphologic abnormalities, such as congenital heart disease or cardiac masses. CCTA has uncertain value in the evaluation of asymptomatic persons, evaluation of chest pain in patients after revascularization (percutaneous or surgical), or accurate assessment of left ventricular function postmyocardial infarction. CCTA performs well in ruling out CAD in patients with a low-to-intermediate probability of having the disease. However, in patients with a high pretest probability of CAD, CCTA does not provide additional relevant diagnostic information.[40] Thus, based on the appropriateness criteria, CCTA has little or no value in the evaluation of certain patient subgroups, such as those with a high pretest probability of coronary disease, those who have acute chest pain with positive cardiac enzymes and/or ECG changes, and those with moderate-to-severe ischemia on stress testing.

Noninvasive tests, such as calcium scoring, have been shown to add incremental value in risk assessment for CAD and sudden death.[41-44] However, calcium scoring alone may miss occult CAD in patients with predominantly noncalcified atherosclerotic plaque. Hence, the idea of using CCTA as a screening tool is attractive, particularly in women and young individuals. A recent study examining 1000 consecutive asymptomatic subjects found that 22% of the population had occult CAD, among whom 5% had significant CAD involving at least 1 artery.[45] However, only 15 cardiac events occurred during the mean follow-up period of 15 months. Thus, although CCTA can provide insight into the presence of CAD in asymptomatic individuals, the antecedent risk of radiation exposure precludes use of this technique as a screening tool. Before CCTA can be recommended for screening, long-term follow-up data are required, especially for hard endpoints such as myocardial infarction and cardiac death. Currently, CCTA in asymptomatic individuals is considered to be an inappropriate indication.

Adequate patient preparation is the key to successful CCTA outcomes.

Patient Preparation

Adequate patient preparation is the key to successful CCTA outcomes. It is desirable for the referring physician to prescribe β-blockers for the patient to take before arrival for the test, as this preparation may facilitate the scan. In addition, the indication for the scan should be clearly stated, so that the appropriate protocol may be used. Intolerance to contrast agents and contraindications to β-blockers (asthma, decompensated heart failure, advanced heart block, kidney disease) must be reported. Additionally, patients should be instructed to maintain adequate oral hydration for 24 hours and avoid food intake for 4 to 6 hours prior to the scan. Because nitroglycerin is administered routinely at most centers, medications such as sildenafil must be avoided for at least 48 hours before the scan.

Upon the patient's arrival, the indication for the CCTA and any contraindications are reviewed, and vital signs are monitored. An intravenous catheter is then inserted (preferably 18 gauge), and intravenous β-blockers are administered if necessary. At our institution, metoprolol is given at 5 mg doses at 5-minute intervals, for a total dose of up to 20 mg. When the heart rate is at the desired level (< 65 beats/min), the patient is brought to the CT scanner suite and positioned in the supine, feet-first position, with arms raised above the head. A 3-lead ECG is placed and a stable rhythm is confirmed before proceeding. Sublingual nitroglycerin is given and localizing images are obtained.

Determining Scan Parameters

In planning a CCTA, knowledge of the indication and patient characteristics is of paramount importance.

The main factors to consider are type of scan (eg, coronaries only, triple rule-out, evaluation of pulmonary vein anatomy, congenital abnormalities, evaluation of bypass grafts) and body mass index of the patient. These considerations may result in modification of scan length, timing, and infusion rate of the contrast bolus and alteration of tube current and voltage. Every attempt is made to use ECG-pulsing or dose modulation. At some institutions, further attempts are routinely made to reduce the radiation dose by utilizing a lower tube voltage (eg, 100 kV in nonobese patients), minimal dosing (lowering the tube current to a minimal dose in systolic phases), or prospective gating.

Scan length can be determined in 2 ways: by the initial topogram or by the noncontrast calcium scoring CT scan. Scan length is decreased as much as possible to include the heart from the level of the origin of the left main coronary artery to below the level of the posterior descending artery. Scan length is increased as necessary for evaluation of bypass grafts (to include origin of the left internal mammary artery) or the aorta and pulmonary arteries (in triple rule-out scans).

A high iodine (> 300 mgI/mL) concentration contrast agent is infused at a high flow rate (5-6 mL/sec) to optimize coronary imaging.[46-48] The volume of contrast needed is determined by the scan duration. Contrast administration protocols vary among institutions and include use of contrast injection followed by a saline chaser, contrast injection followed by saline diluted with contrast, or simultaneous contrast and saline injection. Scanning is initiated either by a “timing bolus” method (in which a test bolus is injected and time to opacification of the aortic root determines the contrast injection), or a “bolus tracking” method (in which the scan begins automatically when a preset CT number density threshold is reached in the aortic root). When scan quality is deemed adequate, the patient is taken off the scanner table and discharged from the unit after a brief hemodynamic and clinical evaluation.

Image Reconstruction

The raw data are postprocessed with specific CT reconstruction algorithms, with the filtered backprojection method being the most widely recognized and utilized. Images are typically reconstructed with a slice thickness of 0.6 mm to 0.75 mm and 50% overlap of consecutive transaxial slices. In obese patients, the slice thickness is increased to 1 mm in order to reduce image noise from soft tissue attenuation.

Several different reconstruction techniques are employed in CCTA image analysis. Image postprocessing involves reformatting the original CT images, volume- and surface-rendered displays, and physiologic imaging analysis. Standard methods include the sagittal, coronal, oblique, and curved reformatting. Other reformatting techniques frequently used in cardiac imaging include the volume rendering technique (VRT), maximum intensity projection (MIP), and multiplanar reformatting (MPR). Although 3-dimensional displays (VRT) that emulate gross anatomy are visually captivating, they are rarely used for assessment of luminal stenoses. Two-dimensional reconstructed images (MIP and MPR) that emulate fluoroscopic projections are predominantly used for image analysis.

Future Directions

Noninvasive imaging of atherosclerotic plaque characteristics by CCTA

Main Points

- Cardiac computed tomographic angiography (CCTA) provides data that are analogous to those obtained from intravascular ultrasound. In addition, CCTA provides information regarding the presence and severity of luminal narrowing (with images that are similar to those produced by invasive angiography).
- CCTA has the unique ability to assess extracoronary cardiac findings within the standard field of view, including the anatomy of cardiac structures—atria, ventricles, valves, pericardium, great vessels, and venous anatomy—and any related abnormalities.
- On CCTA, extensive coronary calcium obscures the lumen and may substantially limit analysis of segments or even entire arteries.
- Iso-osmolar contrast offers an optimal CCTA profile with fewer hemodynamic effects. In addition, iso-osmolar contrast has the lowest rates of contrast-induced acute kidney injury when tested in the highest-risk patients.
- Appropriate clinical applications include evaluation of intermediate-risk patients with acute chest pain and those with suspected coronary anomalies, uninterpretable or equivocal stress test results, or suspected cardiac morphologic abnormalities, such as congenital heart disease or cardiac masses.

is of great interest. Invasive angiographic studies have demonstrated the role of the vulnerable plaque and its rupture in myocardial infarction, even in the absence of significant luminal stenosis. Vulnerable plaques are associated with a thin fibrous cap, large lipid core, and inflammatory cells.[49-52] Some preliminary studies have suggested that CCTA can potentially differentiate fat from fibrous tissue.[53] Currently, however, plaque characterization is limited to images of very high quality and may not be applicable in average clinical practice.[54-56]

Limited spatial resolution of 64-slice CCTA results in an inability to differentiate total luminal occlusion from high-grade stenosis and also in characterization of noncalcified plaque. The 256-slice and 320-slice scanners promise to overcome some of these limitations. Preliminary studies with these scanners have demonstrated accuracy comparable to the 64-slice scanners, but with single heartbeat and shorter acquisition times.[57,58] A higher radiation dose is a limitation of these scanners.

Conclusion

Current generation scanning equipment and protocols can provide striking coronary artery images in a large proportion of patients without invasive catheterization. Although this technology has been hailed as an important advance, the success of a given scan is largely dependent on attention to detail. Appropriate patient selection, awareness of limitations, and careful protocol modification are necessary in each case. When performed properly, CCTA provides valuable information in the evaluation and management of CAD. There are a variety of emerging applications for CCTA beyond the coronary arteries that will drive future clinical development of this important imaging modality.[59] ■

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