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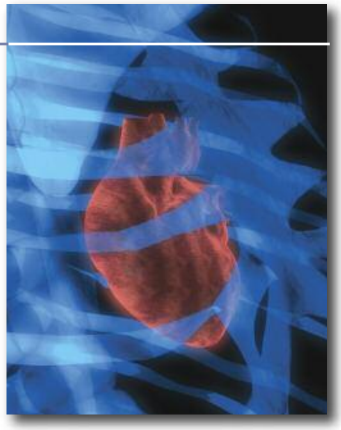

Cardiac Computed Tomographic Angiography and the Primary Care Physician

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Through advancements in computer processing speed and storage capacity, new cardiac imaging modalities have become clinically feasible and useful. Cardiac computed tomographic angiography, a new diagnostic imaging modality, is capable of assessing coronary artery disease and left ventricular function on a par with invasive coronary arteriography in selected patients who meet appropriate use criteria. This imaging modality is of clinical value in the assessment of patients with chest pain who have an intermediate risk of coronary atherosclerosis. The purpose of the present report is to educate primary care physicians about the basic principles of advanced cardiac imaging techniques and to convey a useful strategy for their appropriate use in the current environment of medical economics.

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Since the late 1970s, the mainstays of cardiac diagnostic imaging have been 2-dimensional echocardiography, Doppler echocardiography, nuclear stress perfusion scintigraphy, and cardiac cine-angiography. During this time frame, each of these imaging modalities has undergone substantial improvement and refinement, mainly as a result of the use of digital acquisition and processing techniques. Although these techniques are capable of assessing most forms of cardiac disease, each has limitations that restrict diagnostic accuracy in a variety of clinical situations. For example, 2-dimensional echocardiographic studies of obese patients or patients with advanced pulmonary disease are frequently of nondiagnostic quality. Furthermore, nuclear stress perfusion imaging and cardiac catheterization involve substantial radiation exposure,[1,2] with cardiac catheterization also associated with a small but definable risk of complications stemming from the invasive nature of the imaging procedure.[3]

Through advancements in computer processing speed and storage capacity, 2 new cardiac imaging modalities have become clinically feasible and useful: cardiac computed tomographic angiography (CTA) and cardiac magnetic resonance imaging (MRI). Because considerable expense was incurred in the development of these advanced cardiac imaging procedures, their commercialization has resulted in expensive equipment requiring use by specialized technologists and physician interpreters in specialized facilities. Because these imaging modalities were developed in an era of health care cost containment, most third-party providers of health care insurance implemented strict criteria for use of cardiac CTA and cardiac MRI, mainly through the use of radiology benefit management (RBM) systems, which require preauthorization, and often through peer-to-peer review. The purpose of the present report is to educate primary care physicians about the basic principles of advanced cardiac imaging techniques and also to convey a useful strategy for the appropriate use of such techniques in our current environment of medical economics.

KEY POINTS

IN THE CLINICAL EVALUATION OF PATIENTS WITH CHEST pain, the likelihood of coronary atherosclerosis should be assessed using a validated risk assessment tool such as the Framingham Risk Score or the Diamond-Forrester nomogram.

PATIENTS WITH CHEST PAIN WHO HAVE FRAMINGHAM Risk Scores indicating an intermediate risk for coronary atherosclerosis require diagnostic imaging for further risk stratification. Diagnostic options include treadmill testing, nuclear stress perfusion imaging, stress echocardiography, and coronary computed tomographic angiography (CTA).

CORONARY CTA IS IDEAL FOR PATIENTS WITH CHEST PAIN who have intermediate probability of developing coronary atherosclerosis and who have a normal sinus rhythm with a heart rate of less than 65 beats per minute and a body mass index of less than 40.

PRETREATMENT WITH A β-BLOCKER TO ACHIEVE A HEART rate of less than 65 beats per minute is appropriate before performance of coronary CTA.

Basics of Cardiac CTA

Cardiac CTA is performed in a computed tomography (CT) scanner with high spatial and temporal resolution, while the patient is monitored by electrocardiography (ECG), so that images can be obtained at specific time points in the cardiac cycle, thereby eliminating cardiac motion artifact. Images of the coronary arteries typically are acquired during the end-diastolic phase, when cardiac motion is virtually nil. To accomplish opacification of the coronary arteries, iodinated contrast material is injected via a peripheral vein, and imaging begins after a circulation time delay, to allow enough time for the contrast material bolus to travel through the right side of the heart and the lungs, reaching the coronary arterial circulation as the CT scanning begins.

State-of-the-art cardiac CT scanners are capable of acquiring very thin (0.625-mm), horizontally oriented "slices" across the chest, from the top of the heart down to the bottom of the heart (*Figure 1*). Because the data are digital, all of the cardiac slices can be combined into a 3-dimensional volume unit, which then can be analyzed using a variety of software programs to visualize the heart and its structures in multiple formats. The volume-rendered view (*Figure 2*) provides accurate anatomic images of the cardiac and great vessel surfaces to assess anatomy and uncover possible congenital anomalies. The volume-rendered view is also useful for assessing surgical bypass grafts with great accuracy (*Figure 3*).

Although volume-rendered views provide information about cardiac surface anatomy, analysis of both left ventricular function and the anatomy of the coronary artery lumen is the main purpose of cardiac CTA. Because of the rather tortuous course of coronary artery circulation (*Figure 4*), an individual coronary artery crosses through several planes on CT. To visualize the coronary artery lumen along the entire course of a specific vessel, curved multiplanar reformatted views are required (*Figure 5*). Such views allow imaging of the coronary circulation similar to that achieved by invasive coronary arteriography. Because cardiac CTA provides data that are both digital and 3-dimensional, reconstruction can be accomplished in ways not feasible when using invasive, catheter-based coronary arteriography. By defining a midline along the course of a specific coronary artery (*Figure 6*), the curved multiplanar reformatted image of the vessel can be straightened, creating a "straight-lumen" view that can be digitally rotated around the midline axis of the vessel, allowing 360° imaging of the coronary artery lumen (*Figure 7*). The straight-lumen image can then be sliced along the long axis of the vessel, creating the opportunity for true cross-sectional imaging of atherosclerosis (*Figure 8*). By using all 4 of these CTA visualization techniques, highly accurate analysis of the coronary artery lumen can

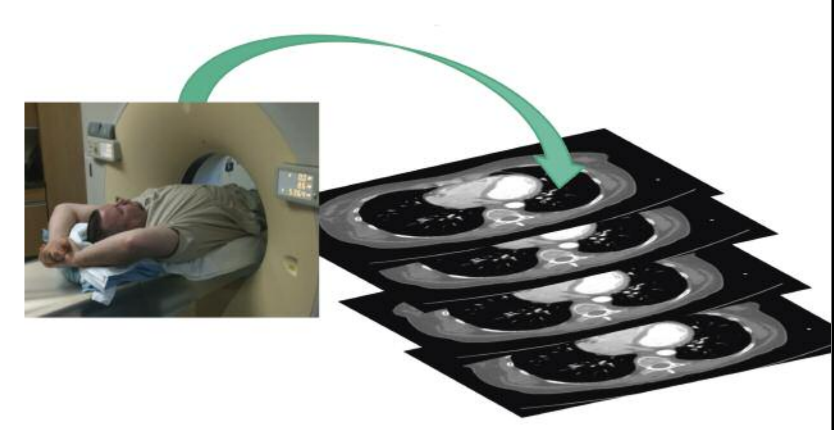


Figure 1. *As the patient moves through the computed tomography scanner, which is rotating at 3 revolutions per second, 0.625-mm-thick digital "slice" images are acquired from the top of the heart down to the bottom of the heart. These cardiac slices are then combined into a digital volume for further analysis of cardiac structure by using specialized software tools.*

Figure 2. *Volume-rendered view of the anterior cardiac surface demonstrates the left anterior descending artery (black arrow), the circumflex coronary artery (yellow arrow), and the right coronary artery (blue arrow).*

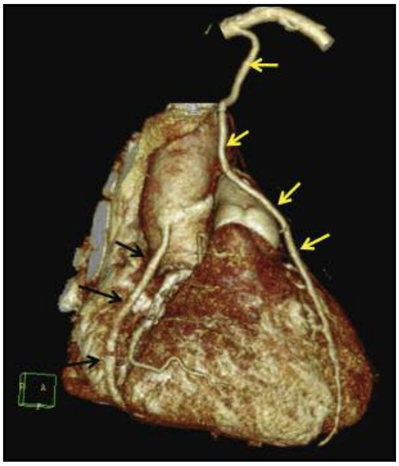


Figure 3. *Volume-rendered view of a patient with a history of aortocoronary bypass surgery, including a left internal mammary artery implant to the left anterior descending coronary artery (yellow arrows) and a saphenous vein bypass graft to the right coronary artery (black arrows).*

Figure 4. *Composite coronary computed tomographic arteriogram of a patient with normal coronary vessels illustrating expected vessel tortuosity. Because of this tortuosity, a curved multiplanar reformatted view is necessary.*

Figure 5. *Curved multiplanar reformatted view of the right coronary artery demonstrates a calcified atherosclerotic plaque along the proximal segment of the vessel (arrow).*

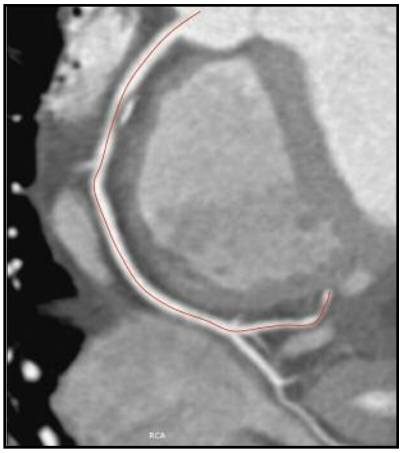


Figure 6. *Curved multiplanar reformatted view of the right coronary artery demonstrates a computer-generated midline (red line) for construction of straight-line and cross-sectional views.*

be achieved, especially in patients with noncalcified atherosclerosis.[4-6]

Electrocardiographic gating is a technique in which the information in 1 heart beat (ie, R wave to R wave) on the ECG is divided into 20 equal segments, taking 1 "picture" of the heart in each of the 20 segments. When played back in movie format, motion of the cardiac structures is adequately displayed. Because cardiac CTA captures cardiac images throughout the entire cardiac cycle when used in association with ECG gating, it can also be used to assess left ventricular wall thickness, cavity size, and systolic function in both short-axis and long-axis views (*Figure 9*). Because cardiac CTA data provide a digital volume, the left ventricle can be sliced along the short axis, allowing accurate volume analysis of stacked disks from the mitral annulus down to the left ventricular apex and thereby offering highly accurate analysis of the left ventricular ejection fraction.

Noting that ECG gating is an essential component of acquiring cardiac CTA images to ensure adequate temporal resolution, careful attention to the heart rate and rhythm is necessary. A heart rate of less than 65 beats per minute is required for the diastolic "still" phase of the cardiac cycle to be of sufficient duration to allow for motionless imaging. Because a 64-slice CT scanner requires the span of approximately 6 heartbeats to image the vertical length of the heart (*Figure 10*), it is important that the heart rate be in normal sinus rhythm to avoid generation of "step" artifact during the 6-second period required to complete the cardiac scan. Accordingly, premedication with a β-blocker or a calcium-channel blocker is useful in lowering the heart rate to less than 65 beats per minute for cardiac CTA studies. Patients with atrial fibrillation, frequent premature atrial beats, and

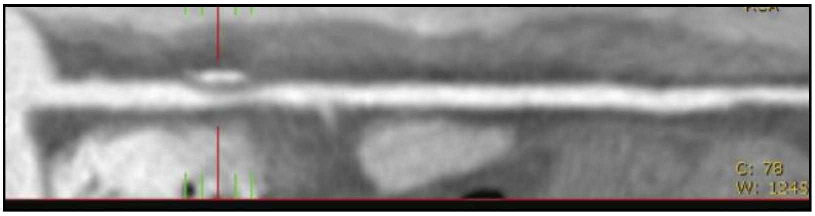


Figure 7. *Straight-lumen view of the right coronary artery with a calcified proximal atherosclerotic plaque. This image was generated from the midline of the multiplanar reformatted view of the right coronary artery depicted in* Figure 6.

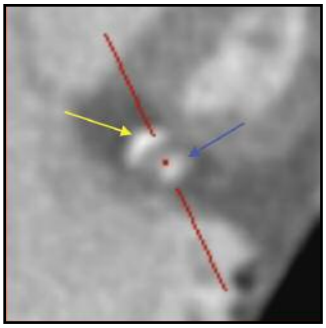


Figure 8. *Cross-sectional view of the proximal right coronary artery plaque shown in the straight-lumen view of* Figure 7 *demonstrates mural calcification (yellow arrow) and concentric luminal atherosclerosis (blue arrow).*

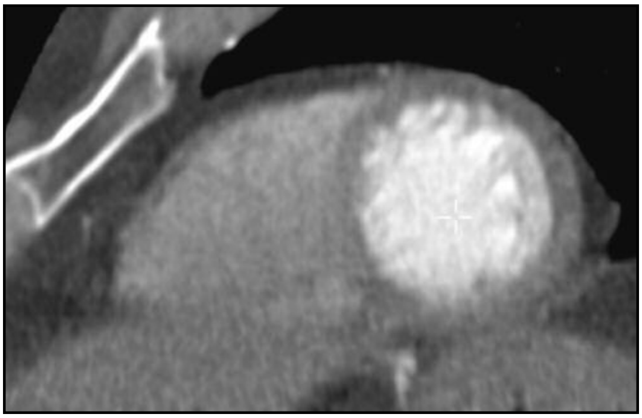


Figure 9. *Two-chamber, short-axis left ventriculogram allowing analysis of both global and regional left ventricular wall motion function. Timing of contrast material administration is optimized to maximize opacification of the left ventricular cavity. For a video of the imaging, visit http://www.jaoa.org/content/112/5/267/suppl/DC1.*

frequent premature ventricular contractions are not good candidates for cardiac CTA. Also, because of x-ray attenuation in adipose tissue, obese patients with a body mass index higher than 40 are not ideal candidates to undergo this form of coronary imaging.[7]

Appropriate Use of Cardiac CTA

Because of cost and radiation exposure, cardiac CTA should be used for patients who are likely to derive definite benefit from the procedure. In the clinical evaluation of a patient with chest pain, the likelihood of coronary atherosclerosis should first be assessed using validated risk assessment tools, such as the Framingham Risk Score (*Figure 11*) or the Diamond-Forrester nomogram[8] (*Table*). These easy-to-use risk assessment tools allow patients with chest pain to be stratified into groups with low, intermediate, or high risk for the development of clinically significant underlying coronary atherosclerosis.

The coronary atherosclerosis risk assessment tool available on the National Cholesterol Education Program Web site (http://hp2010.nhlbihin.net/atpiii/calculator.asp) is very helpful and can be used by office staff before the patient sees the physician. Patients for whom the Framingham Risk Score indicates a low risk of developing coronary atherosclerosis (score, <8%) do not need to undergo imaging procedures, but they should undergo risk modification therapy, including weight reduction, hypertension control, lipid control, and smoking cessation. Patients with chest pain who have a high Framingham Risk Score (>20%) should be considered candidates for invasive coronary arteriography, because their likelihood of developing clinically significant coronary atherosclerosis is greater than 70%.[9] However, for patients with chest pain who have Framingham Risk Scores denoting intermediate risk (8% to 20%), diagnostic imaging is required for further risk stratification. Diagnostic options include treadmill testing, nuclear stress perfusion imaging, stress echocardiography, and coronary CTA.

The Appropriate Use Task Force of the American Col-

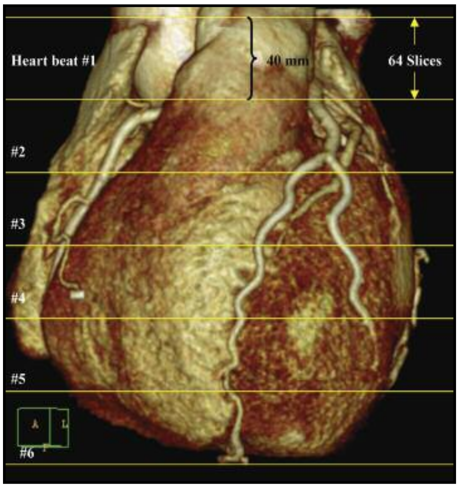
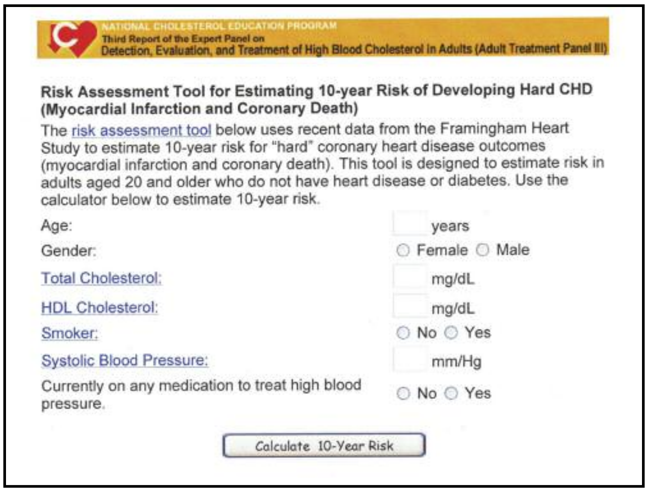


Figure 10. *Because the computed tomography slices are 0.625 mm thick, a 64-slice computed tomography scan covers a length of 40 mm with each heartbeat. Because the average length of the heart is 240 to 300 mm, approximately 6 to 8 heartbeats are required for a 64-slice scanner to image the full length of the heart.*


NATIONAL CHOLESTEROL EDUCATION PROGRAM
Third Report of the Expert Panel on
Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)

Risk Assessment Tool for Estimating 10-year Risk of Developing Hard CHD (Myocardial Infarction and Coronary Death)

The risk assessment tool below uses recent data from the Framingham Heart Study to estimate 10-year risk for "hard" coronary heart disease outcomes (myocardial infarction and coronary death). This tool is designed to estimate risk in adults aged 20 and older who do not have heart disease or diabetes. Use the calculator below to estimate 10-year risk.

Age:	years
Gender:	Female Male
Total Cholesterol:	mg/dL
HDL Cholesterol:	mg/dL
Smoker:	No Yes
Systolic Blood Pressure:	mm/Hg
Currently on any medication to treat high blood pressure.	No Yes

Calculate 10-Year Risk

Figure 11. *Screen shot of the Adult Treatment Panel III risk assessment tool available on the National Cholesterol Education Program Web site at http://hp2010.nhlbihin.net/atpiii/calculator.asp.*

lege of Cardiology (ACC) and the American Heart Association (AHA) has developed appropriate use criteria for each of the diagnostic imaging procedures used in the evaluation of patients with chest pain who have an intermediate risk of coronary atherosclerosis.[7] The appropriate use criteria for coronary CTA most commonly encountered in primary care practices are listed in *Figure 12*. Because patients with a bundle branch block noted during ECG monitoring of the resting heart rate have ST segment changes as a result of conduction disturbance, treadmill testing is not helpful. Presence of a left bundle branch block causes generation of artifact in nuclear stress perfusion images. Many elderly patients with orthopedic disease cannot walk on a treadmill long enough to reach their target heart rate and thereby enable valid test results to be obtained. These are all examples of patients who would benefit from coronary CTA. By adhering to the recommendations of the Appropriate Use Criteria Task Force of the ACC and AHA, primary care physicians not only provide state-of-the-art care for their patients with chest pain, but they also increase the likelihood of receiving preauthorization approval from third-party payers.

The greatest clinical benefit of coronary CTA is its high negative predictive value. If a coronary CTA image shows little or no coronary atherosclerosis and its findings are considered to be normal, there is a 99% probability that an invasive coronary arteriogram will demonstrate the same findings.[4] However, among patients with more advanced coronary atherosclerosis, the positive predictive value decreases to 70% to 80% when compared with that of cardiac catheterization.[6] Generation of artifact from coronary artery calcification (*Figure 13*) is the most frequent cause of this problem. Accordingly, coronary CTA usually is not a substitute for invasive cardiac catheterization in patients with known coronary artery disease, especially those with extensive coronary artery calcification. Coronary artery mural calcification causes "blooming" artifact, which makes the area of calcified atherosclerosis appear larger than it actually is, resulting in false-positive results.[10]

The use of coronary CTA for patients who have previously undergone coronary bypass surgery yields very accurate information about the state of the bypass grafts, but it provides less accurate information about the native coronary arteries distal to the bypass grafts and the nonbypassed native vessels. Because chest pain after bypass surgery might be associated with disease progression in either a graft or a native coronary artery, the difficulty of accurately assessing the native vessels may be a limitation for the clinical use of coronary CTA in the patient who has undergone bypass surgery.[11]

Clinical Case Studies

Case 1

A 52-year-old woman presents with atypical chest pain. She has hypertension, which is controlled at 134/68 mm Hg with the use

Table.
Assessment of the Likelihood of Coronary Atherosclerosis Using the Diamond-Forrester Nomogram

Age, y, and Sex	Angina Pectoris	Typical/Definite Angina Pectoris	Atypical/Probable Chest Pain	Nonanginal Asymptomatic
30-39				
Male	Intermediate	Intermediate	Low	Very low
Female	Intermediate	Very low	Very low	Very low
40-49				
Male	High	Intermediate	Intermediate	Low
Female	Intermediate	Low	Very low	Very low
50-59				
Male	High	Intermediate	Intermediate	Low
Female	Intermediate	Intermediate	Low	Very low
60-69				
Male	High	Intermediate	Intermediate	Low
Female	High	Intermediate	Intermediate	Low

Source: Reprinted with permission from Diamond et al.[8] Copyright 1979, *New England Journal of Medicine*.

Patients with chest pain and an INTERMEDIATE probability of CAD who are unable to exercise

Patients with chest pain and an INTERMEDIATE probability of CAD who have results of an exercise ECG that are uninterpretable (eg, right bundle branch block, left bundle branch block, Wolff-Parkinson-White syndrome, intraventricular conduction delay)

Patients with heart failure of NEW ONSET

Patients with ACUTE chest pain, an INTERMEDIATE probability of CAD, no evidence of ischemia on ECG, and negative results of cardiac enzyme testing

Patients with chest pain and:

- Uninterpretable results of ECG—developed a bundle branch block during exercise or drug infusion
- Equivocal results of stress test—possible ischemia; cannot exclude artifact
- Nondiagnostic results of stress test—developed less than 2.0 mm of ST depression

Patients with chest pain, INTERMEDIATE probability of CAD, normal findings of a myocardial perfusion study, and suspected LEFT MAIN or multivessel "balanced" CAD

Figure 12. *Most common appropriate use criteria encountered in primary care practices.* ***Abbreviations:*** *CAD, coronary artery disease; ECG, electrocardiography.*

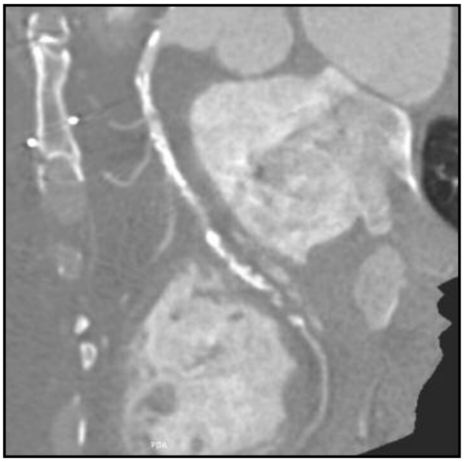


Figure 13. *Diffuse, heavy calcification (bright white areas along the vessel) of the right coronary artery precludes lumen analysis with computed tomographic angiography.*

of lisinopril. Her total cholesterol level is 242 mg/dL, and her high-density lipoprotein cholesterol level is 36 mg/dL. She smokes less than ½ of a pack of cigarettes daily. Results of her 12-lead ECG reveal a right bundle branch block. She wears a knee brace after having been in an automobile accident 2 years ago.

The Framingham Risk Score calculated for this patient with chest pain is 14%, which places her at intermediate risk for coronary atherosclerosis. Risk modification therapy should be pursued in conjunction with further risk stratification. A standard ECG treadmill test and an exercise nuclear stress perfusion study will not be valid because of her right bundle branch block. On the basis of ACC and AHA appropriate use criteria, diagnostic options include stress echocardiography, an adenosine nuclear stress perfusion study, and coronary CTA. Because her orthopedic problem reduces the feasibility of the other diagnostic options, coronary CTA would be appropriate for this patient.

Case 2

A 65-year-old male smoker has chest pain of recent onset that radiates to the jaw, neck, and left arm when he exerts himself. His chest pain usually is associated with mild dyspnea. His blood pressure is 144/90 mm Hg while taking losartan/hydrochlorothiazide. His total cholesterol level is 275 mg/dL, and his high-density lipoprotein cholesterol level is 35 mg/dL.

The Framingham Risk Score calculated for this man is higher than 20%, which places him at high risk for coronary atherosclerosis. His recent onset of symptoms would be construed as unstable angina. Risk modification therapy should be instituted, and arrangements for coronary arteriography should be made in the near future, particularly if the chest pain symptoms are not well controlled by medical therapy. Coronary CTA would not provide incremental clinical benefit to this patient, and it would only delay the most appropriate procedure and add to the patient's radiation dose burden.

Case 3

A 38-year-old woman complains of intermittent sternal pain unrelated to exertion. She has no associated symptoms. She is normotensive (blood pressure, 122/68 mm Hg) and does not smoke. Her total cholesterol level is 174 mg/dL, and her high-density lipoprotein cholesterol level is 68 mg/dL.

The Framingham Risk Score calculated for this patient is 1%, which places her at very low risk for a cardiovascular event over the next 10 years. No further cardiac diagnostic testing is warranted, and a noncardiac etiology for her intermittent chest pain should be pursued.

Radiation and Risks

In cardiac CTA, a limited portion of the chest is exposed to radiation, including the heart, lungs, thoracic wall, and breasts. The longitudinal range of radiation exposure is from the tracheal bifurcation down to the diaphragm. Without radiation-limiting measures, the radiation dose associated with cardiac CTA is in the range of 12 to 18 mSv per procedure. For purposes of comparison, environmental radiation exposure from sunlight, etc, is approximately 3 mSv per year.[12] The radiation dose used in invasive coronary arteriography varies from 2 to 16 mSv per procedure.[11] Because breast tissue is radiosensitive, with a small but definable associated risk of breast cancer, the risk-benefit ratio of coronary CTA should be carefully considered for young women.[13]

Several methods have been developed to reduce radiation exposure during cardiac CTA studies, including ECG dose modulation, "tightening" of the longitudinal exposure window, reduction of the x-ray tube kilovoltage when the body weight of the patient allows, and use of step-and-shoot imaging protocols. Protocols for ECG dose modulation call for delivery of the full radiation dose only during the diastolic still phase of the cardiac cycle, whereas a 40% dose is delivered during the remaining phases of the cardiac cycle, thereby substantially reducing the total radiation dose associated with the procedure. For thin patients (body mass index, <18.5), x-ray tube kilovoltage can be reduced to 100 kV, further reducing the amount of radiation exposure. Step-and-shoot cardiac CTA protocols take the concept of ECG dose modulation 1 step further, delivering radiation only during the diastolic still phase of the cardiac cycle, and they offer the most substantial radiation dose reduction currently available, in the range of 2 to 4 mSv per study.[14] However, it should be noted that analysis of left ventricular function is not feasible with use of the step-and-shoot protocol, because images from all phases of the cardiac cycle are not being acquired. In short, measures for radiation reduction are considered for every patient undergoing a cardiac CTA study, and they are customized by the cardiologist or radiologist supervising the study to keep the radiation dose as low as reasonable to acquire the necessary clinical diagnostic information. Patients with atrial ectopy, ventricular ectopy, and trial fibrillation are not candidates for step-and-shoot cardiac CTA.

Chest pain patients with intermediate risk scores require diagnostic imaging for further risk stratification.

Patients with a glomerular filtration rate (GFR) of 60 or higher have minimal risk of contrast-induced nephropathy. Patients with chronic kidney disease and a GFR below 30 should not be considered candidates for cardiac CTA, because of the increased risk of requiring temporary or permanent dialysis after exposure to contrast material. Patients with a GFR between 30 and 60 should be evaluated by a nephrologist before undergoing cardiac CTA, and they will require periprocedural hydration. Patients with diabetes who take metformin must discontinue its use for 48 hours after contrast material administration during cardiac CTA. In a small percentage of patients who undergo cardiac CTA, an urticarial rash develops 24 to 48 hours after the procedure. This rash can be successfully treated with the use of prednisone prescribed in a tapering-dose pack. Patients with known hypersensitivity to iodinated contrast material are not candidates for cardiac CTA unless they receive pretreatment with steroids before the procedure.

Relative Value of Coronary CTA

What are the advantages of coronary CTA over nuclear stress perfusion imaging? Nuclear stress perfusion imaging is based on a decrease in myocardial blood flow (ie, perfusion) in a specific coronary artery territory resulting from a more proximal obstructive atherosclerotic lesion. The myocardium in the region of the obstructed coronary artery will have a decreased uptake of isotope, causing an ischemic pattern to appear. However, if atherosclerotic disease affects all 3 coronary arteries (right, left anterior descending, and circumflex), there may be no relative area of perfusion defect, presenting a false-negative normal perfusion pattern. This finding is referred to as balanced ischemia. Similarly, atherosclerosis of the proximal right coronary artery and the left main coronary artery can yield a normal-appearing perfusion pattern of balanced ischemia during nuclear stress perfusion imaging. Because cardiac CTA directly visualizes the lumen of the coronary arteries, balanced ischemia is not a confounding factor for this imaging modality. The shadowing artifact often seen on the nuclear perfusion images of patients who are obese or who have large breasts results in false-positive findings, potentially leading to unnecessary invasive coronary arteriography. Coronary CTA may be a better option for such patients, provided that they meet appropriate use criteria.

Each year in the United States, approximately 6 million patients are seen in the emergency department with chest pain.[15] Many of these patients have normal cardiac examination results, 12-lead ECG findings, and cardiac biomarker levels, but they are still admitted to the cardiac unit or a similar hospital facility for nuclear stress perfusion imaging studies to avoid misdiagnosis of the 2% of these patients who have actually had an acute myocardial infarction. This practice usually results in a hospital stay with an average duration of 40.5 hours[16] and considerable associated costs. Recent trials of the use of coronary CTA for patients in the emergency department with acute chest pain have shown decreases in both the length and the cost of hospitalization.[16] Randomized trials based on cost-effectiveness models are currently under way to determine whether this strategy improves patient outcomes.[17] Admitting patients with chest pain from the emergency department, cycling myocardial enzymes, and waiting 12 hours before performing a nuclear stress perfusion study currently adds $10 to $12 billion per year to health care costs in the United States.[17] Certainly, it is reasonable to assume that use of cardiac CTA to establish that a patient's coronary arteries are free of atherosclerosis would eliminate further unnecessary hospitalizations for evaluation of chest pain. With further improvements in cardiac CT scanning (eg, the development of 320-slice scanners that can produce images of the heart in 1 gantry rotation, thereby eliminating heart rate and arrhythmia factors) and low-dose radiation protocols (eg, the step-and-shoot protocol), it is not difficult to envision that, in the near future, cardiac CTA will be the preferred diagnostic imaging modality for patients in the emergency department who have chest pain. Well-designed prognostic models support this approach.[17]

Third-Party Payment Issues

Most health care insurance providers require preauthorization of coronary CTA studies. Information required for preauthorization must be provided by the physician who orders the study. At most primary care physician offices, staff are familiar with the preauthorization process for other noncardiac radiologic procedures. Preauthorization often requires completion of an online form that collects such information as the patient's demographic information; insurance plan identification data; and diagnosis and supportive data, including symptom characteristics, provocative factors, associated symptoms, 12-lead ECG findings, and results of previous testing. These online preauthorization forms are designed to establish that (1) the patient is indeed having chest pain and (2) the patient has an intermediate risk of coronary atherosclerosis, based on the risk assessment tools previously detailed in the present report. Providing these 2 crucial pieces of clinical information about the patient will facilitate the preauthorization process and increase the likelihood of approval without requiring peer-to-peer review. The likelihood of approval is also increased by adherence to ACC and AHA appropriate use criteria.[7]

> **The greatest clinical benefit of coronary CTA comes from its high negative predictive value.**

For several years, RBM systems have been contracted by health care insurance companies to control imaging costs. Frequently, an RBM system will publish criteria for a specific imaging procedure on its Web site, to facilitate physician compliance and the preauthorization process. Most of the time, RBM criteria are based on published appropriate use criteria from a credible specialty professional organization, such as the task force of the ACC and AHA. Recently, to tighten cost control, some RBM systems have implemented more restrictive criteria for certain imaging procedures. Instances of patients being denied appropriate imaging are now coming to light and are provoking scrutiny by both state and federal governments.[18,19] As a sequela of these events, it is now apparent that the physician and his or her office staff must be advocates of the patient. If, on the basis of the criteria previously delineated in the present report, there is justification for performing a cardiac imaging procedure such as coronary CTA, physicians should pursue peer-to-peer review to obtain preauthorization. Peer-to-peer review involves discussing with an imaging physician the appropriate use criteria associated with a specific patient's imaging procedure, and it is likely to result in approval, provided that valid clinical data are presented. For example, when made solely on the basis of a strong family history, a request to perform coronary CTA for a patient with suspected coronary artery disease is not likely to result in approval. However, a request to perform coronary CTA for a patient with chest pain who has undergone an exercise stress test and has received equivocal or nondiagnostic results is likely to get approved. Peer-to-peer review requires preparation of clinical data before engaging the imaging physician in discussion.

- Patients with a bundle branch block or Wolff-Parkinson-White syndrome on 12-lead electrocardiography
- Patients with equivocal or nondiagnostic results of stress testing
- Female patients who have had or who are likely to have breast artifact on scintigraphy
- Clinical suspicion of left main disease or triple-vessel disease with "balanced ischemia" in patients who have normal findings of a nuclear stress perfusion study
- Patients with heart failure of new onset
- Patients who have previously undergone aortocoronary bypass surgery when bypass graft patency is the main clinical question

Figure 14. *Patients most likely to benefit from cardiac computed tomographic angiography.*

Conclusion

Cardiac CTA is a new diagnostic imaging modality that is capable of providing assessment of coronary artery disease and left ventricular function that is on par with that of invasive coronary arteriography in selected patients who meet appropriate use criteria. This imaging modality is of clinical value in the assessment of patients with chest pain who have an intermediate risk of coronary atherosclerosis.[11] Specific clinical situations in which cardiac CTA is of defined clinical benefit are summarized in *Figure 14*. Preauthorization is usually required for this diagnostic procedure and is based on provision of clinical information to justify the request. Peer-to-peer review is sometimes required and can be facilitated by documenting the patient's chest pain symptoms and by categorizing the intermediate probability of coronary atherosclerosis by use of such validated risk assessment tools as the Framingham Risk Score and the Diamond-Forrester nomogram.

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Editor's Note: A supplemental video of ventriculography is available online at http://www.jaoa.org/content/112/5/267/suppl/DC1.