powerful effect on the patient as well. It convinced him that he needed to make significant lifestyle changes, including a decrease in smoking, diet modification, and weight loss.

Patient 2 was a 52-year-old man with a history of mild hypertension and mild hypercholesterolemia. He had been on and off his medications for the last few years. He did not smoke and had no symptoms of angina pectoris. He was actually quite fit and active, and underwent the CT angiogram to find out “how he was doing.”

CTA clearly demonstrated mild to moderate atherosclerosis in many of his coronary arteries. The RCA had nonobstructive, mildly calcified plaque in the proximal portion. In the LAD distribution there was a mild amount of soft plaque, which was contiguous with plaque in the diagonal arteries (Figures 5A and 5B).

After his scan, the patient went back on his medications. The problem was that with the knowledge that he had already started making changes in his life, he had to continue to comply with medical management for the rest of his life.

Patient 3 was a 53-year-old woman with an HDL level >60 mg/dL and an LDL level >100 mg/dL. Previous stress tests had not demonstrated ischemia. Despite this, she was extreming concerned that she would have a heart attack and her life was over. CAD. Her mother had her first heart attack at age 35, had a heart transplant at age 40, and died of complications several years after the transplant.

CTA was performed as part of a research protocol. In addition to her coronary angiogram, the patient’s CT image was reviewed by a trained cardiologist to determine the presence of significant coronary atherosclerosis.

CTA demonstrated the presence of severe, diffuse atherosclerotic plaques in the right coronary artery, left anterior descending artery, and left circumflex artery. The RCA had nonobstructive, mildly calcified plaque in the proximal portion. In the LAD distribution there was a mild amount of soft plaque, which was contiguous with plaque in the diagonal arteries (Figures 5A and 5B).

The patient was referred to a coronary artery bypass grafting surgeon. The patient’s family was also referred to a genetic counselor to determine if she was at risk for a genetic predisposition to premature coronary artery disease.

The ability to detect the presence of plaque in its early stages of development facilitates earlier intervention in a patient’s life, at a time when functional stress tests would not detect disease. For some patients, noninvasive imaging with CTA can help to direct the patient’s treatment plan to include medical therapy. Without her strong family history, she would not have been started on medical therapy.

Conclusions
Calcium scoring and CTA are two new noninvasive imaging modalities that promise to revolutionize the diagnosis and treatment of coronary artery disease.

The authors acknowledge the contributions of the following people to this project:

TABLE 1. COMPARISON OF CALCIUM SCORING, CTA, AND INVASIVE CORONARY ANGIOGRAPHY

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exclusionary</th>
<th>Functional evaluation</th>
<th>Covered by insurance</th>
<th>Scheduling</th>
<th>Risk of procedure</th>
<th>Technical</th>
<th>Therapeutic options at the time of procedure</th>
<th>Availability</th>
<th>Who performs and interprets the test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium score</td>
<td>Approximate 150 cc</td>
<td></td>
<td>Rarely</td>
<td>Can be performed on the same day as it is ordered or may be requested by an individual without a physician order</td>
<td>Very small—risks are theoretical and risks are those of the procedure</td>
<td>Variable, can be as little as 20 cc</td>
<td>Can be ordered and performed on the same day in most cases</td>
<td>Available at some hospitals as well as stand-alone clinics for a fee</td>
<td>Technologists perform and score; test is then reviewed by a staff physician.</td>
</tr>
<tr>
<td>CTA</td>
<td>Inability to hold still or follow instructions</td>
<td></td>
<td>Rarely</td>
<td>Can be ordered and performed on the same day in most cases</td>
<td>Very small—only risks arise from contrast-related complications</td>
<td></td>
<td>Inability to give consent</td>
<td>Available at all- Day-care centers and a large percentage of community hospitals</td>
<td>Technologists perform and score; test is then reviewed by a staff physician.</td>
</tr>
<tr>
<td>Invasive coronary angiography</td>
<td>Irregular or fast heart rate</td>
<td></td>
<td>Rarely</td>
<td>Can be ordered and performed on the same day in most cases</td>
<td>Very small—only risks arise from contrast-related complications</td>
<td></td>
<td></td>
<td>Available at some hospitals as well as stand-alone clinics for a fee</td>
<td>Technologists perform and score; test is then reviewed by a staff physician.</td>
</tr>
</tbody>
</table>

**Determining the presence of coronary atherosclerosis.** This is a safe test, with <1% risk of major complication. "Screening angiograms" could be performed to identify patients who have a high potential risk of coronary disease but in which functional testing is too low yielding. Of course, the high utilization of resources as well as the potential costs of invasive angiography makes this strategy somewhat prohibitive.

This gold standard has limitations in diagnosing mild disease. Angiography defines only the lumen of the coronary artery without giving detailed information about the pathology processes inside the artery’s wall. Since early atherosclerosis may be associated with compensatory expansion of the normal diameter of the artery (the so-called "lumen effect"), the lumen of a normal coronary artery may remain relatively unaffected. Therefore, early disease or subtle plaque in the coronary arteries may go undetected and the diagnosis of atherosclerosis may be delayed.

Intermediate ultrasound (IVUS) can be used to overcome the limitations of coronary angiography. This involves placing a miniaturized ultrasound catheter in the coronary artery and forming a detailed image of the coronary arteries. Patients with the highest calcium scores have a high prevalence of associated coronary plaque burden, stenosis, and coronary events are well established.

**Calcium scoring has been used for several decades as a marker for atherosclerosis.** Calcium scoring using stand-alone CTA made the diagnosis of CAD in this asymptomatic patient. Patients with elevated calcium scores are associated with fewer events, it cannot be said with certainty that these patients do not have CAD. Plaque takes time to calculate and so patients (even asymptomatic patients) can have calcium scores of zero but have significant CAD. For patients who are younger and asymptomatic, calcium scoring may give the false impression that no coronary disease is present. **CT angiography can differentiate between the coronary lumen, soft plaque, and calcified plaque, whereas calcium scoring is limited to defining calcified plaques.** Although the technique for imaging is similar to calcium scoring, the patient is given an intravenous bolus of contrast material. Images of the heart are gated, and the scan of the heart is timed to coincide with the arrival of the contrast in the coronary arteries.

**OTHER OPTIONS**

New modalities and tests are expanding the ways practitioners can visualize anatomy and disease:

- **CT scanning** dramatically increased the resolution at which we could visualize the human body. Originally, CT imaging of the heart was problematic because of the significant motion artifact that occurred while the heart was beating. With ultrafast CT imaging and latest artery sizes, current multi-detector CT scanners (MSCT, or spiral CT) are able to image the coronary arteries of a beating heart.

- **Calcium scoring** is a non-invasive test with a high degree of specificity in detecting coronary disease. It has been shown to be useful in qualifying and quantifying plaque characteristics, detecting stenosis (Figure 5), and evaluating coronary anomalies.**

**CASE STUDIES**

The following case studies highlight the ability of CT angiography to assist in the diagnosis of coronary atherosclerosis and to contribute a crucial piece of information to the treatment plan. Patient 1 was a 40-year-old man with no diagnosis of hypertension or diabetes and no history of CAD. He smoked approximately one pack of cigarettes per day and had a family history of diabetes mellitus and CAD. He had no symptoms of angina pectoris, and had a high blood stress test within the last five years, which he stated was “unnecessary.”

As part of his workup, he underwent CTA on a 16-slice CT scanner (GE LightSpeed). The images clearly demonstrated a moderate-sized plaque in the proximal portion of his left anterior descending artery (LAD) (Figure 6). It was made up of both calcified and noncalcified plaque, and was not flow-limiting. There was minimal disease in his other arteries.

CTA made the diagnosis of CAD in this otherwise asymptomatic patient. Based on these findings, his physician started him on high-dose statin therapy with a goal of reducing his LDL cholesterol level to <100 mg/dL. Seeing the images depicting plaque in his arteries had a CT CORONARY ANGIOGRAPHY: DEFINING A HIGH-RISK ASYMPTOMATIC POPULATION THROUGH NONINVASIVE TESTING

FREE CATEGORY 1 CME CREDIT • TEST CODE #702/ CT CORONARY ANGIOGRAPHY: DEFINING A HIGH-RISK ASYMPTOMATIC POPULATION THROUGH NONINVASIVE TESTING

TABLE 2. PATIENTS WHO WOULD BENEFIT FROM CTA

| Patients who are not asymptomatic, for early detection |
| Patients who have a low to moderate probability of having significant coronary artery disease |
| Patients who have risk factors, but who are reluctant to start on medication |
| Patients with symptoms consistent with coronary artery disease, but who are reluctant to undergo invasive testing |

**Figure 2.** Calcium angiogram of a left anterior descending artery (LAD). (A) 3D reconstruction allows visualization of the same artery in relation to the surrounding structures of the heart. (B) Curved reformatted reconstruction image allows evaluation of the lumen of the artery as well as atherosclerotic plaque formation (arrow).

**Figure 3.** High-grade stenosis of the left anterior descending artery (arrow) visualized by invasive coronary angiography (A) and CTA (B).

**Figure 4.** Stenosis (arrow) visualized in the left anterior descending artery by CTA. It consists of both calcified (bright white) and noncalcified (gray) plaque. The patient was asymptomatic and unaware that he had coronary artery disease.

**Figure 5.** CT coronary angiogram demonstrating atherosclerotic plaque (arrow) in the right coronary (A), left anterior descending (B), and first diagonal (C) arteries. Patient had elevated cholesterol but was asymptomatic and had no previous diagnosis of CAD.

**Figure 6.** CTA (A) and invasive coronary angiogram (B) of a 35-year-old woman with strong family history of coronary artery disease. The plaque seen on the CTA (black arrow) could easily have been missed on the invasive angiogram (white arrow).
TABLE 1. COMPARISON OF CALCIUM SCORING, CTA, AND INVASIVE CORONARY ANGIOGRAPHY

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Calcium Score</th>
<th>CTA</th>
<th>Invasive coronary angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital stay</td>
<td>One hour (includes time to fill out paperwork)</td>
<td>One hour (similar to calcium score time)</td>
<td>Fear to five hour minimum (includes time before procedure and time back after)</td>
</tr>
<tr>
<td>Procedure time</td>
<td>Less than five minutes</td>
<td>Less than five minutes</td>
<td>Roughly one hour (including patient prep time, but not including transport time)</td>
</tr>
<tr>
<td>Level of invasiveness</td>
<td>No IV</td>
<td>N/a</td>
<td>N/a</td>
</tr>
<tr>
<td>Cost</td>
<td>Rarely</td>
<td>Yes, for certain cardiac diagnoses</td>
<td>Yes, for most cardiac diagnoses</td>
</tr>
<tr>
<td>Functional evaluation</td>
<td>No</td>
<td>Yes, ejection fraction</td>
<td>Yes, ejection fraction</td>
</tr>
<tr>
<td>Covered by insurance</td>
<td>Rarely</td>
<td>Yes, for certain diagnoses</td>
<td>Yes, for most cardiac diagnoses</td>
</tr>
<tr>
<td>Scheduling</td>
<td>Can be performed on the same day it is ordered, may be requested by an individual without a physician order</td>
<td>Can be ordered and performed on the same day in most cases</td>
<td>Can be ordered and performed on the same day in most cases</td>
</tr>
<tr>
<td>Risk of procedure</td>
<td>Very small—rare complications</td>
<td>Very small—only failure to hold breath for 30 seconds</td>
<td>Very small—only failure to hold breath for 30 seconds, no IV access, no renal insufficiency, or contrast reactions</td>
</tr>
<tr>
<td>Exclusionary criteria</td>
<td>Irregular or fast heart rate</td>
<td>Irregular or fast heart rate</td>
<td>Irregular or fast heart rate, inability to hold breath for 30 seconds, limited IV access, renal insufficiency, or contrast reactions</td>
</tr>
<tr>
<td>Therapeutic options at the time of procedure</td>
<td>Diagnostic modality only</td>
<td>Diagnostic modality only, ability to transition to therapeutic modality</td>
<td>Diagnostic modality only, ability to transition to therapeutic modality</td>
</tr>
<tr>
<td>Availability</td>
<td>Available at some hospitals only as well as stand-alone clinics for a fee</td>
<td>Available at all hospitals around the country</td>
<td>Available at all hospitals around the country, available at all-care center catheter laboratories and a large percentage of community hospitals</td>
</tr>
<tr>
<td>Who performs the test?</td>
<td>Technologists perform and score test; test is then reviewed by a staff physician.</td>
<td>Cardiologists perform and interpret the test in the cardiac catheterization lab.</td>
<td>Cardiologists perform the test, nursing staff give beta blocker if necessary, physicians perform the reconstruction and interpret images</td>
</tr>
</tbody>
</table>

Figure 2. Criteria for identifying a patient with a high-risk asymptomatic population through noninvasive testing. This is a safe test, with a <1% risk of major complication. “Screening angiograms” could be performed to identify patients who have a high potential risk of coronary disease but in whom functional testing is too low yielding. Of course, the high utilization of resources as well as the potential cost of invasive angiography makes this strategy somewhat prohibitive. This gold standard has limitations in diagnosing mild disease. Angiography defines only the lumen of a coronary artery without giving detailed information about the pathologic processes inside the artery’s wall. Since early atherosclerosis may be associated with compensatory expansion of the outer diameter of the artery (the Glagov effect), the lumen of a diseased coronary artery may remain relatively normal. Therefore, early disease or subtle plaque in the coronary arteries may go undetected and the diagnosis of atherosclerosis may be delayed. Intravascular ultrasound (IVUS) can be used to overcome the limitations of coronary angiography. This involves placing a miniaturized ultrasound catheter within the coronary arteries to form detailed images in the coronary arteries. Patients with the highest calcium scores have increased associated coronary plaque burden, stenosis, and coronary events are well established. The lower calcium scores are associated with fewer events, it cannot be said with certainty that these patients do not have CAD. Plaque takes time to calcify and so patients (even symptomatic patients) can have calcium scores of zero but have significant CAD. For patients who are younger and asymptomatic, calcium scoring may give the false impression that no coronary disease is present. CT angiography can differentiate between the coronary lumen, soft plaque, and calcified plaque, whereas calcium scoring is limited to defining calcified plaques. Although the technique for imaging is similar to calcium scoring, the patient is given an intravenous bolus of contrast material. Images of the heart are gated, and the scan of the heart is timed to coincide with the arrival of contrast in the coronary arteries. Patients are required to hold their breath for up to 30 seconds and must lie still for the duration of the scan. In addition, due to need to time the scan with the beating of the heart, the modality cannot be used in patients who have irregular heart rates. Slow heart rates reduce the amount of artifact in a scan, so beta blockers are routinely given for patients with elevated heart rates. Raw and images can be reconstructed so that the coronary arteries may be evaluated in multiple views. Angiographic-type images can be made using “curved reformat” views, which allow detailed evaluation of the lumen and walls of the coronary arteries. In addition, 3D reconstruction of the coronary arteries allows the practitioner to evaluate for coronary anomalies and to trace the course of the coronary arteries in relation to the other structures of the heart (Figure 2). Through this technique, a detailed image of the coronary anatomy can be made in a short amount of time without an arterial puncture and without the risk involved in placing a catheter directly into the coronary arteries. With the recent introduction of faster, higher resolution scanners, CT coronary angiography (CTA) has been shown to have high sensitivity and specificity in detection of coronary disease. It has been shown to be useful in qualifying and quantifying plaque characteristics, detecting stenoses (Figure 3), and evaluating coronary anomalies. CT angiography can be used for both diagnostic as well as prognostic evaluation (can picture normal as well as single vessel disease).
powerful effect on the patient as well. It convinced him that he needed to make significant lifestyle changes, including a cessation of cigarette smoking, diet modification, and weight loss.

Patient 2 was a 52-year-old man with a history of mild hypertension and mild hypercholesterolemia. He had been on and off his prescribed medical therapy. Without her strong family history, she would never have been a candidate for invasive coronary angiography. What is disturbing is that the subtle irregularities seen on the invasive angiography might be described as "normal" coronary arteries by many cardiologists. However, the CT coronary angiogram clearly demonstrated premature coronary atherosclerosis in many of his coronary arteries. Based on the findings from the CT coronary angiogram, the patient’s treatment plan was changed to include aggressive lipid therapy as well as a more detailed look into his particle size, lipoprotein, and homocysteine levels. Instead of the false reassurance that "nothing was wrong," her doctor was able to give her concrete evidence that she was at higher risk than her peers. This permitted her physician to be more watchful and more aggressive with her present and future medical care.

CONCLUSION
Calcium scoring and CTA are two new noninvasive imaging modalities that provide direct visualization of coronary artery atherosclerosis. Compared to invasive coronary angiography, CTA has the ability to quickly assess coronary arteries for both calcified and noncalcified plaque, without need for invasive instrumentation of the heart (Table 1). Of the many patients who are candidates for CTA (Table 2), those who stand to benefit most are those with the highest potential risk and those who are at the earliest stages of their disease process. A large segment of the population is completely asymptomatic, yet is at higher risk because of lifestyle, comorbidities, or family history. Some of these patients have already begun producing plaque in their coronary arteries but would not be considered for secondary prevention in traditional terms. For patients with low to moderate risk of coronary disease, CTA can be used as a screening tool to evaluate the need for further, invasive testing. For patients who have positive stress tests but very low pretest probability of false-positives, it can take the place of invasive angiography as the next logical step.

The ability to detect the presence of plaque in its early stages of formation facilitates earlier intervention in a patient’s life, at a time when functional stress tests would not detect disease. For some patients, noninvasive testing with CTA can give direct visualization of their coronary atherosclerosis. This powerful message may mean the difference between smoking and not quitting smoking, staying or not staying on medications, and, ultimately, whether or not they go on to develop myocardial damage.

To complete this CME activity free of charge, please go to the accredited provider website www.mhgroup.com.br for post test and Reader Evaluation.

References
5. Messori A, Santarlasci B, Trippoli S, Vaiani M. "Polypill" demonstrates the presence of noncalcified plaque, without need for invasive angiography, CTA has the ability to quickly detect disease. Patients with hypercholesterolemia who are treated aggressively with cholesterol-lowering medications have fewer cardiovascular events. This has held true for both high- and low-risk populations. Although primary prevention is well proven, even more benefit is achieved with secondary prevention (treating patients with known coronary disease). Because these patients have more to gain, it is more cost-effective to treat them. The problem has been in identifying high-risk patients before they have devastating clinical events. Some patients are identified as having coronary disease only when they have begun to have heart failure due to cardiac dysfunction. Even more alarming are patients for whom a heart attack or death is the first indication that they have the disease. Patients with early atherosclerotic disease are often asymptomatic until the time of a myocardial infarction, making them difficult to recognize. Treating patients after a cardiac event is imperative, but can sometimes be too late to significantly affect longevity. Conversely, the "shutgun" approach of treating everyone with risk factors for coronary artery disease (CAD) is expensive and potentially dangerous.

To complete this CME activity free of charge, please go to the accredited provider website www.mhgroup.com.br for post test and Reader Evaluation.