The aim of this chapter is to explain why it is necessary to go beyond routine angiography and use new and innovative techniques to diagnose myocardial ischemia. Anesthesiologists frequently encounter patients with ischemic heart disease (IHD), which is a source of significant cardiac complications in the perioperative period. In the United States alone, nearly 600,000 people die annually of IHD, accounting for 1 in every 4 deaths. IHD is largely preventable, with many contributing modifiable risk factors such as smoking, diet, obesity, hypertension, sedentary lifestyle, and diabetes mellitus (DM). Perioperative ischemia is common, especially in the postoperative period, with the majority of ischemic episodes presenting as “silent” ischemia. In a study of 1487 male patients over the age of 40 years undergoing noncardiac surgery, it was shown that the incidence of postoperative myocardial infarction was approximately 1% in patients without IHD but it increased >4 times in patients with IHD. Patients with IHD demonstrating signs of ischemia in the perioperative period are more likely to sustain myocardial infarction.

DM is an established, independent risk factor for IHD, resulting in more than double the mortality rate found in nondiabetic subjects. The prevalence of DM in the United States has rapidly increased from 4% to 6.3% in the past 20 years, with the result that physicians are seeing
A growing number of such patients with heart disease. Surgical patients with silent ischemia who have no subjective angina may have either diagnosed or undiagnosed IHD. Silent ischemia due to autonomic neuropathy means that diabetics with significant coronary occlusive disease may have no symptoms despite myocardial ischemia. In a study of type 2 adult diabetic subjects asymptomatic with regard to IHD, the incidence of silent ischemia was 22%, highlighting the need for accurate IHD diagnostic testing with good predictive value. Further, the incidence of sudden death in diabetic patients with IHD is higher than in nondiabetic patients with IHD.

The incidence of IHD is growing among women. Of note, its presentation differs in some respects compared with that in men. Angina presents in women as pain in the upper abdomen, neck, or throat, with the nature of the pain more likely to be described as burning, sharp, or intense, rather than the pressing or crushing sensation described by men. As physicians are trained to recognize the symptoms described by men, women are more likely to experience a delay in diagnosis, or to be investigated for ailments other than IHD. In the United States, more women die of IHD than do men. Possible reasons for the increase in prevalence of IHD in women are increases in DM and obesity. Women have risk factors in addition to those found in men—for example, smaller coronary vessels, more frequent vasospasm, and a higher incidence of plaque erosion. Another important difference was identified in the Women’s Ischemia Syndrome Evaluation (WISE) study, in which 60% of women with chest pain who underwent coronary angiography were not found to have significant atherosclerotic lesions (defined as >50% stenosis of a coronary vessel).

A subset of patients routinely encountered in clinical practice comprises those with coronary stents undergoing noncardiac surgical procedures. Evidence shows that some of these patients have stent thrombosis, misalignment, or fracture. These patients may require the diagnostic ability afforded by intravascular ultrasound (IVUS).

An understanding of advances in cardiac ischemia imaging modalities and how those results are interpreted is important for continued leadership in the perioperative setting. This chapter provides information to assist in the interpretation of novel cardiac imaging techniques to accurately diagnose coronary artery disease (CAD) and vessels at risk of causing future infarcts. These new techniques not only increase the diagnostic accuracy but also improve the predictive and prognostic information about patients with IHD. To select appropriate diagnostic tests it is important to understand the pathophysiology of coronary plaques and the coronary occlusive process. Locating and diagnosing vulnerable (Fig. 1) versus stable (Fig. 2) atheromatous plaques is impossible with standard contrast angiography. However, with the help of IVUS it is now possible to evaluate not only what lies within the vessel.
lumen, but also in the vessel wall. The pathology of vulnerable plaques was very well described by Virmani et al,\textsuperscript{17} who showed that the most vulnerable vessel sites leading to myocardial infarcts were usually the

Figure 1. A thin-cap fibroatheroma located in the left anterior descending artery. Note the thread-like fibrous cap (arrow) separating the necrotic core (NC) from the coronary lumen (arrow). Tavora et al\textsuperscript{16} Licensed under Creative Commons CC 4.0 BY http://creativecommons.org/licenses/by/4.0/. Desaturated from original.

Figure 2. Atheroma. A thick fibrous cap (arrows) overlies the necrotic core (NC). Compare the thickness of this cap with that in Figure 1. Tavora et al\textsuperscript{16} Licensed under Creative Commons CC 4.0 BY http://creativecommons.org/licenses/by/4.0/. Desaturated from original.
ones with <50% occlusion as seen on contrast angiography, and hence not the ones likely to be the targets of coronary intervention such as stent placement.\textsuperscript{18}

Nuclear stress imaging and computed tomographic myocardial perfusion imaging (CT-MPI) are additional diagnostic methods discussed in this chapter. They provide anatomic and functional diagnostic information in addition to that provided by coronary angiography and IVUS.

\section*{Coronary Angiography}

Coronary angiography was developed almost a century ago and still remains the most important and frequently used imaging modality for diagnosis of IHD, its anatomic verification, and for treatment interventions. Angiography is a fusion of advances in catheterization equipment and radiography. Catheterization dates back to 1711 when Hales performed a successful catheterization on a horse using brass pipes, a glass tube, and a goose’s trachea.\textsuperscript{19}

In more recent times, Roentgen’s discovery of x-rays started a whirlwind of discovery in modern medicine by making it possible for physicians to “look” inside the human body. In 1929, Werner Forssmann, a 25-year-old medical resident in Germany, was credited with the first documented cardiac catheterization of his own heart!\textsuperscript{20} Forssmann, Cournand, and Richards would later share a Nobel Prize for their early work with cardiac catheterization. On the basis of their discovery, therapeutic interventions such as embolectomy, balloon angioplasty, atherectomy, stenting, and grafting became possible, contributing immensely to advances in health care.\textsuperscript{20–22}

Coronary angiography has been and continues to be the technique of choice for diagnosis of occlusive diseases of vessels and the subsequent treatment by balloon dilatation and/or coronary stent placement. Studies dating back to 1988 have shown that angiography can accurately identify vessels with >50% occlusion. These vessels are subject to stent placement. Little et al.\textsuperscript{23} however, found that the culprit vessels (those more likely to cause future occlusion) are more often the ones with a much smaller percent obstruction. A subsequent study in 2008, the Impact of Stent Deployment Techniques on Clinical Outcomes of Patients Treated With the CYPHER Stent (STLLR),\textsuperscript{24} showed that stents placed with the help of angiography were associated with problems such as geographical misses and the deployment of stents of inappropriate diameter. Both types of problems required more frequent revascularization of the target vessel at a later time compared with vessels that had received properly selected and positioned stents.
Intravascular Ultrasound (IVUS)

Some of the shortcomings of basic contrast angiography are addressed by IVUS. Utilizing catheter technology with ultrasound capability further enhances the diagnostic ability and promotes effective stent placement. Although the ultrasound was initially developed during World War I (1917) to detect submarines and icebergs, its utility gradually expanded to the medical field, where it gained immense importance. In 1971, ultrasound was incorporated into a catheter-based system and used mainly for viewing cardiac structures such as valves and chambers. In the 1980s, highly sophisticated intravascular and intraluminal ultrasound transducers were developed with significant utility in cardiology, vascular surgery, urology, gastroenterology, etc. These probes, capable of emitting high-frequency ultrasound from 10 to 40 MHz, have great resolution at short penetrance, making them especially effective for visualizing all layers of the blood vessel walls, particularly small arteries and arterioles. Most importantly, they have the ability to capture in detail the underlying plaque morphology, which is impossible to determine with basic angiography.

The 2 commonly used IVUS systems in use are mechanical transducers and the electronic multielement phased-array transducers (EMPA). With regard to assembly, the EMPA system with its 64 fixed imaging ports is much easier to put together than the mechanical transducer; however, it has a higher frequency and hence an inferior resolution. The currently available transducers have been made as small as four hundredths of an inch in diameter and are mountable on the tip of a thin catheter. Interventionists simply introduce the IVUS system over the same guidewires already in situ during conventional angiography. The transducers can be guided into the coronary circulation in the same manner. This makes it convenient to perform an IVUS examination of the coronary vessels with simultaneous conventional angiography, adding important information on coronary vessel anatomy not available by coronary angiography. IVUS can ascertain the integrity and vulnerability of plaques in the vessel wall, information critical for the prediction of vessels at risk for occlusion. At a minimum, IVUS can be used to take images of segments that appear most diseased on angiography.

Another important use of IVUS involves determination of the adequacy and stability of stent placement. IVUS is particularly valuable in ascertaining whether the stent covers the entire length of the plaque, and is properly anchored to the vessel wall, and in gauging the integrity of the vessel wall at the time of stent placement. The information provided by IVUS thus ensures proper placement of stents at the time of deployment and prevents future problems of stent migration and restenosis.
Nuclear Myocardial Perfusion Imaging (MPI)

Decreased oxygen delivery to the myocardium is a powerful stimulus for coronary vasodilation. Arterioles downstream from coronary atherosclerosis dilate to maintain flow, even when a person is at rest. This baseline dilation means there is less reserve for further dilation to deliver more blood flow, should there be increased metabolic demands such as those that occur during surgical stress or exercise. Although coronary angiography allows visualization of large, stenotic arteries, studies have failed to demonstrate a correlation between the majority of coronary artery obstructions and their associated physiological effects. Thus, the need for improved analytical methods for physiological assessment of angiographically detected coronary obstructions became apparent. Nuclear MPI assists in providing a link between assessment of blood flow and myocardial perfusion.

Nuclear MPI measures uptake of a radioactive perfusion tracer from the coronary arteries into metabolically active myocardium. Briefly, nuclear MPI uses radioisotopes such as rubidium-82, thallium-201, and technetium-99m, in concert with the principles of radioactive decay, to produce and acquire images. Rubidium-82 and thallium-201, in aqueous solutions, exist in the +1 oxidative state and behave in tissues in a similar manner to potassium, replacing the cation in potassium uptake pathways (e.g., the Na⁺-K⁺ ATPase). Alternatively, the chemistry of technetium-99m (a metastable nuclear isomer of technetium-99) allows it to be easily bound to various nonradioactive compounds that are taken up by metabolically active myocardial cells.
With single-photon emission computer tomography (SPECT), γ rays emitted from the isotopes are captured by a gamma camera, creating an image of the distribution of the radioactive compound within the myocardium. During positron emission tomographic (PET) imaging, the collision between a positron and electron produces 2 gamma photons moving in opposite directions. The PET scintillators detect these paired photons arriving from opposite directions within a narrow time window, giving the added advantage of event localization. SPECT and PET are the 2 most commonly used nuclear myocardial imaging modalities. They help in assessment of physiologically significant, occlusive CAD by evaluating myocardial perfusion.

**Single-photon Emission Computer Tomography (SPECT)**

SPECT is well established in the cardiology community for detecting ischemia and determining prognostic outcome following an ischemic event. During imaging, radioisotopes (eg, technitium-99m, thallium-201) are injected intravenously and absorbed into metabolically active myocardial cells. These radioisotopes emit γ rays that are received by crystals in the SPECT scintillator. The scintillator crystals do not directly detect the γ rays, but rather the γ rays produce charged particles that interact in the crystal to produce low-energy photons. Photomultiplier tubes collect the low-energy photons. The summed energy in the photomultiplier tubes determines the energy of the γ ray received. The resulting images are coded according to a gray or color scale depending on the level of perfusion. The gamma camera takes multiple 2D images to produce 3D images of the myocardium. Initial introduction of this technology was plagued by problems with attenuation, which continues to be a common source of false positives despite advances in methods and technology aimed at its reduction. The attenuation of signal is due to the different depths of cardiac tissue and density of other tissues (eg, adipose tissue) that γ rays must travel through to reach the gamma camera. Obese patients and women with large breasts are most likely to have a false positive due to attenuation. Myocardial perfusion SPECT has been shown to possess sensitivity in the range of 85% to 90%, versus 80% to 90% for coronary angiography. Gated SPECT is a technique of coordinating injection and imaging acquisition with EKG to obtain functional information like global and regional ventricular function. Information from gated SPECT compared with perfusion assessment delivers further prognostic value. The commonly used technique for perfusion assessment is stress-rest imaging.

**Positron Emission Tomographic (PET) Imaging**

Myocardial PET is the most recent nuclear perfusion imaging technique. When compared with SPECT, PET has inherently better
image resolution, superior attenuation correction, and can also quantify blood flow. Many of these improvements are due to the 360-degree geometry of the scintillators and the simultaneous arrival of dual $\gamma$ rays from positron annihilation within the myocardial cells that absorb rubidium-82, as well as the lack of need for a collimator. However, PET perfusion tracers are expensive, limiting its use. A normal result perfusion study indicates low risk (<1% annualized rate of cardiac death and nonfatal myocardial infarction), whereas an abnormal study result indicates high risk.\textsuperscript{31}

The diagnostic accuracy of myocardial perfusion PET in detecting significant CAD is superior to SPECT. For detection of significant CAD, the sensitivity and specificity of myocardial perfusion PET are 93% and 92%, respectively.\textsuperscript{32} Myocardial perfusion PET is particularly useful in reducing the number of false-positive scans for obese patients and women, where the attenuation artifact from SPECT can become an obstacle in the diagnosis of CAD.\textsuperscript{28}

**Stress Nuclear Imaging**

A stress test is performed to evaluate the heart under strain in a controlled environment. To decrease the risk of a false negative, the physician ensures that the patient attains a heart rate above 85% of the age-predicted maximum while on the exercise machine. The heart rate is calculated simply as $(220 - \text{age}) \times 0.85$. Once the heart rate is at the required level, the radiotracer is injected while the patient continues to exercise for 1 minute further to ensure the radiotracer has reached the myocardial cells. A similar routine is followed during a pharmacologic stress test, except that an infusion of a pharmacologic stressor agent is administered to the patient instead of exercise to increase the heart rate and cause coronary vasodilation. The stressor agents used are dobutamine, adenosine, dipyridamole, and regadenoson. During both exercise and pharmacologic stress tests, additional imaging measurements are taken while the patient is at rest.

The exercise stress test is recommended over the pharmacologic stress test when performing myocardial perfusion SPECT and PET. Pharmacologic stress testing is carried out on patients who have physical limitations such as orthopedic, neurological, or vascular disease preventing exercise stress testing. With PET, imaging using rubidium-82 can be carried out with the rest period first, because the half-life of rubidium-82 is short. Otherwise, imaging during the stress period precedes that during rest. Images taken under the 2 conditions are compared. If a section of myocardium displays decreased uptake of radiotracer during stress, the result indicates a perfusion defect and is interpreted as ischemia. Infarcted myocardium displays a defect that
does not change during stress or rest. Differences exist in protocols between nuclear myocardial SPECT and PET, as well as among the protocols of the different radiotracers due to their different half-lives.

### Appropriate Use for Nuclear MPI

In 2009, the American College of Cardiology Foundation along with other subspecialty societies created guidelines for the appropriate use of radionuclide scanning. Their review of the literature addressed current and anticipated clinical applications, in conjunction with current clinical practice guidelines.

In general, nuclear MPI for the diagnosis and assessment of intermediate-risk and high-risk patients was considered to be appropriate, whereas the testing of low-risk patients, routine repeat testing, and general screening were deemed less appropriate. Also addressed was the appropriate use of nuclear MPI in the perioperative setting. Currently, nuclear MPI in the perioperative setting is deemed inappropriate unless the patient is undergoing intermediate-risk or high-risk surgery, has poor or unknown functional capacity, and has 1 or more of the following risk factors: history of IHD, compensated or prior heart failure, cerebrovascular disease, insulin-dependent DM, or renal insufficiency (Fig. 4).

### Perioperative Risk Assessment and Nuclear MPI

The use of perioperative nuclear MPI, similar to other perioperative imaging modalities and investigations, should be performed if it has the potential to change clinical decision making or direct therapeutic intervention. Perioperative risk assessment and the use of nuclear MPI have been investigated in several studies, and the reader is directed to the 2014 American Heart Association/American College of Cardiology Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery for further review. To summarize, abnormal MPI studies are associated with a high sensitivity for detecting patients at risk for perioperative cardiac events while studies demonstrating moderate-to-large reversible perfusion defects indicate the greatest risk for perioperative cardiac death or MI. A normal MPI study will provide the clinician and patient with some reassurance as the negative predictive value for myocardial infarction or cardiac death is high. Fixed perfusion defects on MPI have a low predictive value for perioperative cardiac events.
Computed Tomography (CT)-MPI

Cardiac computed tomography (CCT), which uses x-rays, has been applied to both structural and functional heart imaging including coronary artery calcium scanning, coronary CT angiography (CTA), ventricular morphology and functional assessment, coronary blood flow, and MPI.\textsuperscript{35} CCT has short acquisition time and high spatial resolution.\textsuperscript{36} Although CCT has many clinical and experimental applications, this section will focus on CT-MPI for ischemia and myocardial viability assessment.

Like all CT imaging, CT-MPI works on the principle that emitted x-rays pass through the patient and are collected by detectors that measure the x-ray intensity to generate the image (Fig. 5).\textsuperscript{36} CT coronary angiography and coronary calcium scoring can be performed initially to elucidate the anatomic pathology such as stenosis, coronary calcification, and ventricular geometry.\textsuperscript{35} This is followed by a CT-MPI scan that can potentially demonstrate the hemodynamic consequences of the coronary disease. Stress and rest CT-MPI may be acquired to evaluate myocardial perfusion changes during increased myocardial work, with the downside that dynamic CT-MPI may double the radiation dose to the patient.\textsuperscript{36–38} A CT-MPI scan approximately 15 minutes after initial CT-MPI imaging can show regions of delayed enhancement that represent regions of
likely myocardial scarring after acute myocardial infarction that are unlikely to have functional improvement.\textsuperscript{39} The addition of CT-MPI provides almost simultaneous assessment for functionally ischemic myocardium and the diseased coronary vessels.\textsuperscript{36}

CT-MPI has cautions and contraindications similar to those of general CT imaging, including patient size relative to the size of the gantry opening, existence of pregnancy, and allergy to the iodinated IV contrast. In addition, CCT and CT-MPI may require a patient to lie supine and perform a short breath-hold maneuver for optimal imaging. The reader is referred to the following guidelines that provide a comprehensive overview of essential staff, facilities, and patient selection factors for CCT: “SCCT guidelines for performance of coronary computed tomographic angiography: A report of the Society of Cardiovascular Computed Tomography Guidelines Committee.”\textsuperscript{40,41}

The results of human studies of CT-MPI are in agreement with the results of SPECT and invasive coronary angiography (ICA) for myocardial perfusion defects in patients with known or suspected CAD.\textsuperscript{36,42} A more recent, multicenter study compared ICA/SPECT with CTA/CT-MPI and found that CTA/CT-MPI correctly identifies patients with flow-limiting CAD causing a perfusion defect by SPECT.\textsuperscript{43} A meta-analysis in 2012 found that CT-MPI has an overall sensitivity of 0.87, specificity of 0.69, PPV of 0.72, and NPV of 0.83 compared with radionuclide myocardial perfusion scanning.\textsuperscript{42} In clinical practice, ICA and CTA have each been combined with myocardial SPECT to evaluate the coronary anatomy and myocardial perfusion, respectively. However, each combination requires 2 separate tests. Utilizing CTA and CT-MPI instead of SPECT limits testing to a single site and may reduce the radiation dose to less than half used in ICA with SPECT.\textsuperscript{43} At present, CT-MPI is not performed in routine clinical practice. However, as this technology advances and becomes more cost-effective, it may be incorporated into the standard workup for cardiac ischemia.
Magnetic Resonance MPI

Cardiac magnetic resonance (CMR) imaging has been applied to structural and functional imaging of the heart and vasculature and is extensively used in MPI, using gadolinium-based contrast agents (GBCAs), as well as in magnetic resonance angiography. CMR imaging offers excellent spatial and temporal resolution, allowing for accurate measurement of cardiac structures, including cardiac chamber quantification, coronary anatomy, ejection fraction, and myocardial viability assessment. Although CMR imaging comprises a validated and mature set of techniques for multifaceted cardiac evaluation, this section of the review will focus primarily on CMR-MPI.

Typically, CMR imaging is first performed with synchronized gating to the ECG; patient breath-holding is often necessary to reduce motion artifacts. After delivery of a GBCA bolus, magnetic resonance angiography and MPI sequences are acquired during the first-pass of contrast through the myocardial vascular beds. Well-perfused regions of the myocardium show strong contrast enhancement, whereas poorly perfused areas are less enhanced (Fig. 6). During the equilibrium phase, approximately 5 to 30 minutes after contrast injection, late gadolinium enhancement MPI data are collected. Late gadolinium enhancement has been shown to be a very accurate method for quantifying acute and chronic infarct size and location.

The CE-MARC trial that compared CMR-MPI diagnostic accuracy with that of SPECT showed that CMR-MPI had a higher sensitivity (0.865 CMR-MPI vs. 0.665 SPECT) and higher negative predictive value (0.905 CMR-MPI vs. 0.791 SPECT). The study also concluded that specificity and positive predictive value are not significantly different between CMR-MPI and SPECT. A multicenter MR-IMPACT II study that compared CMR-MPI and SPECT using ICA as a reference standard showed CMR-MPI to have a higher sensitivity than SPECT (0.67 CMR-MPI vs. 0.59 SPECT) but lower specificity than SPECT (0.61 CMR-MPI vs. 0.69 SPECT).

![Figure 6. CMR-MPI first-pass perfusion of gadolinium in short-axis basal, mid, and apical segments. CMR-MPI indicates cardiac magnetic resonance myocardial perfusion imaging. Reprinted from Qayyum and Kastrup. Yellow arrows point to the perfusion defect. Copyright (2015) with permission from Elsevier. Copyright Elsevier, Philadelphia, PA. All permission requests for this image should be made to the copyright holder.](https://www.anesthesiaclinics.com)
vs. 0.72 SPECT). In addition, these investigators found CMR-MPI to be superior to SPECT for evaluation of multivessel coronary disease and noninfarcted patients.

CMR-MPI has also been compared with fractional flow reserve (FFR, the ratio of maximal blood flow in a stenotic artery to normal maximal flow) measured from coronary angiography. CMR-MPI identified ischemic LV regions with <0.75 FFR with a sensitivity of 0.91, specificity of 0.94, PPV of 0.91, and NPV of 0.94.

Although the prognostic value of CMR-MPI is high, more long-term studies are needed. Patients with normal CMR-MPI studies using both adenosine and dobutamine stress testing had a 3-year, event-free survival of 99.2%. Patients with abnormal CMR-MPI studies using adenosine and dobutamine had a 3-year, event-free survival of 83.5%.

In another study of patients with abnormal CMR-MPI studies, the 12-month rate for major cardiac events was 2/218 patients and the negative predictive value was 0.991%. Regadenoson has been investigated as an alternative to both dobutamine and adenosine for CMR-MPI stress testing and was shown to yield fewer side effects. The absence of rest and stress CMR-MPI abnormalities was shown to have a negative predictive value for major cardiac events of 0.99%.

CMR-MPI has cautions, limitations, contraindications, and warnings similar to those for MRI with GBCAs. These include patient size and cooperation within the scanner and the presence of MRI-safe or MRI-compatible metal implants, wires, and pacemakers. In addition, patients with renal insufficiency may not be candidates for gadolinium contrast. The results of a large study on the incidence of acute adverse reactions to CMR-MPI with gadolinium contrast were no different from those published by US Food and Drug Administration for standard gadolinium contrast.

CMR-MPI has emerged as a very accurate method for assessing functional myocardial perfusion and viability and delivers useful prognostic information about disease burden. Coupled with MR coronary angiography, CMR-MPI provides excellent anatomic and functional assessment of myocardial ischemic disease (Fig. 6).

### Summary

The practicing anesthesiologist commonly encounters patients with IHD. Of particular concern is the increasing prevalence of DM leading to an increased incidence of silent ischemia. Advancements in cardiac ischemia imaging allow physicians to more accurately assess at-risk myocardium perioperatively and potentially mitigate its effects. IVUS can provide assessment of intraluminal plaque morphology. This helps identify and stratify plaque at risk of rupture in addition to evaluating for stent anomalies of patients presenting for surgery after stenting procedures. Nuclear MPI
provides a link between blood flow and the perfusion of myocardial cells regionally. Nuclear MPI has increased the sensitivity for detecting ischemia when compared with coronary angiography. Both CT-MPI and CMR-MPI provide simultaneous assessment of functionally ischemic myocardium paired with anatomic delineation of diseased coronary vessels. Studies suggest that CMR-MPI has a higher sensitivity for diagnosing coronary ischemia when compared with SPECT. CMR-MPI has emerged as a very accurate method for assessing functional myocardial perfusion and viability. As the fields of nuclear medicine and radiology advance, evaluation of patients with ischemia or at risk for ischemic events will improve. Further studies are warranted to help with perioperative assessment of at-risk individuals and determine whether additional risk stratification is needed to justify these expensive imaging techniques.

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The authors declare that they have nothing to disclose.

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