N oninvasive techniques for assessing coronary artery disease (CAD) have improved dramatically over the past 20 years. This is particularly true with the advent of pharmacological stress testing in patients who are unable to exercise. Because myocardial perfusion and function are closely coupled, state-of-the-art stress imaging modalities have involved assessment of myocardial perfusion with radionuclide techniques or wall motion with echocardiography. Echocardiography is currently the preferred method for ascertaining regional ventricular function during stress because of its high diagnostic accuracy, feasibility, versatility, and relatively low cost. Echocardiography has been combined with various stress modalities besides exercise. Of the various agents that can produce cardiovascular stress, dobutamine has been the most widely used. Results from dobutamine stress echocardiography (DSE) have been consistent with those of exercise echo and radionuclide imaging.\textsuperscript{1,2} In addition to detecting CAD, current clinical applications of DSE include risk stratification and assessment of residual myocardial viability in patients with ventricular dysfunction.\textsuperscript{1-3} One of the main limitations of stress echocardiography has been the suboptimal visualization of myocardial segments in 5% to 10% of patients and the need for considerable technical aptitude to acquire the images. However, DSE requires less technical prowess than does exercise echo. Image quality and delineation of endocardial motion have been greatly improved by advances in transducer technology. More recently, the discovery of harmonic imaging and the availability of intravenous contrast agents that can opacify the left ventricle\textsuperscript{4-6} have further enhanced the efficacy of this technique.

Parallel to this evolution of echocardiography into the stress arena has been the progression of cardiac magnetic resonance imaging (MRI). Current spin-echo and gradient-echo techniques allow visualization of the heart in any tomographic plane with good spatial resolution and tissue contrast, without ionizing radiation. MRI allows excellent identification of the endocardial and epicardial borders such that wall motion and thickening can be analyzed qualitatively and quantitatively. Images are gated to the QRS complex and can be displayed in a cine format. Several studies have demonstrated the high accuracy of MRI in determining ventricular volumes, ejection fraction, and left ventricular mass.\textsuperscript{7} More recently, MRI has been combined with stress modalities for the evaluation of CAD. Pharmacological stressors have a special utility with MRI because physical exercise, even bicycling, is made impractical by patient discomfort in the current closed magnet and the fact that movement artifacts are exacerbated by hyperventilation. Pennell et al\textsuperscript{8} (1992) reported the first use of dobutamine stress in conjunction with MRI (DMRI) in 25 patients with exertional chest pain by using an intermediate dose of dobutamine (up to 20 $\mu$g/kg per minute). The patients were also evaluated with dobutamine thallium-201 single-photon emission computed tomography. There was 90% agreement between the 2 stress modalities. Two other studies have evaluated the accuracy of DMRI in detecting CAD\textsuperscript{9,10} in small populations ($n$ = 28 and 39, respectively) by using similar doses of dobutamine. Sensitivity for CAD was 85%\textsuperscript{9} and 91%,\textsuperscript{10} with a specificity of 80%.\textsuperscript{10} Low-dose dobutamine has also been combined with MRI for the identification of residual myocardial viability in patients with ventricular dysfunction.\textsuperscript{11,12} Moderate doses of dobutamine, however, are insufficient to induce ischemia in the majority of patients with CAD. In this issue of Circulation, Nagel et al\textsuperscript{13} provide the first report on the efficacy of high-dose dobutamine (up to 40 $\mu$g/kg per minute and atropine as needed) combined with MRI for detecting CAD, and they compare the results with DSE in a large population that underwent coronary angiography.

**Current Study**

Nagel and colleagues\textsuperscript{13} used a similar protocol of high-dose dobutamine infusion for both echocardiography and MRI in 208 patients, of whom 172 could be studied by both modalities and compared. DSE preceded DMRI, resulting in exclusion of few patients (3%) from DMRI because of severe ischemia or hemodynamic changes during DSE. Other exclusions (10.6%) were similar for both tests: Feasibility of DMRI was hampered both by claustrophobia and obesity and echocardiography by suboptimal image quality. The authors found that DMRI image quality was better than DSE overall (good or very good in 82% vs 51%). DMRI proved to be superior to DSE in terms of sensitivity (88.7% vs 74.3%; $P<0.05$) and specificity for CAD (85.7% vs 69.8%; $P<0.05$) compared with coronary angiography. The authors attributed the superior results of DMRI to its better overall image quality.
This carefully conducted study convincingly demonstrates that MRI with pharmacological stress by high-dose dobutamine is effective. From these results, DMRI appears to be more accurate in detecting ischemia than the time-honored DSE, which has been widely used in clinical practice. DMRI may indeed be more accurate in assessment of wall motion because of better image quality. Nonetheless, given the reported results and their implications, a few issues bear mentioning. It is somewhat surprising that the quality of images with the use of DSE was good or very good in only 50% of cases despite the use of harmonic imaging in 70% of the patients. It is also intriguing that both sensitivity and specificity of DSE were lower than those in recently published reports in which high-dose dobutamine-atropine protocols were used. Several factors could account for the differences between DSE and DMRI in detection of CAD. In addition to image quality, these include variability in interpretation of wall motion and the presence of wall motion abnormalities at rest. The authors were careful to display the tomographic images in a similar fashion for the 2 tests, using identical segmentation of the ventricle and qualitative criteria for wall motion and ischemia. This set the stage for a comprehensive comparison between the 2 techniques, but little information is provided regarding concordance of interpretation of stress or rest wall motion, either regionally or globally. Such data are essential for determining the advantages and limitations of each technique in evaluating wall motion and ischemia as well as assessing the effect of image quality on concordance and accuracy of results. On the other hand, although patients with previous myocardial infarction were excluded, those with baseline wall motion abnormalities were not. Detection of ischemia in the presence of baseline wall motion abnormalities can be difficult, and this may account for some of the differences observed. A comparison of patients with normal wall motion at rest to those with baseline wall motion abnormalities would clarify these issues.

Whether MRI better detects ischemia in patients with baseline abnormal wall motion thus remains unclear and merits further investigation. Last, interpretation of wall motion may still be in its infancy, similar to the early days of echocardiography or angiography. In the meantime, however, MRI acquisition at each tomographic plane, patients must perform repeated breath-holds of =16 seconds throughout the study. This may hinder communication with the patient and, if symptoms arise, will interfere with image acquisition. These safety issues are even more important when the patient population is less select than in the current study (prescreened with DSE for tolerability), for example, including patients with previous infarction or depressed ventricular function. Recent studies on myocardial viability with DSE have also emphasized the importance of using low-dose as well as high-dose dobutamine in patients with depressed function to assess ischemia, recovery of function, and prognosis. In view of the need of aggressive dobutamine stress protocols in the majority of patients, inadequate monitoring and concern over patient safety is, in our opinion, the most important limitation of current MRI technology.

**Prominent of MRI in Heart Disease**

Both echocardiography and MRI have an essential characteristic of the ideal noninvasive imaging modality to assess regional function: viz, a tomographic technique that allows evaluation of endocardial motion as well as myocardial thickening. Nagel et al provide a comprehensive discussion of the advantages and limitations of each imaging modality. Major advantages of MRI in this regard include less dependency on the examiner and “imaging windows” and better endocardial and epicardial definition, which allows quantitation of regional function. Recent developments in this area show that regional myocardial strains can be estimated and the 4-dimensional motion of individual voxels of myocardium can be tracked by myocardial MRI tagging. Furthermore, new MRI contrast agents specifically designed for cardiac imaging may augment the generally high contrast between endocardium and cardiac cavity, thus facilitating automated computer analysis of regional function. The relatively slow imaging speed of current MRI technology, however, presents a major impediment to the widespread use of this technique. Images must be built up over multiple cardiac cycles, necessitating gating and compensation for respiratory motion. Although breath-hold techniques can be effective in selected patients, they may be difficult or impossible to use in patients with pulmonary disease or heart failure. “Real-time” MRI would eliminate the need for cardiac gating and respiratory motion compensation. Further advances in MRI technology that allow real-time imaging are under way and will undoubtedly enhance its overall application, particularly with pharmacological stress testing.

Currently, only a few MRI facilities and physicians are dedicated to cardiac imaging. The Task Force of The European Society of Cardiology on MRI recently recommended that current applications of MRI in CAD be limited mostly to class III indications and research. Improvement in MRI technology, however, still offers the promise of evaluating not only cardiac function but also proximal coronary anatomy, myocardial perfusion, and metabolism and provides a “one-stop” shop for the cardiac patient. Although cardiac MRI has been around for almost 2 decades, MRI technology may still be in its infancy, similar to the early days of echocardiography or angiography. In the meantime, however,
competing imaging technologies are evolving at a rapid rate. In echocardiography, for example, the recent introduction of harmonic imaging, contrast echocardiography, anatomic M-mode, and tissue Doppler techniques have significantly improved the evaluation of cardiac function.1,4,6,24,25 For MRI technology to be a contender among current cardiac imaging modalities, innovations in technology, methodology, and applications are needed. The incremental diagnostic value of MRI over existing technologies, its cost effectiveness, and impact on patient outcome will ultimately need to be demonstrated for MRI to have a major role in the overall assessment of the patient with CAD.

Acknowledgments

The authors would like to thank G. Wesley Vick III, MD, PhD, for秘书arial assistance.

References


KEY WORDS: Editorials ■ coronary disease ■ echocardiography ■ stress ■ magnetic resonance imaging
Dobutamine MRI:: A Serious Contender in Pharmacological Stress Imaging?
William A. Zoghbi and Eddy Barasch

Circulation. 1999;99:730-732
doi: 10.1161/01.CIR.99.6.730
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1999 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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