Magnetic resonance perfusion imaging for detection of ischemic heart disease

Eike Nagel
King's College London, Rayne Institute, St Thomas' Hospital, London, UK

Correspondence: Prof. Eike Nagel, King's College London, Imaging Sciences, Rayne Institute, St Thomas' Hospital, London SE1 7EH, UK.
E-mail: eike.nagel@kcl.ac.uk

Abstract

In recent years, magnetic resonance first-pass perfusion imaging (MRPI) has developed from a research technique to a mature clinical application. Sufficient evidence has been presented to demonstrate that a high-quality MRPI scan is at least as good as a single photon emission computed tomography scan for the diagnosis of significant coronary artery disease. The ability of this new technique to assess the hemodynamic relevance of a stenosis has been shown by its close correlation with invasive coronary flow and pressure measurements. Initial data demonstrate that patients with a negative MRPI scan have an excellent prognosis.
■ *Heart Metab.* 2008;38:19–21.

Keywords: Diagnosis, ischemic heart disease, magnetic resonance perfusion imaging

Introduction

The non invasive assessment of myocardial perfusion is one of the most attractive methods for detecting coronary artery disease (CAD), because a decrease in myocardial blood flow is the first event after induction of myocardial ischemia (ischemic cascade) [1]. Currently, single photon emission computed tomography (SPECT) is the technique most widely used to prove or exclude significant CAD. However, several limitations of SPECT, such as attenuation artifacts and its relatively low spatial resolution, make the introduction of a new technique attractive. The techniques used for magnetic resonance first-pass perfusion imaging (MRPI) have been improved considerably in recent years, are sufficiently robust, and yield high-quality images if used with some experience and a state-of-the art scanner. Several single-center and initial multicenter trials [2,3] have demonstrated the high accuracy of the technique in comparison with invasive coronary angiography. In addition, a close correlation has been shown between the findings of MRPI and the assessment of coronary artery flow reserve or fractional flow reserve. The main limitations of the new technique are the needs to understand potential artifacts and to have sufficient practice to obtain high-quality imaging and image interpretation.

Pathophysiology

Myocardial perfusion depends on the driving pressure gradient and the resistance of the coronary vascular bed. Coronary autoregulation makes it possible to keep myocardial perfusion stable for a wide range of coronary perfusion pressures, even in the presence of a stenosis that narrows the coronary artery diameter by up to 90% [4]. During exercise or pharmacological stress, autoregulation becomes exhausted, leading to a relative reduction in blood flow distal to a coronary artery stenosis. With perfusion imaging, these relative changes in blood flow can be visualized and the hemodynamic significance of a coronary artery stenosis demonstrated. It is important to remember that there is no direct correlation between alterations in blood flow and the degree of a coronary artery stenosis. Consequently, there is a limited agreement between MRPI measurements and invasive angiography, but a closer agreement with invasive measurements of fractional flow reserve.

Imaging technique

Usually a T1-weighted sequence is used to visualize the first passage of a gadolinium contrast agent through the myocardium. Three to five short-axis views with an in-plane resolution less than 3 mm × 3 mm are acquired at each heart beat (*Figure 1*). Images are first acquired during adenosine stress, and then imaging is repeated approximately 10 min later with the patient at rest. At some stage during the procedure, cine wall-motion images are acquired with the patient at rest; finally, delayed enhancement imaging, as described elsewhere [5], is performed.

Image analysis

For clinical purposes, a rapid visual assessment is performed by comparing the contrast enhancement in different myocardial regions. Importantly, the speed of the increase in signal (contrast agent wash-in), rather than the absolute maximum signal, is the most important parameter for visual assessment [6]. Patients with suspected CAD may be considered to be positive for CAD based on a positive late gadolinium enhancement scan, independent of the

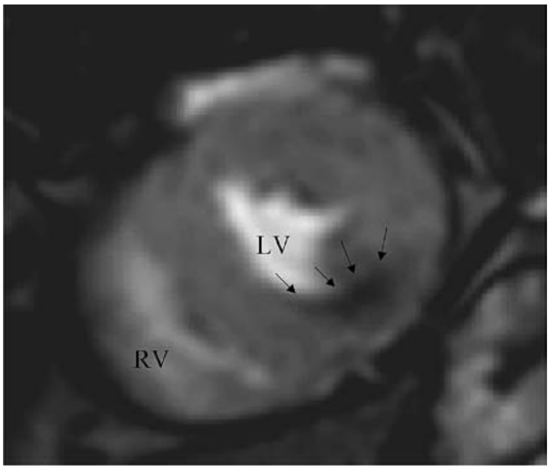

Figure 1. Equatorial short axis view of a first pass perfusion scan. An image during peak myocardial enhancement was chosen. The arrows indicate a subendocardial perfusion defect in the inferior wall, most likely due to a significant stenosis of the right coronary artery. Spatial resolution is app. 3 mm x 3 mm which allows visualization of subendocardial defects.

perfusion results [7]. However, in patients whose condition is complex (known myocardial infarction, previous revascularization), the approach is less straightforward. In these patients, the stress perfusion images need to be compared carefully with the scar images, and only those patients with perfusion defects that are larger than the scar territory are regarded as positive for ischemia.

For a more precise analysis, and for research purposes, semiquantitative or quantitative analyses are available [8].

Accuracy and prognostic value

The overall accuracy of MRPI is about 90% sensitivity and 70–80% specificity compared with invasive angiography. The main reasons for false-positive results are artifacts in patients in whom image quality is suboptimal (a problem that has lessened significantly in recent years) and the physiologic differences between measuring ischemia and coronary artery stenoses (as outlined above). The correlation between MRPI and functional measurements of the severity of stenosis (coronary flow reserve, fractional flow reserve) is good [9] and Kühl et al [10] have reported a sensitivity of 92% with a specificity of 92% for MRPI compared with fractional flow reserve. These findings demonstrate the high accuracy of MRPI. In addition, patients with a negative MRPI scan have an excellent prognosis, with an event rate of only 0.7% for major cardiac events within the next 2 years [11]. Thus this technique can be safely applied in patients referred for invasive angiography without proven evidence of ischemia or who demonstrate an intermediate pretest likelihood of CAD. Recently, MRPI was regarded as an appropriate indication in a variety of situations, most importantly in patients with chest pain, who have an intermediate risk for CAD and are unable to exercise, or in whom the electrocardiogram cannot be interpreted, and in patients who have an intermediate stenosis of unclear hemodynamic significance found by coronary artery imaging (either cardiac computed tomography or invasive angiography) [12].

Summary

Despite the lack of large multicenter trials for the assessment of MRPI, the technique can be regarded at least as not inferior to SPECT. A negative study has an excellent negative predictive value for the occurrence of major cardiac events. The test has several accepted indications, mainly in patients with chest pain, who have an intermediate risk for coronary artery disease and are unable to exercise, or in whom the electrocardiogram cannot be interpreted, and in patients who have an intermediate stenosis of unclear hemodynamic significance found by coronary artery imaging (either cardiac computed tomography or invasive angiography). ■

REFERENCES

1. Nesto RW, Kowalchuk GJ. The ischemic cascade: temporal sequence of hemodynamic, electrocardiographic and symptomatic expressions of ischemia. *Am J Cardiol*. 1987;59:23C–30C.
2. Wolff SD, Schwitter J, Coulden R, et al. Myocardial first-pass perfusion magnetic resonance imaging: a multicenter dose-ranging study. *Circulation*. 2004;110:732–737.
3. Giang TH, Nanz D, Coulden R, et al. Detection of coronary artery disease by magnetic resonance myocardial perfusion imaging with various contrast medium doses: first European multi-centre experience. *Eur Heart J*. 2004;25:1657–1665.
4. Gould KL, Kirkeeide RL, Buchi M. Coronary flow reserve as a physiologic measure of stenosis severity. *J Am Coll Cardiol*. 1990;15:459–474.
5. Kim RJ, Shah DJ, Judd RM. How we perform delayed enhancement imaging. *J Cardiovasc Magn Reson*. 2003;5:505–514.
6. al-Saadi N, Gross M, Bornstedt A, et al. [Comparison of various parameters for determining an index of myocardial perfusion reserve in detecting coronary stenosis with cardiovascular magnetic resonance tomography]. *Z Kardiol*. 2001;90:824–834.
7. Klem I, Heitner JF, Shah DJ, et al. Improved detection of coronary artery disease by stress perfusion cardiovascular magnetic resonance with the use of delayed enhancement infarction imaging. *J Am Coll Cardiol*. 2006;47:1630–1638.
8. Jerosch-Herold M, Swingen C, Seethamraju RT. Myocardial blood flow quantification with MRI by model-independent deconvolution. *Med Phys*. 2002;29:886–897.
9. Futamatsu H, Wilke N, Klassen C, et al. Evaluation of cardiac magnetic resonance imaging parameters to detect anatomically and hemodynamically significant coronary artery disease. *Am Heart J*. 2007;154:298–305.
10. Kuhl HP, Katoh M, Buhr C, et al. Comparison of magnetic resonance perfusion imaging versus invasive fractional flow reserve for assessment of the hemodynamic significance of epicardial coronary artery stenosis. *Am J Cardiol*. 2007;99:1090–1095.
11. Jahnke C, Nagel E, Gebker R, et al. Prognostic value of cardiac magnetic resonance stress tests: adenosine stress perfusion and dobutamine stress wall motion imaging. *Circulation*. 2007;115:1769–1776.
12. Hendel RC, Patel MR, Kramer CM, et al., for the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group; American College of Radiology; Society of Cardiovascular Computed Tomography; Society for Cardiovascular Magnetic Resonance; American Society of Nuclear Cardiology; North American Society for Cardiac Imaging; Society for Cardiovascular Angiography and Interventions; Society of Interventional Radiology. ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 appropriateness criteria for cardiac computed tomography and cardiac magnetic resonance imaging: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American College of Radiology, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, American Society of Nuclear Cardiology, North American Society for Cardiac Imaging, Society for Cardiovascular Angiography and Interventions, and Society of Interventional Radiology. *J Am Coll Cardiol*. 2006;48:1475–1497.