Why Does Magnetic Resonance Imaging Remain Underused in Patients With Heart Disease?

José A. San Román,[a] Paula Tejedor,[a,*] and Edwin Wu[b]

[a]Instituto de Ciencias del Corazón (ICICOR), Hospital Clínico Universitario, Valladolid, Spain.
[b]Feinberg Cardiovascular Research Institute, Northwestern University, Chicago, USA.

The spectacular advance in cardiologic imaging techniques has led to considerable improvements in the diagnosis and treatment of our patients. This advance, and the importance afforded to it by REVISTA ESPAÑOLA DE CARDIOLOGÍA, is exemplified by the publication of an excellent update on clinical decision making based on imaging techniques.[1] Of the many possible imaging techniques available, magnetic resonance (MR) stands out for the quality of its images. Moreover, the technique is highly reproducible, has a very low rate of variability, is safe because no ionizing radiation is used, and is versatile, permitting both a morphologic and a functional study, including quantification not only of ventricular function, but also of myocardial perfusion and viability. The limited use we cardiologists make of this technique is therefore all the more surprising. The reason why cardiologists fail to rely more on MR for the diagnosis and follow-up of their patients may be partly due to lack of availability of the technique in some centers, but we who work with MR are also to blame as we have been unable to transmit its enormous potential. The article by Pons Lladó et al[2] published in this issue of the REVISTA should help to remedy this situation.

Reduction in myocardial perfusion is a sensitive indicator of myocardial ischemia. Initially, the perfusion defect involves the subendocardial regions,[3] but as blood flow is reduced the perfusion defect becomes transmural. These effects take place before the appearance of changes on the ECG and the presentation of clinical symptoms.[4] The early onset of alterations in myocardial perfusion in the pathophysiologic cascade of the myocardial ischemic process makes the heterogeneity of myocardial perfusion a sensitive indicator of ischemia. The technique most commonly used in clinical practice to study myocardial perfusion is single photon emission computed tomography (SPECT).[5] The sensitivity and specificity of SPECT to detect important coronary disease range from 83%-95% and 53%-95%, respectively. One of the limitations of SPECT, however, is its low spatial resolution, which impedes identification of subendocardial perfusion defects.[6]

Magnetic resonance imaging has been used for myocardial perfusion studies since the 90s. The high degree of spatial resolution of MR enables detection of subendocardial perfusion defects, and the temporal resolution currently available permits rapid follow-up of the passage of contrast agents and the characterization of the different tissue properties. As with nuclear imaging techniques using pharmacologic stress to study myocardial perfusion, MR studies can be undertaken with the patient at rest and following maximum hyperemia, generally induced pharmacologically with dipyridamole or adenosine. Magnetic resonance imaging enables analysis of myocardial perfusion by studying the first pass kinetics of a paramagnetic contrast agent, usually gadolinium, administered as an intravenous bolus. The study of myocardial perfusion requires repeated image acquisition to detect the first pass of the contrast agent. Because acquisition of one image per cardiac cycle fails to provide full coverage of the left ventricle, multislice sequences are taken, which in turn has the inconvenience of providing lower temporal resolution and lower image contrast.

Qualitative or visual interpretation consists of the detection of areas of the myocardium showing a delay in the arrival of the contrast agent during maximum hyperemia, but not at rest. This form of analysis is fast and ideal for use in clinical practice. The criteria for

SEE ARTICLE ON PAGES 388-95

*Dr Paula Tejedor is currently training at the Feinberg Cardiovascular Research Institute, Northwestern University, Chicago, USA.

Correspondence: Dr. J.A. San Román.
Instituto de Ciencias del Corazón (ICICOR). Hospital Clínico Universitario.
Ramón y Cajal, 3. 47005 Valladolid. España.
E-mail: asanroman@secardiologia.es

Full English text available at: www.revespcardiol.org

the detection and characterization of perfusion defects include the maximum contrast intensity in the left ventricle and the time taken to reach peak signal intensity. The defects can be defined as reversible (if they only appear under stress) or fixed (if they appear both at rest and under stress). This method of interpretation requires the studies to be read by experienced persons, but as this can be susceptible to subjective variation maximum image contrast is required in order to detect small perfusion defects. Quantitative or semi-quantitative methods of interpretation are based on the definition of the myocardial regions of interest. The data are acquired from signal intensity upslopes[7] or the flow gradient,[8] which require the use of complex mathematical models to analyze the kinetics of the contrast agent. The high degree of heterogeneity of current models for quantitative interpretation demonstrates their complexity and laboriousness, and their use in clinical practice is restricted to centers with sufficient means and experience in the field of MR.

First pass kinetics of contrast agents as a method of studying myocardial perfusion has been validated in experimental studies in animal models.[9] These studies have shown a correlation with microspheres for the measurement of myocardial flow in animals,[10] as well as in healthy volunteers and a small number of patients. Recent studies comparing quantitative MR perfusion measurements in patients with suspected heart disease with those obtained from positron emission tomography (PET) and angiography[11] showed the sensitivity and specificity of MR to be 91% and 94%, respectively, for the detection of coronary disease, defined for the PET as the mean coronary reserve minus 2 SD, and 87% and 85% when compared with quantitative angiography (for coronary stenosis >50%). Nagel et al[12] reported a sensitivity of 84% for the detection of single vessel disease, 90% for two vessel disease and 93% for disease involving three main vessels.

The study by Pons Lladó et al[2] published in this issue of REVISTA ESPAÑOLA DE CARDIOLOGÍA is an important contribution to the incorporation of MR into clinical practice for the diagnosis of myocardial ischemia, since most studies published so far are based on groups of selected patients and use methods of semi-quantitative analysis. The study, which included 32 non-selected patients programmed for cardiac catheterization, compared the results of myocardial perfusion using visual assessment of MR images with those of angiography for the detection of coronary disease. The low rates of sensitivity and specificity compared with previous studies (78% and 75% vs 87% and 85%, respectively) are apparently surprising. Explanations for these differences may relate to the method of analysis which, unlike the other studies, was not quantitative. Although the authors refer to this as a limitation of the study, we believe it in fact adds value to the study, as it reflects what is actually done in daily clinical practice. Moreover, whilst it is true that some small perfusion defects may be detected quantitatively but not visually, it is also possible to misinterpret artifacts as perfusion defects in a quantitative evaluation. We also believe that, although the interobserver variability could not be evaluated because the result of the visual assessment was obtained by agreement of two observers, intraobserver variability should have been included as a measure of the reliability of the results.

As the authors comment, MR protocols should be drawn up which combine techniques having a high degree of specificity (analysis of segment dynamics and viability) with highly sensitive studies (perfusion studies) to increase the overall diagnostic accuracy of MR in patients with suspected or confirmed ischemic heart disease. The development of new MR techniques, such as parallel image acquisition or the use of stronger magnetic fields, might improve image quality and increase the sensitivity and specificity of MR perfusion studies to detect important coronary disease.

Finally, we encourage other groups working in MR to publish their results in REVISTA ESPAÑOLA DE CARDIOLOGÍA, as the group from the Hospital de la Santa Creu i Sant Pau has been doing, and thereby contribute to finally making the question posed in the title of this editorial outdated.

REFERENCES

1. Bermejo J, Alfonso, F, Bosch X. Técnicas de imagen en la medicina cardiovascular moderna. Rev Esp Cardiol 2003;56:193-4.
2. Pons Lladó G, Carreras F, Leta R, Pujadas S, García Picart J. Estudio de perfusión miocárdica por cardiorresonancia magnética: comparación con la angiografía coronaria. Rev Esp Cardiol 2004;57:388-95.
3. Bache RJ, Schwartz JS. Effect of perfusion pressure distal to a coronary stenosis on a trasmural myocardial blood flow. Circulation 1982:65:928-35.
4. Nesto RW, Kowalchuk GJ. The ischemic cascade: temporal sequence of hemodynamic, electrocardiographic and symptomatic expressions of ischemia. Am J Cardiol 1987:59:C23-30.
5. Keijer JT, Bax JJ, Van Rossum AC, Visser FC, Visser CA. Myocardial perfusion imaging: clinical experience and recent progress in radionuclide scintigraphy and magnetic resonance imaging. Int J Card Imaging 1997;13:415-31.
6. Wagner A, Mahrholdt H, Holly TA, Elliot MD, Regerfus M, Parker M, et al. Contrast enhanced MRI and routine single photon emission computed tomography (SPECT) perfusion imaging for detection of subendocardial myocardial infarcts: an imaging study. Lancet 2003;361:374-9.
7. Schwitter J, Nanz D, Kneifel S, Bertschinger K, Büchi M, Knüssel PR, et al. Assessment of myocardial perfusion in coronary artery disease by magnetic resonance. Circulation 2001;103:2230-5.
8. Lee D, Simonetti O, Harris K, Holly TA, Judd RM, Wu E, et al.

Magnetic resonance versus radionuclide pharmacological stress perfusion imaging for flow-limiting stenosis of varying severity [en prensa]. Circulation 2004.
9. Wilke N, Jerosch-Herold M, Wang Y, Huang I, Christensen BV, Stillman AE, et al. Myocardial perfusion reserve: assessment with multisection, quantitative, first pass imaging. Radiology 1997;204:373-84.
10. Klocke FJ, Simonetti O, Judd RM, Kim RJ, Harris KR, Hedjbeli S, et al. Limits of detection of regional differences in vasodilated flow in viable myocardium with first pass magnetic resonance perfusion imaging. Circulation 2001;104:2412-6.
11. Al Saadi N, Nagel E, Gross M, Bornstedt A, Schnackenburg B, Klein C, et al. Noninvasive detection of myocardial ischemia from perfusion reserve based on cardiovascular magnetic resonance. Circulation 2000;101:1379-83.
12. Nagel E, Klein C, Paetsch I, Hettwer S, Schnackenburg B, Wegscheiderk K, et al. Magnetic resonance perfusion measurements for the noninvasive detection of coronary artery disease. Circulation 2003;108:432-7.