EDITORIAL

CARDIAC MAGNETIC RESONANCE IMAGING

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SINGAPORE MED J 1991; Vol 32: 296-298

Both anatomic and functional data are important in the evaluation of patients with cardiovascular diseases[1]. For example, in patients with aortic stenosis, anatomical imaging could reveal an underlying stenosed aortic valve but it is the gradient across the valve which determines the severity of the lesion and the need for valvuloplasty or surgery. Therefore, new imaging techniques for the study of cardiovascular diseases must be able to evaluate cardiac function as well as anatomy. Magnetic Resonance (MR) imaging has joined echocardiography, radionuclide techniques and angiography as a tool for evaluation of the cardiovascular system.

MR imaging is non-invasive. The images produced are generated by signals released by the tissue being imaged in response to changes in magnetic field and radiofrequency waves. Hence, there is no need for ionizing irradiation. The inherent difference in tissue relaxation time of the various structures imaged, together with the effect on the spins created by flowing blood provide natural soft tissue contrast of the cardiac structure and the blood filled cavities and vessels. Thus, the need for and hazards associated with contrast usage are eliminated[2]. To reiterate, the important attributes which render MR imaging suitable for cardiovascular study include:

(1) the natural contrast between blood pool and cardiovascular structures,
(2) wide range of contrast between the soft tissues, and
(3) its extreme sensitivity to flow and motion[3].

As MR imaging permits slice acquisition in all spatial orientations using electronic angulation, the images can be acquired not only in orthogonal but also in oblique planes without difficult patient positioning[4-6]. This is important as the main axes of the heart do no coincide with the main axes of the body. The ability to obtain images in the planes parallel and perpendicular to the cardiac long axis of the ventricules is most important in the assessment of ventricular function.

Because the heart is a moving structure, ECG gating (or more appropriately, triggering) is necessary in most instances in cardiovascular MR imaging[7,8]. Imaging without cardiac gating gives rise to images which show poor cardiac anatomy because the heart is at a different stage in its cycle at the time of acquisition pulse sequence. The pulse sequences in MR imaging are rather long usually. Hence, motion artifacts may occur during image acquisition and gating helps in reducing this. In addition, using the ECG R waves to trigger the pulse sequence also allows us to time and acquire images at various period of the cardiac cycle. Diastolic images are acquired immediately after the R wave. By estimating an appropriate delay in echo acquisition in accordance with the prevailing heart rate at the time of imaging, images that coincide with the T waves, ie end-systolic images can be produced. This enables us to calculate cardiac volumes in end sytole and diastole and hence obtain the ejection fraction.

The techniques used in MR imaging of the heart depend primarily on the goal of the study[9]. The ECG-gated spin-echo technique provides high spatial resolution static images that clearly depict cardiac anatomy and a variety of cardiac abnormalities. However, sufficient temporal resolution is necessary for the evaluation of cardiac function. Cine MR imaging is most suited for the study of dynamic cardiac function as it produces tomographic images of up to 40 to 50 frames per cardiac cycle. MR flow imaging, using a whole new set of pulse sequences, holds great promises in the field of non-invasive vascular assessment. MR spectroscopy, although an older technique than MR imaging, still remains largely an investigative tool. The technique separates the signal from a given tissue into its different chemical forms and hence allows study of cellular metabolism. It is a rapidly advancing technology and is expected to have a greater impact in the clinical arena in the coming years.

Useful anatomic information can be obtained in a wide variety of cardiovascular diseases using MR imaging[10,11]. However, due to the cost, the relatively long imaging time required and the fact that some of the information can be obtained by a variety of other techniques (eg. echocardiography), spin-echo MR imaging of the cardiovascular system is best preserved for more specific indications which include the following:

(1) In the pre-operative assessment of complex congenital heart diseases and its post-operative follow-up[10,12-14];
(2) In the assessment of paracardiac masses[15-18];
(3) In the assessment of intra-cardiac masses that are not suitably or suboptimally demonstrated by other imaging modalities[16-20];
(4) Pericardial pathologies (indeed, it is of great value in distinguishing constrictive from restrictive pericarditis)[21-24]; and
(5) Great vessels pathology eg. aortic coarctation/dissection and pulmonary atresia. In these conditions, MR imaging is in fact the investigation of choice[10,25-30].

Although ischaemic heart disease and cardiomyopathies can be defined by spin-echo MR imaging, reliable in-vivo tissue characterization between the normal and reversibly ischaemic/hypertrophic myocardial tissue is still not possible at this point in time[31]. However, Wisenberg et al[32] has reported that in their experience, patients after cardiac transplantation with an increase in T1 and T2 relaxation times at more than 2 weeks after operation were associated with transplant rejection. Study of valvular diseases using ECG-gated spin-echo sequences has been a little disappointing as the heart valves are usually suboptimally visualized. Accurate measurement of the myocardial mass[33] and cardiac volumes[34,35] can be made using this technique, with little assumption of the geometric configuration of the ventricles.

Cine MR imaging, using fast pulse sequences, not only results in shorter study time but also allows for functional cardiac assessment because of its inherent superior temporal resolution. Flowing blood gives rise to a contrast effect in the cardiac cine images. Between successive excitations, fully magnetized spins enter the imaging slice, causing the flowing blood

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to appear 'white' (Note: in spin-echo images, blood appears black)[36,37]. Normal signal-void patterns in cardiac cine MR imaging has been described by Mirowitz et al[38]. Turbulence in blood flow and a high velocity regurgitant jet or jets through stenosis causing various degrees of signal-void in the expected jet flow direction can thus be easily identified. Qualitive assessment of regurgitant jet's severity can then be estimated[39-41]. Cine MR is useful in obtaining cardiac chamber volumes[42,43], assessing myocardial wall dynamics[44] and in visualizing intracardiac or vascular flow shunts[45]. Various indices of ventricular function such as biventricular ejection fraction (regional and global)[46], cardiac output[36,47,48], regurgitant fractions[41], measurement of pulmonic and aortic flow volumes and hence pulmonary/systemic and flow ratio can be obtained[49]. Cine MR imaging has also been shown to be of use in the assessment of patency or obstruction of proximal native coronary arteries and also that of saphenous vein grafts or internal mammary bypass grafts to the coronary arteries[50,51].

The ability of MR imaging to measure flow is one the reasons why it is an especially powerful tool for cardiologists[3]. MR flow imaging is based on either 'wash-in' and 'wash-out' of spins, 'Time-of-flight' or 'Phase shift' techniques. Magnetic Resonance velocity mapping, a technique reported by Underwood et al[52], is able to generate signals from rapidly flowing blood, together with a cine display of the surrounding anatomy[53]. Velocity mapping allows noninvasive measurement of velocities at any point and in any chosen direction in a selected image plane through the heart and great vessels. It is useful in the assessment of conditions like complex congenital heart disease (pre- and post correction), coarctation of aorta, flow through stenotic valves or implanted conduits and also flow in any sizeable artery or vein[54-56]. Kilner et al[57] recently demonstrated that with the use of short echo time (TE 3.6 msec) field even echo rephasing (FEER) mapping sequences, one could reliably detect peak jet velocity of up to 9 m/sec. This, in combination with spin-echo and cine-MR imaging, provides an alternative non-invasive method for quantitative assessment of flow and stenosis in cardiovascular diseases. This technique is especially useful at sites where the use of Doppler echocardiography is precluded by limited or absent anatomic windows and when the alignment with the transtenotic jet is difficult or impossible.

Implanted cardiac pacemakers, the presence of metallic foreign bodies in the eyes and some metallic implants in the body remain the main contraindication to MRI studies[58-60]. Common relative contraindications include ill and pregnant patients and those who suffer from claustrophobia. At present, MR imaging also has the disadvantages of being non-portable, requiring relatively long study time and non-real time imaging compared to some other imaging modalities.

In conclusion, the initial use of MR in cardiac assessment has focused on the display of normal and abnormal cardiac anatomy. With recent advances, the acquisition of functional data including blood flow imaging and velocity flow in vivo have been achieved. The role of MR spectroscopy in the intact human heart has yet to be fully evaluated, but holds great promise for the future. With constant research and technological advancement, together with discovery of faster and new scanning sequences, MR imaging holds great potential in clinical application and research in the field of cardiovascular diseases.

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