Cardiac Magnetic Resonance Imaging: Where are we?

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Introduction

Cardiac magnetic resonance imaging (CMR) has a well-established value in diagnosing uncommon diseases like complex congenital heart diseases or rare cardiomyopathies, such as arrhythmogenic right ventricular dysplasia. It is also useful in characterisation of tumour mass or imaging pericardial diseases. However, with the advancement in technology, CMR has an ever-expanding role in everyday cardiology practice. CMR, a unique imaging modality, provides assessment on ventricular function and volume, myocardial ischaemia, viability of myocardium, and extent of atherosclerosis with identification of vulnerable plaque (Table 1) in one stop.

Myocardial Function

Studies have shown that the left ventricular function is a powerful independent prognostic index for patients with heart failure and it guides their treatment options[1]. Echocardiography, the standard technique for measuring chambers volume, is easily available but is limited by technical problems such as poor echo windows, poor endocardial definition. In fact, echocardiography has significant inter-observer and intra-observer variability[2]. In contrast, CMR provides a highly reproducible volumetric measurement with the high tissue contrast between the endocardial border and the blood pool (Fig. 1). CMR acquires three-dimensional data, which allows direct measurement of the heart without depending on any geometry assumption. There is no limitation in imaging windows. Therefore, it allows accurate and precise assessment and monitoring of ventricular function and volume. It also allows a better assessment of regional wall contraction and provides a better way of assessing the functional recovery after revascularisation among significant coronary artery disease patients. On the other hand, nuclear ventriculography is free from many of these problems but radiation exposure is unavoidable.

Myocardial Viability

Several cardiac MRI techniques can detect myocardial viability. It includes 1) contrast enhanced imaging, 2) low dose dobutamine MRI and 3) MR spectroscopy.

MR spectroscopy which is used to determine preserved myocardial metabolism mainly employs in research studies. Dobutamine MRI is only available in limited centres over the world. On the contrary, contrast enhanced imaging is applied in clinical practice for detection of infarcted myocardium. The kinetics of gadolinium is different between infarcted myocardium and viable myocardium. The infarcted myocardium has delay in gadolinium washout. Therefore, 10 to 15 minutes after injection of intravenous gadolinium, infarcted myocardium appears bright or hyperenhanced compared to viable myocardium (Fig. 2). As validated from numerous animal studies[3], contrast enhanced MRI can identify a wide range of infarct size that varies from small subendocardial or subepicardial infarcts to transmural myocardial damage. In fact, with such a high resolution imaging technique, contrast enhanced MRI does not only identify the extent of infarct area, but also the thickness of transmural scar involvement precisely. The likelihood of functional improvement after revascularisation increases as the extent of transmural hyperenhancement decreases[4].

Myocardial Ischaemia

The first- pass MRI perfusion imaging technique can identify ischaemic myocardial segments. By detecting the rate of a bolus of contrast arrival in the myocardium, hypoperfused areas represent regions supplied by a significantly diseased artery (>70% stenosis). Apart from performing qualitative analysis on the myocardial perfusion, objective methods including semi-quantitative and full quantitative analysis are also feasible. Vasodilators such as adenosine or dipyridamole are commonly engaged in the first-pass perfusion imaging to detect myocardial perfusion reserve. Al Saadi et al[5] calculated the myocardial perfusion reserve by MRI dipyridamole perfusion study among 34 patients undergoing cardiac catheterization. They found that MRI had a sensitivity of 90% and a specificity of 83% for detecting coronary artery stenosis greater than 75% with reference to coronary angiogram.

Coronary artery imaging and atherosclerotic plaque imaging

There is no doubt in the ability of coronary arteries imaging by cardiac MRI. Coronary MRA has become a standard for imaging anomalous coronary arteries and quantifying the degree of patency of coronary artery bypass grafts. With the recent advancement of technology, the coronary wall and the atherosclerotic plaque on the lumen wall can be directly visualised. However, there are still some challenges to overcome

before the widespread clinical use of coronary MRA, such as cardiac and respiratory motion artifacts and limited spatial resolution. With further improvement in intravascular contrast agents, pulse sequence design, surface coil technology and image reconstruction technique, cardiac MRI promises to become a noninvasive alternative method to coronary angiography..

The following cases demonstrate some clinical applications of cardiac MRI in daily practice.

Case 1

A 45 years old obese woman, chronic smoker with good past health, complained of chest pain for 3 months. Exercise ECG revealed borderline positive treadmill and echo study was suboptimal. She underwent a CMR exam to detect any myocardial ischaemia and viability. Myocardial function assessment was normal without any regional wall motion abnormality. Myocardial perfusion scan at rest and after adenosine infusion showed no perfusion defect. There was no contrast enhancement at delay contrast imaging indicating that all the myocardium is viable. Thus, it was concluded that the patient was free from significant coronary artery stenosis and had saved from radiation exposure in other invasive imaging modalities. She was advised to start risk factors and life style modifications.

Case 2

A seventy years old woman had history of hypertension, diabetes and mild renal impairment. She complained of recurrent chest pain for one month. Twelve leads electrocardiogram revealed left ventricular hypertrophy with strain pattern. She underwent cardiac MRI including functional assessment, myocardial perfusion and viability assessment. The MRI findings confirmed concentric left ventricular hypertrophy (by measuring left ventricular wall thickness and left ventricular mass index) with normal left ventricular function. There was a perfusion defect (Fig. 3) over the left anterior descending territory (LAD) but absence of delay contrast enhancement is suggestive of viable myocardium. The patient was subjected to lesser risk of contrast nephropathy as gadolinium was less renal toxic than iodinated contrast. The patient was eventually referred to a cardiologist and had undergone successful angioplasty to mid LAD.

Case 3

A sixty years old man who was suffering from chronic rheumatic heart disease with aortic valve replacement performed 4 years ago presented with shortness of breath. He underwent a cardiac MRI exam to reassess his left ventricular function and valve function.

MRI findings showed functioning aortic valve prostheses (Fig. 4) with a left ventricular ejection fraction of 58%. There was no significant difference in left ventricular end diastolic volume index when compared with the result of last year. CMR is safe in majority prosthetic heart valves at 1.5 Tesla since prosthetic heart valves have no substantial interaction with magnetic field and the heating is negligible. However, metal containing prostheses do produce focal artifacts and signal loss due to distortion of the magnetic field.

Conclusion

MRI is becoming more widely available. Cardiac MRI is accessible in many private and public hospitals. It is well tolerated and safe. The absolute contraindications are few. Cardiac MRI, a single imaging tool, is able to provide comprehensive assessment in myocardial function, ischaemia and viability. Besides, it also detects coronary stenosis, determine coronary reserve and characterise individual atherosclerosis plaques in one stop. It promises to become a noninvasive imaging modality alternative to invasive angiography and widely applied in daily clinical practice.

Table 1 Clinical Application of Cardiac Magnetic Resonance Imaging

Congenital heart diseases
Anatomy
Quantification of shunts
Anomalous coronary arteries

Cardiomyopathies
Ischaemic cardiomyopathies
Arrhythmogenic right ventricular dysplasia
Sarcoidosis
Amyloidosis
Haemochromatosis

Myocardial Function
LV end systolic and diastolic function
LV/RV ejection fraction
LV mass

Myocardial Ischaemia
First pass perfusion imaging (adenosine, dipyridamole)
MRI coronary flow reserve
Dobutamine MRI

Myocardial Viability
Delay contrast imaging
Low dose dobutamine MRI
Spectroscopy

Pericardial Diseases

Cardiac Masses

Coronary artery imaging
Black blood / white blood MRI
MRA

Valvular disease
Flow measurement by phase contrast
Plannimetry of valve area
Atherosclerosis imaging
Black blood MRI
Intravascular MRI
Transesophageal MRI

Fig1. A 4 chamber view (left panel) and 3 chamber view (right panel) of the heart during diastole

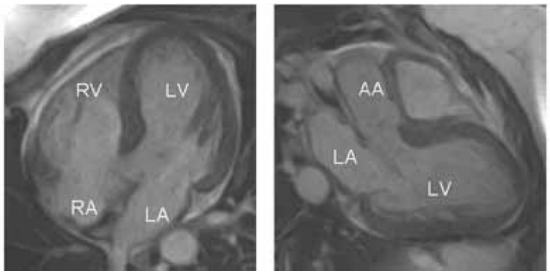


Fig2 . Using the double inversion recovery contrast imaging technique infarcted myocardium appears bright (hyperenhanced) while viable myocardial appears dark

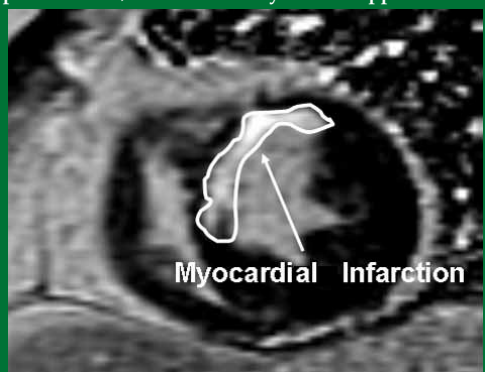


Fig3. First pass perfusion images for assessment of myocardial ischaemia.
There are perfusion defects at mid to apical septum due to late arrival of contrast agent with significant diseased left anterior descending coronary artery

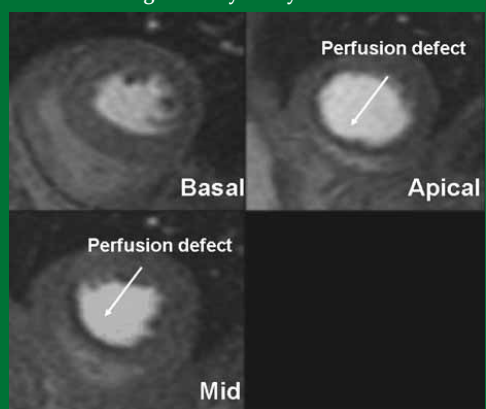
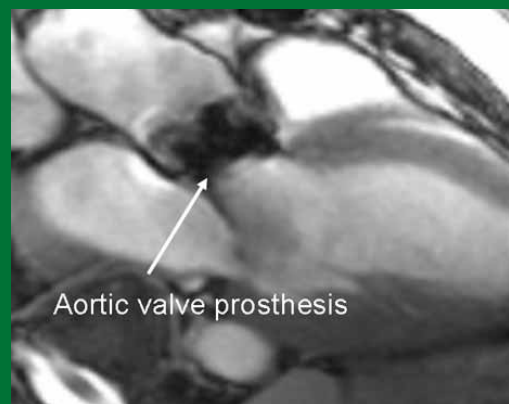


Fig 4. Patient has mechanical aortic valve prosthesis implantation 4 years ago undergone CMR for reassessment of ventricular function and volume



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