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REVIEW ARTICLE

Cardiac Magnetic Resonance Imaging: The New Tool for Clinicians

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ABSTRACT

Cardiac magnetic resonance imaging (cMRI) scan is rapidly becoming an indispensable tool for the management of various disorders. This technique has the advantages of good temporal and spatial resolution and no exposure to radiation. Various ischemic and non-ischemic conditions of the heart may be diagnosed with high sensitivity and specificity. This review article aims to introduce the clinicians to the various uses of cardiac MRI and its future potential.

Keywords: Cardiac, Contraindications, Gadolinium, Magnetic resonance imaging

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INTRODUCTION

Cardiac magnetic resonance imaging (cMRI) is an imaging technique that is now widely used for structural and functional assessment of the heart.[1] Not only the myocardial disease but also intracardiac shunts may be diagnosed with the help of cMRI; pericardial diseases are also diagnosed with the newer, more sensitive MRI techniques.[2] This technique allows for high spatial and temporal resolution in imaging and thus, accurate diagnosis may be obtained in most of the cases. Unlike Echocardiography, this is not much operator dependent or dependent on the acoustic window, and unlike computed tomography (CT) scan, there is no risk of radiation exposure.

Now, with recent advances in imaging techniques and software algorithms, cMRI can be used for not only structural diagnosis but also for prognosis in different cardiac diseases.[1] More details will be given later in this article. As the evidence for benefit of cMRI is accumulating, different professional bodies are also incorporating this novel technique in their position statements. CMRI has been accepted in standard clinical protocols according to different guidelines.[3] In the most recent 2018 American College of Cardiology (ACC) guideline on congenital heart diseases, cMRI has been mentioned as an important test for evaluation and follow up of conditions like coarctation of the aorta, congenital aortic stenosis, and tetralogy of fallot.[4] Thus, clinicians should be familiar with this emerging technique as this is likely to be an indispensable tool in the near future.

Cardiac magnetic resonance imaging (cMRI) is now used in many advanced centers of India. A recent study from Bangalore depicted the usefulness of this technique in the Indian setting.[5] Even myocardial iron overload and coronary anatomy could be studied.[5] In another study from Hyderabad, valvular morphology in rheumatic heart disease could be assessed quite well by cMRI.[6] Thus, clinicians in India are also becoming familiar with this new technique and can use it for daily clinical management.

This treatise is not meant to be an exhaustive discussion on all the uses of cMRI. In this article, the author aims to introduce the readers to the most common uses of cMRI and the usefulness of those techniques in daily patient care.

Technical Details[7]

Cardiac magnetic resonance imaging (cMRI) may be done with both 1.5 T and 3 T machines. However, a dedicated cardiac RF coil should be used.

Contraindications

Presence of some metal implants or devices inside the body is generally considered a contraindication to MRI of any part of the body. But now, this view is changing. Many patients now get pacemakers or implantable cardioverter-defibrillator (ICD) devices which are MRI compatible. Also, there are some recent studies which have shown that the risk of a pacemaker or ICD dysfunction, even the old models, after MRI scan is not as great as it was once feared.[8] There are safety measures, during the scanning procedure, which can be used to protect the pacemaker from the influence of the magnetic field. Another study of 2011 further showed that even cMRI can be safely done in patients with either pacemakers or ICD.[9] However, these should only be done in centers experienced with cMRI.

Nowadays, many patients get artificial metallic heart valves and coronary stents. Most of these are considered to be absolutely safe for MRI scan, including cardiac MRI.[10] However, there are certain technical details which have to be followed during MRI scanning. Those details can be obtained from the valve manufacturer product insert. Another valuable resource is http://www.mri-

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safety.com/ which can be freely accessed for resolving any confusion regarding contraindication before MRI.

But other metal objects like metallic artificial eyes, insulin pumps or metallic prosthetic joints (unless made of compatible metal) are contraindications to cMRI. Similarly, intracranial aneurysm clips and some hearing devices are also contraindications to MRI.

Thus, before ordering cMRI, clinicians should try to elicit if any of these forbidden implants or devices are present. However, unnecessary confusion, like forbidding MRI scan because of the presence of artificial cardiac valves, should be avoided.

Common Techniques

One main advantage of cMRI over other cardiac imaging techniques like single-photon emission computed tomography (SPECT) or CT scan is the availability of cine images. These are movie clips which can show cardiac function in real time. Also, the flow of blood and presence of clots can be seen easily.

CMRI sequences are divided into black-blood and bright blood sequences.[11] Bright blood imaging gives a better idea of LV function. But these are of more interest to radiologists. However, for clinicians, the MRI feature that is most useful is late gadolinium enhancement (LGE). Thus, in cardiac MRI, the contrast must be used. If there is a significant renal failure, cMRI can't be done.

Breath holding is essential during some phases of cMRI. Thus, patients who are severely dyspneic should not be sent for cMRI, and it should be scheduled for a later date. To reduce cardiac motion-related artifacts, the technique of electrocardiography (ECG) gating is used, where the image is acquired only during one specific part of the cardiac cycle, as determined by the ECG. In patients with arrhythmia, ECG gating may not be successful. Then, other methods like cine imaging and prospective triggering may be used.

There is another technique called "myocardial tagging" which can be used to get a better image of myocardial function in conditions like restrictive cardiomyopathy.

Uses

Late Gadolinium Enhancement

The concept behind this technique is that the contrast stays longer in the myocardium if extracellular space is more. This increase in extracellular space occurs if there is myocardial edema (e.g., after acute infarction), myocardial scar (e.g., old AMI) or myocardial infiltration (e.g., amyloidosis). In all of these cases, there is LGE, and the pattern of this enhancement helps in diagnosis.[12] Like other MRI contrast studies, the LGE pattern is seen in T1 sequences. Usually, the "late" images are acquired after 20 to 30 minutes. The pattern of LGE is estimated mostly by eye estimation but there is also software for objective assessment.[12]

Linear gingival erythema (LGE) can help to diagnose both acute and chronic myocardial insult like infarction. Acute myocardial injury can be diagnosed by cMRI even before ECG changes or echocardiographic wall motion abnormalities appear.[13]Another advantage is that cMRI not only shows the area of infarction but can also show the myocardial area, besides the infarct zone, at risk of damage.[12] While actual infarct is seen as LGE, the at-risk myocardium is seen as high intensity in T2 black blood images.[12]

In AMI, LGE can also give information about prognosis.[12] The extent of LGE can predict the left ventricle (LV) ejection fraction after recovery and return of contractility.[12] This is said to be a better predictor than cardiac enzyme levels.[14] In chronic ischemic heart disease (IHD), the extent of LGE can predict the chance of success after revascularization.[15] As the transmural extent of the LGE increases, the chance of recovery of myocardial contractility after revascularization decreases.[15] Preoperative cMRI can also predict the likelihood of graft success before coronary artery bypass graft (CABG).[16]

Linear gingival erythema (LGE) technique is also useful in the diagnosis of other causes of myocardial dysfunction like myocarditis (septal, subepicardial and basal enhancement), hypertrophic cardiomyopathy (junction of RV and septum enhancement), amyloidosis (diffuse enhancement) and endomyocardial fibrosis (biventricular enhancement).[12] In myocarditis, the extent of LGE has been found to correlate with biopsy-proven inflammation of the myocardium.[17] Thus, cMRI is emerging as a viable non-invasive option for diagnosis of myocarditis. In cases of dilated cardiomyopathy (DCM) or unexplained heart failure, often there is confusion whether the underlying etiology is ischemic or myocarditis. While the area of LGE in infarct follows a vascular territory, that of myocarditis will be diffuse. This is one important diagnostic clue.

One important use of cMRI is differentiation of hypertrophic cardiomyopathy (HCM) from athlete's heart.[18] In athletes, there may be some amount of LV hypertrophy due to physical training. This may often cause confusion during echocardiography as to whether HCM is present. But the distinction is important because athletes with HCM are forbidden from many sports. CMRI helps in this differentiation by accurate wall thickness measurement and features of LGE.[18] Also, another emerging technique called T1 mapping can help in the diagnosis of HCM in contentious cases.

Cardiac sarcoidosis is another disease whose diagnosis is facilitated by cMRI.[19] The LGE areas are predominantly basal and sub-epicardial.[19] There is also a significant correlation between the extent of LGE and plasma brain natriuretic peptide (BNP) levels in sarcoidosis.[19]

Another use of cMRI, which is growing very fast, is coronary MR angiography.[20] Two specific indications where MR coronary angiography has important use are: coronary artery aneurysm and anomalous coronary artery[20] CT scan is still the preferred method for noninvasive imaging of coronary arteries in suspected coronary

artery disease (CAD) cases.[20] But with improvement in techniques and decrease in image acquisition times, MR coronary angiography is fast becoming a viable option. Especially the 3-T machines with improved software can provide sensitivity and specificity for detection of CAD that can rival the 64-slice coronary CT images.[20] But adequate physician training for MR coronary angiography is still an issue.

Future

The use of cMRI is likely to increase manifold in the near future. Newer techniques like parallel image acquisition will further shorten the scan time.[21] Novel computer analysis methods like feature tracking will allow measurement of tissue strain within the scanning time. Four-dimensional (4D) flow measurement will allow the characterization of complex congenital heart diseases.[21] Parametric myocardial mapping and MR fingerprinting will allow better diagnosis of conditions like myocardial iron overload and Fabry's disease.[21] Oxygen-sensitive cMRI is another technique that is being developed to assess myocardial ischemia without contrast use.

However, cMRI is not going to replace all the current standards of cardiac imaging like SPECT or coronary CT. Instead, it will be a good complementary technique which will help in better patient management.

Summary

In summary, the following issues should be noted for cardiac MRI:

- Presence of devices like ICD is no longer considered an absolute contraindication to cardiac MRI.
- Cardiac magnetic resonance imaging (cMRI) can rival echocardiography in the noninvasive assessment of the myocardium.
- Use of contrast and LGE can further raise the diagnostic accuracy of cMRI.
- Cardiac magnetic resonance imaging (cMRI) can help in the diagnosis of the etiology and assessment of the prognosis in both ischemic and non-ischemic heart diseases.
- Especially for complex congenital heart diseases, cMRI is a valuable diagnostic tool.

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