Cardiovascular Imaging for Nuclear Cardiologists: First Step of Cardiac Magnetic Resonance Imaging for Nuclear Cardiologists

Yasutaka Ichikawa, MD and Hajime Sakuma, MD, PhD

Received: April 1, 2016/Revised manuscript received: June 20, 2016/Accepted: June 21, 2016
© The Japanese Society of Nuclear Cardiology 2016

Abstract

Cardiac magnetic resonance (CMR) is a rapidly evolving technology that is increasingly being used for the noninvasive imaging in the diagnosis of cardiac diseases. CMR allows for the accurate and reproducible assessments of anatomy, function and tissue characterization of the heart. It is important for cardiologists to know the advantages and the clinical applications of CMR examination. This review article describes the essentials of CMR study and the key points of the interpretation in patients with cardiac disease.

Keywords: Cardiac function, Cardiac sarcoidosis, Cardiovascular magnetic resonance, Myocardial infarction, Myocardial viability

Assessment of myocardial function with cine CMR

In contrast to echocardiography, CMR has the ability to image in any desired plane and with a nearly unrestricted field of view. This feature of CMR is attractive particularly in patients who may have body habitus limitations with other imaging modalities, such as obesity and pulmonary emphysema in echocardiography (1-3). A unique feature of CMR is the availability of multiple types of pulse sequences for evaluating cardiac anatomy, function, and tissue characterization. CMR is regarded as a gold standard imaging technique to assess myocardial regional and global function (4, 5), and myocardial infarction and fibrosis (6). CMR images can be acquired without application of ionizing radiation or the administration of radioactive isotopes or iodinated contrast. The noninvasive feature of the imaging facilitates the diagnosis and the subsequent monitoring of cardiac diseases. Now, it is important for cardiologists to become familiar with the advantages and the clinical applications of CMR examination. This review article would focus on three topics regarding CMR clinical applications, including myocardial function, myocardial infarction, and cardiac sarcoidosis (CS).
Cine CMR can also measure the diastolic function. Time-volume curves generated from cine CMR provide indexes of global diastolic function, such as peak filling rate and time to peak filling rate (12). With regard to regional ventricular function, cine CMR enables the accurate identification of even subtle regional contractile abnormalities, since cine CMR can provide an excellent delineation of the blood-myocardial interface without use of contrast medium (6).

**Assessment of myocardial infarction and viability with late gadolinium enhancement CMR**

In contrast to radioactive tracers used for myocardial perfusion scintigraphy, conventional gadolinium contrast media non-specifically distributes in the extracellular space. Approximately 10 minutes after intravenous administration of gadolinium contrast medium, distribution of the contrast medium in the intravascular and extra-cellular space reaches equilibrium state. In patients with myocardial infarction, concentration of the contrast medium in necrotic or fibrotic myocardium is substantially higher than that in normal myocardium due to increased extra-cellular space (Fig. 2). This is typically referred to as “delayed enhancement” or “late gadolinium enhancement (LGE)” (13). LGE accurately delineates infarcted tissue as defined by histology, with high spatial resolution and contrast-to-noise ratio (14). Thus, LGE CMR is more reliable in detecting subendocardial infarction when compared with single photon emission computed tomography (15, 16). In addition, LGE CMR improves the detection of RV infarction (17).

Previous studies demonstrated that transmural extent of LGE (percent transmural extent) is correlated with a lack of improvement of regional contractile function in patients with acute myocardial infarction (18, 19). In the setting of old myocardial infarction, percent transmural enhancement has been shown to be predictive of recovery of regional contraction after revascularization (20, 21). The best predictor of improved wall thickening and global function after revascularization was the extent of the dysfunctional myocardium that had either no LGE or less than 25% transmurality of LGE (20). By contrast, the likelihood of regional functional recovery was very limited in the myocardial segment with a 76% to 100% transmurality of LGE in patients with old...
Evidence suggests that LGE CMR can also provide valuable information for predicting major adverse cardiac events and cardiac mortality in patients with suspected coronary artery disease. Previous studies also demonstrated that the presence of LGE was found to be the strongest predictor of major or adverse cardiac events, independent of LV ejection fraction and other conventional clinical markers (22, 23).

Role of CMR in the evaluation of cardiac sarcoidosis (CS)

Sarcoidosis is a multisystem disorder of unknown cause, and CS affects at least 25% of patients and accounts for substantial mortality and morbidity from this disease. CS may present with heart failure, atrioventricular block, atrial or ventricular arrhythmias, and sudden cardiac death. An early identification of CS is crucial to install immunosuppressive therapy and thereby prevent the development of severe cardiomyopathy and heart failure symptoms (24).

Recent studies demonstrated LGE CMR can readily identify individuals with CS that are not otherwise clinically recognized because of its ability to accurately detect even small areas of granuloma and scar by CS (25). In fact, >15% of patients with sarcoidosis have cardiac involvement based on CMR, despite the absence of significant LV dysfunction (26). A recent study demonstrated that LGE is associated with an increased risk of death or ventricular tachycardia, even with preserved LV function (27). These observations suggest that LGE CMR is a valuable tool for the cardiac risk stratification of patients with extracardiac sarcoidosis, as well as for ruling out CS in patients with suspected CS. Updated guidelines have evidence of regional cardiac fibrosis and/or wall motion abnormalities on CMR studies as minor criteria (28). In CS patients, LGE is frequently found isolated to the mid-

myocardial infarction (20).

Fig. 2 Mechanisms of late gadolinium enhancement (LGE) in myocardial infarction. Gadolinium distributes in the extracellular space. In normal myocardium, majority of the volume is myocyte intracellular space (≈80%). Thus, the distribution volume of gadolinium in normal myocardium is relatively small. In the setting of myocardial infarction, there is myocyte membrane rupture or replacement with collagenous scar. This in turn results in increased gadolinium concentration in the infarcted tissue. The right column displays 4 chamber image of LGE cardiac magnetic resonance (CMR) obtained 10 minutes after the intravenous administration of 0.15mmol/kg of gadolinium. Note subendocardial infarction is clearly depicted in the anteroseptal wall of the left ventricle (arrows).

Fig. 3 Late gadolinium enhancement in a patient with cardiac sarcoidosis. Note the epicardial hyperenhancement, suggesting a „non-ischemic” etiology, is depicted in the anterior and inferior wall of the left ventricle (arrows).
myocardial wall or epicardium, indicative of a non-ischemic type of pattern (Fig. 3). However, we should acknowledge the facts that subendocardial or transmural hyperenhancement is also observed in sarcoidosis, mimicking the pattern of myocardial infarction.

It should be also noted that activity of CS lesion and effectiveness of therapy cannot be assessed by LGE CMR, since scar tissue as well as granulation exhibits LGE. Cardiac $^{18}$F-fluorodeoxyglucose positron emission tomography plays a decisive role to not only detect the presence of CS but also to potentially guide immunosuppressive therapy (24, 29, 30). The relationship between positron emission tomography and CMR for the evaluation of CS has not yet to be fully elucidated, but the two modalities are likely complementary with each provide unique information in the care of CS patients.

### Conclusion

This review described the roles of CMR study and the key points of the CMR findings in patients with myocardial infarction and cardiac sarcoidosis. The summary of the CMR techniques and their clinical implications is shown in Table 1. CMR is an imaging modality that provides a mean to assess cardiac anatomy, function, and tissue characteristics in a highly reproducible manner during a single examination. The authors hope that this article serves as a first step to recognize the clinical applications and interpretation of CMR study.

### Acknowledgments

The authors cordially acknowledge Dr. Keiichiro Yoshinaga (Molecular Imaging Research Center, National Institute of Radiological Sciences) for his assistance in preparing the manuscript.

### Sources of funding

None

### Conflicts of interest

None

---

**Table 1** Summary of the CMR characteristics and clinical implications described in this article

<table>
<thead>
<tr>
<th>CMR scan</th>
<th>Technical characteristics</th>
<th>Clinical indications/implications</th>
</tr>
</thead>
</table>
| Cine     | · High accuracy and reproducibility  
          · High temporal resolution       | · Cardiac morphological assessment  
          · LV and RV volumes and ejection fraction, such as in heart failure  
          · LV and RV regional wall motion |
| LGE      | · Sensitive for necrosis, fibrosis, and granuloma in the myocardium | · Identification of the extent and location of myocardial necrosis  
          · Transmurality of LGE is associated with regional contractile recovery after revascularization  
          · Identification of granuloma and scar by cardiac sarcoidosis |

CMR: cardiac magnetic resonance; LGE: late gadolinium enhancement; LV: left ventricular; RV: right ventricular

---

Reprint requests and correspondence:
Yasutaka Ichikawa, MD
Department of Radiology, Mie University Hospital, 2-174 Edobashi, Tsu, Mie, Japan 514-8507
E-mail: yasutaka@clin.med.mie-u.ac.jp

### References


10. Grothues F, Smith GC, Moon JC, et al. Comparison of
interstudy reproducibility of cardiovascular magnetic resonance with 2-dimensional echocardiography in normal subjects and in patients with heart failure or left ventricular hypertrophy. Am J Cardiol 2002; 90: 29-34.


