Cardiac Magnetic Resonance Imaging for Stage B Heart Failure

Sara L. Partington, MD[a,b], Susan Cheng, MD[c], João A.C. Lima, MD[d,e,*]

KEYWORDS

• Cardiac MRI • Heart failure • Stage B heart failure

Cardiac imaging plays an essential role in the assessment of patients with heart failure (HF) at all stages of disease. However, cardiac imaging may have the most to offer individuals with stage B disease, defined as the presence of asymptomatic cardiac structure or functional abnormalities, because these patients stand to substantially benefit from early interventions before the onset of overt HF. As such, cardiac magnetic resonance (CMR) imaging can serve as a particularly important imaging modality for providing both diagnostic and prognostic information in the setting of stage B disease. CMR is already considered the reference standard for conventional measurements of left and right ventricular structure and systolic function.[1] In addition, CMR allows for detailed myocardial tissue characterization, which can aid clinicians in identifying the cause of a given cardiomyopathy. Furthermore, CMR techniques can be used to quantify variations in regional and global myocardial performance, even in the presence of a normal ejection fraction (EF). In turn, both conventional and novel CMR measures of cardiac structure and function can be used to estimate prognosis and could also serve as potential targets of therapy.

CARDIAC MAGNETIC RESONANCE IMAGING FOR HEART FAILURE: TECHNICAL CONSIDERATIONS

Multiple imaging modalities are available for assessing cardiac structure and function in the setting of HF. The unique and complementary role of CMR can be appreciated in the context of several technical considerations.

Advantages

It remains widely recognized that CMR provides the most precise and reproducible noninvasive assessment of cardiac systolic function. Compared with echocardiography, CMR offers the advantage of excellent visualization of the endocardial border in addition to high spatial resolution

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[a] Non-Invasive Cardiovascular Imaging Program, Department of Medicine, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA
[b] Non-Invasive Cardiovascular Imaging Program, Department of Radiology, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA
[c] Division of Cardiovascular Medicine, Department of Medicine, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA
[d] Department of Medicine, Johns Hopkins School of Medicine and Johns Hopkins Hospital, Baltimore, MD, USA
[e] Department of Radiology, Johns Hopkins School of Medicine and Johns Hopkins Hospital, Baltimore, MD, USA
* Corresponding author. Division of Cardiology, Johns Hopkins Hospital, Blalock 524D Cardiology Division, 600 North Wolfe Street, Blalock 524, Baltimore, MD 21287.
E-mail address: jlima@jhmi.edu

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(up to 1.5 mm × 1.5 mm in plane resolution), without the limitation of poor echo windows. In addition, CMR-based assessments of left ventricular (LV) architecture do not require geometric assumptions. These features lead to very high intrareader and inter-reader reproducibility when assessing LV volumes and LVEF, with coefficients of variation less than 5%.[2] Such low variability makes CMR particularly valuable for serial follow-up evaluations of the same patient. The combination of high spatial resolution and low variability can be especially important in clinical settings whereby a precise cutoff value for a given therapy is required, such as for evaluating LVEF in patients being considered for implantable cardiac defibrillator (ICD) therapy.

In addition to providing precise and highly reproducible assessments of EF, CMR offers several additional technical advantages: CMR is currently the only noninvasive imaging modality that can be used for myocardial tissue characterization; standard assessment of cardiac structure and function, in addition to tissue characterization, can be performed within a single study that can be completed in less than 1 hour; and, compared with radiograph-based imaging modalities, CMR does not use ionizing radiation, which is favorable in younger patients or patients in need of repeat imaging.

Limitations

Notwithstanding the advantages of CMR, several limitations merit consideration. In patients with severe kidney failure, gadolinium-containing contrast agents pose the risk of nephrogenic systemic fibrosis (NSF). NSF results in bilateral, fibrotic, indurated papules; plaques; and subcutaneous nodules commonly involving the extremities. The fibrosis may be sufficiently severe to cause flexion contractures, joint immobility, pain, paresthesias, and severe puritis. Systemic involvement resulting in muscle induration; joint contracture; or fibrosis of the lung, myocardium, pericardium, or pleura has also been reported.[3] Although the symptoms are disabling and not treatable, NSF is rare and occurs exclusively in patients with kidney failure, with most cases involving patients with advanced kidney disease (dialysis or a glomerular filtration rate <30 mL/min),[4] acute kidney injury,[5] or those hospitalized for a proinflammatory event.[5]

Preventing NSF involves avoiding gadolinium-containing contrast in higher-risk patients. In cases whereby the benefits of administering gadolinium outweigh the risks and adequate diagnostic information cannot be obtained with a noncontrast study, decreasing the gadolinium dose to the lowest dose deemed necessary (ie, single dose [0.1 mmol/Kg] rather than double dose [0.2 mmol/Kg]) may reduce the risk.[6] Although NSF is presumed to occur with any gadolinium-containing contrast agent, most reported cases of NSF have occurred using gadodiamide,[5,6] a contrast agent that contains a chelating agent that less tightly binds gadolinium. Thus, the overall risk may be decreased by using a gadolinium formulation with a tighter-binding chelating agent (eg, gadoteridol). In renal patients without alternative imaging options, the overall risk for NSF may be further reduced by performing dialysis within 12 to 24 hours after gadolinium exposure.

The presence of a pacemaker or ICD currently remains a contraindication to CMR. Growing evidence suggests that patients with pacemakers manufactured in recent years can undergo CMR safely when a modified magnetic resonance imaging (MRI) pulse sequence protocol is used under close supervision in an experienced center. Recently, MRI-compatible pacemakers have been manufactured and clinical trials of these devices are underway to assess safety.

Even in the absence of internal cardiac devices, CMR remains challenging in patients with irregular heart rhythms or with difficultly holding their breath. Modified sequences that are less sensitive to cardiac gating and respiratory motion can compensate for some of these challenges. However, some of these modified sequences are longer in duration and can result in reduced image quality.

ASSESSMENT OF LEFT VENTRICULAR FUNCTION

In the presence of abnormal cardiac structure, it is important to obtain an accurate assessment of associated cardiac function. Although common manifestations of LV remodeling are known to increase an individual's overall risk for cardiovascular events, the presence of asymptomatic LV dysfunction, even when mild, is particularly associated with the development of clinical HF as well as all-cause death.[7]

The standard metric of global systolic function remains the LVEF. CMR provides the reference standard assessment of LVEF given its excellent temporal resolution, spatial resolution, and tissue contrast abilities differentiating the endocardial border from the blood pool.[8] Cine movie images to assess LV systolic function are most often performed with steady state free precession (SSFP) imaging by displaying the same myocardial slice at different points within the cardiac cycle. The