Commentary

An Introduction and Emerging Techniques in Cardiac MRI

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Background: Heart imaging is critical to the diagnosis and management of a wide variety of cardiac pathologies. The expanding importance of cardiac magnetic resonance imaging (CMR) in clinical practice and its application to the medical field are discussed here. Nowadays, CMR is a recognized diagnostic technique with many practical applications. Compared to echocardiography and other radiologic modalities, it offers numerous benefits, such as non-invasiveness, low ionizing radiation, and good spatial and temporal resolution. It is appropriate for long-term treatment monitoring and disease process follow-up due to its non-invasive nature.

Objective: The benefits of CMR over other imaging modalities are covered in this article, along with a brief overview of the indications, new methods, and standard CMR procedures for characterizing cardiac diseases and myocardial tissue.

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Introduction

Heart anatomy, function, and pathology are studied using magnetic resonance imaging (MRI) in cardiac MRI. Cardiovascular illnesses heavily rely on cardiac magnetic resonance imaging (CMR). With great accuracy, CMR offers an assessment of structural and functional cardiac disorders. When under stress or at rest, it enables precise measurement of heart volume and flow as well as wall motion studies.[1]

Advantages of CMR

Better image quality, no risk of ionizing radiation, precise measurement of ejection fraction, detection of suspected myocarditis which cannot be confirmed on echocardiography, a utility for evaluating newly diagnosed cardiomyopathy with advantages over echocardiography in terms of both diagnosis and prognosis and assistance in assessing myocardial viability and perfusion during the work-up for coronary artery bypass surgery are all provided by CMR. In addition to helping with the identification of congenital heart disease and cardiac masses, CMR may evaluate the structure of the heart.

The number of cardiac devices that are thought to be MRI-conditional is currently rising. After these devices have been implanted, patients can undergo CMR with the necessary safety measures and device inspections.[2]

Indications of Cardiac MRI

Heart magnetic resonance imaging (MRI) can be useful in evaluating a variety of pathologies, such as cardiomyopathies (e.g., dilated, hypertrophic, tako-tsubo, arrhythmogenic right ventricular cardiomyopathy, iron overload cardiomyopathy), myocarditis and cardiac sarcoidosis, cardiac masses & tumors, and congenital heart diseases.[3]

Contrast agents in CMR

When it comes to cardiac MRI perfusion, angiography, and late gadolinium enhancement (LGE), gadolinium-based contrast agents (GBCAs) are the standard contrast medium. Even in cases of severe renal impairment, macrocyclic GBCAs can be taken without risk. Gadoplicenol and gadoquatrane are two novel high-relaxivity GBCAs that may enable reduced dosages or enhanced vascular imaging.[4,5]

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Cardiovascular Imaging Techniques

Cardiac magnetic resonance imaging (CMR) is a vital diagnostic tool for cardiovascular diseases (CVDs), offering detailed information on tissue properties, shape, function, flow, and features. Many novel techniques have been introduced into routine clinical practice as a result of advancements in cardiac MRI over the past 20 years. These techniques have greatly simplified cardiac magnetic resonance imaging (CMR) and yielded fresh insights into cardiovascular diseases (CVDs). CMR offers a variety of techniques for characterizing cardiac tissue.

Dark blood imaging

Fast spin echo or double inversion recovery sequences are the basis for this imaging technique. The sequences' quick capture time reduces the amount of cardiac and respiratory movement artifacts. Nevertheless, poor spatial resolution is the outcome of a low signal/noise ratio. T1, T2, or proton density-weighted sequences can be used for these. While T2 and PD-weighted sequences yield greater tissue characterization, T1-weighted sequences obtain superior anatomic definition..

Dark blood imaging is routinely used in the assessment of vascular abnormalities such as aortic or vascular disease and myocardial abnormalities such as cardiomyopathy, myocarditis and cardiac tumors.[6]

White blood imaging

Steady-state free precession MRI (SSFP) and gradient echo sequences are used in this imaging technique. White blood imaging's primary benefit is its quick acquisition time. It is possible to obtain movement sequences and examine the movement and function of the heart.[7]

Myocardial Perfusion Imaging

Using a bolus injection of Gd, this technique evaluates the myocardium's microcirculation (first-pass contrast-enhanced -MRI, also known as FPCE-MRI). It is typically done in both relaxed and tense situations. Vasodilators like adenosine or dipyridamole are used pharmacologically to induce the stress state, causing hyperemia in the myocardium and increasing perfusion. Myocardial perfusion reserve (MPR) is the ratio of myocardial perfusion during stress to that during rest. Normal cardiac MPR is greater than 2. If the MPR is less than 1.5, ischemia is suspected. Ten minutes separate the stress and rest studies. In determining myocardial ischemia, first-pass MR perfusion is highly accurate; it performs similarly to invasive fractional low reserve and PET and is superior to echocardiography, SPECT and invasive angiography[8]. Hence, MR perfusion is now included in guidelines for chronic coronary syndromes[9].

Late Gadolinium Enhancement MRI (LGE -MRI)

Owing to increased GBCA uptake and delayed washout, LGE images obtained 10 to 15 minutes after GBCA administration reveal scar, fibrosis, and infiltration as high-signal-intensity areas. Acute myocardial infarction and myocarditis are also associated with high signal intensity, which is thought to be caused by GBCA entering the intracellular space as a result of damaged cell membranes. Cardiomyopathies can be categorized using the pattern of myocardial LGE.[10] In acute myocardial infarction, non-enhancing areas within the left ventricular ejection fraction (LGE) are indicative of microvascular obstruction and intramyocardial hemorrhage, which suggest reperfusion injury, an adverse remodeling risk and a poor prognosis.[11] When separating scar from fat—as occurs in lipomatous metaplasia in chronic myocardial infarction and arrhythmogenic cardiomyopathy—a multi-echo water and fat-separated sequence can be helpful.

Parametric Mapping

The pixel-by-pixel mapping of magnetic relaxation parameters enables the direct visualization and measurement of tissue characteristics. The most commonly used parameters are extracellular volume (ECV), T1, T2, and T2*. T1 mapping uses T1-weighted images at various inversion times to measure longitudinal relaxation. Techniques based on inversion recovery, like shortened modified look-locker inversion recovery (shMOLLI) and modified look-locker inversion recovery (MOLLI), are accurate but heavily reliant on heart rate.

The relaxation properties of the myocardium, blood pool, and interstitium are measured by native T1, which enables tissue characterization without the need for a GBCA. Native T1 levels are lowered in fat and iron and elevated in fibrosis, amyloid, and edema. T1 mapping is useful in the context of Fabry disease, especially when separating it from hypertrophic cardiomyopathy, which presents similarly with high T1 and low T1 in Fabry disease. Additionally, lipid and fibrosis—which seem similar in LGE—can be distinguished via T1 mapping.

Coronary Artery Imaging

In patients at low to intermediate risk, coronary MR angiography using the whole-heart ECG-gated technique can be used to assess coronary stenosis and coronary artery anomalies without radiation, nephrotoxic contrast

material, and calcium blooming associated with CT angiography.[12,13] However, because of its drawbacks, which include low spatial resolution, complicated planning required, motion artifacts, and a lengthy scan time owing to respiratory inefficiency, MR angiography is not frequently used for coronary stenosis.

Conclusion

Comprehensive evaluation of cardiac function, flow, tissue properties, and energetics is made possible by modern cardiac MRI. Innovative methods are developing and getting approved for use in clinical settings.

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