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Diagnosing Myocarditis: The Role of Cardiovascular Magnetic Resonance Imaging.

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Abstract: Background: Myocarditis is a challenging disease to diagnose, with a diverse range of symptoms and causes. Cardiovascular magnetic resonance (CMR) imaging has emerged as a valuable non-invasive diagnostic tool for suspected myocarditis, thanks to its ability to characterize tissue properties in multiple ways. While CMR has proven useful in clinical practice, it also has its limitations. This review aims to provide an updated summary of the strengths and limitations of CMR imaging in diagnosing patients with suspected myocarditis in a broad clinical setting.

Keywords: *myocarditis, LLC, CMR, COVID-19*

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Introduction

Myocarditis, a disease that affects the heart muscle, is notoriously difficult to diagnose due to its varied clinical presentation and diverse range of underlying causes. While viral infections and other infectious agents are the most common causes, myocarditis can also be triggered by systemic diseases, drugs, or toxins. In some cases, myocarditis can resolve on its own, but it can also lead to severe heart disease and even sudden cardiac death. The gold standard for diagnosing myocarditis is endomyocardial biopsy (EMB), but it has several limitations, including its invasive nature and low sensitivity. As a result, cardiovascular magnetic resonance (CMR) has emerged as a valuable non-invasive alternative. CMR not only helps diagnose the presence of myocardial inflammation but also provides valuable prognostic information [1-5]. Major cardiology organizations, including the European Society of Cardiology and the American Heart Association, recognize CMR as a useful tool in diagnosing patients with suspected myocarditis. However, CMR also has its limitations, which must be carefully considered when making clinical decisions [6].

The Clinical Context of Myocarditis Diagnosis

This review aims to provide an updated overview of the strengths and limitations of cardiovascular magnetic resonance (CMR) in diagnosing patients with clinically suspected myocarditis. To understand the challenges of diagnosing myocarditis, it is essential to first consider the clinical presentation of the disease [7-9].

Clinical Presentation of Myocarditis

Myocarditis can affect patients of all ages, although the underlying causes have different age spectra. In Western countries, most cases are seen in younger individuals, typically caused by viral infections. The symptoms of myocarditis are often nonspecific, ranging from mild discomfort to severe manifestations such as heart failure, arrhythmias, and conduction abnormalities. The presence of infectious prodrome or symptoms associated with systemic diseases can be indicative of myocarditis. Due to the nonspecific nature of symptoms, many cases may go undetected or are discovered too late [9 & 10].

Diagnostic Work-Up

In 2013, the European Society of Cardiology (ESC) Working Group on Myocardial and Pericardial Diseases proposed new diagnostic criteria to improve the recognition of myocarditis. However, these recommendations were primarily based on viral myocarditis and may need to be adapted for other underlying causes. The evaluation of patients with clinically suspected myocarditis is often extensive, as multiple differential diagnoses must be considered [5]. An integrative diagnostic approach is necessary, incorporating clinical history, physical examination, and various diagnostic methods [10].

Diagnostic Methods

Several diagnostic methods can be valuable in diagnosing patients with clinically suspected myocarditis:

1.12-lead electrocardiogram: While an electrocardiogram may be abnormal in patients with myocarditis, its diagnostic value is limited due to its nonspecific findings [1-3].

2. Biomarkers: Biomarkers of myocardial injury and inflammation can be elevated in patients with myocarditis, but their specificity is limited [1, 2, 3].

3. Echocardiography: Echocardiography is often used as a first-line imaging tool, but it may not show specific findings in patients with myocarditis [5].

4. Viral testing: Viral testing is generally not recommended due to its unreliability [6].

5. Cardiac computed tomography angiography: This imaging modality can be useful in patients with an acute coronary syndrome-like presentation or other clinical scenarios where coronary artery disease needs to be ruled out [7].

6. Cardiac magnetic resonance (CMR): CMR has emerged as a valuable non-invasive diagnostic tool for diagnosing patients with suspected myocarditis [8].

Cardiac Magnetic Resonance (CMR) Imaging in Myocarditis

CMR imaging has revolutionized the diagnosis of myocarditis, allowing for non-invasive visualization of the heart's structure and function. Its unique multiparametric tissue characterization ability enables detection of changes caused by myocardial inflammation, independent of the underlying etiology. This method has altered clinical decision-making for many patients [1, 2, 3, 4, 6 & 8].

CMR Mapping Techniques

Parametric mapping techniques, such as T1 and T2 mapping, allow for objective quantification of magnetic tissue properties. These techniques display maps of T1 and T2 relaxation times, which can be used to evaluate global or regional myocardial properties. Each deviation from normal tissue values indicates potential changes in tissue composition or disease [2-8].

Myocardial Oedema

Myocardial inflammation is characterized by the development of oedema, which is mediated by an array of cytokines. Increased tissue water content (oedema) results in prolongation of both T1 and T2 relaxation times. CMR techniques, such as T2-weighted imaging and T2 mapping, can visualize myocardial oedema [8-10].

Myocardial Hyperaemia and Capillary Leak

Myocardial inflammation also leads to hyperaemia and capillary leak, resulting in prolongation of the T1 relaxation time and increased uptake of gadolinium-based contrast agents. CMR techniques, such as native T1 mapping and early gadolinium enhancement, can visualize these changes (Fig 1) [8-10].

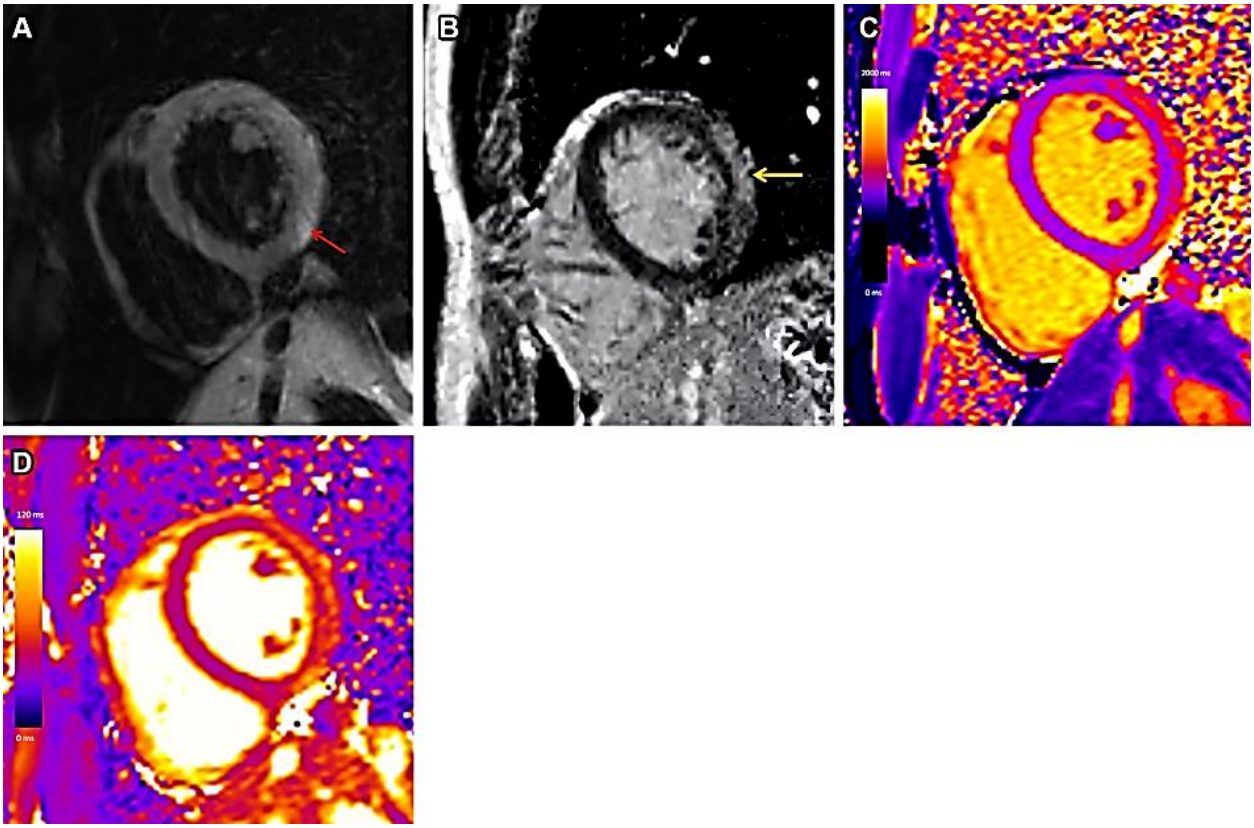

Figure 1: *Myocarditis in a 20-year-old man with acute COVID-19 who was admitted to the hospital with chest pain and an increased cardiac troponin level.* ***(A)*** *Cardiac T2-weighted short-axis MR image shows focal hyperintensity in the lateral wall suggestive of edema (arrow).* ***(B)*** *Short-axis MR image shows corresponding linear subepicardial LGE (arrow).* ***(C, D)*** *Short-axis native T1* ***(C)*** *and T2* ***(D)*** *maps show increased T1 and T2 times at the subepicardial anterolateral and inferolateral walls, respectively* ***(Quoted from 10)****.*

Myocardial Necrosis and Fibrosis

Myocardial inflammation can lead to myocyte injury, necrosis, and fibrosis, resulting in characteristic patterns on late gadolinium enhancement (LGE) images [8 & 10].

Functional and Pericardial Alterations

Myocardial inflammation can also lead to structural or functional alterations of the heart, such as regional wall motion abnormalities, ventricular dilatation, or impairment of diastolic/systolic function. Pericardial involvement can also occur, resulting in pericardial effusion or characteristic CMR findings [10-15].

Updated Lake Louise Criteria

The original Lake Louise Criteria (LLC) have been updated to include CMR mapping techniques. The updated LLC propose a "2 out of 2" approach for the diagnosis of myocardial inflammation, which requires one positive T2-based criterion and one T1-based criterion (Fig 2) [15-20].

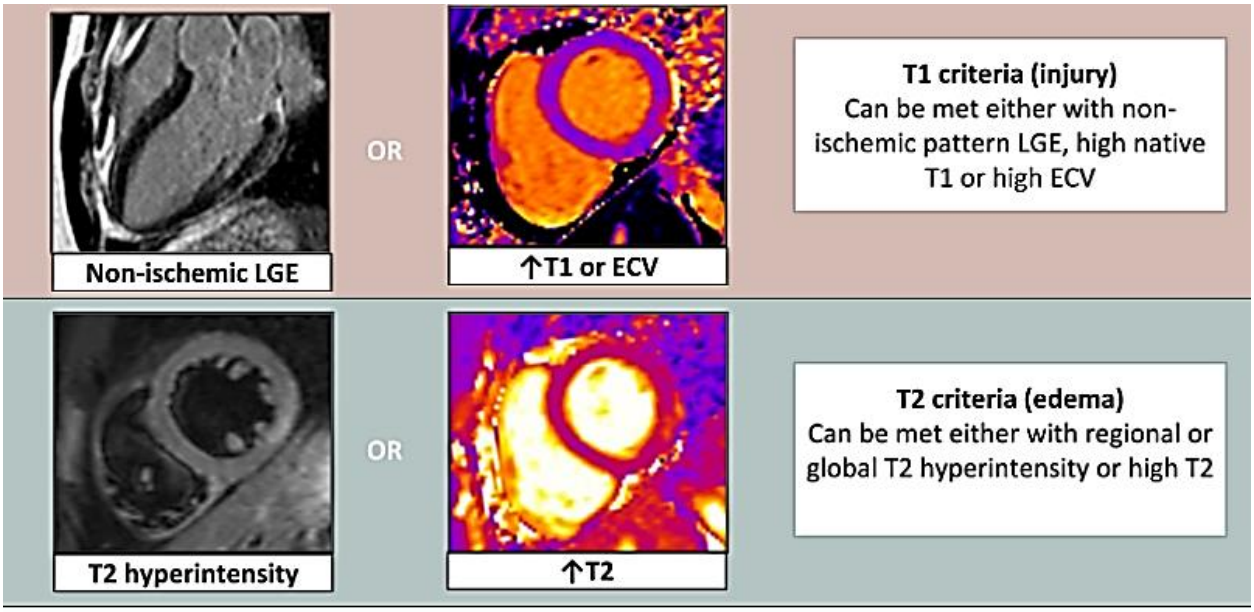

Figure 2: *Summary of the revised Lake Louise criteria for myocarditis, with representative images in a 27-year-old man with myocarditis after COVID-19. Cardiac MRI provides strong evidence of myocardial inflammation if there is at least one T1-based criterion of myocardial injury (high native T1-mapping values, increased extracellular volume fraction [ECV], or nonischemic LGE) and at least one T2-based criterion of myocardial edema (high T2 mapping values or hyperintensity on T2-weighted MR images) are present. The presence of only one marker (either T1- or T2-based) may still support diagnosis of myocarditis in the appropriate clinical context but with lower specificity. Global or regional left ventricular systolic dysfunction and signs of pericarditis constitute supportive criteria but are not required for a diagnosis of myocarditis* ***(Quoted from 10).***

Conclusion: In conclusion, CMR imaging has revolutionized the diagnosis of myocarditis by allowing for non-invasive visualization of the heart's structure and function. Its unique multiparametric tissue characterization ability enables detection of changes caused by myocardial inflammation, independent of the underlying etiology. The updated LLC provide a framework for diagnosis using CMR imaging techniques.

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