The role of the "Rotational Scan Plane" in the evaluation of Myocarditis by Contrast Enhanced Cardiac Magnetic Resonance (CE-CMRI)

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**Authors:** S. Battisti, A. Di Sibio, V. Felli, A. Gennarelli, M. ARMELLANI, L. M. GENTILE, G. Lanni, E. Di Cesare, C. Masciocchi; L'AQUILA/IT  
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Purpose

The aim of our study is to compare the conventional CMRI approach to the radial one, through the use of "rotational scan plane", in patients with clinical suspicion of myocarditis.

Myocarditis is an acute or chronic inflammatory disease of the myocardium which can be viral, post-infectious immune or primarily organ-specific autoimmune. Clinical manifestations of acute and chronic myocarditis are extremely varied, ranging from mild to severe. The diagnosis of myocarditis is a challenging process; other problems are limited sensitivity of endomyocardial biopsies (EMB) and overlapping symptoms. Furthermore, the diagnosis is not well defined. Currently, EMB remains the only way to confirm the presence of a viral genome and other histopathological findings allowing proper treatment to be implemented in cases of myocarditis. Increased recognition of the role of myocardial inflammatory changes has given rise to interest in noninvasive imaging as a diagnostic tool, especially cardiovascular magnetic resonance imaging (CMR) \(^1\).

Recent studies have demonstrated that CMR has shown promising results in the early diagnosis and the follow-up of acute myocarditis (AM) and its subsequent stages. CMR includes several techniques that can be used in various combinations to assess left ventricular (LV) functional parameters, morphology, myocardial perfusion, and myocardial disorders within one examination\(^2\). Presence of delayed enhancement is reported in 44 to 95% of patients with myocarditis \(^3,4\). In acute myocarditis, DE is frequently located in the lateral wall originating from the epicardial layer; enhancement patterns in myocarditis generally exclude the subendocardium with the exception of eosinophilic myocarditis frequently involving the endomyocardium \(^5,6\). Cardiac Troponin-T (cTnT) is a cardio-specific indicator of myocardial necrosis due to ischemic or non-ischemic events; although the detection of cTnT in blood is specific for myocardial injury, it is not specific as to the cause of the myocardial damage \(^7,8,9,10\).
Methods and Materials

**Patients.** The patient group consisted of 55 patients (34 male; 21 females) aging 39±12.0 years, range 21-63, referred to MRI with presumptive, clinical diagnosis of myocarditis.

They underwent CE-CMRI on a 1.5 T MRI device. Patients were enlisted with the collaboration of Cardiologic Unit, San Salvatore Hospital, L'Aquila. Acute chest pain was the most common clinical presentation (35/55 patients), often resembling ischemia-like chest pain. An obvious viral syndrome was only present in 6/55 patients. ECG findings ranged from normal to non-specific abnormalities (39/55 patients): ST-segment depression, ST-segment elevation, and negative T-waves mostly in the inferolateral LV wall, less frequently anterior. Increased troponin I levels were found in 51/55 patients (9.7±8.6 µg/l). Six patients withdrew from the study for claustrophobia. Four patients were excluded for motion artefacts during the examination.

**MR Imaging.** The average duration between symptom onset and MRI exam was 9±7.5 days. All MRI studies were performed on a 1.5-T MRI unit, dedicated cardiac software package and the standard eight channel phased array cardiac coil with VectorCardioGram possibilities. Imaging was started with acquisition of survey scans in three orthogonal planes to localize the heart within the chest. Afterwards, real-time interactive scanning was used to determine the intrinsic cardiac axes. Black blood, T2-weighted triple IR and Cine steady-state sequences (SSFP) in 4-chamber and short axis views were obtained at first. The same three sequences (Black blood, T2-weighted triple IR and SSFP) were repeated using a rotational view (Fig.1), made by 10 planes with a 15° inclination one to the others, put in the centre of the left ventricle (LV). A contrast agent (Gd-BOTPA) was injected (0.15 mmol/kg dose) to obtain the late enhancement (LE) study in 4-chamber, short axis and rotational views. The inversion time was adjusted for optimal suppression of normal myocardial signal (inversion time approximately 200-220 ms), and the images were obtained within 10-20 min after injection of gadolinium.

**MRI Interpretation.** LV kinesis, edema and LE were evaluated and quantified by 2 independent radiologists, blinded to clinical information. The first observer examined short axis and rotational sequences; the second one examined short axis and 4-chamber sequences. A score for kinesis (0-4=from normal to aneurysmatic), edema and LE (0-2=from absent to transmural) was given in the predefined 17 LV segments, respectively (Fig.2).

Cases of disagreement between the observers resolved by reviewing the images and reaching a consensus.
Fig. 0: The rotational scan plane, made by 10 slices with a 15° inclination one to the others, put in the centre of the left ventricle (LV)

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Results

The first observer examined DE and edema on short axis and rotational views (Fig.1). He displayed an abnormal myocardial enhancement on DE-MRI giving a final score of 92. The first observer analyzed also increased myocardial signal intensity on T2-weighted-STIR images, and he gave a final score of 76.

The second observer evaluated DE and edema on short axis and 4-chamber views, giving a score of 78 for DE and 45 for edema (Fig.2). The scores obtained by the first observer showed a superiority in detection of edema (score 76 vs 45) and in LE evaluation (score 92 vs 78) (Fig.3, Fig.4). No significant differences in kinetic evaluation were observed (25 vs 23) (Fig.5) and minimal wall motion abnormalities were found. According to the 17-segment model, the lateral LV wall (segments 5, 6, 11, 12, 16) was most frequently involved and involvement of the interventricular septum was found in six patients, presenting as a focal midwall enhancement. There was never isolated subendocardial DE. Even though some patients showed transmural (usually patchy) enhancement, the subepicardial myocardial region was the most frequent site of DE (71% of enhanced segments), less common were midwall and transmural enhancement. In no patients was right ventricular DE found.

All patients received supportive, anti-inflammatory and if necessary anti-arrhythmic and heart failure treatment.
Fig. 0: Evaluations of the First observer

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Fig. 0: Evaluations of the Second observer

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Fig. 0: Differences between the score assigned by the two observers

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**Fig. 0:** Difference between the classic "4-chamber" scan plane and the rotational scan plane for delayed enhancement evaluation.

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Fig. 0: No significant differences were observed in kinetic evaluation by the two observers.
Conclusion

The diagnosis of myocarditis remains difficult. Myocarditis is rarely recognized clinically, mainly because of lack of specific clinical signs, and the diagnosis is generally one of exclusion\textsuperscript{11}. In conclusion, cardiac MRI is an important diagnostic tool in patients with a clinical suspicion of acute myocarditis, especially in patients with unexplained chest pain, elevated cardiac enzymes and normal coronary arteries. Not only does it allow detection of the presence and extent of myocardial damage but it also allows differentiation of other entities (e.g., ischemia-related), to detect the presence of concomitant pericardial involvement and to quantify the impact on regional and global function\textsuperscript{12}. The rotational approach allows to investigate all part of the left ventricle through the use of perpendicular sections, according to the left ventricular shape. This technique is able to avoid the "partial volume" artefact linked to the obliquity of the cardiac wall section, with an increment of diagnostic accuracy for detection of edema and LE in patients with myocarditis.
1. M.A.G.M. Olimulder, J. van Es, M.A. Galjee The importance of cardiac MRI as a diagnostic tool in viral myocarditis-induced cardiomyopathy, review article, Netherlands Heart Journal, Volume 17, Number 12, December 2009, 481-6


Personal Information

Sara Battisti, MD

Department of Radiology

University of L'Aquila, 67100 L'Aquila, Italy

sarabattisti@alice.it