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The value of delayed enhanced cardiac MRI and cine cardiac MRI in assessment of myocardial viability

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ABSTRACT— After reperfusion, viable myocardium can contract. Identifying viable myocardium helps determine which patients will benefit from revascularization and have increased LVEF and survival. This study evaluated the relevance of delayed contrast enhanced cardiac MRI in assessing myocardial viability before revascularization and the efficacy of cardiac MRI in detecting and categorising regional wall motion anomalies. After reperfusion, viable myocardium can contract. Identifying viable myocardium helps determine which patients will benefit from revascularization and have increased LVEF and survival. This study evaluated the relevance of delayed contrast enhanced cardiac MRI in assessing myocardial viability before revascularization and the efficacy of cardiac MRI in detecting and categorising regional wall motion anomalies. 39 cases and those without enhancement were 11 cases. The mean infarct size by delayed enhanced cardiac MRI was 22 ± 15.8% of the left ventricle. There was a moderate positive correlation between cardiac MRI and two dimensions' echocardiography. Left ventricular ejection fraction correlates inversely with the size of infarcted myocardium. There was a strong positive correlation between infarct size and wall motion abnormalities. A strong positive correlation was found between the percent of LAD stenosis and percent of infarction size in LV as well as LCX, while a moderate positive correlation was found regarding the RCA. Cine MRI and tissue characterization allow exact observation of myocardial scar, hibernating myocardium, and normal myocardium. Echocardiogram infarction size percent and LV ejection fraction are related. Hypokinetic, akinesic, and dyskinetic cardiac regions experienced delayed improvements.

KEYWORDS: Myocardial viability, delayed enhanced cardiac MRI, cine cardiac MRI

1. INTRODUCTION

Ischemic heart diseases and heart failure as well as a range of other cardiac conditions, often require advanced imaging modalities to provide effective diagnosis and patient management. As a result, cardiac magnetic resonance imaging (CMRI) and other imaging methods have been introduced to supplement the echocardiography that has been traditionally done in patients suspected to be suffering from cardiac dysfunction [1]. A variety of tests are available in routine clinical practice for the noninvasive diagnosis of coronary artery disease (CAD), such as exercise electrocardiography (ECG), echocardiography, single photon emission computed tomography (SPECT), positron emission tomography (PET), and cardiovascular magnetic resonance imaging (CMR). Many noninvasive diagnostic tools are suboptimal, and both patients and physicians want a reliable diagnosis [2]. CMRI is commonly useful for the assessment of myocardial viability in patients with ischemic ventricular dysfunction, and it has potential benefits more than single-photon emission computed tomography (SPECT) and dobutamine stress echocardiography (DSE). CMR-based techniques for viability assessment comprise the evaluation of transmural extent of the scar by late gadolinium enhancement (LGE), evaluating the end-diastolic wall thickness from resting cine images and the assessment of inotropic reserve after low-dose dobutamine infusion. With LGE, both viable and

nonviable dysfunctional myocardium can be seen in a single image, allowing a direct quantification of the extent of regional viability, with a significant impact on the estimation of chance for recovery [3]. CMRI with its developed spatial and temporal resolution now used for cardiac morphology evaluation, function assessment, global and regional wall motion (RWM) abnormalities, myocardial edema, perfusion, viability and scar assessment [4]. Delayed enhanced cardiac MRI (DE-CMRI) imaging can be used to characterize tissue injury after MI, with excellent histopathology correlation [5]. DE-CMRI is the best current technique in discriminating myocardial scar versus viable myocardium [6]. The combination of cine and DE-CMRI can be used in patients before revascularization procedures to predict the likelihood of wall motion recovery following revascularization [7]. CMRI versatility and accuracy is unmatched by any other individual cardiac imaging modality [8]. The aims of this study to evaluate the role of delayed contrast enhanced cardiac MRI in the assessment of myocardial viability before revascularization and to highlight the value of cardiac MRI in detection and categorization of regional wall motion abnormalities.

2. Method

A cross sectional analytic study was conducted during the period from February 2016 to the end of December 2016 in MRI unit at the radiology department in Al Shaheed Ghazi Al Hariri teaching hospital-Medical City. Fifty patients were included in the study (38 males and 12 females). All cases were referred from Ibn Al- Bitar Cardiac Surgical Center for assessment of myocardial viability. Each patient was diagnosed as a case of MI by clinical history, ECG, laboratory finding and coronary angiography for more than two months before CMRI some patients had history of previous percutaneous trans-luminal coronary angioplasty (PTCA) and stenting. CMRI was requested following diagnostic conventional coronary angiography (CCA) and two dimensions echocardiography. Inclusion Criteria: Patients were included in this study for assessment of myocardial viability to plan further revascularization strategies and they should have sinus heart rhythm, and normal serum creatinine. Exclusion Criteria: Hemodynamic instability. Contra-indications for MR imaging as claustrophobia, patients with pacemaker. Contraindication for contrast material including known allergy and renal insufficiency (serum creatinine more than 1.2 mg /dl and GFR is less than 30ml/minute /1.73 m^2). At first detailed medical history was taken then Patients were screened for contraindication to MR imaging. All steps of the study were explained in details for each patient and the consents were taken from all patients included in this study. Each patient had intravenous line (cannula) to allow administration of the contrast agent.

The MRI examination for all study cases were performed with Siemens Magnetom Avanto 1.5T scanner using a surface coil. The wireless ECG sensor has a monitoring capability based on three electrodes. Three ECG electrodes were placed on the anterior chest wall, the position of first electrode (green) was approximately 1 cm left of xiphoid. the second (white) and the third (red) electrodes were placed to form a triangle around the nipple, the distance between the electrodes should be approximately 15 cm. The green, white and red leads were connected to ECG electrodes. We checked the quality of ECG in the integrated ECG display on scanner terminal if the signal was not satisfactory and consistent the positions of electrodes were adjusted accordingly.

3. Results

The final analysis included 50 patients, 38 cases were males (76%) and 12 cases were females (24%), their mean age was 54±9.7 year.

Table (1): Descriptive statistics for patients age and sex.

Variables	No. of cases	Minimum age	Maximum age	Mean ±SD

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Age	50	28Y	80Y	54±9.7
.				
		No. of cases	%	
Sex	Male	38	76%	
	Female	12	24%	

Table (2): Distribution of patient's risk factors.

Risk factor		No. of cases	%
DM	Yes	21	42%
	No	29	58%
Hypertension	Yes	41	82%
	No	9	18%
Smoker	Yes	33	66%
	No	17	34%
Total		50	

Out of 50 cases, there were twenty-five cases (50%) had LAD territory stenosis, three cases (6%) had RCA stenosis, five cases (10%) had LCX stenosis, ten cases (20%) had the three territories stenosis, four cases (8%) had LAD and RCA stenosis and three cases (6%) had LAD and LCX stenosis.

Table (3): Evaluation of segmental wall motion abnormalities by Cine MRI:

SWM SCORE	**NUMBER**	**percent**
0	12	24%
1	23	46%
2	10	20%
3	3	6%
4	2	4%
Total	50	100%

Regarding the segmental wall motion abnormalities, twelve cases had score zero (24%), twenty-three cases had score one (46%), ten cases had score two (20%), three cases had score three (6%) and two cases with score four (4%). From the twenty-three cases with score one, 4 cases (17%) had no enhancement in DE-MRI (segments with dysfunctional but viable myocardium), the other 19 cases had segments showing non-viable enhanced myocardium. Five cases from 12 cases with no SWM abnormality have subendocardial delayed enhancement. There was a moderate positive correlation between Cardiac MRI and echocardiography (r= 0.6, p=0.01) regarding SWM abnormalities, we recorded 17 cases normal by Echo compared to only 12 cases by CMRI.

Table (4): Detection of enhancement in the left ventricular myocardium by DE-CMRI

MRI Infarct detection	NO. of patients	Percent
Enhanced (nonviable)	39	78%
Not enhanced (viable)	11	22%
Total	50	100

In this study the cases that had myocardial delayed enhancement were 39 cases and those without were 11 cases. Six cases with no enhancement had significant (> 70%) coronary stenosis at conventional coronary angiography. Three cases with grade three and four delayed enhancement had non critical (< 70%) coronary stenosis.

Table (5): Distribution of spatial extent of the delayed enhanced non-viable myocardium within each segment by delayed enhanced CMRI.

Extent of Delayed enhancement	No. segments	Percentage
<25%	**43**	**18.6 %**
26-50%	**35**	**15.2%**
%75-51	**44**	**19.2%**
>75%	**108**	**%47**
Total	**230**	**100%**

According to the 17 model for segmentation recommended by American Heart Association/American College of Cardiology (AHA/ACC), we had 850 segments, 230 segments had areas of DE as:

1. Forty-three segments (18%) from the 230 segments had sub endocardial enhancement<25%
2. Thirty-five segments (15%) had partial thickness MI (26-50%).
3. Forty-four segments (20%) had (50-75%) DE.
4. One hundred eight segments (47%) had transmural enhancement >75%. The mean infarct size by DE-CMRI was 22 ± 15.8% of the LV.

Among the 43 segments with sub endocardial infarction, twenty-nine (67.4%) segments had no SWM abnormality and fourteen (32.6%) segments had mild hypokinesis. All segments with transmural infarction had SWM abnormality (from sore 2 to 4).

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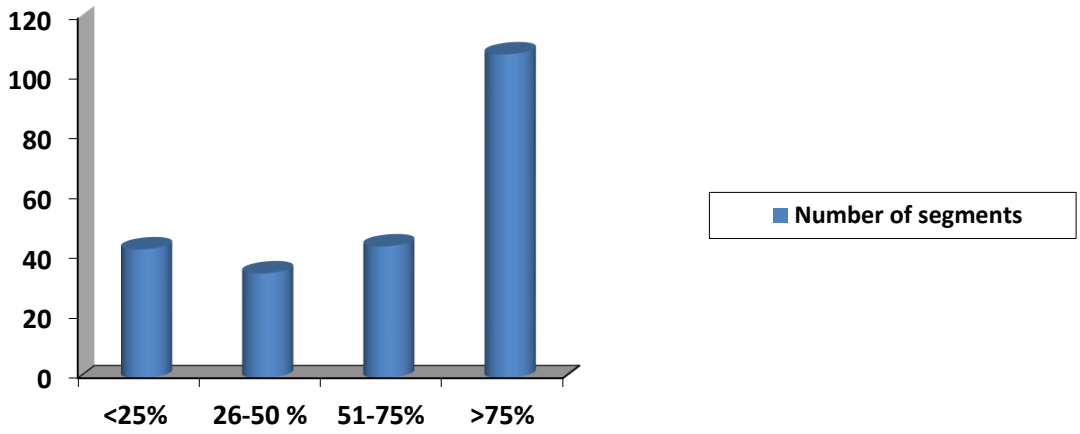

Figure (1) Charts represents the distribution of spatial extent of the delayed hyper enhanced myocardium within each segment.

4. Discussion

Most cardiac MRI institutions employ delayed gadolinium enhancement to measure myocardial viability. Before surgery, it's vital to separate healthy myocardium from necrotic tissue. Patients with persistent ischemic left ventricular dysfunction and viable myocardium may benefit from revascularization [9]. Infarct size is inversely proportional to prognosis; therefore, recovery is less likely if 50% of the myocardium is infarcted [10]. In this study, we used steady state free precession (SSFP) sequences for Cine images and inversion recovery gradient echo (IR-GRE) for delayed post contrast study. [11], [12] reported that SSFP sequences is the technique of choice in evaluating LV functions because they have higher temporal resolution, better blood to myocardium contrast, and higher signal intensity than other FFE (fast field echo) sequences. In our study, we performed delayed contrast enhancement 10–15 minutes after IV contrast administration, similar time had been used by [13], while [9] revealed that heart is imaged 15–30 minutes after intravenous contrast administration, [14] examined the late enhancement after 6–12 min. [15] used 205 minutes to determine infarct size. In this investigation, we employed the AHA-recommended 17-segment model to measure wall motion and myocardial viability. It gives the greatest agreement with available anatomic data. [16] used a 72-segment model: 6 slices 12 segments each slice. [17] mostly had RCA lesions. [15] found an equal frequency of RCA and LAD stenosis patients. In this investigation, the scar in each of the 17 standardised myocardial segments was visually evaluated for evaluation of regional wall motion anomalies and amount of delay augmentation inside the ischemic myocardium [18], [19]. In our study, infarct size was quantified as a percentage of LV from segments with delayed enhancement on each short axis slice covering the LV. [10], [20], [15] did the same. [21] used the mass of infracted hyper enhanced area expressed in grammes while [19] measured the late In our investigation, the mean infarct size by DE MRI was 22 15.8% of the LV; [22] reported 16 12%, [15] reported 1515%, and [16] reported 12 5%. We found that echocardiography LV ejection fraction correlates inversely with LV infarction size %. This was in agreement with [22], [21] who found a 0.5% reduction in ejection fraction for each gramme of infarct and a 0.67 % reduction for each 1% increase in infarcted myocardium. 29 (67.4%) of 43 subendocardial infarction segments exhibited normal wall motion, while 14 (32.6%) had moderate hypokinesia. This was lower than [23], who reported that 94.3% and 90% of segments with subendocardial infarction display normal wall motion, but we agreed with them since they verified that all segments with > 75% hyper enhancement showed dysfunctional regional wall motion. We found 4 of 23 cases (17%) with mild hypokinesia (score1) that had no enhancement in DE MRI; these were hibernating myocardium. [24] explained that late gadolinium enhanced MRI is useful to differentiate dysfunctional but viable myocardium

from non-viable sacred myocardium in patients with MI. Five of 12 instances with subendocardial delayed enhanced segment had normal wall motion. [16] discovered that wall motion problems emerge when more than 20% of wall thickness is infarcted in a particular segment. We discovered that segments with more hyperenhancement (>75%) showed more hypokinesia or akinesia. [25] found the same thing, suggesting these segments won't restore contractile function. Multiple investigations on revascularization outcomes in MI patients, such as [26], demonstrated that 90% of myocardial segments with hyperenhancement between 51% and 75% of tissue and practically all with transmural infarction did not improve following revascularization. 256 out of 339 (78%) hypokinetic segments with no hyperenhancement improved contractility after revascularization. [27] in 60 patients with recent MI confirmed that segments with >75% transmural enhancement are unlikely to function completely at follow-up, while in about half of the segments with less than 25% transmural enhancement function improved completely. We couldn't assess our results since we didn't follow up on our cases. In this study, we considered hemodynamic significant stenosis 70% of the lumen as [17], but three cases with multiple segments had grade III and IV delayed enhancement supplied by coronary arteries with insignificant (70%) stenosis, and six cases with significant (70-100%) stenosis exhibited no delay enhancement. In this investigation, CMRI was more sensitive in detecting segmental wall motion abnormalities than echocardiography, which missed 17 instances. [28] found normal wall motion in 15 patients assessed by echocardiography, compared to only 2 by CMRI. This could be explained by the fact that echocardiography is still largely dependent on the operator, low spatial (and temporal) resolution of echocardiography, especially at far field, suboptimal acoustic windows in some patients with less complete visualisation of wall segments, and greater "blooping."

5. Conclusion

The combination of Cine MRI and tissue characterization with delayed enhanced cardiac MRI allow precise visualization of myocardial scar, hibernating myocardium and normal myocardium. There is parallel relationship between the infarction size percent of LV myocardium and LV ejection fraction that measured by echocardiogram. Myocardial segments with sever hypokinesia, akinesia and dyskinesia had delayed myocardial enhancements.

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